



**HAL**  
open science

## Growth, institutions and "socialist transition with chinese characteristics"

Zhiming Long

► **To cite this version:**

Zhiming Long. Growth, institutions and "socialist transition with chinese characteristics". Economics and Finance. Université Panthéon-Sorbonne - Paris I, 2017. English. NNT : 2017PA01E043 . tel-01798699

**HAL Id: tel-01798699**

**<https://theses.hal.science/tel-01798699>**

Submitted on 23 May 2018

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

**Université Paris 1 Panthéon-Sorbonne**

**THESE**

Pour l'obtention du grade de docteur en Sciences Économiques  
de l'Université Paris 1 Panthéon-Sorbonne

Présentée et soutenue publiquement le 11 Mai 2017 par

**Zhiming LONG**

**Growth, Institutions and "Socialist Transition with  
Chinese Characteristics"**

Directeur de thèse : Rémy HERRERA

**Composition du jury:**

Rapporteurs:

**Valérie MIGNON**

Professeur des Universités à l'Université Paris Nanterre  
Directrice d'EconomiX, CNRS – UMR 7235

**Ben FINE**

Professor à SOAS University of London

Directeur:

**Rémy HERRERA**

Chercheur au CNRS – UMR 8174 Centre d'Économie de la Sorbonne

Examineurs:

**Marie COTTRELL**

Professeur émérite à l'Université Paris 1 Panthéon-Sorbonne

**Jean-Bernard Châtelain**

Professeur des Universités à l'Université Paris 1 Panthéon-Sorbonne

**Karim AZIZI**

Maître de conférences à l'Université Paris 1 Panthéon-Sorbonne



**Université Paris 1 Panthéon-Sorbonne**

**PhD Thesis**

Submitted to Université Paris 1 Panthéon-Sorbonne  
For the Degree of Doctor of Philosophy in Economics

Prepared and defended publicly at Centre d'Économie de la Sorbonne on 11<sup>th</sup> May 2017 by

**Zhiming LONG**

**Growth, Institutions and "Socialist Transition with  
Chinese Characteristics"**

Advisor of thesis : Rémy HERRERA

**Jury:**

Reviewers:

**Valérie MIGNON**

Professor at l'Université Paris Nanterre  
Director of EconomiX, CNRS – UMR 7235

**Ben FINE**

Professor at SOAS University of London

Advisor:

**Rémy HERRERA**

Researcher at the CNRS – UMR 8174 CES

Examinators:

**Marie COTTRELL**

Professor emerita at l'Université Paris 1 Panthéon-Sorbonne

**Jean-Bernard Châtelain**

Professor at l'Université Paris 1 Panthéon-Sorbonne

**Karim AZIZI**

Associate Professor at l'Université Paris 1 Panthéon-Sorbonne

*To the best age in my life:*

起屠维赤奋若，尽强圉作噩，凡八年

## Acknowledgments

This piece of work is submitted to university for the grant of Doctor's Degree of Philosophy in Economics. The vocabulary "Philosophy" recalls me a story about Pythagoras. About 2500 years ago, it happened one day, when Leon, tyrant of Phlious, asked Pythagoras who he was and what he did for a living. He answered: "I am a philosopher", thereby coining the word - "philosopher", i.e. lover of knowledge. Since then, human beings got the "Philosophy" and the civilization of mankind turned to a new page. I will feel very glorious if my work merits such a tile.

Somebody says that a good Ph.D. thesis should create new knowledge to the world. I hope my work could be proved by the members of Jury that it has contributed something new and useful, even very insignificant. However, numerous insignificant efforts by generation after generation of researchers have promoted the development of our civilization. Just like in mathematics, the sum of infinite zero is not zero any longer, it makes a sense. This is why I'd like to thank firstly the hard work of all the members of Jury for evaluating my thesis.

Secondly, who I'd like to thank mostly is my supervisor Mr. Rémy Herrera. Over the past four years we work together and carried out many interesting and exciting scientific findings. I study in Paris for almost eight years and I have met so many kind persons and met so many luck things. But the most luck one during my sojourn in Paris is that I have a best professor. Mr. Herrera has done so many things for me; but the only thing what I can do as a return is writing a thesis with all my efforts. For me, he is not only a supervisor, but also a member of family, a best friend in France, a like-minded comrade. I decide to stop praise my professor because my English is so poor that I cannot use such a poor language to tarnish his kindness.

I'd like to thank my family, my mother Mz. WANG Ju, my father Mr. LONG Congbo and my sister LONG Qiao for their endless love. Maybe they will never understand what I have written in this thesis but I know that no matter what happened they will support me without any condition.

Now I'd like to thank the members of Jury separately. Some of them I have known for a longtime. Prof. Valérie Mignon was my professor from undergraduate to Master. She is so kind and patient for her students, all our classmates worship her. With what I have learned from her teaching, I could finally undertake my research. She has shown the door of research to me and given me all the necessary keys. Professor Karim Azizi was my professor of macroeconomics. When I was a master student we had already lots nice discussions. I'm really great thankful for those helps. I expect a nice discussion again in the defense.

Some of them I have never met before but just have read their papers and books. When I was a teenage boy in China, I have already heard of the name of Prof. Ben Fine. This name is legend for me. I have never expected that ten years later I could discuss with the legend face to face. What a great honor for me! It is also my great honor that Prof. Jean-Bernard Châtelain has accepted as member of Jury. As I have ever read the Spurious Regressions problem that he published in *Journal of Macroeconomics*, I believe that we will have many common topics both in macroeconomics and econometrics. I really appreciate that Prof. Marie Cottrell has accepted as the member of Jury in a so limited time. I have pressure but also feel exciting to discuss my paper with such an excellent mathematician.

Next I'd like to thank all the professors who have taught me in all my three universities - Sichuan University, Paris 10 and Paris 1: Prof. Balázs Égert, Prof. Julie Valentin, Prof. Corinne Perraudin, Prof. Jean-Pierre Allegret, Prof. Christian Bidard, Prof. Cécile Couharde, Prof. Olivier de Bandt, Prof. Sessi Tokpavi, Prof. Angelo Secchi, Prof. Xiaoping Li and many others (forgive me that I cannot list all the names). Thanks for their strict academic training and kindness help during my studies over the past decade.

I'd also like to thank the editors of journals: Prof. Belton Fleisher, Prof. Harald Uhlig, Prof. Annika Andreasson, Prof. Tarik Tazdait, Prof. Thierry Kamionka, Prof Blandine Laperche and many others for their kind help and suggestion for the publications. Of course I'd like to thank all the anonymous reviewers. I don't know their names but they help me a lot to improve the quality of our papers.

I'd like to thank Prof. Thomas Piketty, Prof. Robert Barro, Prof. Tao Zha and Prof. Dominique Lévy for their kind discussions about my papers. They encourage me a lot. And particularly I'd like to thank two professors in mathematics – Mr. Jie Liao and Mz. Yan Qin who helped me a lot in mathematics.

I'd also like to thank all the administrative staffs of universities: Mr. Loic Sorel, Prof. Annie Cot, Mz. Elda André and many others. Grace to their efficient work, our institution work well and my defense could be held.

I'd like to thank all the classmates and friends who have ever helped me. I remember forever that we have passed our best age in our life together. In the beginning years, I can hardly speak French that I have many difficulties in both life and study, and loneliness tortured me. It was Laura, Yuzun and many other good friends helped me.

In the end, I'd like to thank China Scholarship Council. With their allocation, I could concentrate my mind in research without worry of income. CSC considered me as an “outstanding student” so that they grant me the fellowship. I feel ashamed that my contribution is not “outstanding” enough for their expectation. Limited by ability, I have no way to return but work hard. I know the fellowship comes from the hard work of Chinese people, so I wish my work might be a little useful for my country. I also wish my work will contribute positively though insignificantly to the future development of China. And more ambitiously, if it will help a little for the some people of other countries to understand the economy of China, maybe it will be positive to against poverty.

I have sacrificed my energy for this piece of work, alone. So I decide to dedicate my thesis to the best age in my life and people who might need it. I apologize all the errors and insufficiencies of this work. And let me apologize with the poem of Szymborska:

*My apologies to great questions for small answers.*

*Truth, please don't pay me much attention.*

*Dignity, please be magnanimous.*

*Bear with me, O mystery of existence, as I pluck the occasional thread from your train.*

*Soul, don't take offense that I've only got you now and then.*

*My apologies to everything that I can't be everywhere at once.*

*My apologies to everyone that I can't be each woman and each man*

Zhiming LONG

9<sup>th</sup> Mars 2017

# Contents

- Acknowledgments ..... 4**
  
- Chapter 1 Introduction..... 9**
  - 1.1 General Introduction ..... 9
  - 1.2 Problems ..... 10
  - 1.3 Organization of thesis ..... 13
  
- Chapter 2 SPURIOUS OLS ESTIMATORS OF DETRENDING METHOD BY ADDING A LINEAR TREND IN DIFFERENCE-STATIONARY PROCESSES  
A Mathematical Proof and Its Verification by Simulation ..... 16**
  - 2.1 Introducing the problematic ..... 16
  - 2.2 A mathematical proof ..... 18
  - 2.3 Verification by simulation ..... 23
  - 2.4 Concluding remarks ..... 25
  
- Chapter 3 BUILDING ORIGINAL SERIES OF PHYSICAL CAPITAL STOCKS FOR CHINA’S ECONOMY Methodological Problems, Proposals for Solutions and a New Database ..... 27**
  - 3.1 Introduction ..... 27
  - 3.2 General issues and the construction method of physical capital stocks ..... 27
  - 3.3 Conclusion ..... 43
  
- Chapter 4 ORIGINAL SERIES OF HUMAN CAPITAL STOCKS FOR CHINA’S ECONOMY FROM 1949 TO 2014 Concepts and Methods for Constructing a New Database ..... 44**
  - 4.1 Introduction and Literature Review of Labor Input Measurements ..... 44
  - 4.2 Methodologies and Models ..... 48
  - 4.3 Details of Parameterization ..... 51
  - 4.4 Human Capital and Conclusions ..... 70
  
- Chapter 5 EXPLAINING ECONOMIC GROWTH IN CHINA New Time Series and Econometric Tests of Various Models ..... 72**

5.1 Introduction .....	72
5.2 Quantifying Institutional Changes by Using Asymmetric Compressed Dummies .....	73
5.3 Econometric Estimates within the Framework of Various Theoretical Growth Models .....	77
5.4 Conclusion .....	83
<b>Chapter 6 PIKETTY IN BEIJING The Laws of Capital in the Twenty-First Century in China.....</b>	<b>84</b>
6.1 Introduction.....	84
6.2 Construction of a time series of general capital à la Piketty for China .....	85
6.3 Piketty’s Dynamic “Laws” of Capital in China .....	87
6.4 Estimates for the sub-period 1978-2012 .....	94
6.5 Conclusion .....	96
<b>Chapter 7 SOME CONSIDERATIONS ON CHINA’S LONG-RUN ECONOMIC GROWTH: 1952-2014 From the Analysis of Factor Contributions to that of the profit rate .....</b>	<b>98</b>
7.1 Contribution of production factors to China’s growth: measures and limits.....	98
7.2 Piketty’s “laws” in the case of China: attempts of verification and their limits .....	99
7.3 Growth and cycles in China: some elements for a methodological reflection .....	100
7.4 Econometric Methodologies for Trend and Cycles: Spectral Analysis and Filters ....	107
7.5 Conclusion .....	112
<b>Chapter 8 CAPITAL ACCUMULATION AND CYCLES IN CHINA’S ECONOMY FROM 1952 TO 2014 Two Methods of Analysis through Industrial Profit Rates .....</b>	<b>113</b>
8.1 Introduction.....	113
8.2 The industrial sector in the Chinese accounting systems .....	115
8.3 Calculation of industrial profit rates at the microeconomic level .....	116
8.4 Calculation of industrial profit rates at the macroeconomic level .....	119
8.5 Changes in the micro and macroeconomic rates of profit: a comparison.....	124
8.6 Conclusion .....	129



<b>Chapter 9 ECONOMIC STRUCTURE, CYCLES AND CRISES IN CHINA'S ECONOMY FROM 1952 TO 2014 Methods of Analysis through Reviewed Marxist Point of View .....</b>	<b>130</b>
9.1 Introduction .....	130
9.2 Framework of Data .....	132
9.3 Framework of Analysis .....	133
9.4 Econometric Estimations: SVARs and BVARs .....	138
9.5 Decompositions of Profit Rates .....	151
9.6 Conclusion .....	154
<b>Chapter 10 Conclusions and Future Researches .....</b>	<b>155</b>
<b>References .....</b>	<b>160</b>
<b>Appendices .....</b>	<b>176</b>
<b>Abstract in English .....</b>	<b>237</b>
<b>Résumé en français .....</b>	<b>241</b>
<b>Résumé en français étendu.....</b>	<b>245</b>

# Chapter 1 Introduction

## 1.1 General Introduction

The rise of emerging economies and their increasing contributions to the world's economy has led to the development of the science of economics. China is a typical representative of emerging market economies. This economic phenomenon pushes the development of economic growth theory, and the problems in empirical analyses also promote econometric techniques. China's real GDP has increased 129 times in 1949–2015, and its annual growth rate has been approximately 10% since 1978. The poorest countries in the 1960s remain in the poorest situation today and have not caught up, as predicted by the Solow model. The growing gap between the North and the South exacerbated the conflict in the world. However, China has successfully dragged itself out of absolute poverty. For instance, in the 1980s, the nominal GDP per capita (current US dollars) of China was only 205.115 dollars, but it has reached 8,027.684 dollars in 2015<sup>1</sup>. According to the criterion of the World Bank, China is now a middle-income country<sup>2</sup>. China is still a developing country. However, considering its huge population, China has made a surprising achievement in addressing poverty. Is the technique of China's economic development an alternative method for the struggle against the poverty of other poor countries?

Although China is considered an “emerging” country, China is a country with a 5,000-year-long civilization and is the oldest civilization still existing today. With the lack of modern international standard data, the empirical analyses of modern economic growth theories in the literature are generally focused on the period after the opening-up reform in 1978 or the period after the fiscal reform in 1993. Clearly, 20 to 30 years of experience is insufficient to understand China's economy, which has more than 5,000 years of civilization history. In this thesis, the author attempts to extend the vision, by further analyzing China's economy using modern economic approaches since the foundation of the People's Republic of China in 1949.

In the long course of history, the Chinese people have significantly contributed to world civilization in terms of science, philosophy, and art. China has always been a prosperous, wealthy, and industrious country until the end of the Qing Dynasty. However, the Qing government's isolationist policy obstructed the burgeoning of capitalism in China, which has caused this great country to close its door to the outside world while the politics, economy, military, and culture of outside world boomed. In 1840, the British imperialists launched the Opium War against China. China gradually turned into a semi-feudal and semi-colonial country. After the long-run struggle for independence and freedom, the People's Republic of China was established with Mao Zedong as the chairman. Since then, the Chinese people have taken control of state power and become masters of their country. After the founding of the People's Republic, China has gradually achieved its socialist transition.

According to the Constitution of China (1982)<sup>3</sup>, “The People's Republic of China is a socialist state under the people's democratic dictatorship led by the working class and based on the alliance of workers and peasants.” However, after the death of Chairman Mao and the introduction of economic reforms in 1978, China's political structure cannot be characterized

---

<sup>1</sup> World Bank data

<sup>2</sup> MICs are countries having a per capita gross national income of US\$1,026 to \$12,475 (World Bank, 2011). See <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519>.

<sup>3</sup> Chapter I, Article 1. See: [http://www.npc.gov.cn/npc/xinwen/node\\_505.htm](http://www.npc.gov.cn/npc/xinwen/node_505.htm)

so simply, even though Marxism–Leninism remains the official ideological reference of the state. At present, China is considered by the authority itself as a country governed by “socialism with Chinese characteristics.”

Alongside the wave of privatization, marketization, and liberalization in the countries of the former Soviet Union, socialist countries, and developing countries, China has also begun its economic reform since 1978 in which it has achieved great economic success. For instance, China has gradually become the largest exporter and second largest economy in the world. China’s institutional changes have attracted considerable attention; such institutional changes are being used by economists to explain China’s economic growth<sup>4</sup>. Have the institutional changes during the economic reforms significantly contributed the economic growth? The evidence from the studies of other countries shows that the institutional changes are the fundamental cause of long-term economic growth. Among such evidence is the work of Acemoglu, Daron, Johnson, and Robinson (2005). Although the evidence from China is unclear, Chinese policymakers themselves contribute the rapid economic growth to the success of the institutional choice. However, contrary to the general conception of privatization, marketization, and liberalization, these institutional changes are considered the foundation of “socialism with Chinese characteristics.” For instance, Hu Jintao’s report at the 17th Party Congress (2007)<sup>5</sup> has the following assertion: “To sum up, the fundamental reason behind all our achievements and progress since the reform and opening up policy was introduced is that we have blazed a path of socialism with Chinese characteristics and established a system of theories of socialism with Chinese characteristics.” However, what does the so-called “socialism with Chinese characteristics” really mean? How does it work on the path of economic growth?

China also incurs costs alongside the rapid economic growth, for example, inequality increases sharply, pollution becomes increasingly serious, and corruption is aggravated during the development. Some economists, such as Huang (2008), argued that the current political regime in China is not socialism with Chinese characteristics, as claimed by the authority, but its opposite—capitalism with Chinese characteristics. Baumol, Litan, and Schramm (2007) also claimed that the current political regime in China is “bad capitalism” due to fierce privatization, extreme inequality, polarization, and corruption. Such assertion is reasonable to a certain extent. However, China’s current political regime is difficult to identify by rule and line. China’s economic and political realities are rather complex due to historical and natural reasons. In the next section, the difficulties in applying modern economic growth theories to China will be presented as regards: 1) definitions and notions, 2) theories and models, and 3) data and econometric problems. This thesis does not evade those challenges and attempts to find possible solutions.

## **1.2 Problems**

### **Particularity of China**

First, the biggest problem is that the research object is not a “pure” market economic system. Considering the official-oriented culture and high concentration of power to authorities, many hypotheses of modern macroeconomic models are not applicable for the reality of China. This

---

<sup>4</sup> For example, Montinola, Qian, and Weingast (1995) argued that the economic success of China rests on a foundation of political reform providing a considerable degree of credible commitment to markets. The authors call this reform as “federalism, Chinese style,” which reflects a special type of institutionalized decentralization.

<sup>5</sup> See for example: <http://cpc.people.com.cn/GB/104019/104099/6429414.html>.

situation leads to a double jeopardy: either we do not pay attention to such characteristics, which often leads to a blind copy of mainstream economic models, or we overemphasize the so-called “Chinese characteristics,” causing us to make an arbitrary interpretation. In the latter case, Chinese economists and their foreign colleagues have difficulty in fully communicating with each other.

Consequently, we need to find and work in an appropriate framework. That is, we need an open mind and should not restrict ourselves in the mainstream framework if they do not match the reality of China. The next several chapters of this thesis will gradually show the insufficiency of mainstream economic growth models to explain China’s economic growth and the necessity to step out from neoclassical framework. The analysis gradually turns to Marxist approaches and concentrates on profit rate analysis.

Second, China is a sizeable country. China’s population, which is the biggest in the world, and its vast territorial area are sources of complexity. With an area of 9,641,144 km<sup>2</sup>, China is the third largest country in the world. The geological complexity increased the difficulties of industrialization of some industries, such as agriculture, transportation, and communication. Together with the historical reasons, the difference between regions can therefore be extremely large, and the developments across regions are unbalanced. The richest regions, such as Shanghai, could catch up with the success of other developed countries, whereas the living conditions of the poorest province, such as Guizhou, are considerably low. The researchers must consider heterogeneity owing to China’s large population and territory.

Another particularity of China is the Chinese language. It is one of the most complex and difficult languages in the world. Most occidental researchers cannot speak Chinese. Therefore, they cannot make use of the original and first-hand materials during their research. They can only use second-hand sources to explore the questions they are interested in. However, abundant useful and important information are hidden in the original language literature. This thesis uses original data sources as much as possible to reduce the biases and maximize the using of Chinese historical literature.

### **Problem of data**

The problem of data is the most difficult part when studying the problems of China. The difficulties are concentrated in three aspects: quality of data, length of data, and irregularity.

The National Bureau of Statistics of China (NBS) was founded in 1952 to help in the preparation of calculations of the first five-year plan (1953–1957). Moreover, NBS has shifted from Material Product System (MPS) to the System of National Accounts (SNA) in 1993. Consequently, many commonly used macroeconomic indicators were found in a considerably late time or are still missing. For example, the basic series for economic growth models—physical capital stock and human capital stock data—have not been found.

Some data are not in good quality due to multiple reasons: 1) limitations in the data collection and collation methods (e.g., the unemployment rate of China only accounts for registered unemployed persons in urban areas, which severely distorts the data), 2) NBS does not have sufficient experience to collect data (such as the *R&D* in the beginning years), or 3) the pressure of “promotion competition” (where the local government is motivated to manipulate GDP data). Ordinary people might also cause biases of data. For example, due to the radical

birth control policy, families will attempt to hide the actual number of their children to avoid severe punishment.

In addition, as China turns from MPS to NSA in a late time, many indicators remain to have a number of characteristics of planned economy period, which do not match the definitions of SNA. For example, the “total investment in fixed assets” of NBS includes the expenditures on old machines, old buildings, and their lands. Thus, the total investment is not the investment defined in the national economic accounting equation:

$$Y = C + I + G + X - M \quad (1.1)$$

The usage of this series and its price index started in 1990 and essentially belongs to MPS. Direct application of those series in modern economic growth models will cause some biases.

Data irregularity also comes from the frequent changes of the statistical criteria of NBS. For example, due to the adjustment of administrative divisions, Sichuan has been divided into two new provinces—Sichuan and Chongqing—in 1997<sup>6</sup>. If we do not pay attention to this adjustment, then one might conclude that the population of Sichuan in 1997 decreased 30%. Direct application of those data in a panel regression will result in a catastrophe. NBS also frequently changed their statistical criteria and scopes. For example, NBS adopted new criteria for the household survey since 2012, which led to a disposable income data that is totally incomparable to previous data.

Faced with many difficulties, this thesis attempts to earnestly address these problems. The author has examined the quality, completeness, and consistency before using each series. For example, the author has estimated the missing data of physical capital stock and human capital in Chapters 3 and 4. The *R&D* series have been estimated according to the definition of *Frascati Manual* in Chapter 5. The biases between provincial data and national data of GDP have been corrected in Chapter 7. The details are discussed in corresponding chapters.

### **Econometric problems**

Econometric problems are manifold. First, the econometric problems are associated with the spurious regression with inappropriate detrending method in the literature. Following Nelson and Kang (1981), the author provides a mathematical proof in Chapter 2 to show that ordinary least squares (OLS) estimators of detrending method with a linear trend in difference-stationary processes are spurious. The author also provides a Monte Carlo simulation.

Second, the econometric problems are associated with the difficulty of quantitative analysis of institutional changes. Dummy variables are typically introduced into regressions as qualitative indicators of institutional changes. However, having excessive dummies implies overfitting and multicollinearity problems or can even make the matrix of regressors singular. To avoid such problems, the author proposed a method to design compressed dummy variables and a test to determine whether the a priori selected dummy variables are statistically significant and should be included among the dummies. The details are discussed in Chapter 5.

Third, the econometric problems are associated with the nature of macroeconomic data. Considering the small sample and the number of parameters to be estimated, the standard errors of estimated coefficients might be large. The author has tried Bayesian approaches to

---

<sup>6</sup> Similarly, Hainan province was founded in 1988 and previously belonged to Guangdong.

improve the estimations in Chapter 9. The author has also proposed a test for ergodicity and a bootstrap method to test the stationarity in the small sample. However, this part is an incomplete work that needs further study.

### 1.3 Organization of thesis

Chapter 2 provides a mathematical proof to show that OLS estimators of detrending method with a linear trend in difference-stationary processes are spurious. The OLS estimator of the trend converges toward zero in probability, and the other OLS estimators are divergent when the sample size tends to infinity. To perform this proof, the author uses Chebyshev's inequality. The author then designs a statistical series through Monte Carlo simulation to verify it, with a sample size of a million points as an approximation of infinity. The seed values used correspond to the true random numbers generated by a hardware random number generator to avoid the pseudo-randomness of random numbers given by software. The author repeats such experiment 100 times and obtains results consistent with the mathematical proof provided.

Chapter 3 indicates that to date, no official Chinese statistics relating to capital stocks exist. The lack of data hinders the econometric studies of economic growth in this country. A series of such stocks are proposed in the literature, but most available empirical works on this topic suffer from multiple deficiencies. This chapter aims to develop the most reliable and longest possible statistical series of capital stocks for China. The initial capital stocks are calculated by an iteration procedure. The investment flows are consistent with the perimeters of the initial stocks. The investment price indices are strictly tailored to the content of these stocks, and the unit root tests show that all the indices are non-stationary and integrated to the order of 2, which means that they cannot be substitutes, as supposed in many other studies. The depreciation rates are estimated by type of capital, under assumptions consistent with age efficiency and retirement. Investment shares are used to approximate an overall capital structure and to calculate a total depreciation rate. Built from 1952 to 2014, the original series are available to econometricians seeking to conduct new long-term empirical studies on China.

Chapter 4 estimates the missing human capital data. Penn World Tables (PWT, 2013) has extremely underestimated this series of China. The frequency of Barro–Lee indicator about China is in a 5-year level and began in 1970 that is far from enough for econometric analysis. This chapter has distinguished the difference between total human capital and productive human capital in employed persons. The author has considered the influence of education reform in the 1950s and Cultural Revolution on the human capital level. By comparing the new statistical database with those in the existing literature, the author feels confident in suggesting that the original estimates of human capital stocks, which the author offers, are substantially more reliable than the series provided by PTW. The stocks are even improving in quality, frequency, and/or length, compared with that of Cai and Du (2003) or Barro and Lee (2012), although remaining relatively close to the latter.

Supported by new statistical series of physical capital stocks and of human capital, Chapter 5 attempts to improve the explanation of China's long-term economic growth. It offers econometric estimates performed within the framework of a broad range of theoretical models, going from standard specifications to more sophisticated endogenous models with *R&D* indicators. The author also proposed a method for designing a compressed dummy variable and tests to quantitatively analyze institutional changes. The author provides a theoretical justification of the use of regressions in OLS on the first differences of logarithmic forms in

levels. Finally, the author finds that productive physical capital and human capital stocks, R&D, and institutional changes positively and significantly contribute to the Chinese GDP growth.

With the insufficiency of mainstream frameworks, Chapter 6 passed from endogenous models to Thomas Piketty. This chapter builds a capital stock à la Piketty for China over 1952–2012 and estimates elasticities associated with it through specifications also integrating human capital, R&D, and institutional changes. This chapter calculates an implicit rate of return of this capital to test the validity of what Piketty states as a “fundamental inequality,” comparing the rate of return on capital and the income growth rate in the long run. Piketty’s “law” then connects the coefficient of capital with the ratio between savings rate and income growth rate. These results are compared with estimates over 1978–2012, i.e., the sub-period of “capitalism with Chinese characteristics.”

Chapter 7 offers some methodological reflections on the theme of China’s long-term economic growth. With the supported data and tests above, the author highlights the limitations of those tests, which are problematic and insurmountable. In the meantime, an original framework is mobilized, in the spirit of the recent studies provided by Piketty, who combines mainstream references with components borrowed from Keynesian and neo-institutionalist formalizations. In this study, several problems associated with such studies are identified. Finally, the author moves the discussion toward a more heterodox and promising approach, involving profit rate indicators, to deepen future studies of China’s long-term economic growth. The author suggests that the economic growth and cycles should not be considered independently. Therefore, the author suggests the need for an “exit” from the usual framework of the neoclassical mainstream and—after having tried to apply Piketty (2013)’s “laws” to the case of post-1978 China—the relevance of more heterodox reflections, using profit rate as a key indicator. The author also suggests the need for an “exit” from the usual framework of the time domain and turning to the spectral analysis and filter analysis in an econometric perspective.

Based on various originally constructed statistical series of stocks of productive physical capital and of enterprises’ fixed assets and on a rigorous definition of the industrial sector’s scope, Chapter 8 calculates several indicators of profit rates at the micro- and macroeconomic levels for China from 1952 to 2014. The results obtained by these two methods (micro and macro) are quite similar and can be summarized as follows: 1) A tendency of the profit rate to fall is observed over a long period, for the two levels of analysis. 2) At the macro level, the short-term fluctuations in the profit rates show a succession of (rarely complete) cycles whose amplitude decreases with time. 3) More than a third of the period is affected by recessive years for the cyclical component of the profit rates. The largest declines are recorded, in descending order, after the separation between China and the Soviet Union (1961–1963), during the Cultural Revolution (1968), in the course of the 1950s, during the post-Mao transition (1976–1977), when a neoliberal experiment has been tempted (1989–1991), and with the spread of the globalization crises (which affected China in 1998, 2001, 2009, and 2012). 4) The increasing organic composition of capital tendentially pushes down the macro rate of profit.

In Chapter 9, the author first calculated four different total profit rates of all economic sectors in 1952–2014 from a reviewed Marxist perspective. The profit rates have a long-term decline trend and present cyclical fluctuations. The author then used the structural vector autoregressive models (SVARs) to analyze China’s economic structure. The author examined

the influences of profit rates on several key economic variables such as investment growth, capital accumulation, and economic growth by impulse response functions. The short-run *a priori* restriction assumptions are difficult to validate, and the long-run restrictions are valid only in the subsample over 1993–2014. Bayesian approaches fail to improve the estimation. The key identifiable condition is ambiguous, which implies that if Chinese leaders observe economic crisis, then they might subjectively increase the investment as an anti-crisis policy rather than let the profit rate determine whether the investment should be more or less. This implication is also one of the most important characteristics of China's economy: highly powerful governmental intervention for anti-crisis. The author has used the full sample and sub-sample models to predict the values of some economic variables of 2015. The forecast is successful. In addition, the author has extended the economic decomposition of profit rates of Chapter 8. The author proposed three different decompositions and then applied filter to those components. The economic cycles and crises in Chapter 8 have been confirmed by the economic indicators of all economic sectors with a reviewed Marxist perspective.

The last chapter concludes and prospects the future research directions and points out that this thesis is still a preliminary and explorative work to study China's economic growth trajectory and its institutional transition. Many promising research works are left to be done.



## **Chapter 2 SPURIOUS OLS ESTIMATORS OF DETRENDING METHOD BY ADDING A LINEAR TREND IN DIFFERENCE-STATIONARY PROCESSES**

### *A Mathematical Proof and Its Verification by Simulation*

In the literature, adding a linear trend in regressions is a frequent detrending method, due to its simplicity and its compatibility with various theoretical models. Some researchers, such as Chan, Hayya and Ord (1977) or Nelson and Kang (1981, 1984), pointed out that if the variable considered is a difference-stationary process, then it will artificially create pseudo-periodicity in the residuals. However, their analyses focused on the latter only, and the size of their simulation samples was relative small. Following Nelson and Kang (1981, 1984), this chapter provides a mathematical proof to show that OLS estimators of detrending method by adding a linear trend in difference stationary processes are spurious. The OLS estimator of the trend converges toward zero in probability, and the other OLS estimator is divergent when the sample size tends to infinity. To perform this proof, the author uses the Chebyshev's inequality. Then, the author designs a statistical series through Monte-Carlo simulation to verify it, with a sample size of a million points as an approximation of infinity. The seed values used correspond to the true random number generated by hardware random number generator in order to avoid the pseudo-randomness of random number given by software. The author repeats such an experiment 100 times, and gets results consistent with the mathematical proof provided.

### **2.1 Introducing the problematic**

The traditional time-series models focused on stationary processes. As a matter of fact, Wold (1954)'s famous decomposition theorem indicated that any covariance-stationary process could be formulated as the sum of infinite white noises. Thanks to this stationary process' property, the ARMA models applying the method proposed by Box and Jenkins (1970) gradually became the main modeling in time-series analysis. But what happens when the series are not stationary?

By simulating two distinct random walks and regressing one to another, Granger and Newbold (1974) revealed the "spurious regression problem." The OLS estimators of the correlation between these two independent random walks should be zero, but the Monte Carlo simulations performed by the econometricians indicated OLS estimators significantly different from zero, along with very high  $R^2$ . They put forward the idea that such a regression is "spurious," because it makes no sense, even when it exhibits very high  $R^2$ . Other authors, such as Phillips (1986) or Davidson and MacKinnon (1993), revealed similar results, leading to the following conclusions: *i*) If the dependent variable is integrated of order 1, that is to say,  $I(1)$ , then under null hypothesis, the residuals of the regression would also be  $I(1)$ . However, as the usual statistical tests of the OLS estimators (Fisher or Student tests) are based on a hypothesis of residuals as white noise, these tests are no longer effective if such an assumption is not maintained. *ii*) Some asymptotic properties are no longer valid, such as those of the ADF statistics, because they did not obey the same laws in the case of stationary processes. *iii*) As the residuals are also  $I(1)$ , the previsions are not efficient - except when there exists a cointegration relationship between variables.

Here, the author only examines time-series nonstationarity in average, to be distinguished from that in variance. Since Nelson and Plosser (1982)'s contribution, nonstationarity in average can itself be classified into two categories: the first one is related to trend-stationary (TS) processes which present nonstationarity because of the deterministic trends characterizing their structure; the second category is linked to difference-stationary (DS) processes which contain a stochastic structure, or unit root. The processes considered can be made stationary by adding or removing the deterministic trends in the regressions in the case of TS processes, or, alternatively, in the case of DS processes, through difference operators, going from ARMA to ARIMA.

Unit root tests are generally used to identify the nature of a nonstationary process, whether deterministic or stochastic. For DS, in particular, a solution is offered within ARIMA models through difference operators or the cointegration methods respectively proposed by Engle and Granger (1987) in a univariate approach, and by Johansen (1991) in a multivariate approach. Meanwhile, Stock (1987) has demonstrated that, within such frameworks, the OLS estimators converge toward the real values if the variables are cointegrated, and the speed of convergence is faster than that of the usual case (that is,  $1/T$  instead of  $1/\sqrt{T}$ , where  $T$  is the sample size).

The cointegration theory achieved great success, but it has several inconveniences. It requires indeed that all the variables must be integrated in the same order; otherwise, the cointegration models cannot be applied. However, it is difficult to make sure that all series have the same order of integration in the economic model which is tested. For example, GDP growth rates are often  $I(0)$ , while some price indices can be  $I(2)$ . Moreover, a supplementary difficulty in using difference operators destined to stabilize a DS process comes from the fact that variables in various orders of difference may not match the theoretical models which are employed.

It comes that the detrending method consisting in adding a linear trend in the regression has become common in the empirical studies, due to its simplicity and its compatibility with a wide range of models. Many authors have chosen to add a linear trend in their regressions when they considered their dependent variables as nonstationary. Thus, detrending methods are often used in TS processes despite the nonstationary nature of the latter. Nevertheless, TS detrending method cause specific problems when the series is in fact a DS process.

Studying the implications of treating TS processes as DS processes with the application of a difference operator, Chan, Hayya and Ord (1977) found that the difference operator creates an artificial disturbance in the differentiated series. Indeed, the autocorrelation function equals to  $-1/2$  when  $lag = \pm 1$ . Later, Nelson and Kang (1981) examined the reverse case, i.e., the effects of treating DS processes as TS processes by adding a linear trend in the regression, and stated that, when a detrending method is used, the covariance of the residuals depends on the size of the sample and on time. By simulation, they showed that adding a linear trend in the regressions for DS processes generates a strong artificial autocorrelation of the residuals for the first lags, and thus induces a pseudo-periodicity - the corresponding spectral density function exhibiting a single peak at a period equal to 0.83 of the sample size. More precisely, treating TS processes as DS processes by difference operator artificially creates a "short-run" cyclical movement in the series, while, conversely, a "long-run" cyclical movement is artificially generated when treating DS processes as TS processes.<sup>7</sup>

---

<sup>7</sup> We speak about "short-run," since the disturbance happens when  $lag = \pm 1$ , and "long-run," because the problem appears when the period corresponds to 0.83 of the sample size, or almost the same importance than the latter.

These fundamental studies have shown the importance of distinguishing between TS and DS processes, but remained concentrated on artificial correlations of the residuals. None of them focused on the OLS estimators themselves. In addition, the samples which are used are relatively small. Following Nelson and Kang (1981)'s research line, we shall mathematically demonstrate that the OLS estimators of detrending method by adding a linear trend in DS processes can be considered as spurious. As we shall see, the OLS estimator of the trend tends to zero when the sample size tends to infinity, while the other OLS estimator (intercept) is divergent in the same situation. After this, we shall design a simulation series to be experimented on a sample of a million observations. The seed values are given by Rand Corporation (2001). As the dataset of simulation contains more than 100 million points, we shall present in *Appendix 2.1* the program built by SAS with the seed values table, so that the readers will be in condition to reproduce the simulations with the same codifications.

## 2.2 A mathematical proof

We suppose that  $y_t$  is a DS; for example, the random walk:

$$y_t = y_{t-1} + v_t \quad (2.1)$$

Where  $v_t$  is a white noise that  $E(v_t) = 0$  (2.2) and  $E(v_i v_j) = \begin{cases} \sigma^2, & \text{for } i = j \\ 0, & \text{for } i \neq j \end{cases}$  (2.3)

Let us apply a time detrending method by adding a linear trend in the regression; that is to say, we have the model:

$$y_t = \alpha + \beta t + \varepsilon_t \quad (2.4)$$

where  $\alpha$  and  $\beta$  are coefficients to be estimated, and  $t$  is the time variable:  $t = 1, 2, 3 \dots T$ , with  $T$  the sample size, or number of observations.  $\varepsilon_t$  is the innovation.

Suppose:  $X_t = \begin{pmatrix} 1 \\ t \end{pmatrix}$ ,  $\gamma = \begin{pmatrix} \alpha \\ \beta \end{pmatrix}$ , and  $b_T$  is the OLS estimators of  $\gamma$  based on a sample of size  $T$ . We get:

$$b_T = \begin{pmatrix} \widehat{\alpha}_T \\ \widehat{\beta}_T \end{pmatrix} = \left[ \sum_{t=1}^T X_t X_t' \right]^{-1} \left[ \sum_{t=1}^T X_t y_t \right] \quad (2.5)$$

For the term:

$$\left[ \sum_{t=1}^T X_t X_t' \right] = \begin{bmatrix} \sum_{t=1}^T 1 & \sum_{t=1}^T t \\ \sum_{t=1}^T t & \sum_{t=1}^T t^2 \end{bmatrix} = \begin{bmatrix} T & T(T+1)/2 \\ T(T+1)/2 & T(T+1)(2T+1)/6 \end{bmatrix}$$

then<sup>8</sup>:

$$\begin{aligned} & \left[ \sum_{t=1}^T X_t X_t' \right]^{-1} \\ &= \frac{1}{T^2(T+1)(2T+1)/6 - T^2(T+1)^2/4} \begin{bmatrix} T(T+1)(2T+1)/6 & -T(T+1)/2 \\ -T(T+1)/2 & T \end{bmatrix} \\ &= \frac{2}{T(T-1)} \begin{bmatrix} 2T+1 & -3 \\ -3 & 6/(T+1) \end{bmatrix} \end{aligned}$$

And for the term:

---

<sup>8</sup> Because  $\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{ad-bc} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$

$$\left[ \sum_{t=1}^T X_t y_t \right] = \begin{pmatrix} \sum_{t=1}^T y_t \\ \sum_{t=1}^T t y_t \end{pmatrix}$$

so:

$$\begin{aligned} \begin{pmatrix} \widehat{\alpha}_T \\ \widehat{\beta}_T \end{pmatrix} &= \frac{2}{T(T-1)} \begin{bmatrix} 2T+1 & -3 \\ -3 & 6/(T+1) \end{bmatrix} \begin{pmatrix} \sum_{t=1}^T y_t \\ \sum_{t=1}^T t y_t \end{pmatrix} \\ &= \frac{2}{T(T-1)} \begin{pmatrix} (2T+1) \sum y_t - 3 \sum t y_t \\ -3 \sum y_t + \frac{6}{T+1} \sum t y_t \end{pmatrix} \quad (2.6) \end{aligned}$$

Thus, we have, respectively:

$$\begin{cases} \widehat{\alpha}_T = \frac{2}{T(T-1)} [(2T+1) \sum y_t - 3 \sum t y_t] \\ \widehat{\beta}_T = \frac{6}{T(T-1)} \left( - \sum y_t + \frac{2}{T+1} \sum t y_t \right) \end{cases} \quad (2.7)$$

However, initially, we have seen that:

$$y_t = y_{t-1} + v_t$$

That is:

$$y_t = y_0 + \sum_{j=1}^t v_j \quad (2.8)$$

Therefore:

$$\begin{aligned} \sum_{t=1}^T y_t &= \sum_{t=1}^T \left( y_0 + \sum_{j=1}^t v_j \right) = T y_0 + T v_1 + (T-1) v_2 + \dots + 2 v_{T-2} + v_T \\ &= T y_0 + \sum_{t=1}^T (T+1-t) v_t = T y_0 + (T+1) \sum_{t=1}^T v_t - \sum_{t=1}^T t v_t \quad (2.9) \end{aligned}$$

and:

$$\begin{aligned} \sum_{t=1}^T t y_t &= \sum_{t=1}^T t \left( y_0 + \sum_{j=1}^t v_j \right) = y_0 \sum_{t=1}^T t + \sum_{t=1}^T t \left( \sum_{j=1}^t v_j \right) \\ &= y_0 \frac{(T+1)T}{2} + (1 + \dots + T) v_1 + (2 + \dots + T) v_2 + \dots + (T-1 + T) v_{T-2} + T v_T \\ &= y_0 \frac{(T+1)T}{2} + \sum_{t=1}^T \frac{(T+t)(T-t+1)}{2} v_t \\ &= y_0 \frac{(T+1)T}{2} + \frac{T(T+1)}{2} \sum_{t=1}^T v_t + \frac{1}{2} \sum_{t=1}^T t v_t - \frac{1}{2} \sum_{t=1}^T t^2 v_t \quad (2.10) \end{aligned}$$

It becomes:

$$\widehat{\alpha}_T = y_0 + \frac{(T+1)(T+2)}{(T-1)T} \sum_{t=1}^T v_t - \frac{4T+5}{T-1} \sum_{t=1}^T \frac{t}{T} v_t + \frac{3T}{T-1} \sum_{t=1}^T \frac{t^2}{T^2} v_t \quad (2.11)$$

and

$$\widehat{\beta}_T = -\frac{6}{(T-1)} \cdot \frac{1}{T} \sum_{t=1}^T v_t + \frac{6T(T+2)}{(T+1)(T-1)} \cdot \frac{1}{T} \sum_{t=1}^T \frac{t}{T} v_t - \frac{6T^2}{(T+1)(T-1)} \cdot \frac{1}{T} \sum_{t=1}^T \frac{t^2}{T^2} v_t \quad (2.12)$$

We denote that:

$$\begin{cases} \widehat{\alpha}_T = y_0 + \theta_1 A + \theta_2 B + \theta_3 C \\ \widehat{\beta}_T = \theta_4 D + \theta_5 E + \theta_6 F \end{cases} \quad (2.13)$$

Where  $\theta_1 = \frac{(T+1)(T+2)}{(T-1)T}$ ,  $\theta_2 = -\frac{4T+5}{T-1}$ ,  $\theta_3 = \frac{3T}{T-1}$ ,  $\theta_4 = -\frac{6}{(T-1)}$ ,  $\theta_5 = \frac{6T(T+2)}{(T+1)(T-1)}$ ,  $\theta_6 = -\frac{6T^2}{(T+1)(T-1)}$ . And  $A = \sum_{t=1}^T v_t$ ,  $B = \sum_{t=1}^T \frac{t}{T} v_t$ ,  $C = \sum_{t=1}^T \frac{t^2}{T^2} v_t$ ,  $D = \frac{1}{T} A$ ,  $E = \frac{1}{T} B$ ,  $F = \frac{1}{T} C$ .

As  $v_t$  is white noise obviously:

$$\begin{cases} E(\widehat{\alpha}_T) = y_0 \\ E(\widehat{\beta}_T) = 0 \end{cases} \quad (2.14)$$

For their variances:

$$\begin{cases} \text{Var}(\widehat{\alpha}_T) = E(\widehat{\alpha}_T - y_0)^2 = E(\theta_1 A + \theta_2 B + \theta_3 C)^2 \\ \text{Var}(\widehat{\beta}_T) = E(\widehat{\beta}_T - 0)^2 = E(\widehat{\beta}_T)^2 = E(\theta_4 \frac{1}{T} A + \theta_5 \frac{1}{T} B + \theta_6 \frac{1}{T} C)^2 \end{cases} \quad (2.15)$$

More precisely

$$\text{Var}(\widehat{\alpha}_T) = \theta_1^2 \text{Var}(A) + \theta_2^2 \text{Var}(B) + \theta_3^2 \text{Var}(C) + 2\theta_1\theta_2 \text{Cov}(A, B) + 2\theta_1\theta_3 \text{Cov}(A, C) + 2\theta_2\theta_3 \text{Cov}(B, C) \quad (2.16)$$

$$\text{Var}(\widehat{\beta}_T) = \frac{1}{T^2} [\theta_4^2 \text{Var}(A) + \theta_5^2 \text{Var}(B) + \theta_6^2 \text{Var}(C) + 2\theta_4\theta_5 \text{Cov}(A, B) + 2\theta_4\theta_6 \text{Cov}(A, C) + 2\theta_5\theta_6 \text{Cov}(B, C)] \quad (2.17)$$

We can calculate that<sup>9</sup>:

$$\text{Var}(A) = T\sigma^2 \quad (2.18)$$

$$\text{Var}(B) = \frac{(T+1)(2T+1)}{6T} \sigma^2 \quad (2.19)$$

$$\text{Var}(C) = \frac{(T+1)(2T+1)(3T^2+3T-1)}{30T^3} \sigma^2 \quad (2.20)$$

$$\text{Cov}(A, B) = \frac{T+1}{2} \sigma^2 \quad (2.21)$$

$$\text{Cov}(A, C) = \frac{(T+1)(2T+1)}{6T} \sigma^2 \quad (2.22)$$

$$\text{Cov}(B, C) = \frac{(T+1)^2}{4T} \sigma^2 \quad (2.23)$$

When  $T \rightarrow +\infty$ , we get, respectively:

$\theta_1 \rightarrow 1$ ,  $\theta_2 \rightarrow -4$ ,  $\theta_3 \rightarrow 3$ ,  $\theta_4 \rightarrow 0$ ,  $\theta_5 \rightarrow 6$ , and  $\theta_6 \rightarrow -6$ . All of them are constant and as consequence:

$$\begin{cases} \text{Var}(\widehat{\alpha}_T) \rightarrow \infty \\ \text{Var}(\widehat{\beta}_T) \rightarrow 0 \end{cases} \quad (2.24)$$

<sup>9</sup> We have used the Faulhaber's formula to calculate the sum of the  $p$ -th powers of the first  $T$  positive integers for  $p=1,2,3$  and 4.

We see that  $\widehat{\alpha}_T$  is a random variable with infinite variance as the sample size  $T$  goes to infinity and on the other hand the variance of  $\widehat{\beta}_T$  tends toward to zero. Thus for each realization of the sequence  $\{y_t\}_{t=1}^T$ ,  $\widehat{\alpha}_T$  is divergent and  $\widehat{\beta}_T$  converges to zero according to the Chebyshev's inequality.<sup>10</sup>

According to the general version of the Chebyshev's inequality, we know that, for  $\widehat{\beta}_T$ :

$$\begin{aligned}\Pr(|\widehat{\beta}_T - E(\widehat{\beta}_T)| \geq k\sigma_{\widehat{\beta}_T}) &\leq \frac{1}{k^2} \\ \Pr(|\widehat{\beta}_T - 0| \geq k\sigma_{\widehat{\beta}_T}) &\leq \frac{1}{k^2} \\ 1 - \Pr(|\widehat{\beta}_T| \geq k\sigma_{\widehat{\beta}_T}) &\geq 1 - \frac{1}{k^2} \quad (2.25)\end{aligned}$$

As

$$\begin{aligned}1 - \Pr(|\widehat{\beta}_T| \geq k\sigma_{\widehat{\beta}_T}) &= \Pr(|\widehat{\beta}_T| \leq k\sigma_{\widehat{\beta}_T}) \\ \Pr(|\widehat{\beta}_T| \leq k\sigma_{\widehat{\beta}_T}) &\geq 1 - \frac{1}{k^2} \quad (2.26)\end{aligned}$$

From above we already know that when  $T \rightarrow +\infty$ ,  $\sigma_{\widehat{\beta}_T} \rightarrow 0$  and evidently  $|\widehat{\beta}_T| \geq 0$

So:

$$\lim_{T \rightarrow +\infty} \Pr(|\widehat{\beta}_T| \leq k\sigma_{\widehat{\beta}_T}) = \Pr(|\widehat{\beta}_T| = 0) \geq 1 - \frac{1}{k^2} \quad (2.27)$$

for any  $k > 0$ , when  $k \rightarrow +\infty$ ,  $\Pr(|\widehat{\beta}_T| \leq 0) \geq 1$ .

Obviously:

$$\Pr(\widehat{\beta}_T = 0) = 1 \quad (2.28)$$

Consequently<sup>11</sup>, we can infer that, when  $T \rightarrow +\infty$ , then:  $\widehat{\beta}_T \xrightarrow{P} 0$ .

The disturbance terms  $\{v_t\}$  are assumed to be identical independent white noise. In fact, we can relax this assumption. Only if  $\{v_t\}$  is martingale difference sequence, we could use the law of large number for  $L^1$ -Mixingale sequence proposed by Andrews (1988). The conclusions are still hold. That is to say, the spurious regression exists in a much more border sense in reality.

Turning back to the OLS estimator  $b_T$ , we see that, when  $T \rightarrow +\infty$ ,  $\widehat{\alpha}_T$  is not convergent, and  $\widehat{\beta}_T$  converges to zero in probability. So, when the sample size grows to infinity, the coefficient of the trend will tend to zero. This means that this trend is useless. We are still regressing indeed a random walk to another one. The high  $R^2$  of the regressions observed in the literature might just be caused by the similarity between a trend and a random walk in the short run, like in the simulations performed by Newbold and Granger (1974). In other words, adding a linear trend in the regressions for DS processes would not play any significant role; and it would even involve “new” spurious regressions in the sense of Granger and Newbold (1974).

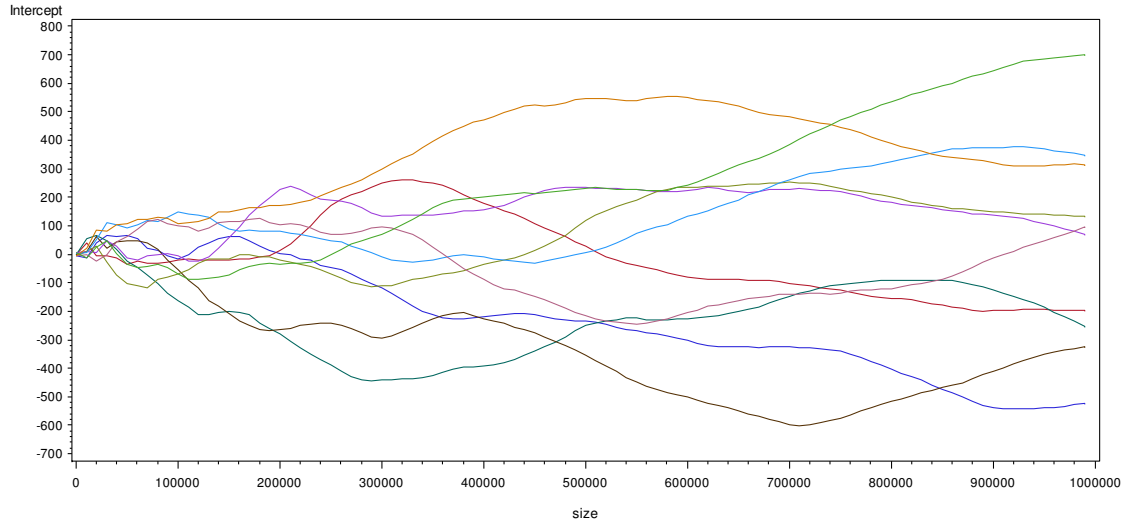
As Box and Draper (1987) pertinently wrote it: “Essentially, all models are wrong, but some are useful” (p. 424).

<sup>10</sup> See here, among many others: Fischer (2010). Also: Knuth (1997). And originally: Chebyshev (1867). We use the version of: If  $X$  is a random variable,  $E(X) = \mu$ ,  $V(X) = \sigma^2$  for  $\forall k \in R$  and  $k > 0$ , and then:

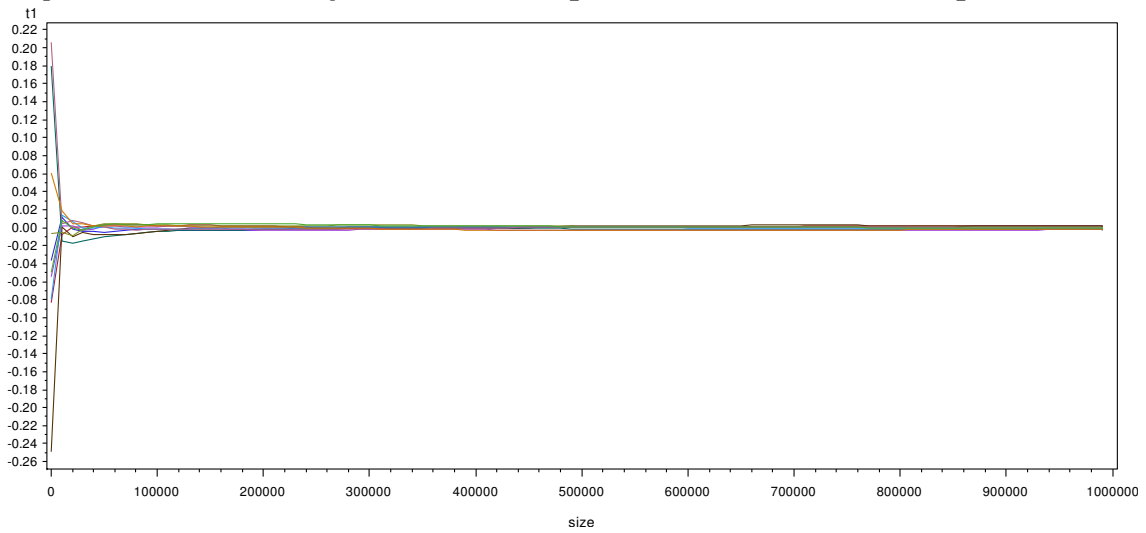
$$\Pr(|X - \mu| \geq k\sigma) \leq \frac{1}{k^2}$$

<sup>11</sup> Or simply we say that as  $\widehat{\beta}_T \xrightarrow{m.s.} 0$  according to Chebyshev's inequality we must have  $\widehat{\beta}_T \xrightarrow{P} 0$ .

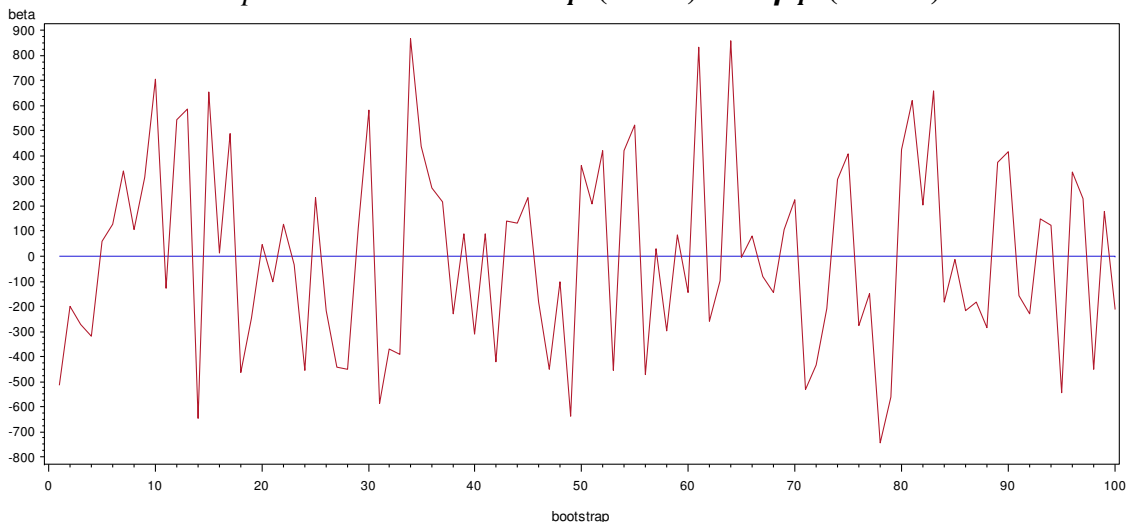
**Graph 2.1 Evolutions of  $\widehat{\alpha}_T$  when the sample size increases from 100 up to 1,000,000**



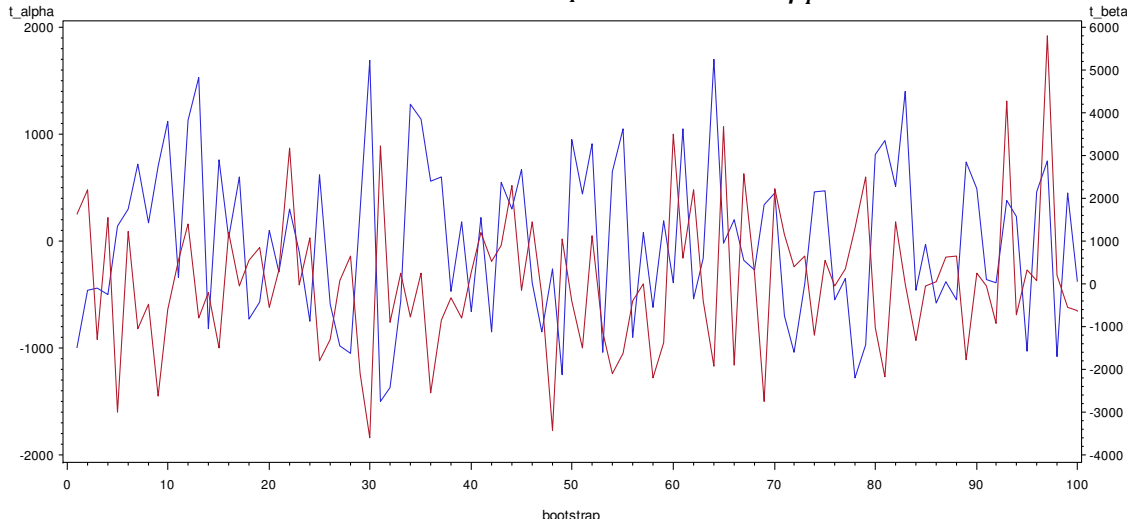
**Graph 2.2 Evolutions of  $\widehat{\beta}_T$  when the sample size increases from 100 up to 1,000,000**



**Graph 2.3 Simulations of  $\widehat{\alpha}_T$  (in red) and  $\widehat{\beta}_T$  (in blue)**



**Graph 2.4 Simulations of  $\widehat{t}_{\widehat{\alpha}_T}$  (in red) and  $\widehat{t}_{\widehat{\beta}_T}$  (in blue)**



### 2.3 Verification by simulation

Now, in order to verify this mathematical proof, let us simulate the model by SAS through Monte-Carlo simulation. To do that, we shall follow four successive steps:

- *Step 1:* We generate a white noise,  $v_t$ , with a sample size of  $T = 1,000,000$ . Here, we set the white noise as Gaussian. The seed values employed for the simulations at this step are provided by Rand Corporation (2001) with a hardware random number generator to make sure that the simulations effectively use true random numbers (*Appendix 2.2*), because the random number generated by software is in fact a “pseudorandom.”
- *Step 2:* We generate a random walk,  $y_t$ , in our original equation by setting  $y_0 = 0$ :

$$y_t = y_{t-1} + v_t$$

$y_t$  also having a million observations.

- *Step 3:* We then regress the DS,  $y_t$ , to a linear trend with an intercept.
- *Step 4:* We repeat this experiment 100 times successively, and each time, we use a different true random number as a seed value.

The simulation results appear to be consistent with the mathematical proof. The details of  $\widehat{\alpha}_T$ ,  $\widehat{\beta}_T$ , and  $R^2$  are summarized in *Table 2.1* and in *Appendix 2.3*. Besides, *Graphs 2.1* and *2.2* (presenting the first 10 simulations only to make them concise) show the evolutions of  $\widehat{\alpha}_T$  and  $\widehat{\beta}_T$  when the sample size grows from 100 up to 1,000,000 points, while the simulations of  $\widehat{\alpha}_T$ ,  $\widehat{\beta}_T$ ,  $\widehat{t}_{\widehat{\alpha}_T}$ , and  $\widehat{t}_{\widehat{\beta}_T}$  generated by various seed values with a true random number are shown in *Graphs 2.3* and *2.4*.

**Table 2.1 Summary of the simulation results, with a sample size of  $T = 1,000,000$**

	$\widehat{\alpha}_T$	$\widehat{t}_{\widehat{\alpha}_T}$	$\widehat{\beta}_T$	$\widehat{t}_{\widehat{\beta}_T}$	$R^2$
<b>Mean</b>	6.11764361	6.14650186	0.00002174	60.0860629	0.45983
<b>Variance</b>	143633.942	554191.079	1.57763E-6	2744822.52	0.10287
<b>Standard Deviation</b>	378.990689	744.440111	0.00125604	1656.75059	0.32073
<b>Max</b>	867.64848	1707.15789	0.00307578	5799.95595	0.97113
<b>Min</b>	-743.23667	-1501.88113	-0.00245505	-3604.89913	1.15357E-05
<b>P-value of null test</b>	0	-	0	-	-

*Note:* The location tests of  $\widehat{\alpha}_T$  and  $\widehat{\beta}_T$  cannot be the judgments of convergence to zero because the convergence means that the latter occurs within the sample when  $T$  tends to infinity.



At this level of the reasoning, several important results must be underlined:

(1) From *Graphs 2.1* and *2.2*, we can observe that  $\widehat{\alpha}_T$  is divergent, with its variance increasing when the sample size grows, while  $\widehat{\beta}_T$  converges to zero. The simulation results therefore confirm the mathematical proof previously provided. In addition, from *Graph 2.2*, we see that the sample size should be greater than at least 1,000 to get a conclusion of convergence becoming clear. That is, the size of the samples simulated by Granger and Newbold (1974) or Nelson and Kang (1981) seem to be not big enough to support their conclusions, even if the latter are right, and can be confirmed and re-obtained by our own simulations mobilizing 1,000,000 observations as an approximation of infinity.<sup>12</sup>

(2) From *Graph 2.3*, we observe that, as expected, when  $T \rightarrow +\infty$ ,  $\widehat{\beta}_T$  converges to zero<sup>13</sup> and  $\widehat{\alpha}_T$  is divergent even if the seed values are modified. For 100 different simulations, the conclusions still hold, which indicates that there is no problem of pseudo-randomness in our simulations.<sup>14</sup> By performing them, as we set all  $y_0$  equal to zero, if  $\widehat{\alpha}_T$  is convergent, then it must converge to  $y_0$ , *i.e.*, to zero. However,  $\widehat{\alpha}_T$  seriously deviates from its mathematical expectation zero for different simulations. Thus, the regressions are spurious because the OLS estimator of the trend converges to zero and the other OLS estimator diverges when the sample size tends to infinity.

(3) From the last column of *Table 2.1*, we see that, sometimes, these regressions get a very high  $R^2$  (the highest being 0.97, with an average of 0.45 for the 100 experiments). This is a classic result associated to spurious regressions, already pointed out by Granger and Newbold (1974).

(4) From *Table 2.1* and *Graph 2.4*, we see that the t-statistics of the OLS estimators are very high, and that all the p-values of  $H_0: \widehat{\alpha}_T = 0$  and  $H_0: \widehat{\beta}_T = 0$  are zero. Thus, the OLS estimators are definitely significant when the sample size tends to infinity. This is also a well-known result associated to spurious regressions, since the residuals are not white noises<sup>15</sup>. In these conditions, we understand that the usual and fundamental Fisher or Student tests of the OLS estimators are no longer valid, precisely because they are based on the assumption of residuals as white noises. If we use such a detrending method in DS processes, we will indeed get wrong conclusions of significance of the explicative variables.

We understand that our results call for a re-examination of the robustness of the classic findings in macroeconomics. To give an example, in a famous paper, Mankiw, Romer and Weil (1992) identified a significant and positive contribution of education to the *per capita* GDP growth rate. In a theoretical framework close to a Solowian model, their approach consisted in augmenting a production function with constant returns to scale and decreasing marginal factorial returns, by including a variable of human capital in order to regress in logarithms *per capita* GDP to the investment rates of physical capital and of schooling. Their conclusion is probably accurate; but, as they added a linear trend as a detrending method, whatever the input variable that is selected, it will be found statistically significant as long as

---

<sup>12</sup> The sample size was 50 for Granger and Newbold (1974) and 101 (in order to calculate a sample autocorrelation function of 100 lags) for Nelson and Kang (1981). This is probably because the computers' calculation capacity was much less powerful in the 1970s than today. Thanks to the progress in computing science, we can reinforce the statistical credibility of their findings.

<sup>13</sup> The magnitude level of  $\widehat{\beta}_T$  is  $10^{-5}$  considering that the decimal precision of the 32-bits computer used is  $10^{-7}$ , which is almost not-different from zero.

<sup>14</sup> Even if their conclusions are correct, the simulations by Granger and Newbold (1974) as well as by Nelson and Kang (1981) did not pay attention to the pseudo-randomness, nor specify how the random numbers are obtained.

<sup>15</sup> As indicated above, and studied by Nelson and Kang (1981), we did not test the correlation of the residuals here.

the size of their sample is sufficiently large. Our own study has described, in an original manner, the behavior of OLS estimators themselves when the sample size tends to infinity. By comparison, the samples used for simulation by Chan, Hayya and Ord (1977), or Nelson and Kang (1981), are relatively small – even if, obviously, they were extremely useful.

## 2.4 Concluding remarks

The introduction of a linear trend generally aimed at avoiding spurious regressions. However, Nelson and Kang (1981), following Chan, Hayya and Ord (1977), had showed that, in OLS estimates, the assimilation of a difference-stationary process (DS) – the most probable process for GDP, with that of unit root, according to Nelson and Plosser (1982) - to a trend-stationary process (TS),<sup>16</sup> can lead to a situation where the covariance of the residuals depends on the size of the sample, which artificially induces an autocorrelation of the residuals for the lags, and, by generating a pseudo-periodicity in the latter, generates a cyclical movement into the series. But their analyses mainly focused on the residuals, and their simulated sample size remained small. Here, following Nelson and Kang (1981)'s research line, and using the Chebyshev's inequality, we have given a strict mathematical proof of the fact that the OLS estimators of a detrending method by adding a linear trend in DS processes are spurious. When the sample size tends to infinity, the OLS estimator of the trend converges toward zero in probability, while the other OLS estimator is divergent. The empirical verification attempted by designing a series through Monte-Carlo method and by performing simulations on a sample of a million observations as an approximation of infinity and true random numbers as seed values has finally provided results consistent with the mathematical proof.

Thus, in the context which has been specified here, our main conclusion according to which the OLS estimators themselves are spurious when the sample size increases also implies that identifying the nature of time series becomes extremely important. For example, it is crucial to decide whether GDP series are to be treated as TS or DS processes - in a short-run context in which random walks usually look like TS processes.<sup>17</sup> Even if their effectiveness is questioned, especially because of the sensitivity of the choice of the truncation parameters, we recommend using unit root tests to reduce the risk of inappropriately selecting the detrending method, but by regressing the variables of the models used in the first differences of the logarithm forms when such tests show that they contain unit roots.<sup>18</sup> From a theoretical point of view, regressions in the first differences of the logarithm forms<sup>19</sup> are acceptable both by neoclassic and Keynesian modeling, in which they can easily be interpreted in terms of growth-rate dynamics; and from an econometric point of view, logarithms might be useful when a problem of heteroscedasticity appears, while difference operators can help to avoid spurious regressions if there are unit roots. To avoid the over-differencing problem, we finally recommend using inverse autocorrelation functions (IACF) to determine the order of integration, along with unit root tests and correlogram.<sup>20</sup> That is to say, we suggest the following modelling strategy: *i*) if the unit roots tests and correlogram indicate that the variables are stationary in the first differences of the logarithm forms; we stay in traditional time series regressions. *ii*) If the variables contain unit roots in the first differences of the

---

<sup>16</sup> As did it Chow and Li (2002), among others, while the log of China's GDP may present a unit root...

<sup>17</sup> On the basis of many macroeconomic series, Nelson and Plosser (1982) have stated that GDP series would be DS rather than TS processes. More recent studies, such as that by Darné (2009), have reexamined GNP series with new unit root tests, and shown that the US GNP expressed in real terms seems to be a stochastic trend.

<sup>18</sup> Such an advice has been applied in a recent study on China's long-run growth using a new time-series database of capital stocks from 1952 to 2014 built through an original methodology. See: Long and Herrera (2016a, 2017a).

<sup>19</sup> Just like the same suggestion of Hamilton (1994, Page110) for ARMA modelling.

<sup>20</sup> See: Cleveland (1972), Chatfield (1980), and Priestley (1981).

logarithm forms, we could pass to cointegration framework or effectuate a second difference operation. *iii*) If unit root tests and correlogram both indicate that the series seem be stationary but IACF indicates that the series might be over-differenced<sup>21</sup> that implies an integer order of integration is not sufficient, the true order of integration might be between 0 and 1. That is to say, we might need to pass from traditional time series models to fractal theory<sup>22</sup> such as ARFIMA models or fractional cointegration.

---

<sup>21</sup> In this case, ACF and PACF present characteristics of stationary process (or decrease hyperbolically) while IACF presents characteristics of nonstationary process.

<sup>22</sup> Hosking (1981)

## **Chapter 3**

# **BUILDING ORIGINAL SERIES OF PHYSICAL CAPITAL STOCKS FOR CHINA'S ECONOMY**

### *Methodological Problems, Proposals for Solutions and a New Database*

There are to date no official Chinese statistics relating to capital stocks. This lack data hinders econometric studies of growth in this country. Series of such stocks are proposed in the literature, but most available empirical work on this topic suffers multiple deficiencies. The purpose of this chapter is to build the most reliable and longest possible statistical series of capital stocks for China. Our initial capital stocks are calculated on the basis of an output-capital ratio which is less approximate (and lower) than those generally provided and the ration is obtained by an iteration procedure. Our investment flows are consistent with the perimeters of the initial stocks. Our investment price indices are strictly tailored to the content of these stocks, and the unit root tests show that all the indices are non-stationary and integrated to the order of 2. This means they cannot be substitutes, as supposed in many other studies. Our depreciation rates are estimated by type of capital, under assumptions consistent with age-efficiency and retirement. Investment shares are used to approximate an overall capital structure and to calculate a total depreciation rate. Built from 1952 to 2014, our original series are available to econometricians seeking to conduct new empirical studies on China, over the long run.

### **3.1 Introduction**

As of today, there are still no official statistics issued by the People's Republic of China for physical capital stocks, even though this is a fundamental variable for understanding the accumulation and growth dynamics of this economy. Although China is working with the Organisation for Economic Co-operation and Development (OECD), especially in the context of a "resolution of enhanced engagement", there is no plan in the near future for the National Bureau of Statistics (NBS) of China<sup>23</sup> to publish such series, in line with the harmonized standards of the OECD.<sup>24</sup> This lack of referential data greatly hinders the possibilities of performing econometric estimates of growth models using time-series, as well as panel-data, for this country. Nevertheless, many empirical analyses of the current extraordinary expansion of China exist in the literature, but a vast majority of them does not use capital stocks. Of course, some attempts of building China's capital stock series have been made, beginning with those by the Penn World Tables (PWT).<sup>25</sup> However, it must be observed that most of them face difficulties and reveal multiple deficiencies. The purpose of this chapter is to identify these methodological problems and suggest proposals for solutions in order to build original series of China's physical capital stocks which are as reliable and long as possible.

### **3.2 General issues and the construction method of physical capital stocks**

In the area that concerns us here, problems stem primarily from the scarcity of historical data prior to 1949 (the date of China's independence). But there are also problems with the recent

---

<sup>23</sup> See: [www.stats.gov.cn/english/](http://www.stats.gov.cn/english/).

<sup>24</sup> Read, for example: OECD (2001). Also: Ward (1976).

<sup>25</sup> Cf. <https://ptw-sas.upenn.edu> and, for the most recent version (8.1): [www.rug.nl/research/ggdc/data/ptw](http://www.rug.nl/research/ggdc/data/ptw).

period, stemming from statistical breaks; the most significant of which occurred in 1993 with the transition from the Chinese accounting established according to balances in the Material Product System (MPS) to the implementation of the System of National Accounts (SNA).<sup>26</sup> This change has made comparisons involving both chronological and transversal series risky. In addition, it is an understatement to say that for people who do not read Chinese, the task is difficult to find the information needed for the construction of new statistics from the abundant but scattered yearbooks published by the Chinese authorities. Several economists, be they foreigners or Chinese (including Gregory C. Chow) have used capital stocks they had built themselves with varying success, at the national, provincial or sectorial level. The series that can be considered as the most credible and seriously conceived are those of Chow (1993) and his co-authors. However, the statistical regime transformation in 1993 led to the suspension of the issuing of the documents used as a basis for elaborating these series, which are now unavailable. The PWT include China. But for many critical points, the explanatory notes provided by their compilers are strangely blurred, by not distinguishing the methodology employed for the country studied here from those applied to the numerous other countries covered by this famous inter-university program. Some other databases are available in the literature (*Table 3.1*), but their calculation modalities, even when inspired by the perpetual inventory method (PIM),<sup>27</sup> are frequently tarnished by estimation biases, due to an approximate application of this approach. Our criticisms mainly focus on the questionable parameterization of initial capital stock and of the depreciation rate. They also relate to the uncertain content of investment series and, above all, to inappropriate choices of price indices.

**Table 3.1 Some examples of series of physical capital stocks for China**

<b>Authors</b>	<b>Level of analysis</b>	<b>Period</b>
Zhang Junk. (1991)	National	1952-1990
He J.H. (1992)	National	1952-1992
Chow (1993)	National	1952-1993
Jefferson, Rawski and Zheng (1996)	National	1952-1992
Hu and Khan (1997)	National	1952-1994
Wu F.W. (1999)	Agricultural sector	1980-1999
Wang X. and Fan (2000)	National	1952-1998
Young (2000)	National	1978-1998
Huang, Ren and Liu (2002)	13 manufacturing industries	1978-1995
Li and Tang (2003)	National	1978-2000
Zhang Jun and Zhang Y. (2003)	National	1952-2001
He F., Chen and He L. (2003)	National	1952-2001
Sun and Ren (2003)	33 industrial sectors	1980-1999
Wang Y.X. and Wu Y. (2003)	16 industrial sectors	1980-1998
Zhang Jun, Wu G. and Zhang Ji. (2004)	Provincial	1952-2000
Mao (2005)	National	1978-2002
Holz (2006)	National	1953-2003
Ge (2012)	Infrastructural sector	1953-2008
Wang L. and Szirmai (2012)	National, industrial, manufacturing	1953-(1985)-2007
Wu (2014)	National and 5 sectors	1949-2007

One of the major problems encountered in the current literature is the vagueness of the outlines of the aggregated capital. It is often unclear whether it contains built-up lands or

<sup>26</sup> The last revision (2008) of the SNA is available on: [unstats.un.org/unsd/nationalaccount/sna2008.asp](http://unstats.un.org/unsd/nationalaccount/sna2008.asp).

<sup>27</sup> Read here: Goldsmith (1951), Harberger (1978) and OECD (1993).

developed real property (B)<sup>28</sup> or not, and/or inventories (V). To avoid such a confusion and provide several series enabling the readers to focus their researches according to the conception of capital they use, we distinguish four categories of physical capital stock: (1) a narrowly-defined productive capital stock,  $K_{Pe}$ , excluding the residential buildings and the value of their lands (*i.e.*, built-up land), as well as the inventories; (2) a large stock of productive capital,  $K_{Pl}$ , including the inventories, but not the built-up lands as defined above; (3) a fixed capital stock,  $K_F$ , including built-up lands, but not the inventories; and (4) a total capital stock,  $K_T$ , including built-up lands and inventories.

$$\text{Stock of physical capital} \begin{cases} \text{productive narrowly defined (no built. up lands, no inventories)} & K_{Pe} \\ \text{productive broadly defined (no built. up lands, with inventories)} & K_{Pe} + V = K_{Pl} \\ \text{fixed (with built. up lands, without inventories)} & K_{Pe} + B = K_F \\ \text{total (with built. up lands, with inventories)} & K_{Pe} + B + V = K_T \end{cases}$$

To build these series according to the PIM, we use the standard formula of accumulation<sup>29</sup>:

$$K_t = (1 - \sigma) K_{t-1} + \frac{I_t}{P_t} \quad (3.1)$$

where  $K_t$  is the level of capital stock at the end of year  $t$ ,  $I_t$  the flow of investment in the same year  $t$ ,  $P_t$  the corresponding price index and  $\sigma$  the depreciation rate of capital stock.

Let us examine in turn the four components needed to build our original capital stock series: the level of initial capital; the investment flow; the price index; and the depreciation rate. As usual in Chinese accounting, the monetary unit of measurement of great writing we will use hereafter is hundreds of millions ( $10^8$ , or  $yì$  [in Chinese: 亿]) of yuans (RMB).

### Initial levels of physical capital stocks

To estimate the initial levels of physical capital stocks, we go back to the earliest possible base year, namely 1952. It was then (and not in 1949) that China's mainland territory was completely unified and that the NBS modern statistical system was founded, in order to help prepare calculations of the first five-year plan (1953-1957). The lack of data prior to 1952 prevents the direct recourse to capital stocks derived from reliable historical series. Empirical studies using initial capital stocks for 1952 exhibit significant divergences, due to the different methodologies used by the authors. But even when their assumptions are the same, some discrepancies are found. This is the case, for example, between Hao (2006) and Shan (2008). Although they retain the assumption of a steady state (*i.e.* equal growth rates of capital and product), they clearly obtain different capital stocks for 1952. The differences generally observed can also be explained, as we have said, by the content of these stocks which is often left in limbo. Even the most cited study on the subject does not exhaustively expose the details of calculations, namely that of Chow (1993) whose 1952 initial capital stock was built on the basis of the net value of fixed assets of the state-owned enterprises (SOEs). Here are some of the reasons why we consider it useful to offer readers our own series of physical capital stocks.

<sup>28</sup> The component "built-up lands" is unproductive and does not contain agricultural lands - which are considered to be productive, and valued by land improvement investments.

<sup>29</sup> For the deviation of equation of PIM, see Appendix 3.1.

**Table 3.2 Some estimates of initial physical capital stocks for China**

Authors	Year	Level ( <i>yuans expressed in yì</i> )	Content
He J.H. (1992)	1952	946.000 ( <i>at 1990 prices</i> )	Unspecified
Chow (1993)	1952	1,030.000 ( <i>at 1952 prices</i> )	No land
Hu and Khan (1997)	1978	235.200 ( <i>at 1978 prices</i> )	No land
Wang and Fan (2000)	1952	1,600.000 ( <i>at 1952 prices</i> )	Unspecified
Young (2000)	1952	815.000 ( <i>at 1952 prices</i> )	Probably with land
Huang, Ren and Liu (2002)	1978	5,821.660 ( <i>at 1978 prices</i> )	No land
Zhang Jun and Zhang Y. (2003)	1952	800.000 ( <i>at 1952 prices</i> )	No land
He F., Chen and He L. (2003)	1952	5,428.260 ( <i>at 1990 prices</i> )	Probably with land and inventories
Li and Tang (2003)	1978	14,112.000 ( <i>at 1978 prices</i> )	Probably without land
Sun and Ren (2003)	1980	6,959.350 ( <i>at 1980 prices</i> )	No land
Hao (2006)	1952	1,607.121 ( <i>at 1952 prices</i> )	Probably with land
Shan (2008)	1952	342.000 ( <i>at 1952 prices</i> )	No land

One of the methods to estimate the 1952 level of capital stock is to write it as the sum of investments during several preceding years, weighted by the age-efficiency of various capital goods according to their seniority. Some authors have adopted this approach, despite the scarcity of the available data.<sup>30</sup> In doing so, they had to accept assumptions which we believe are quite exaggerated. In particular, they have assumed that very old macroeconomic data is reliable, such as the data established by Maddison (1995) or, before him, by H.X. Wu (1993), for China's GDP in the 1920-1940s: a period of great upheaval, marked by wars and the absence of data collection (including censuses). These series seem indefensible to us, for several reasons related both to their spatial-temporal incomparability,<sup>31</sup> to inconsistencies in the evaluation of the cost of wars, which is admittedly difficult.<sup>32</sup> Yet it is in general on the basis of such approximations that the investment series are constructed, which are subsequently used to estimate capital stocks. In addition, such series assume, in a usual but quite unjustified manner, that proportions of investment in the GDP are invariable.<sup>33</sup>

A second method consists in rebuilding, by retropolation, a complete series of capital stock thanks to one of its recent, one-off estimates, and to the investment flows. This is what was done, for example, Wang and Wu (2003), using a 1997 value of the SOEs' fixed capital, provided by the Ministry of Finance, and by going back in time to 1980. Here, however, the risk lies in seeing whether any calculation errors contained in this initial value are then conserved throughout the retropolated series of the capital stock.

Consequently, we prefer to move towards a third alternative: that of deriving our capital stock from an evaluation of a capital-output ratio. Most authors who have preceded us in this way (like Zhang [1991] or He *et al.* [2003], among others), base their estimates on a hypothesis of a high coefficient of capital for China in 1952, usually equal to 3, as proposed by Perkins (1988). The PWT suggest a somewhat lower coefficient of 2.6. However, these values seem too strong, for several reasons. It is not likely that China in the early 1950s had a capital-output ratio comparable to India, a country that at the time was relatively more industrialized and for which various official reports<sup>34</sup> give parameters of around 2.5. In addition, it seems illogical that the coefficient of capital for China taken as a whole exceeds

<sup>30</sup> Some examples are: Huang, Ren and Liu (2002) or Sun and Ren (2003).

<sup>31</sup> They cover a China whose territorial space significantly changed with historical events.

<sup>32</sup> The production losses due to the wars suffered by China are most often those that had affected Japan (as calculated by Maddison [1994] to -25%). Therefore, they are largely underestimated when applied to China.

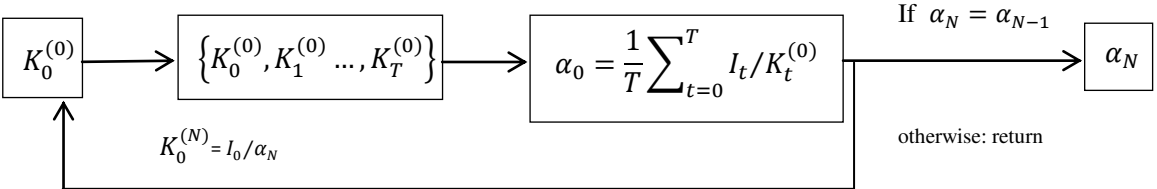
<sup>33</sup> Liu and Yeh (1965, 1973) estimated this ratio to be 5.1% for 1933; a value supported by Feuerwerker (1977).

<sup>34</sup> Among others: Government of India (various years) or The World Bank (1995).

that of Shanghai, which was and is the most developed region, for which statistics of quality also exist.

However, our own calculations, consisting in evaluating a “price” of built-up or construction lands derived from data<sup>35</sup> of the surfaces of built land in 1952 (4,886 x 10,000 m<sup>2</sup>) and 1953 (5,015 x 10,000 m<sup>2</sup>) and of the value corresponding to this property investment (an increase of 129 x 10,000 m<sup>2</sup> being estimated to 0.28 x 100 million yuans), lead to a lower coefficient for Shanghai. If the implicit price of built-up lands is found to be 10.60, and the inventory changes are indicated at 25.10, then it follows that Shanghai’s total capital stock in 1952 would be 69.35; and then the coefficient of capital is 1.89. Although the influence of the level of initial capital on that of current capital decreases with time, the setting of an excessive initial capital stock may lead to the risk of an artificially low growth rate of this stock. It is therefore preferable to calculate, cautiously, the coefficient of capital for the whole China – a coefficient which is probably significantly below that of the Shanghai region.

A determination of the initial level of total capital by an iterative procedure leads to a capital-output ratio at 1.50 in 1952. By setting any (positive non-zero) value of the base capital  $K_0^{(0)}$  and by estimating the stock series  $\{K_0^{(0)}, \dots, K_T^{(0)}\}$  according to the PIM, we get the average share  $I_t/K_t$  as  $\alpha_0 = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(0)}$ ; a share used to recalculate a second initial capital stock  $K_0^{(1)}$  and get the capital series  $\{K_0^{(1)}, \dots, K_T^{(1)}\}$  as well as a new average proportion of  $I_t/K_t$ :  $\alpha_1 = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(1)}$ , until we finally find an unchanged  $K_0^{(N)}$ , that is,  $\alpha_N = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(N)} = \alpha_{N-1} = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(N-1)}$ . This procedure by iterations can be used because the proportion  $I_t/K_t$  is mathematically convergent when  $t$  tends towards  $\infty$ . It is represented by the following chart:



Our procedure (*Appendix 3.2*) converges towards a value of  $K_0$  of 1,018.5 in 1952, equivalent to a coefficient of capital of 1.50<sup>36</sup>. Its main advantage is to eliminate the need for the hypothesis of a steady state reached as of the base year. Such a hypothesis, which is usual (Harberger [1978], Nehru and Dhareshwar [1993], or Caselli [2005]) is delicate, since it is highly unlikely. To summarize, by comparing our method to that proposed by Nehru and Dhareshwar (1993), we see that the economic and mathematical foundations of our equation for China are more robust:

<sup>35</sup> See: *Shanghai Statistical Yearbook, Tables 20.56 and 20.57* (Shanghai Municipal Bureau of Statistics [2001]).  
<sup>36</sup> In order to get a faster speed of convergence, we could set an initial value closer to the true value. For example, as total capital must be greater than productive capital, we could set the initial value of total capital at 696.25. As  $\alpha_N$  is convergent, we can do the iterations through two methods: the first one is by setting a sufficiently high number of iterations, such as  $N=10\ 000$ ; the other one is by stopping the iterations when the condition is satisfied. Convergence is achieved after 3 iterations with second method, while the first one gives a value of 1.52876...



**Table 3.3 Comparison between Nehru and Dhareshwar’s method and author’s**

	<b>Nehru and Dhareshwar (1993)</b>	<b>Method of author</b>
Formula	$K_0 = I_0 / (g_Y + \sigma)$ where $g_Y$ is economic growth rate	$E(K_0) = I_0 \frac{1 + g}{g + \sigma}$ where $g$ is average growth rate of investment
Economic hypothesis	The economy was at the steady state in the base year.	The economy will tend to a steady state in the long run.
Mathematical hypothesis	Solow model’s steady state condition	1) Convergence of $I_t/K_t$ with $K_t$ constructed by the PIM method. 2) Ergodicity of $I_t/K_t$ and verification by post-estimation unit root tests.

The initial capital obtained by iteration procedure could also be verified by the Inada Conditions. The *2001 Shanghai Statistical Yearbook* provides a series of the estimated initial values of operating fixed assets in Shanghai since 1949 (Table 20.18). This value, without the built-up lands and the inventories, is similar to our definition of productive capital stock narrowly defined. We will use it in order to estimate such an indicator for China as a whole in 1952. To do this, we assume that Inada’s second condition is verified:  $Y = \lambda f(K, M) = f(\lambda K, \lambda M)$ , where  $Y$  is China’s output,  $K$  the capital stock,  $M$  an aggregate of other inputs and  $\lambda$  a constant. If the production function is homogeneous to 1 degree (i.e. with constant returns to scale),<sup>37</sup> and if Shanghai’s GDP is a proportion  $\lambda$  of China’s GDP, then Shanghai’s capital  $K_S$  is also a proportion  $\lambda$  of China’s capital  $K$ :  $Y_S = f(K_S, M_S) = \lambda Y = \lambda f(K, M) = f(\lambda K, \lambda M)$ ,  $M_S$  being the aggregate of non-capital inputs in Shanghai. As other researchers have done,<sup>38</sup> we assume that:  $K_S / K = Y_S / Y$ . The proportion of Shanghai’s capital stock in national capital is equal to that of Shanghai’s GDP in the Chinese GDP. Thus, the coefficient of capital in Shanghai is assumed to be the same as it is nationally.

Knowing that in 1952, Shanghai’s productive capital as defined narrowly was 33.65 and the GDPs of Shanghai and China were 36.66 and 679.00 respectively, then the narrowly-defined productive capital stock of China ( $K_{Pe}$ ) should have been 623.25. It is 18.5 times more than Shanghai’s capital; that is to say, a lower proportion than given by Zhang and Zhang (2003) who, we believe, overestimate initial stock levels. Our productive capital for 1952 is, however, close to that estimated by Chow (1993), under the name of “fixed capital” and equivalent to 582.76. As changes in the inventories were 73.00 at the national level for the same year,<sup>39</sup> we can deduce the broadly defined productive capital ( $K_{P1}$ ) for the whole China was 696.25. By applying the Kaldorian stylized fact of a constant capital-output ratio to the whole country, we get a total capital stock for China  $K_T$  of 1,018.50. Then, once built-up lands (322.25) is removed, the fixed capital stock  $K_F$  is 945.50 (Table 3.4). Thus, if Chow (1993) correctly determines the productive capital, he may have overstated the land (720.00) and the agriculture capital (450.00) in China in the 1950s, when the agricultural sector was little capitalistic and the land allocated almost freely.

<sup>37</sup> A Wald test using a Solowian production function confirms such an assumption of homogeneity of 1 degree. Here one implicitly assumes that the technical coefficient  $A$  of production function  $Y = A f(K, M)$  could be normalized to 1. We have calculated three types of Hicks-neutral TFP using two hypotheses: constant returns to scale (H1) and perfect competition on factor markets (H2). H1 is verified by the Wald test, but obviously H2 does not suit China. TFP1 assumes H1 and H2, TFP2 H1 only, TFP3 neither H1 nor H2. The Student tests show that none of them is significant in log forms; that is, log  $A$  can be assumed to be zero, i.e.,  $A$  can be normalized to 1.

<sup>38</sup> For example: Zhang and Zhang (2003).

<sup>39</sup> Source: NBS database with annual statistics of GDP calculated according to the approach by expenditure. Let’s precise that the inventories are considered to be a stock (incremented by changes in the inventories) and equivalent to the difference between  $K_{P1}$  and  $K_e$ , with an implicit assumption that their stock was zero in 1951.

**Table 3.4 Estimated initial levels of four capital stocks for China, in 1952**

<b>Productive capital stock narrowly defined</b> $K_{Pc}$ (no built-up lands, no inventories)	<b>Productive capital stock broadly defined</b> $K_{Pl}$ (no built-up lands, with inventories)	<b>Fixed capital stock</b> $K_F$ (with built-up lands, no inventories)	<b>Total capital stock</b> $K_T$ (with built-up lands and inventories)
623.250	696.250	945.500	1,018.500

### Investment flows

The content of the initial capital is rarely explained in the literature with the rigor required by this issue, on which the productive or unproductive nature of the various components of this stock also depends. Relatedly, the investment series selected to proceed properly with the accretion of the different capital stocks must be strictly compatible with the perimeters of these stocks. But the error of incrementing a capital stock with an investment series that does not match it, in particular for what concerns the built-up lands and the inventories, is very frequently made (Table 3.5). For example, Zhang and Zhang (2003) use an initial capital stock which excludes the built-up lands, but investment series containing some land transactions. To avoid such inconsistencies, we have to ensure that the investment flows coincide with our four initial capital stocks as closely as possible.

The “productive accumulation investment” series has no longer been published, among the various available investment series, after the transition from the MPS to the SNA. This series was already depreciated and so was preferred by many authors, including Chow (1993). However, complete series have existed since 1952 for the gross capital formation and the gross fixed capital formation. The first of these two concepts (gross capital formation), which stems from an approach of GDP calculated by expenditure, adapted to the definitions of investment given by the PIM and the SNA, includes the second one (gross fixed capital formation), as well as the inventories. The difference between these series thus corresponds to the inventories, to be considered as productive or not, according to the capital chosen (productive capital as narrowly defined or broadly defined). A share of these two gross formations concerns spending on land acquisition and housing construction: i.e. not directly productive elements, unlike spending related to building factories and buying equipment. The fixed asset series, provided by the NBS (series called in Chinese “固定资产投资”), involve an investment as it is interpreted by the MPS, exceeding that of the definition by the SNA.<sup>40</sup>

**Table 3.5 Examples of China’s investment series used in the literature**

<b>Investment series</b>	<b>Content of the series</b>	<b>Length</b>	<b>Authors</b>
Gross capital formation	with land and inventories	1952-present	Zhang (2004), Shan (2008), Hao <i>et al.</i> (2009)
Gross fixed capital formation	with land, no inventories	1952-present	He F., R. Chen and He L. (2003)
Total investment in fixed assets (national level)	with land	1980-present	Wang X. and Fan (2000), Li and Tang (2003),
Total investment in fixed assets (SOEs)	with land	1952-present	Chen K., Wang H., Zheng, Jefferson and Rawski (1988)
New increase in fixed assets (national level)	with land (excluding real estate), no inventories	1952-1995	Jefferson, Rawski and Zheng (1996)
Productive accumulation investment	with land, with inventories	1952-1993	Zhang (1991), He J.H. (1992) Chow (1993), Zhang and Zhang (2003)

Consequently and logically, we will mobilize the series of gross capital formation ( $F_{BC}$  or  $I_T$ ), over the period from 1952 to the present, in order to build that of total capital stock ( $K_T$ ),

<sup>40</sup> See: NBS (various years).

since both of them integrate the built-up lands and the inventories; and the gross fixed capital formation series ( $F_{BCF}$  or  $I_F$ ), which contains built-up lands but not the inventories, for that of fixed capital stock ( $K_F$ ). To get the profiles of productive investments required for elaborating our two other productive capital stocks ( $K_{Pe}$  and  $K_{Pl}$ ), we still need to deduct from gross fixed capital formation all investments that are not directly productive, especially investments in the land. The *Finance Yearbooks of China* (Ministry of Finance - P.R. of China [1999], in Chinese: 中国财政年鉴) contain a series of investment in residential housing including unproductive investments and investments in the land. As these data have only been available since 1982 (see: NBS [1983] *China Statistical Yearbook*, p. 339), we will use a very similar series for the previous years (before 1982), namely that of investment in non-productive basic construction which includes investments in residential housing (i.e., in Chinese: 非生产性基本建设). However, its scope only covers the SOE investments and does not incorporate those of the various collective institutions nor those of the private sector. Therefore, we need to estimate investment in non-productive buildings for the entire economy. So we write as a preliminary approximation the investment in productive capital destined to increment  $K_{Pe}$  as follows:

$$I_{Pe} = \begin{cases} F_{BCF} - C_{NP} & [1952 - 1981] \\ F_{BCF} - C_{HR} & [1982 - \text{present}] \end{cases} \quad (3.2)$$

where  $I_{Pe}$  is the investment in productive capital,  $F_{BCF}$  gross fixed capital formation,  $C_{NP}$  the investment in non-productive buildings and  $C_{HR}$  that in residential housing.

This formula tends to underestimate non-productive investments from 1952 to 1981, because  $C_{NP}$  only concerns SOEs. To correct this bias, we will consider the relative weight of the latter ( $\alpha_j$ ) in the economy during the successive plans ( $j$ ) until 1981:

$$I_{Pe} = \begin{cases} F_{BCF} - \alpha_1 \cdot C_{NP} & [1952-1957] \\ F_{BCF} - \alpha_2 \cdot C_{NP} & [1958-1962] \\ F_{BCF} - \alpha_3 \cdot C_{NP} & [1963-1965] \\ F_{BCF} - \alpha_4 \cdot C_{NP} & [1966-1970] \\ F_{BCF} - \alpha_5 \cdot C_{NP} & [1971-1975] \\ F_{BCF} - \alpha_6 \cdot C_{NP} & [1976-1980] \\ F_{BCF} - \alpha_7 \cdot C_{NP} & [1981] \\ F_{BCF} - C_{HR} & [1982-\text{present}] \end{cases} \quad (3.3)$$

To calculate these relative weights, we use the respective proportions of investment in SOEs' fixed assets in that corresponding to the national level and assume them to be equal to those given by the non-productive investment series, for a five-year average (*Table 3.6*). To do this, we accept the hypothesis (defended by He [1992], among others) of the stability of the economic institutions and policies over each sub-plan period.

**Table 3.6 Calculated proportions of the investment in fixed assets of the state-owned enterprises as compared to the national investment in fixed assets in five-year average: 1953-1980**

Period	Years	Calculated average proportion
First Plan	1953-1957	83.95%
Second Plan	1958-1962	99.00%
<i>Period of recovery</i>	1963-1965	81.82%
Third Plan	1966-1970	79.57%
Fourth Plan	1971-1975	89.62%
Fifth Plan	1976-1980	87.09%

**Table 3.7 Comparison of the actual and calculated average proportions of the investment in fixed assets by the state-owned enterprises in national investment in fixed assets: 1981-1995**

Period	Years	Calculated proportion	Actual proportion	Gaps
Sixth Plan	1981-1985	66.98%	66.70%	0.42%
Seventh Plan	1986-1990	64.48%	64.80%	-0.49%
Eighth Plan	1991-1995	65.58%	59.00%	11.15%
<i>15-year average</i>	1981-1995	65.68%	61.20%	7.30%

The relevance of our estimates is confirmed by comparing them to the actual proportions after 1980 (Table 3.7), as issued by the *China Statistical Yearbook on Investment in Fixed Assets: 1950-1995* (NBS [1997b], p. 22). The differences observed between actual and calculated data from 1981 to 1995 are quite small. They are negligible in the 1980s, and exceed 10% only during the 8<sup>th</sup> Plan, when the change of accounting system occurred. Our method is valid for the period before 1993, and thus also over that before 1980, for which we use the relative weights, as follows:

$$\left\{ \begin{array}{ll} \alpha_1 = 1 / 0,8395 & [1952 - 1957] \\ \alpha_2 = 1 / 0,9900 & [1958 - 1962] \\ \alpha_3 = 1 / 0,8182 & [1963 - 1965] \\ \alpha_4 = 1 / 0,7957 & [1966 - 1970] \\ \alpha_5 = 1 / 0,8962 & [1971 - 1975] \\ \alpha_6 = 1 / 0,8709 & [1976 - 1980] \\ \alpha_7 = 1 / 0,6950 & [1981] \end{array} \right. \quad (3.4)$$

Then, we deduce our second series of investment in productive capital (with the inventories):

$$I_{Pl} = I_{Pe} + F_{BC} - F_{BCF} \quad (3.5)$$

**Table 3.8 Investment series corresponding to the four types of capital stocks**

Productive capital stock narrowly defined $K_{Pe}$ (no built-up lands, no inventories)	Productive capital stock broadly defined $K_{Pl}$ (no built-up lands, with inventories)	Fixed capital stock $K_F$ (with built-up lands, no inventories)	Total capital stock $K_T$ (with built-up lands and inventories)
Narrowly-defined productive investment $I_{Pe}$	Broadly-defined productive investment $I_{Pl}$	Gross fixed capital formation $F_{BCF}$	Gross capital formation $F_{BC}$

### Price indices

The passage from current prices to constant prices is particularly delicate. As a matter of fact, it requires the availability of price indices for our investment series. A basic problem comes from the absence of continuous and homogeneous series provided by the NBS's statistical yearbooks of *Data of Gross Domestic Products of China* ([中国国内生产总值核算历史资料 1952-1995], [中国国内生产总值核算历史资料 1996-2002], [中国国内生产总值核算历史资料 1952-2004]). In this section, we propose a new method based on advanced cointegration techniques to get price index series for investment in China over the period 1952-2014, rigorously predicting the missing data (2005-2014), thanks to Shanghai's surveys. Such a method, carefully defining cointegration relationships between price indices, is original – to our knowledge –, and needed because, as we shall see, this difficulty is treated unsatisfactorily in the literature, where, very frequently, the price indices of capital investment have been wrongly selected.

As the PIM uses constant prices, we must use price indices for our investment flows which are expressed in current prices through to now. It should be noted that only a few authors give this issue the attention it deserves, as this is the PIM component with the most decisive impact on the construction of the different series of capital stocks. Moreover, a majority of researchers extend their partially incomplete price series by using sections of distinct price indices. Or they even substitute a missing index with another one, which is available but may be quite different. This risks leading to spurious regressions *à la* Granger and Newbold (1974).

The official price index of fixed capital investment for the whole China has only been available since 1990. Its missing series for the past period has been partly or fully replaced, sometimes by the production price index, sometimes by that of consumer prices (Huang, Ren and Liu [2002]). Jefferson, Rawski and Zheng (1996) simplify things, assuming that price variations were negligible before 1980. Wu (1999) regresses a price index of investment in fixed capital on that of production after 1990. As to Li and Tang (2003), they regress price indices of investment in fixed capital for China and Shanghai with each other, and are not surprised to obtain an adjusted  $R^2$  close to 1, for a sample of only 10 observations –this borders on statistical nonsense. Their study does not consider the stationarity of the price index time series, which are often deemed to be non-stationary or even non-linear. Shan (2008) tinkers: he fills the holes of lacking data thanks to points taken from other index series. Zhang and Zhang (2003) do not bother further: they take Shanghai’s price index of investment in fixed assets to replace the national one. Nevertheless, this forgets that the substitution of an index by another one assumes a linear relationship between them, with a unitary coefficient and a null constant in their regression... In short, it can only be remarked that almost all empirical studies in our subject involving price indices are incorrectly carried out. He (1992) and Chow (1993) are exceptions – the latter using an “accumulation index” to calculate an implicit index of fixed assets.

Given such problems, we must first clarify the nature of the relationship which exists between the price indices of fixed capital investment in Shanghai ( $P_S$ ) and China ( $P_C$ ). The bi-univocal Granger-causality tests do not yield sliced results, for a sample of relatively small size (22 observations) to be sure, with low p-values compared to the null hypothesis  $H_0$  “there is no Granger-causality” suggesting that a relationship probably exists between  $P_S$  and  $P_C$ . A glance at the series graph allows us to think that these series look as if they are non-stationary; in addition, the associated correlograms reveal auto-correlation functions which decrease slowly, and which are characteristic of non-stationary processes. To verify this intuition, and clarify the issue of the stationarity of these series, and therefore also that of the possibility of using the price index  $P_S$  to reconstruct the series  $P_C$ , we make unit root tests on these variables, expressed in levels. Their results will depend on the size of the sample  $T$  (24 observations), but above all on the – difficult – choice of truncation which sets the number of delays of the auto-correlation function. Several values, obtained from various criteria formulas (*Table 3.9*), are put forward:

**Table 3.9 Selection criteria for truncation setting of the number of delays (for T = 24)**

	<b>Lardic and Mignon (2002)</b>	<b>Newey and West (1994)</b>	<b>Schwert (1989)</b>
<b>Formula(s)</b>	$L = T^{1/4}$	$L = \text{int} [4 (\frac{T}{100})^{2/9}]$	$l_4 = \text{int} [4 (\frac{T}{100})^{1/4}]$ , $l_{12} = \text{int} [12 (\frac{T}{100})^{1/4}]$
<b>Delay(s)</b>	2.2	2	2 and/or 8

Most criteria lead to a number of delays of 2. To fix the optimal delay of the unit root tests, we select as the maximum delay the estimated value. Four types of tests are performed on  $P_C$  and  $P_S$ : *i*) an augmented Dickey-Fuller (ADF); *ii*) an Elliott-Rothenberg-Stock (ERS, in the event of price index non-linearity); *iii*) an Kwiatkowski-Phillips-Schmidt-Shin (KPSS); and *iv*) an Phillips-Perron (PP).<sup>41</sup> Out of 24 tests performed, 19 indicate that both price indices are non-stationary (*Table A3.3.1*). Ng-Perron test improves the PP test through a GLS detrended procedure.<sup>42</sup> For ADF and PP, the information criteria give significant delays (up to 8). As these two tests are problematic in the case of a high autoregressive root, because of a risk of loss in their explanatory power,<sup>43</sup> and as too many delays restrict the degrees of freedom and so the credibility of our tests, it appears reasonable to determine our truncation parameter at 2. The test statistics, (almost) all superior to the critical values, indicate that the null hypothesis  $H_0$  “ $P_C$  has a unit root” cannot be rejected. The NP tests confirm that  $P_C$  is not stationary. This result shows that the authors who do not examine the stationarity of their time series are wrong, as for example Li and Tang (2003). We need to determine the degree of integration of  $P_C$  in order to stationarize our series and thus be allowed to perform linear regressions. All our unit root tests consistency indicate that the first difference of  $P_C$  (denoted by  $DP_C$ ) is non-stationary, but that its second difference ( $D2P_C$ ) is stationary. Therefore,  $P_C$  is integrated to the order 2:  $P_C \sim I(2)$ .

Turning to  $P_S$ , the same method is applied to the first difference (noted  $DP_S$ ) and, if necessary, to the second difference ( $D2P_S$ ) of  $P_S$ . Here, the results of the unit root tests are somewhat less unanimous than in the case of  $P_C$ , but allow us to conclude that the variable  $P_S$  expressed in level is non-stationary (for all tests, except one [NP]), as  $DP_S$  (for all tests, except two [ADF and NP]), but that  $D2P_S$  is stationary (for all tests, except two [ERS (PO) and NP]). Given the consistency of a majority of tests, we conclude that  $P_S$  is also integrated to the order 2:  $P_S \sim I(2)$ . As a result, there cannot be any linear relationship ( $P_C \equiv P_S$ ) nor any relationship of cointegration of order 1 between  $P_C$  and  $P_S$  –in contrast to what presupposed (though usually without explanation) many authors, like Zhang and Zhang (2003), who use  $P_S$  instead of  $P_C$ .

**Table 3.10 OLS Estimates of the relationship between  $DP_C$  and  $DP_S$**   
with  $DP_C$  as the dependent variable

	Coefficient		Std. Error		t-Statistic
C	1.995699		0.560579		3.560068
$DP_S$	0.883542		0.049292		17.92482
R-squared	0.938650	Adjusted R-squared	0.935729	Mean dependent variable	7.609882
Log likelihood	-50.03208	Sum squared resid.	104.4003	S.D. dependent variable	8.794940
F-statistic	321.2992	S.E. of regression	2.229674	Akaike info criterion	4.524529
Prob. (F-statistic)	0.000000	Schwarz criterion	4.623267	Schwarz criterion	4.522367
				Hannan-Quinn criterion	4.549361
				Durbin-Watson statistic	2.265485

To avoid spurious regressions and to be surer about the appropriateness of using the series  $P_S$  to reconstruct that of  $P_C$  requires knowing more about the cointegration relationship which may exist between  $P_S$  and  $P_C$ . This is probably of order 2, if we consider the similarity of their fluctuations, despite a certain divergence of their curves. We reject beforehand the use of a vector error correction model (VECM), which is suited more for studying long-term links and whose explanatory power is reduced by the size of the sample. This we do after having

<sup>41</sup> See: Dickey and Fuller (1979), Elliott *et al.* (1996), Kwiatkowski *et al.* (1992), Phillips and Perron (1988).

<sup>42</sup> Ng and Perron (2001).

<sup>43</sup> DeJong *et al.* (1992). Also: Ng and Perron (1995).

applied a multivariate approach to test a second order cointegration relationship *à la* Johansen (1988). We prefer a univariate approach *à la* Engle-Granger (1987), testing a first order cointegration relationship between  $DP_S$  and  $DP_C$  in order to use such a link, if it exists, to estimate the relationship between  $P_S$  and  $P_C$ . If  $DP_S$  and  $DP_C$  are found to be cointegrated to the order 1, then, following Stock (1987), we could use the super-convergent and efficient estimators of ordinary least squares (OLS) as a cointegration relationship which allows us to estimate the linkages between  $P_S$  and  $P_C$ . For, if the series of residuals in the OLS regression is stationary, then the relationship between stationary explanatory and explained variables will be linear. The estimators describe a cointegration relationship:  $Y_t = \alpha + \beta X_t + z_t$ , where  $X_t$  is the vector of explanatory variables. Therefore, the cointegration test becomes a stationarity test of the residuals  $z_t$ . If  $\hat{z}_t$  is the estimator of  $z_t$ , their distribution functions are different and ADF critical values cannot be used to describe the stationarity of  $z_t$ . By determining a simulation critical value *à la* MacKinnon (1991), we thus get the series of residuals  $\hat{z}_t$  thanks to the estimation:

$$DP_{Ct} = C_1 + C_2 \cdot DP_{St} \quad (3.6)$$

By using the values of the parameters  $\widehat{C}_1 = 1.995699$  and  $\widehat{C}_2 = 0.883542$ , given in Table 3.10, the equation allowing  $\hat{z}_t$  to be estimated is:  $\hat{z}_t = DP_{Ct} - 1.995699 - 0.883542 \cdot DP_{St}$ . The optimal delays are determined from information criteria which all propose a delay equal to zero. Our unit root tests reveal an ADF of  $-5.314350 < -4.41$  *à la* Mackinnon, leading to a rejection of the null hypothesis  $H_0$  “ $\hat{z}_t$  has a unit root”:  $\hat{z}_t$  is stationary;  $DP_S$  and  $DP_C$  are cointegrated. Since  $\widehat{C}_1$  and  $\widehat{C}_2$  are super-convergent, the equation of  $\hat{z}_t$  can be considered as a cointegration relationship. We thus consider the following relationship between  $P_S$  and  $P_C$ , which is recursively related to the previous one:

$$P_{Ct} = P_{C0} + 1.995699 t + 0.883542 \cdot (P_{St} - P_{S0}) \quad (3.7)$$

This non-linear relationship confirms that  $P_S$  and  $P_C$  are not substitutable, but it characterizes the connection between their post-1990 evolutions; so, it cannot be used to estimate the prior trajectory of  $P_{Ct}$  – and price changes have been much stronger in recent decades than they were during the period of planning.

Therefore, we complement the series  $P_{St}$  thanks to that of the price index of capital formation ( $Index_t$ , with  $Index_{1952} = 100$ ), as it appears in Table 20.17 of the 2001 *Shanghai Statistical Yearbook* (Shanghai Municipal Bureau of Statistics [2001], in Chinese: 上海统计年鉴):

$$\frac{I_{St} / P_{St}}{I_{S1952} / 100} = \frac{Index_t}{100}, \text{ i.e. } P_{St} = \frac{10\,000 \cdot I_{St}}{I_{S1952} \cdot Index_t} \quad (3.8)$$

Two indices  $Index_t$  are at our disposal: one for gross capital formation and another one for gross fixed capital formation. We thus calculate two separate price indices (with or without inventories),<sup>44</sup> in order to build the corresponding investment flows. We note, respectively,  $P_{FBCS}$  and  $P_{FBCc}$  the price indices of gross capital formation (including inventories) for Shanghai and China, and  $P_{FBCFS}$  and  $P_{FBCFC}$  those of gross fixed capital formation at Shanghai and national levels. These indices are calculated using the method presented above on historical data taken from *Shanghai Statistical Yearbooks* (Shanghai Municipal Bureau of Statistics [various years], in Chinese: 上海统计年鉴) and *Data of Gross Domestic Product of China* (NBS [various years], *i.e.* 中国国内生产总值核算历史资料). The sample size increases from 24 to 53 and 63 observations, and consequently reaches the minimum level required by MacKinnon (1991), reinforcing the relevance of our tests. The econometric results for the

<sup>44</sup> Here, we support the thesis of Ramey and West (1999) that the inventories have a pro-cyclical role.

sub-period 1952-2004 are used to predict the values of the indices between 2005 and 2014 (or 10 points).

As the four price indices are found to be cointegrated of order 2 (Appendix 3.3), two separate cointegration relationships have to be estimated, respectively, between  $P_{FBC St}$  and  $P_{FBC Ct}$ , and between  $P_{FBCF St}$  and  $P_{FBCF Ct}$ . We get, for price indices expressed in first differences:

$$DP_{FBC Ct} = 2.602348 + 0.709832 \cdot DP_{FBC St} \quad (3.9)$$

with an ADF test obtained at  $-6.051569 < -4.41$ ,

And

$$DP_{FBCF Ct} = 3.486494 + 0.652279 \cdot DP_{FBCF St} \quad (3.10)$$

with an ADF at  $-5.648787 < -4.41$ .

Thus, we deduce the equations which allow us to calculate  $P_{FBC C}$  and  $P_{FBCF C}$  from 2005 to 2014:

$$P_{FBC Ct} = 381.7975 + 2.6023 \cdot (t - 2004) + 0.7098 \cdot (P_{FBC St} - 306.3523) \quad (3.11)$$

And

$$P_{FBCF Ct} = 388.1796 + 3.4864 \cdot (t - 2004) + 0.65227 \cdot (P_{FBCF St} - 263.8592) \quad (3.12)$$

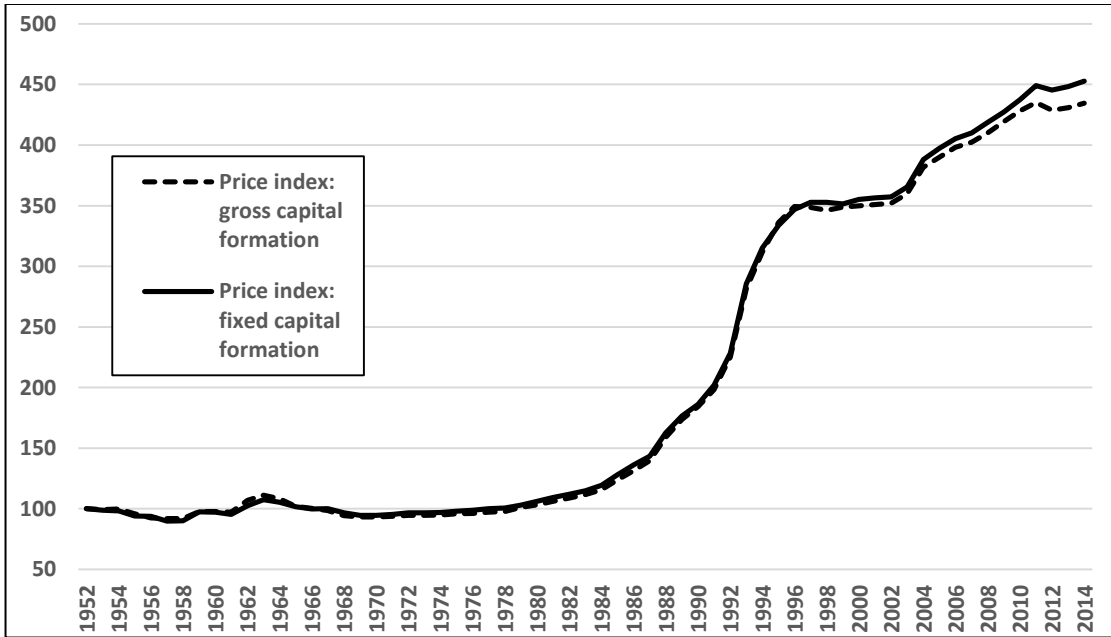
with  $t = 2005, \dots, 2014$ .

Then, for Shanghai and China, there are two price index series, with or without inventories:

**Table 3.11 Construction of the four price indices**

Price indices	Length	Sources	Order	Size	Delay
$P_{FBC St}$	1952-2014	Data for the periods 1952-2000 and 1978-2014 respectively taken from the 2001 and 2014 <i>Shanghai Statistical Yearbooks</i>	$I(2)$	63	3
$P_{FBCF St}$			$I(2)$		
$P_{FBC Ct}$	1952-2004 and 2005-2014	Data for 1952-1995 and 1978-2004 respectively taken from <i>Gross Domestic Product of China</i> (1952-1995) and (1952-2004) + Data for 2005-2014 calculated thanks to cointegration relations	$I(2)$	53 + 10	3

**Graph 3.1 Gross capital formation and gross fixed capital formation price indices: China, 1952-2014 (base 100 = 1952)**





## Depreciation rate

It would have been possible, as some authors argue (Ye [2010]), to dynamically calculate one (or several) depreciation rate(s) of capital stocks, influencing the amortization of capital goods in a structure that is itself variable with the time. Nevertheless, to remain consistent with the PIM, which does not use dynamic rates, we will select a constant total depreciation rate. Such a simplification, which is permitted by this hypothesis, is quite common in the literature. It does not prevent many authors from ignoring some of its implications. Mathematically, assuming a hypothesis of a constant depreciation rate of capital stock is equivalent to being within an axiomatic configuration, where four assumptions are to be satisfied simultaneously, including: (1) the age-efficiency of the capital goods geometrically declines, and (2) is proportional to the price index (at constant prices); but (3) the replacement rate of capital equals the chosen depreciation rate; and (4) the profile of mortality of the various categories of assets is such that the retirements of capital goods that reach the end of life are done at the same time. The quite common mistake of not taking account of the equivalence of these assumptions often leads to a certain confusion about the concepts of age-efficiency and replacement rates (Sun and Ren [2005]), or even about those of “wealth” and capital stock (Shan [2006]). Following the PIM, capital stock  $K$  is a sum at infinity of past investments weighted by age-efficiency (at constant prices):

$$K_t = \sum_{\tau=0}^{\infty} d_{\tau} I_{t-\tau} \quad (3.13)$$

$I_{t-\tau}$  being the investment made  $\tau$  years ago and  $d_{\tau}$  the age-efficiency of goods of  $\tau$  years. Without new investment, we have  $I_t = K_0$  if  $t = 0$ , and  $I_t = 0$  otherwise.

By assuming, as others do and quite reasonably,<sup>45</sup> that the age-efficiency of capital goods will decline geometrically, then the depreciation rate can be written as follows:  $\sigma_i = 1 - d_i^{1/\tau}$ , with  $\sigma_i$  the depreciation rate for the category of capital goods noted  $i$ ,  $\tau$  the lifetime of such goods and  $d_i$  the age-efficiency at the retirement of the residual assets of the same type.

Thus, we use the total depreciation rate for the calculation of the respective trajectories of our four different capital stocks, after having incorporated the price indices (with the inventories):

$$\sigma = \sum_i \alpha_i \sigma_i = \sum_i \frac{\sum_j^t \frac{I_{ij}}{P_j}}{\sum_j^t \frac{I_j}{P_j}} \sigma_i \quad (3.14)$$

where  $\alpha_i$  is the proportion of capital goods of type  $i$  in the structure of total capital.

Capital goods are classified by the NBS *Yearbooks* in three broad categories: buildings and facilities, equipment and materials, and others. We have their respective lifetimes and residual values. For developing countries, China included, the OECD recommends using the following depreciation rates: 80 years for housing, and 40 for other buildings; 15 years for machinery; and 20 for the rest. In China, the lifetimes of such goods are regulated: 70 years for houses, 40 for commercial buildings; the latter constituting a minority building stock compared to the former. We choose the following values: 55 years for buildings and facilities; 16 years for equipment and materials; 25 for the rest. Unlike the usually-accepted 5%, we assume a 10% value for residual goods, because of the running competition between local governments to

<sup>45</sup> This is the opinion expressed by Hulten and Wycoff (1995), Jorgenson (1996) and Fraumeni (1997), among others.

obtain a “good ranking” for their production growth rate. Such competition results in frequent demolitions and retirements of properties, which often still have high use values.

Our calculations of the weighted sum of different depreciation rates by type of goods lead us to a total depreciation rate of  $\sigma = 6.6789\%$ . In comparison, a depreciation of around 3.6% is proposed for fixed assets by the NBS (Xu [1999]). But this rate takes into account physical wear and tear only, and not retirement, implying an underestimation of the rate of depreciation. The latter is selected at 3.1% by the PWT, which excessively rely on US data. Furthermore, numerous authors often simply accept, without comments, the usual rate of 4% to 5% given in the literature (Wang and Fan [2000]). Others assume a depreciation rate equal to the “official” one of 3.6%, plus GDP growth, by assuming a “golden rule” placing China on a growth path considered to be “optimal”. But this leads to a very high depreciation rate (Song *et al.* [2001]). Others still (Shan [2008]) use calculation methods similar to ours, but get depreciation rates of more than 10%, which is excessively high, because of different choices of lifetimes, residual values, weights of capital goods, and above all inadequate estimates of price indices.

Nevertheless, the depreciation rate cannot exceed a threshold; otherwise, the risk is that the investment is insufficiently strong to compensate for a too high depreciation rate for capital. This makes the growth rate of capital stock artificially low, or even negative in the early years. Based on a distinct methodology, with an input-output table *à la* Leontief on post-1990 data, Xue and Zheng (2007) for their part obtain a depreciation rate of 7.17%, which is close to ours. To the extent that our estimate contains information relating to the period from the beginning of planning, during which infrastructure investments (with longer amortization, thus smaller depreciation) were important, it seems logical and acceptable to propose a depreciation rate of 6.6789% (Table 3.12). This value is close to the average depreciation rates (around 6.50%) for the industrial SOEs’ fixed assets registered in each province, provided by the *China Finance Yearbook 1999* (Ministry of Finance - P.R. of China [1999], p. 219, in Chinese: 中国财政年鉴 1999).

**Table 3.12 Amortization of capital goods by category and total depreciation rate**

	Constructions and installations	Equipment and materials	Other goods
<b>Proportion <math>\alpha_i</math></b>	62.6710%	22.4742%	14.8546%
<b>Lifetime <math>\tau</math></b>	55 years	16 years	25 years
<b>Depreciation rate <math>\sigma_i</math></b>	3.7649 %	13.4035 %	8.7989 %
<b>Total depreciation rate <math>\sigma</math></b>	6.6789 %		

Such a setting is confirmed by an error analysis, or sensitivity tests, from which we can draw several lessons. As a matter of fact, based on an assumption of a positive average growth rate of capital  $\overline{\dot{K}_t}/K_t > 0$ , we get:

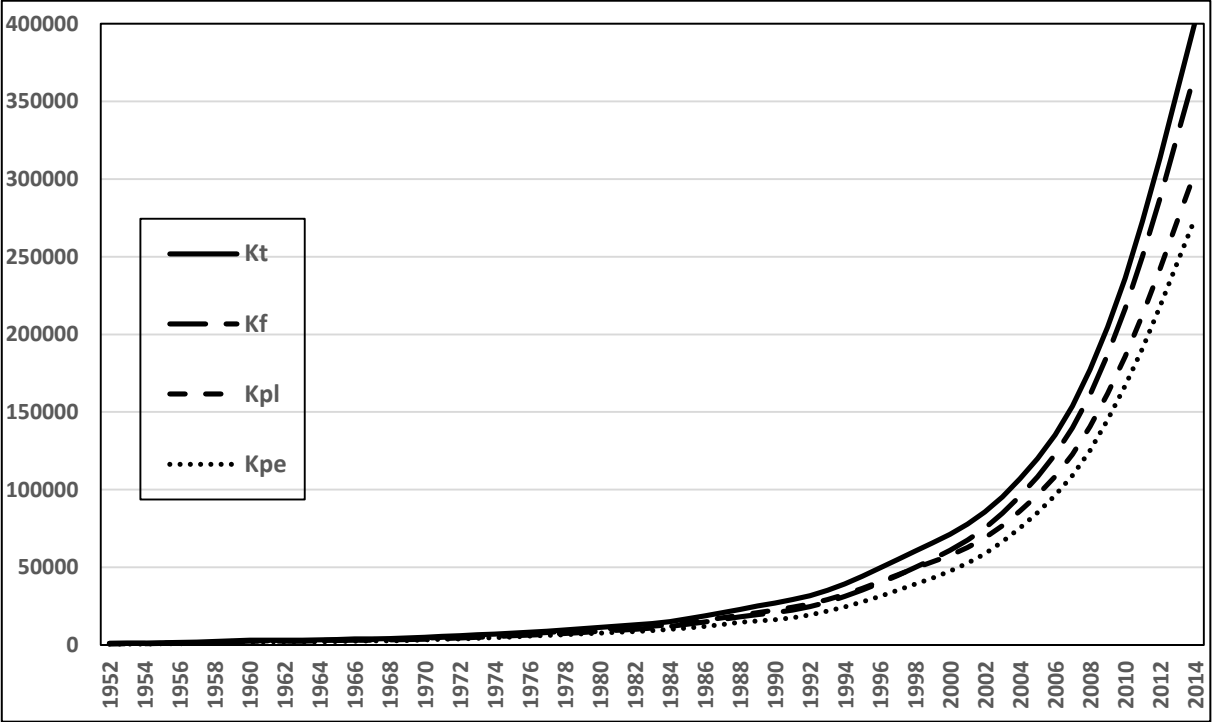
$$\sigma < \frac{1}{T} \sum_{t=0}^T \frac{I_t/P_t}{K_{t-1}} \quad (3.15)$$

Thus the depreciation rate should not exceed the average investment rate, which is calculated at 9.221% using our data. Our estimate is well below this threshold, but those by the authors retaining a higher rate introduce a bias: for them, the capital stock growth rate is excessively low (or even negative) during the first years of accumulation. If  $\sigma_1$  and  $\sigma_2$  are two depreciation rates and  $\sigma_2 - \sigma_1 > 0$ , then  $K_{1T}/K_{2T} \rightarrow +\infty$  when  $T \rightarrow +\infty$ . So, a slight difference in depreciation rates will make the levels of capital stocks diverge. Moreover, the rate of depreciation will influence the level of capital growth, but not its fluctuations<sup>46</sup>.

<sup>46</sup>See Appendix 3.5 for the details of error analysis.

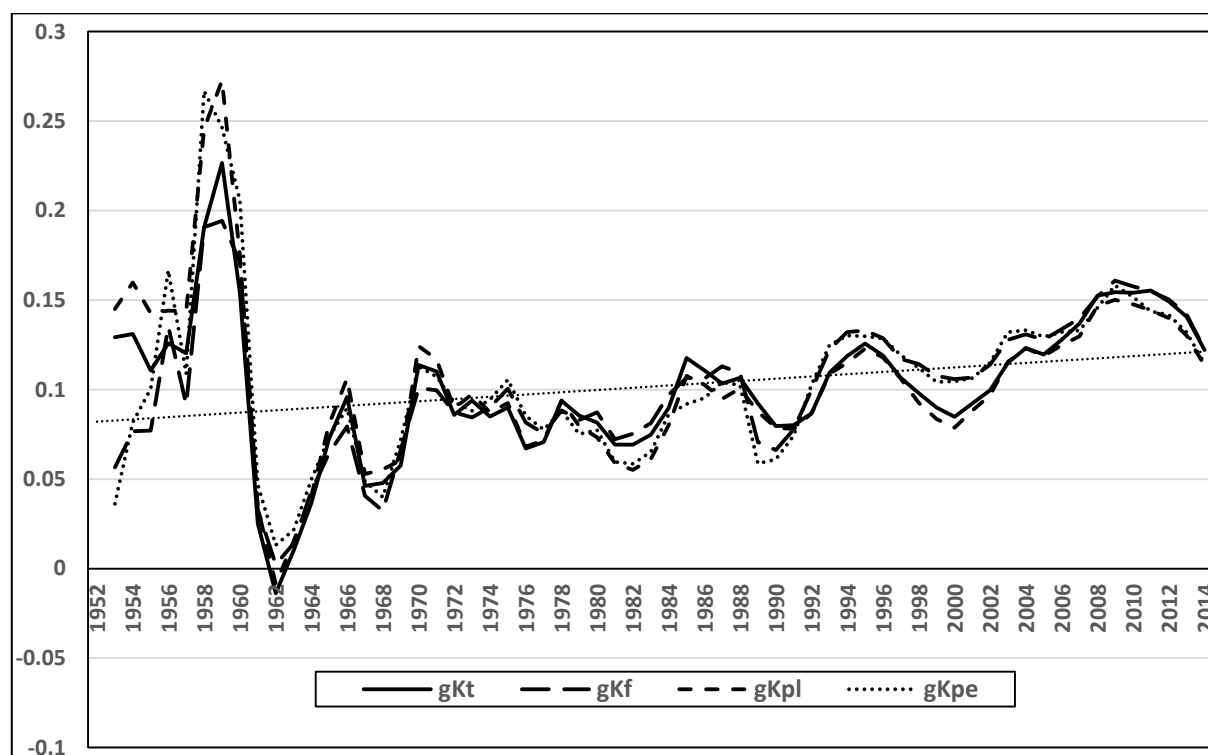
We are now able to present our new series of physical capital stocks for China from 1952 to 2014, according to four definitions: *stricto sensu* productive capital  $K_{Pe}$ , *lato sensu* productive capital  $K_{Pl}$  with the inventories, fixed capital  $K_F$  including unproductive built-up lands, and total capital  $K_T$  including both built-up lands and inventories (see *Graph 3.2* in levels and *Graph 3.3* in growth rates). *Appendix 3.4* (*Table A3.4.3*) provides our alternative database for readers, while *Appendix 3.6* compares it with some others available in the literature.

**Graph 3.2 Capital stocks (according to four definitions): China, 1952-2014**



Notes: The monetary unit is hundreds of millions of yuans (RMB).  
 $K_{Pe}$  = narrowly-defined productive capital stock (without the built-up lands, without the inventories);  
 $K_{Pl}$  = broadly-defined productive capital stock (without the built-up lands, with the inventories);  
 $K_F$  = fixed capital stock (with the built-up lands, without the inventories);  
 $K_T$  = total capital stock (with the built-up lands, with the inventories).

**Graph 3.3 Growth rates of the four capital stocks: China, 1953-2014**



Note: 0.05 = 5 percent increase, 0.1 = 10 percent increase...

### 3.3 Conclusion

In this paper, we propose original time series for various definitions of physical capital stock in China, from 1952 to the present (2014). Several arguments can be given to support the fact that these series are better than those currently available in the literature, even when built with the PIM we use. Our initial capital stocks are calculated on the basis of a capital-output ratio which is less approximate (and lower) than those usually put forward. Our investment flows are consistent with the statistical perimeters of these initial stocks. Our price indices of investments are strictly adjusted to the respective contents of such stocks, and the unit root tests show that all these price indices are non-stationary and integrated of order 2: this means they cannot be used instead of each other. This is done by numerous authors (with rare exceptions), who are not interested enough in the issue of the stationarity of their time series. However, price indices are the PIM components that determine more decisively both the level and the structure of the categories of capital stocks the care taken in constructing them is crucial. Finally, our depreciation rates are estimated by type of capital goods, under consistent assumptions concerning age-efficiency and retirement, while the investment shares are used to approximate the overall capital structure and to calculate a total depreciation rate. An error analysis ultimately shows that our capital stock series are solidly built and could benefit researchers who want to carry out econometric estimates on China in the long run.

# Chapter 4 ORIGINAL SERIES OF HUMAN CAPITAL STOCKS FOR CHINA'S ECONOMY FROM 1949 TO 2014

## *Concepts and Methods for Constructing a New Database*

In this Chapter, we first examine the methodologies used in the literature to estimate China's human capital, and their limitations. Then, we expose our own approach, based on the permanent inventory method, for the period 1949-2014. We therefore explain, in turn, the ways in which are determined the depreciation rates of this stock, which involve mortality rates, retirement rates and unemployment rates; then, the new increases in the stocks of human capital, which require the calculation of the numbers of new graduates for each type of education and the duration of the cycles; lastly, the values of human capital stocks corresponding to the reference years, which imply to identify the average numbers of training years of the persons by type of education and their weight in the population. Finally, we provide two original human capital stock series for China from 1949 to 2014, as well as the intermediate indicators by which these stocks have been elaborated.

### **4.1 Introduction and Literature Review of Labor Input Measurements**

The very rapid growth rate of China's gross domestic product (GDP) for several decades now raises many questions about the contributions of the various factors of production to this phenomenon, foremost among which is the stock of physical capital.<sup>47</sup> This sustained economic pace contrasts sharply with the moderation in demographic change, particularly in the labor force, due in large part to the long-term policy of birth control led in this country. In standard macrodynamic models applied to empirical estimation, most commonly mobilizing a Solowian theoretical framework or a formalization close to it, the use of the number of people employed to approximate simple labor very often leads to an excessively high coefficient of elasticity associated with this input – reflecting a total factor productivity underestimation and, at the same time, an invalidation of the assumption of constant returns to scale in the production function.<sup>48</sup> There is little doubt that statistical differentiation between simple and complex labor (or unskilled and skilled labor) is necessary to verify that a workforce with a higher level of education is actually more productive. We should instead use econometrically an indicator of Chinese human capital as a labor factor. But for that, we will have to build it, for, as we shall see, the series available for this country are far from being satisfactory. This is particularly true of those developed on the basis of the Kendrick *et al.* (1976) method or on that of Jorgenson and Fraumeli (1989), or even those based on an average educational attainment, such as the Penn World Tables (PWT).<sup>49</sup>

In this chapter we will first examine the different approaches used in the literature to estimate China's human capital, and the limits of each one, in order to identify precisely the points on which our efforts should focus. Then, using two distinct definitions of the stock of human capital, respectively productive or total, we will present our own methodology, based on the permanent inventory method (PIM), and extended over the period from the founding of the People's Republic In 1949 until the most recent date of collection of information from the National Bureau of Statistics of China (NBS), that is, 2014. Thus, after a brief presentation of the general conceptual and methodological framework, we shall explain in turn the ways in

---

<sup>47</sup> See: Herrera (2015), Long and Herrera (2015, 2016, 2017).

<sup>48</sup> Examples: Jefferson (1990), Zhang (1991), Su and Xu (2002), Guo and Jia (2005), Perkins and Rawski (2008).

<sup>49</sup> Cf. <https://ptw-sas.upenn.edu> and, for the latest 8.1 version: [www.rug.nl/research/ggdc/data/ptw](http://www.rug.nl/research/ggdc/data/ptw).

which are determined the depreciation rates of this stock, which put mortality rates, retirement rates and unemployment rates into action; then the new increases in human capital, requiring the calculation of the number of new graduates and the duration of studies for each type of education in order to obtain the new investments that increment these stocks; and the values of human capital stocks corresponding to several base years chosen over the 66-year period covered by the present work, which implies to identify the average duration of studies by type of education of the persons and the number of the latter in the population concerned. In these conditions, we will be able to provide the reader with two original series of human capital stocks for China's economy from 1949 to 2014, as well as those of the average educational – called “cultural” levels attained in the original Chinese documents – attainment of the population.

### **Different measurements of labor input**

The measurement of labor input in economic growth theory has experienced four stages: 1) simple labor or coefficients of simplified labor (rate of labor simplification, labor predigested rate); 2) expenditures on education; 3) labor income; and 4) educational attainment.

The early economic growth theory directly uses number of laborers as measurement of labor input, such as the numbers of employed persons. Solow model is the typical presentation. Modern human capital theory proposed by Schultz (1961) has pointed out that we should distinguish the laborers due to their heterogeneity. On the other hand, Marxist Labor Value Theory argues that the values created by complex labor equal to the multiplication of that created by simple labor. So former soviet economists such as Stanislav Strumilin (1962) and some Chinese economists during the planned economy period usually used the coefficients of simplified labor to measure and convert laborers with different abilities. In China, Qu (1985)<sup>50</sup>, Han (1990), Jiao (1990) have calculated the “coefficients of simplified labor” with different approaches.

Schultz (1961) argued that laborers' human capital should be measured by the replacement costs. That is the educational cost paid for training laborers for complex work. Kendrick (1976) estimated human capital of U.S. based on this idea with PIM. In China, Zhang (2000) has estimated the intangible non-human capital and human capital stock of China over 1953-1995 with the same method of Kendrick (1976). Zhang argued that in 1978 the capital share (elasticity) was 0.35, human capital share (elasticity) was 0.15, labor share (elasticity) was 0.5; and in 1995 the three terms were respectively 0.35, 0.26 and 0.39. But when Zhang (2000) calculated the shares of input factors, he assumed that the income of university graduates is twice as simple labor, and the average income of high school graduates is 1.5 times of simple labor's income. Such assumption is evidently too simple and arbitrary. And we see clearly that it was a natural continuation of the idea of "coefficients of simplified labor". Qian et al. (2008) has estimated the human capital in provincial level over 1995-2005. And Qiao and Shen (2015) have estimated human capital in national level over 1978-2011. There are great differences between those estimations because their statistical scopes are not consistent<sup>51</sup>.

---

<sup>50</sup> As the early Chinese literatures are often missing (for example one of the most important Chinese bibliographic database CPVIP only collects the Chinese literatures after 1989), Qu's work is cited in the paper of Cui (1999).

<sup>51</sup>The author has also calculated the human capital with the method of Kendrick (1976) see *Appendix 4.2*; however its growth rate is not stationary so that it cannot be directly used in the regressions.

After Schultz, Jorgenson and Fraumeni (1989, 1992) proposed using the discounted value of laborers' future incomes to measure the human capital. Mulligan and Martin (1995) proposed "Labor Income Based Human Capital" (LIBK) to calculate the human capital index. The implicit basic logic of those labor economics methods is:

$$\text{wage} = \text{MR} = \text{MP} = \text{HC} \quad (4.1)$$

That is because under the assumption of perfect competition of market, labor's compensation (wage) is the marginal revenue of laborer (MR), laborer's marginal revenue should equal to its marginal contribution of production (MP), and the marginal production reflects the level of laborer's human capital (HC). In China, Zhu and Xu(2007) has calculated the human capital stock of 35 big cities of China over 1990-2004 with the method of LIBK. Li and Fraumeni et. al. (2013) have calculated China's human capital stock over 1985-2008 with the method of Jorgenson-Fraumeni.

In parallel, in the field of education economics, Psacharopoulos (1974, 1981 and 1985) has used educational level to measure the capital return. Barro and Lee (1993) proposed a perspective that laborers' education level reflects their levels of human capital. They firstly used adult literacy rates or/and school enrollment rates as indicators of measurements of human capital<sup>52</sup>. And later they used the average years of schooling. This indicator has gradually become the most popular human capital indicator in economics. The database of Barro-Lee has also provided the human capital index of China, but the frequency is 5 years that is far from enough for econometric analysis.

PWT (Version8.0, 2013) has estimated this index based on "years of schooling" (Barro/Lee, 2012) and "returns to education" (Psacharopoulos, 1994). But they have seriously underestimated the level of human capital stock of China. According to the PWT data, the average educational attainment of Chinese people in 2010 is only 2.58 years. However, we could calculate from the population census data of 2010, the educational level of total population has already achieved 8.24 years in 2010. In the meantime, the data of Barro-Lee of the "educational attainment in over 15-years old population" is 7.51 years in 2010. It can clearly be seen that the PWT data of China's human capital is far below the real level. However, econometric results based on different human capital estimation are so different. For example, *Table 4.1* summarized the contribution of human capital to economic growth with different notions of human capital in literature. Thus we decide to estimate this indicator ourselves.

---

<sup>52</sup>This approach has great influence in China; there are still numerous Chinese literatures using literacy and enrollment rates as human capital indicators due to lack of official data of years of schooling

**Table 4.1 Contribution of Different Notions of Human Capital to Economic Growth (Elasticity)**

Method	Authors	Period	Level	Elasticity
Kendrick	Zhang (2000)	1953-1995	National level	0.15
	Qian et al. (2008)	1995-2005	National and provincial level	-
	Qiao and Shen (2015)	1978-2011	National level	-
Jorgenson - Fraumeni	Zhu and Xu (2007)	1990-2004	35 big cities	-
Mulligan - Martin	Li and Fraumeni et al. (2013)	1985-2008	National level	-
Barro and Lee	Cai and Wang (1999)	1982-1997	National level	0.555
	Cai and Du (2003)	1949-1982	National level	-
	Li (2001)	1949-2000	National level	-
		1964-1995	provincial level	-
	Yue and Liu (2006)	1996-2003	provincial level	-
	Wang (2002)	1990-2010	Predicted values by ARMA	0.306
	Bai (2012)	1952-2008	National and provincial level	-
	Jiao and Jiao (2010)	1978-2007	National level	-
	Yang (2006)	1952-2006	National level	-
	Yang et al. (2006)	1985-2000	provincial level	0.72; 0.41
	Wang et al. (2009)	1952-2008	National level	0.83-0.66
Yao and Lin (2006)	PWT data	0.21		

Note: 1) Human capital estimated by Yang et al. (2006) contain two parts: education and health, 0.72 is the elasticity of educational attainment in Solow model; 0.41 is elasticity of education and health in endogenous economic growth model.

2) It is cointegration relationship for Yao and Lin (2006).

3) Wang et al. (2009) tested endogenous economic growth models with and without constraint.

4) Wang (2001) used ARMA(12,1) to predict the future output, capital and human capital; and then get the elasticities by endogenous economic growth models. In national level, the elasticity of human capital was 0.306; 0.436 for secondary sector, 0.74 for 3<sup>rd</sup> sector<sup>53</sup>.

## Education Attainment

There are no official statistics measuring the average education attainment level in China. However, we have at our disposal China's official data which are numerous, but disparate and incomplete. Since 1993, the NBS has published a table entitled "Population Aged 6 and over by Age, Sex and Educational Attainment"<sup>54</sup> in its *China Population Statistics Yearbooks*<sup>55</sup> based on sample survey of population<sup>56</sup>. Renamed *Population and Employment Statistics Yearbooks*<sup>57</sup>, these documents have also included a series on "Educational Attainment of Employed Persons, table 3-1"<sup>58</sup> according to the labor force sample survey, from 2006 onwards. Furthermore, information is also available about the levels of education<sup>59</sup> through

<sup>53</sup> We argue that it is not very good to use ARMA as prevision. Because as time goes by, the values of prevision of out-sample observations will tend to mean very fast. If we are in the Solow model framework, it is ok because Solow model argues that economic growth will convergent. The theoretical and prevision models are consistent. But the endogenous economic growth model considers that the convergence is no longer necessary in long run. So, the prevision model and economic models used by Wang (2002) are contradictory.

<sup>54</sup> In Chinese: 6 岁以上人口中分年龄、分性别的各种文化程度人口数

<sup>55</sup> In Chinese: 《中国人口统计年鉴》

<sup>56</sup> In 1987, there also exists this table.

<sup>57</sup> In Chinese: 《中国人口与就业统计年鉴》. Hereinafter they are collectively referred as "Population Yearbook"

<sup>58</sup> In Chinese: 全国就业人员受教育程度构成

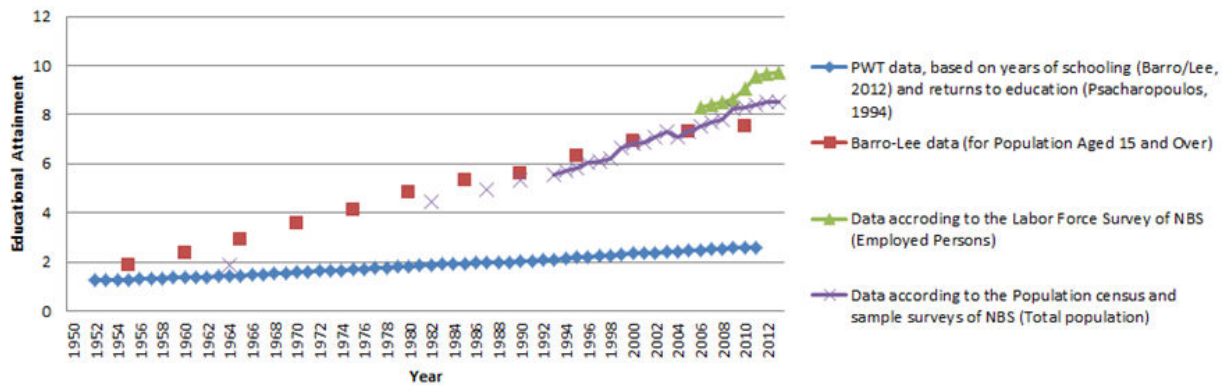
<sup>59</sup> The table entitled "populations of various education levels", in Chinese: 各种文化程度人口数.



censuses (*Population Census Years*), conducted in 1964, 1982, 1990, 2000 and 2010<sup>60</sup>. This allows us to estimate, using historical data for these years, the values of the average educational levels, by multiplying the number of the graduates of the various educational categories and the duration of their education. Knowing the average educational level of the persons over six years<sup>61</sup> and the corresponding population, we calculate the total human capital stock for these five years of censuses, then continuously from 1993 to 2014. For the years 2006-2014, we were also able to obtain values for productive human capital, thanks to the average educational levels of persons employed.

Those indicators of educational attainment are data based on official data; we compared them to the PWT data and Barro-Lee dataset (*graph 4.1*). And we need to estimate the two kinds of human capital for the rest years: the total human capital in the population of 6+ and productive human capital in the employed persons.

**Graph 4.1 Comparison “Official Data” of Human Capital with other Series in Literature**



From *graph 4.1* we see that the data of Barro-Lee is closed to the real level, but the PWT data has seriously underestimated the stock level of China’s human capital. We argue that this is because the assumption of returns to education (Psacharopoulos, 1994) used by PWT is unsuitable for China’s reality. So their results are serious biased. In fact, we will see *infra* caused by China’s political and historical particularity<sup>62</sup>, we have so many details to consider when we try to accurately estimate the human capital that PWT model doesn’t hold.

## 4.2 Methodologies and Models

The human capital is viewed here as the product of an average educational level, or number of years *per capita* of education to obtain diplomas, and a specific population. This human capital is assumed to accumulate in a similar way to physical capital. In year  $t$ , the stock of human capital  $H_t$  is equal to that of the previous period  $H_{t-1}$  (net of the rate of depreciation  $\sigma_{Et}$ ), plus the investment in human capital  $I_{Et}$  in  $t$ .

$$H_t = (1 - \sigma_{Et})H_{t-1} + I_{Et} \quad (4.2)$$

In  $t$ , the increase of human capital  $I_{Et}$  is the sum of the products of the number of the new graduates for each type of education  $i$ ,  $l_{it}$ , and of that of cumulative years of this type,  $\eta_t$  :

$$I_{Et} = \sum_i l_{it} \eta_{it} \quad (4.3)$$

<sup>60</sup> The census of 1953 didn’t provide information about education level of population.

<sup>61</sup> We note *infra* that “6 years old and over” as “6+”

<sup>62</sup> Or the so called “Chinese characteristics”.

And,

$$H_t = \sum_j E_{jt} L_{jt} \quad (4.4)$$

$E_{jt}$  being the average number of persons' years in education with the type of education  $j$ , and  $L_{jt}$  their number in the population considered at time  $t$  ( $E_{jt}$  and  $L_{jt}$  differing from  $\eta_{it}$  and  $l_{it}$ ).

China's education can be classified in two ways. According to educational strata, it could be classified into preschool education, primary education, secondary education and high education. According to the nature of education, it could be classified into ordinary education (or general education), vocational education (or professional education), adult education (or amateur education/ continuing education) and others. Summarized in *table 4.2*:

**Table 4.2 Category of Chinese Education**<sup>63</sup>

	Ordinary Education			Vocational Education				Adult Education		Others				
Preschool Education	Kindergarten													
Primary Education	Ordinary Primary School							Adult Primary School	Literacy Classes					
Secondary Education	Ordinary Junior High School	Ordinary Senior High School		Vocational Junior High Schools	Vocational Senior High School	Skilled Workers [Training] School	Secondary Specialised School (Including Secondary Normal School)	Adult Junior High School	Adult Senior High School			Reform School	Special Education	Other Spare-Time Education (Farmer Schools, Fifty-Seven University, Job Postgraduate, etc.)
High Education	Postsecondary Specialised College	Undergraduate	Graduate (Master, Ph. D.)					Adult College	Adult Undergraduate	Online Education (Network Undergraduate, Network College)	Returned Overseas Students			

*Table 4.2* contains almost all diploma educations since the foundation of PRC<sup>64</sup>. This paper argues that the preschool education is not a diploma so that it doesn't constitute the formation of human capital. Furthermore, due to the particularity of Reform School (adolescent minor offenses) and Special Education (School for the Deaf-Mute), we don't consider those education as formation of human capital neither.

In our calculations, all teaching in the Chinese educational system, beyond the pre-school, is taken into consideration, whatever the classification criterion selected for the education level (primary, secondary, higher) or the nature of training (general, vocational...). Unlike the authors like Cai and Du (2003) who have chosen to exclude adult education in their conception of human capital, we integrate this, as we also do with literacy programs. Moreover, persons who have studied abroad and have returned home once they have obtained their diplomas are also logically incorporated. By contrast, training performed within the enterprises is not integrated, because it does not lead to diplomas and is rather similar to learning-by-doing. We assume that years in education are homogeneous, regardless of their quality likely to rise with the level of knowledge, linked to the technical progress dynamics.

<sup>63</sup> The translation of the names of diploma is based on official translation document "Regulations of the People's Republic of China on Academic Degrees (2004)" (in Chinese: 《中华人民共和国学位条例》).

<sup>64</sup> Some diploma educations tend to die out or have been canceled, such as Vocational Junior High Schools, Farmer Schools, Fifty-Seven University and so on.

Under these circumstances, two categories of stocks will be estimated by using the average educational levels corresponding to two distinct populations: *i*) total human capital, calculated for the population over six years old; and *ii*) productive human capital for the employed population, *i.e.*, for all employed persons over 16 years. Thus we can use the respective values of these stocks<sup>65</sup> as various references to build the complete series of human capital by retropolation, *i.e.*, backcasting for these years, from 1992 back to 1952 for the first series, and from 2005 back to 1952 for the second one. Besides, for the two series, the data are collected in different ways, so the equations for calculating total and productive human capital are different.

### Productive Human Capital

As diplomas are usually delivered by mid-year in China (in the end of June or in the beginning of July), the human capital estimated by equation (4.2) is in fact the human capital stock level in the middle of year  $t$ . While that of physical capital is captured at the end of the year, as usual. However, in a regression model, if we use the physical capital stock in the end of year  $K_t$  as the input factor of capital, and we use the human capital stock in the middle of year  $H_t$  as input factor of labor, there is a 0.5 standard time deviation between the two input factors. The combination of labor input and capital input is not consistent in time. In this situation, the production function should be:

$$Y_t = f(K_t, H_{t+0.5}) \quad (4.5)$$

However, in the traditional time series models, there is no non-integer lag order such as 0.5 except the ARFIMA model<sup>66</sup>. This brings us new difficulties for econometric analysis. In order to correct this time gap between the two inputs, and render consistent their integration into the production functions that will be used later, we propose the following accretion formula<sup>67</sup>:

$$H_t = (1 - \sigma_{Et}) H_{t-1} + \left(1 - \frac{\sigma_{Et}}{2}\right) I_{Et} \quad (4.5)$$

That is using the following formula of retropolation:

$$H_{t-1} = \frac{H_t - \left[1 - \frac{\sigma_{Et}}{2}\right] \cdot I_{Et}}{(1 - \sigma_{Et})} \quad (4.6)$$

With  $H_t$  of reference years calculated by equation (4.4)

### Total Human Capital

It should be pointed out that the formula to calculate total human capital of early years should be different from the equation (4.5) for productive human capital. This is because we shall use 1964 as reference year for calculating the total human capital over 1949-1963 and use 1982 as reference year for calculating this series over 1965-1981. However the reference time of census 1964 and 1982 are 0:00 July 1. If we use equation (4.4) to calculate the total human capital of reference years, the values obtained are essential the level of total human capital in the middle of those years. But equation (4.5) uses the new increased human capital in the end of the year. On the other hand, the reference time of recent censuses is 0:00 November 1. So for the early years, we need to correct equation (4.5) for the total human capital:

$$H_t = (1 - \sigma_{Et})H_{t-1} \left(1 - \sigma_{E,t-1}/2\right) + \left(1 - \sigma_{E,t}/2\right)I_t \quad (4.7)$$

<sup>65</sup> Data illustrated in *graph 4.1* and calculated with equation (4.4). The details of parameterization is presented in section 4.3

<sup>66</sup> Hosking (1981)

<sup>67</sup> For the other possible solutions and proof of equation (4.5), see *Appendix 4.1*

That is to say we firstly convert the human capital stock in the middle of year  $H_{t-1}$  into the level in the end of year  $H_{t-1}(1 - \sigma_{t-1}/2)$  and then apply equation (4.5). For the censuses after 1990, as the reference time is closed to the end of year we don't do the adjustment.

### 4.3 Details of Parameterization

Therefore, we need to determine more parameters than in the case of physical capital, namely: rates of retirement  $r_t$  and/or of mortality  $m_t$ , associated to the depreciation rates  $\sigma_{Et}$ ; the respective increments  $I_{Et}$  in the stocks of human capital, which requires knowledge of the durations of the cycles of education  $\eta_{it}$  and, for each of them, the numbers of graduates  $\lambda_{it}$ ; and the average educational attainment levels achieved  $E_{jt}$  and the numbers of persons  $L_{jt}$  of these levels  $j$ , to assess the values of the stocks for the reference years used as multiple bases. It should be noted that the main choices we have made are distinctive according to the definitions of human capital adopted.

#### Human capital depreciation rate $\sigma_{Et}$ - mortality rate $m_t$ and retirement rates $r_t$

Depreciation rate  $\sigma_{Et}$

The essence of physical capital depreciation is that the relative efficiency declines over time and capital goods retire when service life expires or wearied down. For this reason, the depreciation of human capital should also contain double sense: 1) the knowledge structure of older workers becomes relatively backward due to the technical progress; so that their productivities relatively decline. 2) Laborers exit production areas due to retirement or/and losing work ability (dead, disable due to accident). For the capital goods, the decline of relative efficiency is exactly caused by attrition; under the assumption of "age-efficiency of capital goods declines geometrically", the depreciation rate determined by service life and residuals is consistent with the rate of replacement of capital. However, for the human capital, the decline of relative efficiency is caused by technical progress that makes the knowledge structure of older workers becomes relatively "backward", rather than attrition of human capital. Therefore, from this perspective, human capital depreciation rate should use some kind of technological progress indicator.

But we will meet two problems with technical progress under the circumstance of using "educational attainment" as measurement of human capital

1) Recursive loop problem. In order to estimate the human capital, we need technical progress rate; but in order to get the technical progress rate, we must firstly have human capital (if we use TFP growth rate or certain factor productivity growth rate as technical progress indicator<sup>68</sup>). This is an infinite recursion. Even we can use the iteration method to get asymptotic results, but it is not necessarily convergent.

2) Homogeneity of educational attainment. The human capital defined by the years of schooling of Barro-Lee has a property of homogeneity. This is to say, we cannot distinguish the "quality" between old and new human capital. For example, an undergraduate student in 1990s who has been educated 16 years while another undergraduate student in 2000s has also been educated 16 years. Thus we cannot distinguish the relative efficiency of the two. In a

---

<sup>68</sup> Solow, Harrod, Hicks neutrals.

word, with Barro-Lee indicator, we are essentially unable to consider the upgrading of knowledge due to technical progress.

As this chapter is still in the framework of Barro-Lee, we don't consider technical progress as human capital depreciation, but only consider "attrition"; that is laborers exit production areas due to retirement and losing work ability (in this paper, we only consider death and retirement, we don't consider the disabled). At the meantime, we have also proposed a new human capital indicator with method of Kendrick (1976) as an effort to exceed the Barro-Lee framework so that tries to avoid the limitation of "educational attainment" (see *Appendix 4.2*).

We use the rate of mortality of persons over six years old,  $m_t^{+6}$ , as the depreciation rate affecting total human capital  $\sigma_t^T$ ; and, for that of productive human capital  $\sigma_t^P$ , the weighted depreciation rates of urban ( $\sigma_t^{urb}$ ) and rural ( $\sigma_t^{rur}$ ) workers over 16 years. As the pension system is limited to urban employees only, we calculate for them the depreciation as being equal to the rate of urban mortality  $m_t^{urb}$ , plus the rate of retirement  $r_t$ ; and for rural workers, only the rate of mortality  $m_t^{rur}$ ; in other words:

$$\left\{ \begin{array}{l} \sigma_t^T = m_t^{+6} \\ \sigma_t^P = w_1 \cdot \sigma_t^{rur} + w_2 \cdot \sigma_t^{urb} \\ \sigma_t^{rur} = m_t^{rur} \\ \sigma_t^{urb} = m_t^{urb} + r_t \end{array} \right. \quad (4.8)$$

$w_1$  and  $w_2$  being the proportions of the rural and urban populations of over 16 years in the total number of employed persons, with a normalization of their sum to unity ( $w_1 + w_2 = 1$ ).

#### Mortality rate $m_t$

The respective values of  $m_t^{rur}$  and  $m_t^{urb}$  are calculated directly from demographic yearbooks (*Population and Employment Statistics Yearbooks* and *Population Censuses*) since 1994<sup>69</sup>. For the rest years, the data are missing and we have founded that the urban-rural immigration data of NBS are serious biased so that the calculated  $m_t^{rur}$  and  $m_t^{urb}$  are unreasonable. So we try to make full use of historic information with the following approximations. For 1992-1993, we use mortality rate of population aged 16 and over to instead<sup>70</sup>. For the periods 1954 -1965 and 1972-1985, we respectively use urban and rural mortality rates to instead  $m_t^{urb}$  and  $m_t^{rur}$ <sup>71</sup>. For the period over 1949-1953 (before the foundation of NBS and in the end of civil war<sup>72</sup>), and 1966-1971 (due to the Cultural Revolution), there is not much available data. So for  $m_t^{rur}$ , the data of 1949 is the average data of 7 provinces; and average of 9 provinces for 1950-1953; average of 21 provinces for 1966; average of 20 provinces for 1967-1971. For  $m_t^{urb}$ , the data of 1949 is the average data of 8 provinces; average of 10 provinces for 1950-1953; average of 22 provinces for 1966; average of 21 provinces for 1967-1972<sup>73</sup>. Besides, there is no information about  $m_t^{urb}$  and  $m_t^{rur}$  over 1987-1988, we have to use total population mortality rate to instead. After we have got the productive human capital by such approximation, we have controlled other parameters and extended those approximations to all years to simulate a new series. We have found that the differences between the two are nonsignificant as well as the econometric

<sup>69</sup> Data of 1995 is calculated from population yearbook 1997, data of 2000 and 2010 are calculate with the table 6-4 A-C of census data.

<sup>70</sup> Data comes from the population yearbook 1993 and 1994.

<sup>71</sup> Data comes from *China Population statistics collection 1949-1985* (《中华人民共和国人口统计资料汇编 1949-1985》)

<sup>72</sup> Up to 1951, China has finished territorial reunification of the mainland and NBS was founded in 1952.

<sup>73</sup> Data comes from *China Population statistics collection 1949-1985* pages 402-463

results. This simulation suggests that the errors brought by such approximation are negligible<sup>74</sup>.

Retirement rates  $r_t$

This chapter calculates the statutory retirement rate of urban employed persons, namely the retirement rate calculated according to the official statutory retirement age that is given as the ratio of the population retiring  $P_t^{R,urb}$  to the employed population  $P_t^{E,urb}$ :

$$r_t = P_t^{R,urb} / P_t^{E,urb} = (P_t^{R,T,urb} - P_t^{R,ch\hat{o},urb}) / P_t^{E,urb} \quad (4.9)$$

where  $P_t^{R,urb}$  corresponds to the population of the legal retirement age  $P_t^{R,T,urb}$ , minus the number of unemployed at retirement age  $P_t^{R,ch\hat{o},urb}$ .

The variable  $P_t^{R,urb}$  needs to be calculated very carefully, because the legal age of retirement changed according to the time period, to the sex and to socio-professional category. The classification of the latter divides employed persons into four groups: workers, peasants, cadres, and the military. *Table 4.3* summarizes each adjustment of statutory retirement age since the foundation of PRC:

**Table 4.3 General Statutory Retirement Age (except the Special Industries)**

Time	Cadre		Worker		Laws and Regulations	Execution Time
	Male	Female	Male	Female		
1951	60	50	60	50	《Labour Insurance Regulations》	26-Feb-1951, Modified 26-Jan-1953
1955	60	55	60	50	《State Council Temporary Measures on State Organs' Retirement》	1-Jan-56
1958	60	55	60	55	《State Council Temporary Measures on Workers and Staff's Retirement》	9-Feb-58
1978- Present	60	55	60	50	《State Council Temporary Measures on Providing for Old, Weak, Sick, and Handicapped Cadres》	2-Jun-78
					《State Council Temporary Measures on Workers' Retirement, Resignation》	

*Note:* 1) The retirement age of cadres at the ministerial level is 65, and there is no clear age restriction for the cadres at the deputy national level and above.

2) Since March 1<sup>st</sup> 2015, the retirement age of female cadres at deputy division-level and above has been extended to 60 years old. The delay of retirement in a more border range is in discussion by government.

3) A large proportion of workers retire in advance while the senior cadres defer their retirement. For example, over 2002-2004, there were 250 000 enterprise worker retirees in Hunan province. The average retirement age is 52.3 years old. 94 000 of them have retired in advance, that occupied more than 37%<sup>75</sup>.

However, the definition of cadres in China is very ambiguous. The cadre in the broadest sense means that everyone is cadre except the workers, peasants and soldiers<sup>76</sup>. Although this quartering classification of political identity has almost been abandoned after the economic reform of 1978, but it still plays a role in many areas<sup>77</sup>. Cadres in the strictest sense refer to leading cadres (deputy division level and above) in the party and government departments. And Cadres of general sense is staff in party and administrative sections, as a synonym of

<sup>74</sup> The data of those mortality rates are presented in *Appendix 4.3*.

<sup>75</sup> [http://news.xinhuanet.com/life/2006-08/31/content\\_5029534.htm](http://news.xinhuanet.com/life/2006-08/31/content_5029534.htm)

<sup>76</sup> All university students have a political identity of cadre. Generally speaking, businessman or capitalist's political identities depend on their family register (Hukou) - a capitalist who has an urban Hukou has a political identity of worker and rural Hukou capitalist has a political identity of peasant.

<sup>77</sup> For example, persons with political identity of farmer or worker generally cannot get a job of civil servant.

"civil servant". However, in practice, the senior managers of public enterprises and institutions<sup>78</sup> have also administrative levels; they are treated as cadres in Chinese political framework. For the political identity, the ordinary workers of state-owned enterprise are worker and the senior managers belong to cadre.

Thus, the cadre in *table 2* refers to civil servants and senior managers of public enterprises and institutions, but it doesn't include the staff of grassroots political powers<sup>79</sup> (level of village and neighborhood committee). As a consequence, we define cadres as staff in the Party or the State (at the national, provincial, prefectural, county and township levels), the managers of public or collective institutions, as well as those of the enterprises.

From *table 4.3* we see that the retirement age has remained the same for male workers or cadres, *i.e.*, at 60 years. For women, by contrast, changes are observable, even though this age has often been 50 years for female workers and 55 years for cadres – the latter category only represents a tiny proportion of female employment (around 1% to 5%<sup>80</sup>). We therefore choose the following retirement ages, distinguishing only by gender, from 1952 to the present, and we take 60 years for men and 50 for women (except for the sub-period 1958-1977, for which we retain 55).

We still need to calculate the male and female urban populations of 60 and 50 (or 55) years respectively, as well as the occupied urban population at the age of retirement. However, the NBS has provided data on the urban population by age and sex only since 1983. In order to know the demographic structure prior to this date, only the censuses give information. By drawing on their adjacent points (1953, 1964, 1982), we estimate the urban population at retirement age  $P_t^{R,T,urb}$  for the years before 1983 thanks to a three-dimensional function<sup>81</sup> of the rate mortality of the population  $\rho_t^{ij}$  (age  $i$ , sex  $j$  and year  $t$ ), as:

$$P_{t+\tau}^{i+\tau,j} = P_t^{i,j} \cdot (1 - \rho_t^{ij})^\tau \quad (4.10)$$

where  $P_t^{i,j}$  and  $P_{t+\tau}^{i+\tau,j}$  are the respective numbers of persons of a same group corresponding to censuses which have a time distant of  $\tau$  years, so that mortality rates can be calculated as the geometric mean between two censuses - and in line with the demographic literature (e.g., these rates reach their maximum near the average life expectancy).

*Graph 4.2* shows the average mortality rates of population by age and gender (excluding newborn infant mortality) over 1953-1964 and 1964-1982 (the projection has eliminated the time dimension). The horizontal axis is age, from 0 to 90 years old. The curves presented by *graph 4.2* are in line with the demographic literature: 1) the mortality rate reaches its maximum near the average life expectancy; 2) In infancy period, the girl's mortality rate is generally higher than boy's mortality rate; 3) In the older ages, the female's mortality rate is generally lower than male's mortality rate.

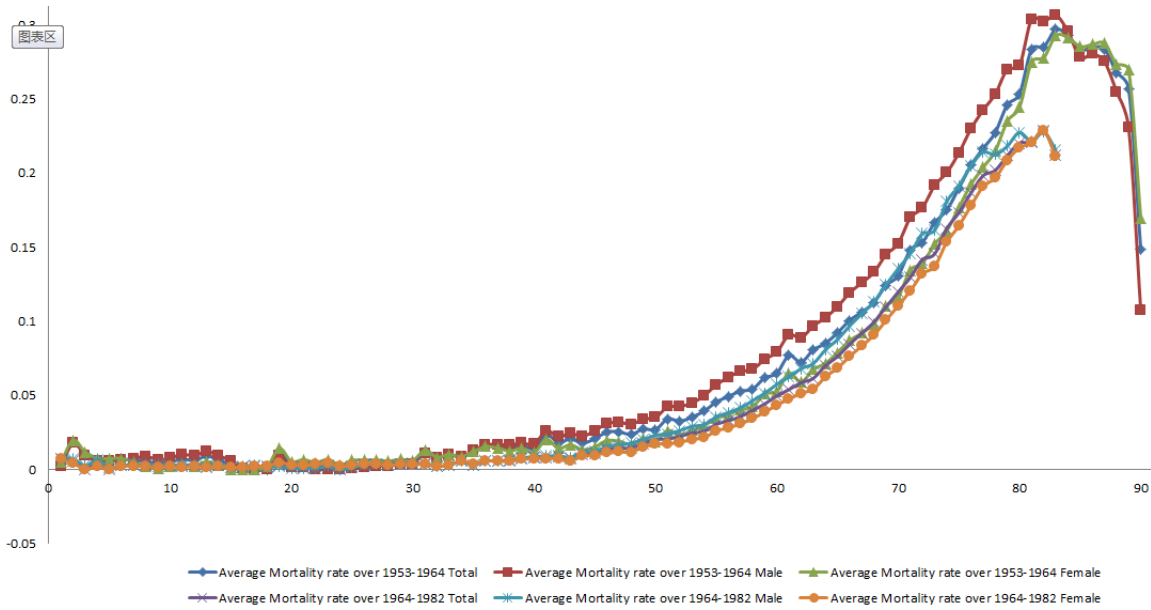
<sup>78</sup> Public schools, public hospitals, state-owned enterprises, collective enterprises, research institutes, and some institutions with governmental natures.

<sup>79</sup> The ascending political levels of China are: Village level (村级或股级), Township level (Section-level 乡镇级或科级), County level (division-level 县级或处级), Prefectural level (department-level 地市级或厅级), Provincial level (ministry-level 省部级), and National level(国家级).

<sup>80</sup> Calculated according to Xinhua News Agency's public news <http://cpc.people.com.cn/GB/64093/64387/4740043.html>

<sup>81</sup> More precisely, we should define a four-dimensional function that adds the dimension of urban-rural. However, in practical calculations, we found that the urban-rural immigration data before 1983 released by NBS is serious biased. So we have abandoned this dimension; we turn to firstly estimate the total number of population in retirement ages, and then use a dynamic proportion of urban population to total population to estimate  $P_t^{R,T,urb}$  indirectly.

**Graph 4.2 Average Mortality Rates of Population by Age (%)**



Note: It should be pointed out that as the two censuses of 1953 and 1964 didn't contain military data, at the meantime,  $\rho_t^{ij}$  is calculated by the population of survivors that didn't contain newborn infant death. So the mortality rate calculated in this manner is underestimated for the young age groups. But what we need here are just the mortality rates of population aged 50, 55 and 60. There is no effect on the estimation. The data is presented in Appendix 4.3.

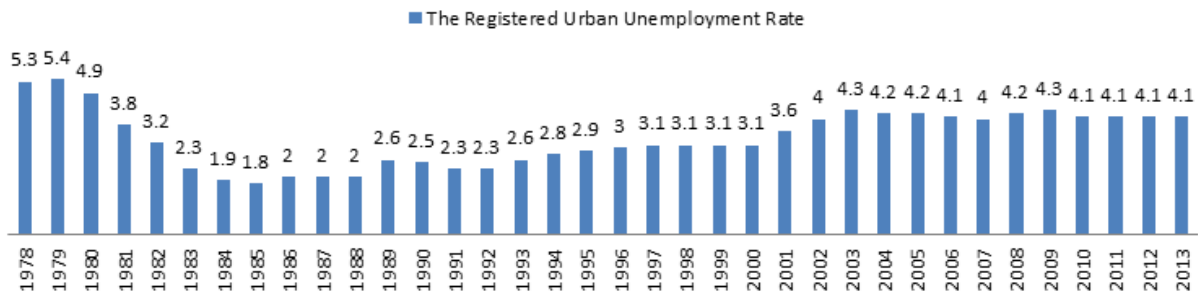
After getting the average mortality rates of population by age and gender  $\rho_t^{ij}$ , we can calculate the total population at the retirement ages  $P_t^{R,T}$  before 1983. Then, we use a dynamic proportion  $\xi_t$  of the urban population to obtain  $P_t^{R,T,urb}$ , that is:

$$P_t^{R,T,urb} = \xi_t \cdot P_t^{R,T} \quad (4.11)$$

Once the unemployed urban population has been deducted, and by assuming an unemployment rate of 4% for the period before 1978 (as observed on average in the long period), we can obtain a rate of retirement of the urban employees, and so ultimately the rate of depreciation of the stock of productive human capital.

We also need urban unemployed population in retirement ages. NBS has only provided "Registered Urban Unemployment Rate" and the number of persons of urban unemployment since 1978 (Graph 4.3) and we have no information about the age structure of unemployment.

**Graph 4.3 The Registered Urban Unemployment Rate (%)**



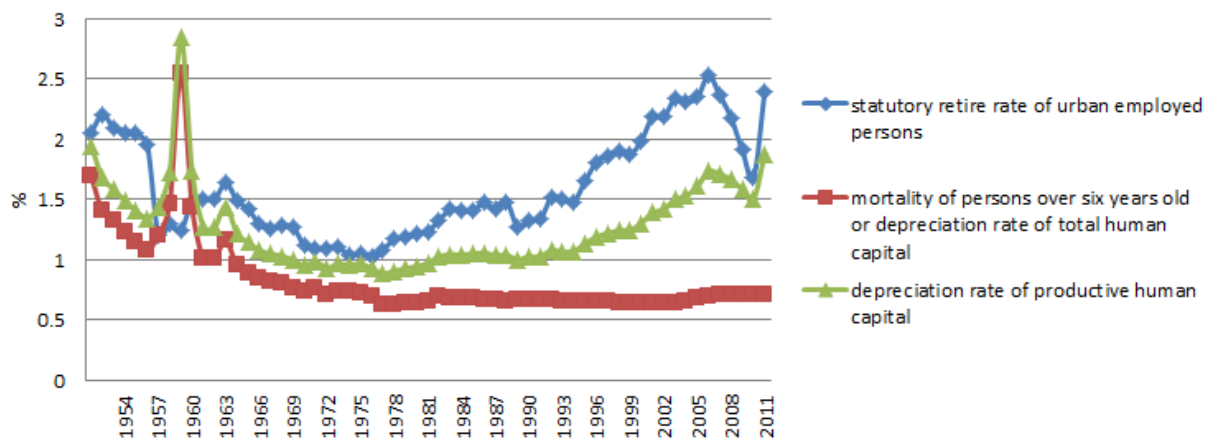


We notice that grace to the rapid economic growth, the “Registered Urban Unemployment Rate” of China is stable and near 4% since 2002. Considering that during the planned economy period before 1978, the unemployment rate should be even more stable. So we suppose that the unemployment rate of urban population in retirement ages  $u_t^{R,urb}$  is 4% before 1978. And after 1978,  $u_t^{R,urb}$  is approximated by the dynamic registered urban unemployment rate:

$$P_t^{R,ch\hat{\delta},urb} = \begin{cases} P_t^{R,T,urb} * 4\% \\ P_t^{R,T,urb} * u_t^{R,urb} \end{cases} \quad (4.12)$$

Substituting equations (4.10) - (4.12) into equation (4.9), we get the statutory retirement rate of urban employed persons, and then get the depreciation rate of productive human capital with equation (4.8) (*Graph 4.4*).

**Graph 4.4 Depreciation Rate of Human Capital and Retirement Rate (%)**



### New Increased Human Capital $I_{Et}$ - Duration of Education $\eta_{it}$ and Number of Graduates $l_{it}$

As to investment in human capital  $I_{Et}$ , all the new increases are used to calculate the total stock, but only increases relating to the appropriate age groups of employed persons are retained for calculations of productive human capital. For this, we need to know the duration  $\eta_{it}$  of the different educational cycles and the number of the graduates  $l_{it}$  by level.

Number of Diploma or Graduates  $l_{it}$

Regarding  $l_{it}$ , some missing data of the NBS have had to be completed, specifically the numbers of graduates of:

1) The numbers of graduates of postsecondary specialized college (called for short as college hereafter) and undergraduate over 1949-1997. During this period, NBS only provides “number of graduates of higher education” that is the sum of the two. However, the durations of college and university are different (respectively 3 years and 4 years) so that we should distinguish the two. Information has been founded in the *China Education Statistical Yearbook 1949-81*<sup>82</sup> and *China Education Statistical Yearbooks* of diverse years during the period 1982-1997.

<sup>82</sup> Page 967. In Chinese: 《中国教育年鉴 1949-1981》

2) Graduate education over 1971-1977. As the graduate education enrollment was paused since 1967 and recovered in 1977, the number is assumed to be zero, due to frequent interruptions of university courses from 1967 to 1977 resulting from the Cultural Revolution<sup>83</sup>.

3) Master's and PhD degrees over 1949-2003. For the period over 1982-2003 data is completed thanks to *China Education Statistical Yearbooks* of corresponding years. For the period before 1982, as the absolute majority part of graduate education is Master degree<sup>84</sup>, we calculate their educational attainment as Masters. At the meantime, as the total number of graduate students is small<sup>85</sup>, such an approximation has insignificant error on total human capital.

4) The number of graduates of vocational high school (junior and senior) for periods 1949-1958 and 1966-1979. As these establishments were opened in 1958<sup>86</sup>, but closed from 1966 to 1979 due to the Cultural Revolution so the numbers are zero.

5) Skilled Workers [Training] School between 1949 and 1981. The data after 1971 could be founded *China Education Statistical Yearbook* of corresponding years. For the period over 1970-1974 the numbers are zero due to the Cultural Revolution. And for the period before 1970, *China Education Statistical Yearbook 1949-1981* only provided the numbers of schooling<sup>87</sup>. We assume that half of those students graduated from two-year training programs on average. We have estimated the numbers of graduates of this education over 1949-1985. As we have available data over 1975-1985, we compared the estimated data with published data over this period; the errors are small that suggests our estimation is acceptable. In additional, the total number of Skilled Workers [Training] School students is small, the errors caused by such an approximation are also negligible.

6) Adult education cycles, as well as literacy training programs, between 1952 and 2003, data obtained from the two specialized yearbooks mentioned above.

7) Returned overseas students over 1949-1952 and 1966-1973, we have confirmed from *China Education Statistical Yearbook 1949-1981* that overseas students began comeback to China since 1953 (16 persons) and interrupted due to the Cultural Revolution (restarted since 1974, 7 persons).

#### Duration of Education $\eta_{it}$

The duration of studies for the ordinary and vocational training have remained rather stable over time, with the exception of educational reforms in the early days of the People's Republic (1949 into the early 1950s) and at particular times (Cultural Revolution). But these experiences have most often concerned only primary education, and have only been applied to certain sections of China's national territory, and not to the whole country. In these cases, in order to calculate the average duration of a given educational cycle (primary, junior or senior

---

<sup>83</sup> *China Education Statistical Yearbook 1949-1981* page 637.

<sup>84</sup> Page 634 of *China Education Statistical Yearbook 1949-1981* has pointed out that: From 1978 to July 1982, 8562 persons have obtained Master's degree and 10 persons have obtained Ph.D. degree.

<sup>85</sup> For most years before 1969, the total number of graduate diploma is less than 2000.

<sup>86</sup> The Fourth Administrative Work Meeting of the Ministry of Education in March 1958.

<sup>87</sup> Page 221

secondary schools...), we use the proportions of the graduates of this cycle - sometimes presenting different durations - in the total number of graduates of the same cycle as weights.

Table 4.4 firstly summarized the standard duration of studies of each education in table 4.2. and then we correct those standard durations according to the reality if necessary.

**Table 4.4 Standard Durations of Educations (Cumulative Years)**

Educational level	Ordinary Primary School	Ordinary Junior High School	Ordinary Senior High School	Postsecondary Specialised College	Undergraduate	Master	Ph.D.
Educational Attainment	6	6+3=9	9+3=12	12+3=15	12+4=16	16+3=19	19+3=22
Educational level	Adult Primary School	Adult Junior High School	Adult College	Adult College	Adult Undergraduate	Online College	Online Undergraduate
Educational Attainment	1	1.5	1.5	1.5	2	1.5	2
Educational level	Literacy classes	Vocational Junior High Schools	Vocational Senior High School	Skilled Workers [Training] School	Secondary Specialised School	Returned Overseas Students	Uneducated
Educational Attainment	1	6+3=9	9+3=12	1	9+3=12	Dynamic Data	0

Thus, we select the following periods: six years for the ordinary primary schools, nine for the ordinary (or vocational) junior high schools, 12 for the ordinary senior (or vocational) high schools, 15 for the post-secondary specialized colleges, vocational high schools and secondary specialized schools, 16 years of education to complete undergraduate study, 19 years to obtain a Master's degree, and 22 a PhD.

As for adult education, as what we have measured here is the new increased human capital, so the previous educational experiences of the adult cannot be counted in new increased human capital because they have already entered into the job market. We can only count the augmented educational attainment. At the same time, adult education is a spare-time education; they make use of their spare time to improve their quality of education. We cannot count the whole duration of years as educational attainment. This is why we decide that we take half duration of adult education as the augmented educational attainment.

Similarly to the adult education, we can only consider half of the whole duration of studies as the new increased years of schooling for literacy classes, skilled-worker training schools and on line education. As a consequence, we take one year for the adult primary schools<sup>88</sup>, literacy classes and skilled-worker training schools, a year-and-a-half for the adult high schools and adult colleges, and two years for the adult undergraduate study. The average duration of studies is set to a year-and-a-half for the on line colleges and two years for the on line undergraduate.

Regarding the students who have studied abroad, we adopt a dynamic educational attainment for returned overseas students. Before the integration of China's economy into world's economy, China's openness is very low so most overseas Chinese students are doctoral students allocated by Chinese government. Entering the 21<sup>st</sup> century, with the rise of China's openness, governmental allocation is not the only way to support Chinese students studying

<sup>88</sup> The adult primary school is senior primary level, so the complete duration is 2 years (not 6 years) and we take 1 year as the augmented educational attainment.

aboard. They are assumed to have returned with a doctorate in the period from 1952 to 1999 (*i.e.*, equivalent to 22 years of study) and with a Master's degree from 2000 to 2004 (19 years); since 2005, the average level is calculated thanks to the data series provided by the Ministry of Education (Service Center for Scholarly Exchange) and *Open Doors Report* of Institute of International Education of U.S.<sup>89</sup>, in the knowledge that more and more young people go abroad to study even at undergraduate level<sup>90</sup>.

The level of education of the illiterate and/or uneducated is set equal to zero; but they are counted as simple labour among the inputs of the various production functions that will be used.

It is reasonable to define the augmented educational attainment of literacy class as 1 year. According to the criteria of illiteracy and "eliminating of illiteracy"<sup>91</sup> we see that after the 3-4 years studies in literacy class (spare-time), their educational levels at least equal to the 2<sup>nd</sup> year of primary school<sup>92</sup>. So it is reasonable to set the augmented educational attainment of literacy classes as 1 year. We didn't overestimate the educational attainment.

Now let's concentrate on the educational reforms and consider its consequence on the durations of education. *Table 4.5* summarized the time line of educational reforms and their background since 1922.

---

<sup>89</sup> Due to lack of diploma structure data of returned overseas students from other countries, we have used the Chinese students in U.S. as approximation.

<sup>90</sup> For example, *Chinese returned overseas students employment Blue Book 2014*(in Chinese: 《中国留学生回国就业蓝皮书 2014》) pointed out that: 63% returned overseas students have Master's degree; 30% have Bachelor's degree; and only 6% have Doctor's degree.

<sup>91</sup> The definition of illiteracy in China is: literacy of words is under in 500 Chinese characters (24-Nov-1953). The criterion of "Eliminating of Illiteracy" is: the literacy of farmer augments to 1000 common Chinese characters in three years (14-Dec.-1950). This criterion had been augmented to 2000 Chinese characters for workers in 1953 that equals to the educational level of 3<sup>rd</sup> or 4<sup>th</sup> year of primary school. And the criterion for farmer had been augmented to 1500 Chinese characters that equals to the educational level of 2<sup>nd</sup> year of primary school in 2011.

<sup>92</sup> *Compulsory Education Curriculum Standards 2011*. In Chinese: 《2011 年义务教育课程标准》

**Table 4.5 Time Line of Educational Reforms in China**

Date	Related laws or events	Details
1922	<i>Renxu Educational System</i> <sup>93</sup>	The primary education contains two stages – 4 years of junior primary school and 2 years senior primary school
1 <sup>st</sup> Oct. 1951	<i>Decision on Reform of Educational System of State Council of P.R.C.</i> <sup>94</sup>	1) The primary education is "5-year consistent system". 2) The duration of University and College were reduced from 4-6 years reduced to 3-5 years.
26 <sup>th</sup> Dec. 1953	The 5-year primary school	was canceled and the duration recovered as 6 years.
1958	Educational Reforms under the background of Great Leap Forward political movement	Large-scale educational system reform experiments: "5-year primary school", "5-year middle school", "7-year primary-middle school", "9-year primary-middle school", "10-year primary-middle school" and "9+2 primary-junior and senior middle school"; for the secondary education, "4-year middle school", "4+2 junior and senior middle school", "3+2 junior and senior middle school" and "2+2 junior and senior middle school" etc.
24 <sup>th</sup> May 1959	<i>Provisions relating to the experimental reforms of the school system of State Council</i> <sup>95</sup>	The educational system reform experiments cooled down.
8 <sup>th</sup> April 1960	Report of <i>Education must be reformed</i> in the Second Session of the Second National People's Congress	The experiments continued. Until Sept. 1960, according to data of 27 provinces, 14.77% primary schools and 18.67% secondary schools have participated such an experimental reform.
Jan.1961 to May 1966	Before the Cultural Revolution	Few schools participated the experiments due to the finish of "Great Leap Forward" political movement.
1966-1976	Cultural Revolution	The durations are generally reduced. Until 1973, 14 provinces are 9 years (5 years for primary and 4 years for secondary education); 7 provinces are 10 years (5+5 or 6+4); 9 provinces distinguished rural and urban (rural: 9 years, urban 10 years); and 5-year primary school and 6-year primary school existed in Tibet in the same time while the junior secondary school is 3 years.
after 1976	Economic reform	The durations have gradually turned back to the standard duration in <i>table 4.4</i> (the first line).
1989	The number of graduates of 6-year primary school exceeded 5-year primary school	
2004-present	All the primary schools are 6-year except Shanghai (5 years for primary school and 4 years for junior high school)	

Arrange according to abundant historical data.

As mentioned above, we use the proportions of the graduates of this cycle - sometimes presenting different durations - in the total number of graduates of the same cycle as weights. For example, for the primary:

$$\eta_{primary,t} = 5 * \alpha_{5,t} + 6 * \alpha_{6,t} \quad (4.13)$$

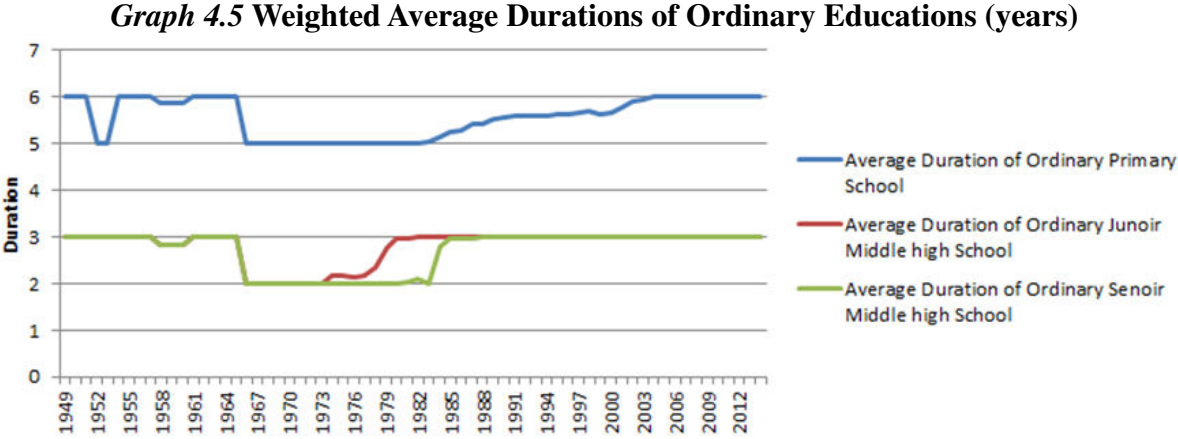
Where  $\alpha_{5,t}$  and  $\alpha_{6,t}$  are respectively the proportions of the numbers of 5-year and 6-year primary school graduates to the total numbers of primary graduates in year  $t$ . With restriction:  $\alpha_{5,t} + \alpha_{6,t} = 1$

<sup>93</sup> In Chinese: 《壬戌学制》.

<sup>94</sup> In Chinese: 《关于改革学制的决定》.

<sup>95</sup> In Chinese: 《关于试验改革学制的决定》

We calculate the dynamic duration for junior and senior high schools<sup>96</sup> with similar method, the results are presented in *graph 4.5*.



**New Increased Human Capital  $I_{Et}$**

Now we can calculate the respective new increased human capital series corresponding to total human capital and productive human capital by equation (4.3). However we still need to pay attention to a new difficulty here that is the age of employed persons.

For the total human capital, the series of  $I_{Et}$  is simple and certain that we include all the new increased human capital in that series. But for the productive human capital, as the legal age for employment is 16<sup>97</sup>, we should exclude a part new increased human capital from the total investment series  $I_{Et}$ . Generally, As a matter of fact, the age of entry into primary school is six years, followed by a compulsory supplement of nine years. So that the legal age which is achieved by a high school (junior secondary) graduate; the increase of productive human capital should therefore include graduates of junior high school - not those of primary school (series 3 in *graph 4.7*). However, the conception of “compulsory education” firstly appeared in a legal form only after 1982<sup>98</sup>, and it has been made clear as nine years in the "*Compulsory Education Law*" of 1986<sup>99</sup>. So before 1982 (more strictly before 1996, see *infra*), if we use the “series 3” as new increased productive human capital, this series is underestimated so that the educational attainment of initial years should be overestimated<sup>100</sup>. Another argument to ameliorate “series 3” is: we can see from *graph 5* that during the Cultural Revolution due to reduction of duration of educations, the junior secondary education graduates may not reach 16 years old. So we need to calculate the series of increase productive human capital period by period.

At the same time, we should also recognize that the realization of "Compulsory Education Law" is progressive. From the proposition of “nine years compulsory education” in 1986 to the prohibition of child labor in 1991 and 1994, and until the complete realization of "*Compulsory Education Law*" in 2006 (when the enrollment target of 100% of the child cohort was achieved in the country), we might use a smooth transition function to reflect the

<sup>96</sup> In 1985 and 1986 there were 4-year junior high schools in a very short period. For the special case of Shanghai, we treat the first year of junior high school as the 6<sup>th</sup> year of primary school in our calculation.  
<sup>97</sup> Article 38, *Law of the P.R.C. on the Protection of Minors*, 4<sup>th</sup> September 1991 and Article XV of Labour Law of the P.R.C. 5<sup>th</sup> July 1994.  
<sup>98</sup> The constitution of 1982.  
<sup>99</sup> Article II of "*Compulsory Education Law*", 1<sup>st</sup> July 1986.  
<sup>100</sup> Because we use equation (4.5) to retoolate.

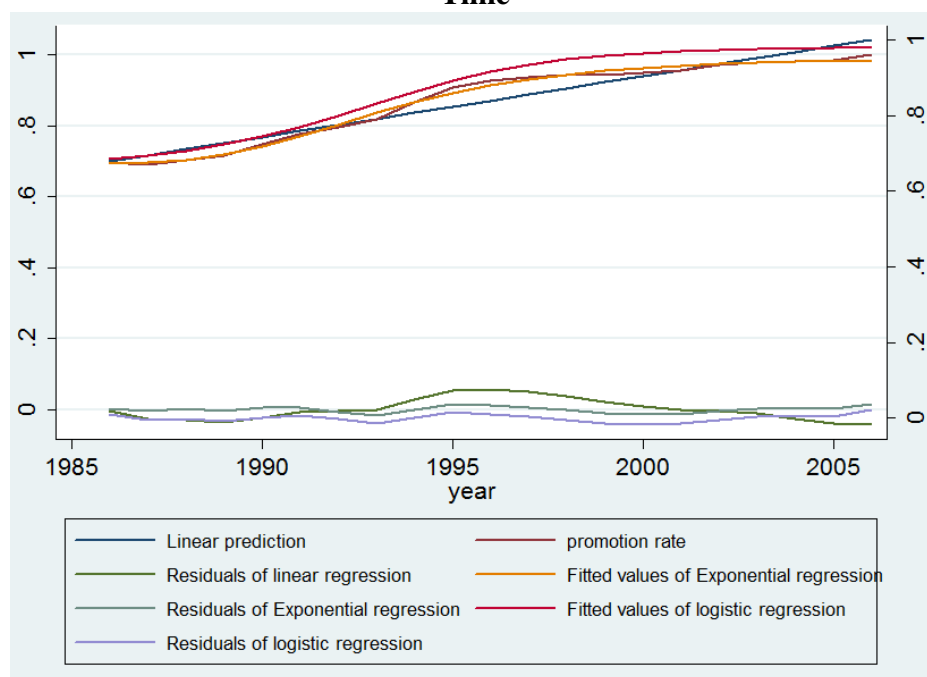
gradual implementation of the compulsory education for nine years. We argue that the “promotion rate of primary school graduates” could reflect this gradual process: higher promotion rate of primary school graduates, higher degree of realization of "Compulsory Education Law". This indicator reached 100% in 2006 that the "Compulsory Education Law" is totally realized since 2006.

From the curve shape of this indicator (*graph 4.6*), we assume the transition function might be: 1) linear (stationary); 2) exponential (accelerating); 3) logical (a “s” curve that the rhythm was rapid in the beginning and slowdown in the end). The econometric results are summarized in *table 4.6*<sup>101</sup>:

**Table 4.6 Fineness of Promotion Rate of Primary School Graduates as a Function of Time**

	<b>Linear function</b>	<b>Exponential function</b>	<b>Logical Functions</b>
<b>Goodness of fit (R2)</b>	0.9219	0.9928	0.9916
<b>p-value of White noise test of residuals</b>	0.4661 (Jarque-Bera Gaussian test)	0.0273 (Portmanteau test)	0.0326 (Portmanteau test)

**Graph 4.6 Fineness of Promotion Rate of Primary School Graduates as a Function of Time**



All the three models have very high goodness of fit and the residuals of all models could pass the white noise tests in some levels of risk. This is maybe caused by the relative small sample size so that the nonlinear models are close to linear model in a small region. And we also notice that the estimated coefficients are  $b_4=1991.904$  in exponential model<sup>102</sup> and  $b_3=1992.734$  in logical model<sup>103</sup>. The inflection points of nonlinear models are highly

<sup>101</sup> For the details of econometric fitness see *appendix 4.4*

<sup>102</sup> and its 95% confidence interval is (1991.419, 1992.389) with the model is: promotion rate =  $b_0 + b_1 \cdot \exp(-\exp(-b_2 \cdot (t - b_3)))$

<sup>103</sup> and its 95% confidence interval is (1992.1, 1993.373) with the model is: promotion rate =  $b_0 + b_1 / (1 + \exp(-b_2 \cdot (t - b_3)))$

consistent with the implementation time of “*Law of Protection of Minors*” and “*Labour Law*” that formally prohibited the recruiting of children under 16 years old.

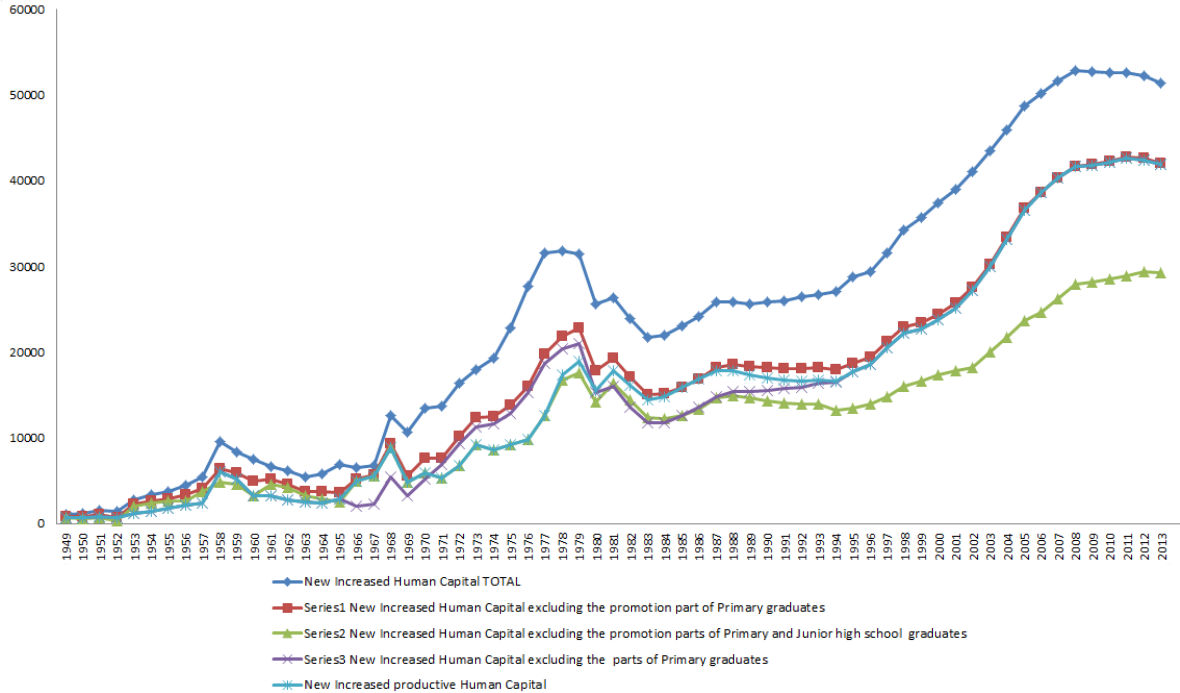
Considering we are in a small sample and the linear model has the best econometric results we should use linear transition function over 1986-2006. That is to say, we assume the new increased productive human capital series linearly passed from series 2 to series 3.

Similarly, as the duration of educations gradually recovered after the end of the Cultural Revolution (see *graph 4.5*), we also assume this process is a linear transition. That is to say, finally we use the following new increased productive human capital series  $I_t$ :

- (1)1949-1965<sup>104</sup>:  $I_t = \text{series 3}$
- (2)1966-1976:  $I_t = \text{series 2}$
- (3)1977-1985:  $I_t = \text{series2} * (1 - f_1(t)) + \text{series1} * f_1(t)$  i.e. a linear combination of series2 and series1
- (4)1986-1995:  $I_t = \text{series1} * (1 - f_2(t)) + \text{series3} * f_2(t)$  i.e a linear combination of series1 and series3.
- (5)1996-2013:  $I_t = \text{series 3}$

Where  $f_1(t)$  and  $f_2(t)$  are the linear transitional functions of time in their respective domains of definition (time), valued within (0,1). So that we get the new increased productive human capital series presented as *graph 4.7*.

**Graph 4.7 New Increased Human Capital (10 000 person\*year)**



<sup>104</sup>More strictly, we should use series 1 not series 3 for the period over 1949-1965 and we should use net promotion rate when we calculate the series 1. But with available historical data, it is almost impossible to calculate the net promotion rate for the early years. So we used the gross promotion rate defined in equation (4.20) as instead. However, as the gap between net and gross promotion rate was great for the early years, it will causes serious basis if we use series 1 over 1949-1965. And the simulations also show that series 3 gives better econometric estimation results.



## Human capital in reference years $H_t$ – educational attainment $E_{jt}$ and population of different educational levels $L_{jt}$

As we use equation (4.6) and equation (4.7) to replotate the human capital, we need to calculate the human capital stock levels of reference years. As the errors accumulate alongside the calculation, in order to use a maximum amount of official historical data and in order to limit the risk of errors as much as possible, contrary to the physical capital stock estimation (a unique base year), we use multiple reference years to calculate the human capital period by period. Summarized in *table 4.7*:

**Table 4.7 Human Capital of Reference Years and Data Sources**

	Period	Base Years	Sources of data of Base Years
Total Human Capital	1949-1963	1964	2 <sup>nd</sup> Population Census
	1965-1981	1982	3 <sup>rd</sup> Population Census
	1983-1986	1987	“China Population Statistics Yearbook 1988”
	1988-1989	1990	4 <sup>th</sup> Population Census
	1991-1992	1993	“China Population Statistics Yearbook 1994”
	1993-2013	Corresponding “Population Statistics Yearbooks” of divers years	
Productive Human Capital	1949-2005	2006	“China Population and Employment Statistics Yearbook 2007”
	2006-2013	Corresponding “Population and Employment Statistics Yearbook” of divers years	

The method of calculation was mentioned in section 4.1 that uses the table entitled “Population Aged 6 and over by Age, Sex and Educational Attainment” in *China Population Statistics Yearbooks*, table entitled “Educational Attainment of Employed Persons, table 3-1” in *Population and Employment Statistics Yearbooks* to estimate the educational attainment of productive human capital for reference years (2006-2014); and uses table entitled “Population Aged 6 and over by Age, Sex and Educational Attainment”<sup>105</sup> in *Population Census Data* to estimate the educational attainment of productive human capital in reference years. As usual we firstly summary the standard educational attainment for each level of education and then ameliorate the parameterization step by step. *Table 4.8* gives the standard educational attainment for productive and total human capital:

**Table 4.8 Standard Parameterization of Educational Attainment (years)**

Population Aged 6 and over by Age, Sex and Educational Attainment (for total human capital)

Cultural Level	No schooling	Primary	Junior Secondary	Senior Secondary	College and higher
Standard Educational Attainment	0	6	9	12	15

Educational Attainment of Employed Persons (for productive human capital)

Educational Level	No schooling	Primary	Junior Secondary	Senior Secondary	College	Undergraduates	Graduates and higher
Standard Educational Attainment	0	6	9	12	15	16	19

It is important to point out that the durations of studies used in the calculation of total human capital are different from that of productive human capital. Total human capital contains the students in school and those who dropped out, but productive human capital includes employed persons who already left school. NBS gives a clear explanation of “primary education”, which refers to the persons whose highest educational level is primary school,

<sup>105</sup> In Chinese: 6 岁及 6 岁以上人口中文化程度

whether they are still in school, graduated, already educated or dropped out. Most authors in the current literature did not pay attention to this problem of the completion of studies. For example, Cai and Du (2003) used a standard duration of studies. More precisely, in the 2010 Census, the *Table B0301a*<sup>106</sup> gives the “population aged 6 and over by sex, status of school completion and educational attainment”<sup>107</sup>. If we set the duration of studies of the persons at school and who dropped out as half of complete duration of education, then the average educational attainment of population in primary school should be 4.9419 years, and not 6 years. With the census data, we can calculate the educational attainments of different cultural levels in total population for several base years (*Table A4.3.5*).

Let’s firstly consider the parameterization of educational attainment for productive human capital. As we have only data of “Educational Attainment of Employed Persons” since 2006, in that time, the durations of education have already totally recovered into standard duration. So except the “Graduates and higher” might be underestimated (because the years of schooling for Ph.D. is 22 years that is higher than 19 years of Master.), all other assignments for  $E_{jt}$  are accurate. Then we use the accumulated (alive) numbers of Ph.D. or Master graduates to ameliorate the educational attainment of “Graduates and higher” in employed persons.

$$E_t^{graduate} = w_t^{Ph.D.} * 22 + w_t^{master} * 19 \quad (4.14)$$

where  $w_t^{Ph.D.} = L_t^{Ph.D.} / (L_t^{Ph.D.} + L_t^{master})$  and  $w_t^{Ph.D.} + w_t^{master} = 1$

$$L_t^{Ph.D.} = L_{t-1}^{Ph.D.} * (1 - \sigma_t) + l_t^{Ph.D.} \quad (4.15)$$

$l_t^{Ph.D.}$  is numbers of graduates of Ph.D. of year  $t$ <sup>108</sup>;  $L_t^{Ph.D.}$  is the population of Ph.D. in employed persons in year;  $\sigma_t$  is the depreciation rate of human capital (because we are in the employed persons, the retirement should be excluded) so we have excluded the reduction numbers of Ph.D. caused by death and retirement. We use similar way to calculate the accumulated population of Master. The corrected average educational attainment for “Graduates and higher” is presented in *table 4.9*:

**Table 4.9 Average Educational Attainment of “Graduates and higher” (years)**

Date	2006	2007	2008	2009	2010	2011	2012	2013	2014
Attainment	19.4184	19.4147	19.4087	19.4062	19.4028	19.3955	19.3847	19.3751	19.3658

Next, for the “Population Aged 6 and over by Age, Sex and Educational Attainment” of total human capital, the situation is much more complicated. This is because:

1) As underlined above, total human capital contains the students in school and those who dropped out. According to the definition of NBS, “primary education” of total population refers to the person whose highest level of education is primary school, whether he/she is in school, graduation, was educated or dropout. The same is true for the other “Cultural Level”<sup>109</sup>. So if we unified their duration of study as the standard parameterization in *table 4.8*, it would seriously overestimate the level of total human capital.

2) The changes of duration of educations. The reference years of productive human capital are started from 2006 that China has already returned back to the standard educational system.

<sup>106</sup> Data available on official website of NBS: <http://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm>

<sup>107</sup> In Chinese: 6岁及以上人口学业完成情况

<sup>108</sup> That is  $l_{it}$  defined above with  $i=PhD$ .

<sup>109</sup> Note that NBS use the expression of “cultural level” (In Chinese: 文化程度) not the educational level to distinguish delicately total population and employed persons.

But for the reference years of total human capital, 1964, 1982, 1987, 1990 and 1993 are early years. We have pointed out *supra*, in those years; the durations of educations are heterogeneous. We should consider this problem in our estimation.

3) Historical issues before PRC. As indicated in *table 4.5*, before 1949, the primary school is divided into two stages: 4-year junior primary school and 2-year senior primary school. However, except the census of 1964, the “population of primary cultural level” in all the other census didn’t distinguish the difference between junior and senior primary. But we can see in our calculation later, in the census of 1982, there were still about 83.6 million population are in junior primary cultural level. Such a huge population cannot be ignored. That is to say, even we have considered the changes of duration of educations, if we don’t pay attention to this problem; the results will still be serious biased (overestimated).

Among all the different  $E_{jt}$  of total human capital, the most complicated is the educational attainment of primary  $E_t^P$ . How many years of education does “primary level” really mean?  $E_t^P$  is time-varying due to the dynamic evolutions of duration of study, promotion rate of primary graduates and mortality rate. From *table 4.7* we see that  $E_t^P$  in 1964 and 1982 are important: firstly the periods estimated based on those two reference years are long; secondly, those two years are both early years so that the historical issues - “junior-senior primary school” problem has more important influence. So we will focus on  $E_t^P$  of those two years.

The census of 1964 has clearly pointed out that: in 1964, 195 824 459 persons are in the primary cultural level while 69 462 240 of them are in senior primary level and 126 362 219 of them are in junior primary level. However, for any other years, the data didn’t distinguish the junior and senior primary. In recent years, this problem could be ignored in a certain degree. The number of this population (with junior primary cultural level before 1949) will become smaller and smaller during a half century<sup>110</sup>. But, in the early years, this problem is unavoidable. We proposed the following equations to estimate  $E_t^P$ :

$$E_t^P = \beta_S * E_t^{S-P} + \beta_J * E_t^{J-P} + \beta_{D-P} * E_t^{D-P} + \beta_{School-P} * E_t^{School-P} + \beta_{Adult-P} * E_t^{Adult-P} \quad (4.16)$$

With constraint:  $\beta_S + \beta_J + \beta_{D-P} + \beta_{School-P} + \beta_{Adult} = 1$

That is to say, the population of “primary level” contains five parts:

- 1) Graduated junior primary population: proportion in the primary population is  $\beta_J$ , educational attainment  $E_t^{J-P} = 4$ .
- 2) Graduated senior primary graduates: complete primary education, proportion  $\beta_S$ , the educational attainment  $E_t^{S-P}$  is the weighted average educational duration  $\eta_t^{primary}$  given by equation (4.13) to consider the influence of educational reforms and Cultural Revolution (reduction of duration of study).
- 3) Adult primary graduates: proportion  $\beta_{Adult-P}$ , educational attainment  $E_t^{Adult-P} = 4+1$ ;
- 4) Schooling and dropout of primary: proportions respectively  $\beta_{School-P}$  and  $\beta_{D-P}$ . As there is no “junior primary” after 1949, we regard the educational attainment of all schooling and dropout as half of the complete primary educational duration. That is to say we have imposed an implicit assumption that the distribution of schooling and dropout population in each grade is uniform.

So the equation (4.16) is simplified as:

---

<sup>110</sup> Promotion of education, adult education and death.

$$E_t^P = \beta_S * \eta_t^{primary} + 4\beta_J + 0.5\eta_t^{primary} * (\beta_{D-P} + \beta_{School-P}) + 5\beta_{Adult-P} \quad (4.17)$$

With  $\eta_t^{primary}$  is given by equation (4.13), we need to calculate the five proportions, that is to say the population of graduated senior primary  $L_t^{S-P}$ , the population of graduated junior primary  $L_t^{J-P}$ , the population of primary students in school  $L_t^{School-P}$ , the population of dropouts  $L_t^{D-P}$  and the population of graduated adult primary  $L_t^{Adult-P}$ .

The simplest is  $L_t^{School-P}$  because NBS database gives this series since 1949 directly<sup>111</sup>. Secondly the population of graduated senior primary  $L_t^{S-P}$  could be calculated by the following equation:

$$L_t^{S-P} = (1 - M_t^{S-P})L_{t-1}^{S-P} + l_t^{S-P}(1 - P_t^{primary}) \quad (4.18)$$

Where  $M_t^{S-P}$  is mortality rate of graduated population of senior primary at the year  $t$ ,  $l_t^{S-P}$  is the numbers of graduates of primary school at the year  $t$  that is the same series of  $l_{it}$  with  $i = \text{“senior primary”}$ .  $P_t^{primary}$  is the promotion rate of primary school.

Equation (4.18) states that  $L_t^{S-P}$  equals to the population of this group in last year minus the death and plus the new graduates of primary school and minus the students promoted into the next stage of study. Two points should be underlined here:

1)  $M_t^{S-P}$  is the mortality rate of the population who owned a primary diploma in the total population that is different from the mortality rate of primary students in school  $M_t^{5-14}$  in equation (4.24). The distribution of age of former is wide. According to the entrance age and the duration of primary study in China, the interval of ages of the later should be 5-14 years old<sup>112</sup>. For  $M_t^{S-P}$ , considering that one should be at least 10 years old to finish the complete primary study, we define that<sup>113</sup>:

$$M_t^{S-P} \equiv M_t^{10+} \quad (4.19)$$

The data source and method of calculation are summarized together with other mortality rates in *table 4.10*.

2) We should use gross promotion rate for  $P_t^{primary}$  here. Because we are in the total population, we should consider the situation that one interrupted his study and returned to school after a period. So the gross promotion rate might be greater than 100%<sup>114</sup>. The promotion rates data before 1978 provided by NBS are only available for specific years. So we have recalculated different gross promotion rates  $P_{jt}$  according to their definitions, the source of students of each level and the ways of promotion:

$$P_{jt} = \frac{N_{j+1,t}}{l_{jt}} \quad (4.20)$$

where  $l_{jt}$  is the number of graduates of education level  $j$ , and  $N_{j+1,t}$  presents the number of the enrollments of the next educational stage. The ways of promotion for primary graduates

<sup>111</sup> It should be pointed out that there is a gap between  $L_t^{Schooling}$  published by NBS dataset each year and the same series calculated from long table of census data. This is because the data published by NBS is the population in school at the end of the year while the reference time of census is 1<sup>st</sup> November or 1<sup>st</sup> July. Besides the long table data is 10% sampling so that there is also a sampling bias. So we use NBS yearly data here.

<sup>112</sup> Assume that children enter the primary school in the age of 5 earliest, 8 for latest; and the duration of primary study is 5 or 6 years. Then the age of primary school student should be 5-14.

<sup>113</sup> We have no reason to argue that the diploma will affect the mortality rate for the population with the same age directly. It is possible that because people with a diploma might have higher income than those without diploma, as a consequence the population with diploma might have a better living condition so that the mortality might be lower. However, we have no evidence to prove this point here and this correlation is weak that is through two instrumental variables - income and living condition. So there is no directly influence of diploma on the mortality rate.

<sup>114</sup> For example, the gross promotion rate of junior high school in 1952 is 168.2%.

are: ordinary junior high school and vocational junior high school (rare); promotion for junior secondary graduates: ordinary senior high school, vocational senior high schools, secondary specialized schools and skilled workers [training] schools; promotion for senior secondary graduates: higher education for ordinary senior high school graduates and postsecondary specialized college for vocational secondary graduates.

$L_t^{Adult-P}$  could be calculated in a similar equation:

$$L_t^{Adult-P} = L_{t-1}^{Adult-P} (1 - M_t^{18+}) + l_t^{Adult-P} - N_t^{Adult-Enrollment2} \quad (4.21)$$

Where  $M_t^{18+}$  is the mortality rate of adult and  $N_t^{Adult-Enrollment2}$  is the number of enrollments for adult junior high school. However, the data of  $N_t^{Adult-Enrollment2}$  is missing, we assume that there is no difficult to get the adult diploma so that the numbers of enrollment two years ago equals to the numbers of graduates two years later, that is to say:

$$N_t^{Adult-Enrollment2} \equiv l_{t+2}^{Adult-P} \quad (4.22)$$

For  $L_t^{D-P}$ , firstly we use the accumulated enrollment of primary school  $\sum_{i=0}^{\infty} N_{t-i}^{P-Enrollment}$  minus the accumulated graduates of primary school  $\sum_{i=0}^{\infty} l_{t-i}^{S-P}$ , the accumulated deaths of students in primary school  $\sum_{i=0}^{\infty} L_{t-i}^{P-Dead}$ , the population of primary students in school  $L_t^{School-P}$  to get the accumulated dropouts of primary students<sup>115</sup>.

$$\sum_{i=0}^{\infty} l_{t-i}^{D-P} = \sum_{i=0}^{\infty} N_{t-i}^{P-Enrollment} - \sum_{i=0}^{\infty} l_{t-i}^{S-P} - \sum_{i=0}^{\infty} L_{t-i}^{P-Dead} - L_t^{School-P} \quad (4.23)$$

With

$$L_t^{P-Dead} = L_t^{School-P} * M_t^{5-14} \quad (4.24)$$

Where  $M_t^{5-14}$  is mortality rate of primary students that should age over 5-14.

As this accumulated dropouts series is since infinite past, if we know the detail data for some reference years (for example a recent census year 2010), then we could calculate the population of primary dropouts in total population for a particular year:

$$L_{t-1}^{D-P} = L_t^{D-P} - \left( \sum_{i=0}^{\infty} l_{t-i}^{D-P} - \sum_{i=0}^{\infty} l_{t-i-1}^{D-P} \right) \quad (4.25)$$

Equation (4.25) states that the population of dropouts in year  $t$   $L_t^{D-P}$  equals this population in last year  $L_{t-1}^{D-P}$  plus the new increased dropouts  $(\sum_{i=0}^{\infty} l_{t-i}^{D-P} - \sum_{i=0}^{\infty} l_{t-i-1}^{D-P})$ <sup>116</sup>. As we need the information of infinite past so we should choose the reference year as recent as possible. That is to say we use 2010 as reference year to calculate  $L_t^{D-P}$ .

For the  $L_t^{J-P}$ , what we have is only the information of 1964. So few information we have that the series calculated by a similar method above (the idea of PIM) will cause invalid constraint condition<sup>117</sup>. So we use the constraint condition to calculate  $L_t^{J-P}$ :

$$L_t^{J-P} = L_t^P - L_t^{School-P} - L_t^{S-P} - L_t^{D-P} - L_t^{Adult-P} \quad (4.26)$$

Finally through equation (4.16) - (4.26) the “primary cultural level” means 3.5895 years of education in 1964.

<sup>115</sup> The idea is simple that in a long period, the total population of enrollment minus the deaths, dropouts and still in school is the population who has got the diploma. See *Appendix 4.5* for an illustration.

<sup>116</sup> As we have already considered the death in equation (4.24) and the return to school for dropouts is considered in equations (4.20) and (4.21) (gross promotion rate and adult education) so there is no “depreciation” of  $L_{t-1}^D$ . And the difference of  $(\sum_{i=0}^{\infty} l_{t-i}^D - \sum_{i=0}^{\infty} l_{t-i-1}^D)$  might be negative that means the population of dropouts reduced.

<sup>117</sup> The constraint condition equals  $1.085882 > 1$ .

For the reference years after 1993, as the “junior primary” problem is ignorable, so we regard “junior primary graduates” and “adult primary” both as some kinds of “primary dropouts”. So there are only three classification of “primary population” after 1993: “primary students in school”, “primary graduates” and “primary dropouts”. That is, the equation (4.17) is simplified:

$$E_t^P = \beta_S * \eta_t^{primary} + 0.5\eta_t^{primary} * (\beta_{D-P} + \beta_{School-P}) \quad (4.27)$$

For the reference years 1982 and 1987, as they are between “early year” and “recent year”, the methods through equation (4.16) - (4.26) or equation (4.27) both cause biases. So we deleted those two years as reference years in *table 4.7*. The new reference years for total human capital and the parameterization are presented in *Table A4.3.5*.

For the educational attainment of “junior secondary cultural”, “senior secondary cultural” and “college and higher cultural”, the situation becomes much simple grace to less changes of educational system and more abundant information. But they still have some particular difficulties respectively.

For the “junior secondary cultural”, the series of dropouts of junior secondary students calculated by a group of equations similar to equations (4.23) - (4.25) is biased. The dropouts of initial year 1949 will be negative. This is probably because the mortality rate ( $M_t^{10-17}$ ) calculated from census data is biased for the young population for the early years. The census data doesn't contain the data of army. As a consequence,  $M_t^{10-17}$  is biased due to the wars of early years<sup>118</sup>. We remedy this problem by assuming that the dropouts of junior secondary was zero in 1948 and using the following equation not by retropolation:

$$L_t^{D-J-S} = L_{t-1}^{D-J-S} + \left( \sum_{i=0}^{\infty} l_{t-i}^{D-J-S} - \sum_{i=0}^{\infty} l_{t-i-1}^{D-J-S} \right) \quad (4.28)$$

Finally, we argue that in 1964, among the 32.346788 million “junior secondary population”, 7.294 million of them are at school; 17.414849 million of them are graduates; 7.637939 million of them are dropouts. The average educational attainment  $E_t^{J-S}$  in 1964 is 8.3076 years.

For the “senior secondary cultural”, the data of total population of senior secondary students in school are missing before 2003. So we use the sum of numbers of students in school of "ordinary high school", "ordinary secondary specialized school", "vocational high school" and "skilled workers [training] school" as instead. So we have ignored the adult secondary school students before 2003. Considering that the particularity of adult education (only the full-time students are students in school), the error of such an approximation is nonsignificant.

For the “college and higher cultural”, in fact it contains 4 levels: college, undergraduate, master and doctor. For higher education, a large number of students prefer studying abroad. We cannot consider this part as “dropouts”<sup>119</sup>. So for this level, the students studying abroad should be excluded from the dropouts. And we use the number of graduates of each level as weights to calculate the dynamic average educational attainment of this level. The parameterization of the new reference years (1982 and 1987 have been deleted) is summarized in *Table A4.3.5* of *Appendix 4.3*.

<sup>118</sup> Korean War (1950-1953) and Sino-Vietnamese War (1979)

<sup>119</sup> They didn't appear in the numerator of gross promotion rate equation.

In additional, we have used different mortality rates in our calculations, to make it clear they are summarized in *table 4.10*:

**Table 4.10 Different Mortality Rates**

Population	Adopted Mortality Rates	Data Sources
Deaths of 6 years old and over	Mortality rate of 6+ $M_t^{6+}$	Data over 1992-2013 are calculated from <i>Population Yearbooks</i> (data of 2000 and 2010 directly come from <i>Census</i> data); data over 1950-1991 are calculated with WPP <sup>120</sup> data (some years of $M_t^{5-14}$ $M_t^{10-17}$ $M_t^{12-20}$ are negative that we use 5-year moving average as instead).
Deaths of senior primary	Mortality rate of 10+ $M_t^{10+}$	
Deaths of junior high school	Mortality rate of 12+ $M_t^{12+}$	
Deaths of senior high school	Mortality rate of 14+ $M_t^{14+}$	
Deaths of college and over	Mortality rate of 17+ $M_t^{17+}$	
Deaths of adult education	Mortality rate of 18+ $M_t^{18+}$	
Deaths of schooling primary school	Average mortality rate over 5-14 $M_t^{5-14}$	
Deaths of schooling junior high school	Average mortality rate over 10-17 $M_t^{10-17}$	
Deaths of schooling senior high school	Average mortality rate over 12-20 $M_t^{12-20}$	

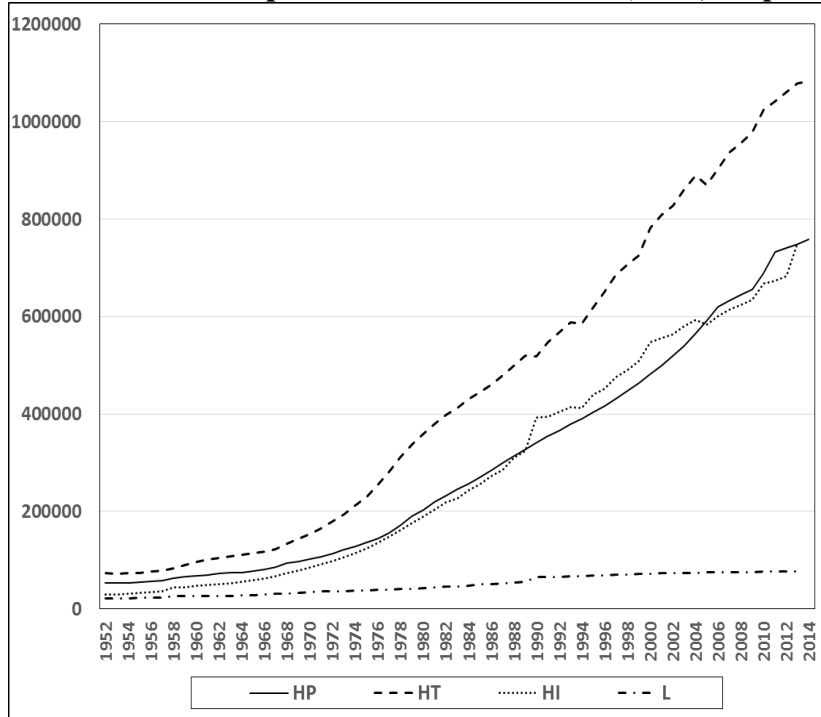
*Note: We assume that children entry primary school in the ages of 5-8 years old; duration of primary education is 5-6 years; duration of junior secondary education is 2-3 years; duration of senior secondary education is 2-3 years. So we get the main age range of students for each level.*

#### 4.4 Human Capital and Conclusions

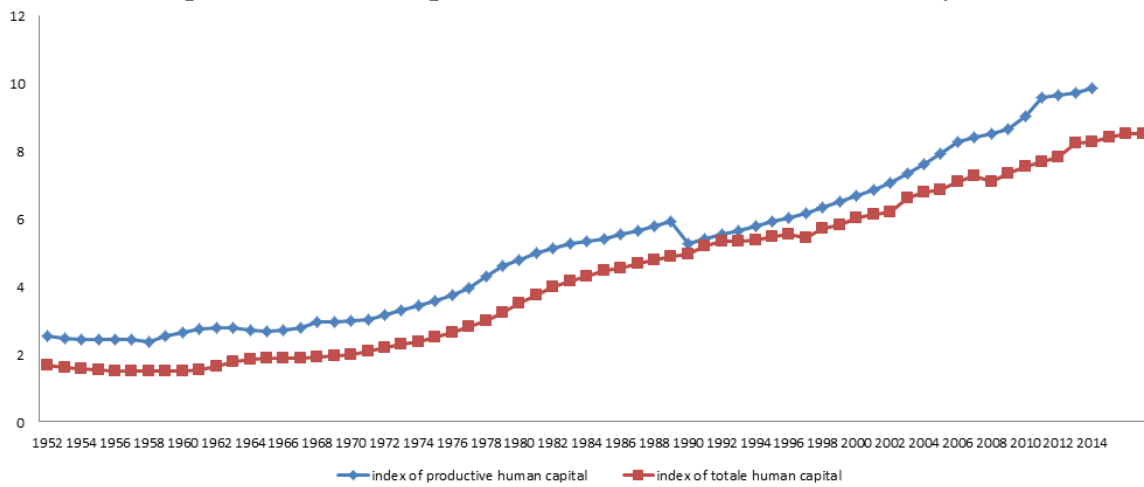
Finally, with the aim of using a maximum amount of official historical data and in order to limit the risk of errors as much as possible (particularly those related to determining the investment flows and depreciation rates), we are able to provide several time series of human capital thanks to a retro-polation method relying on changeover periods or crossing points for our stocks, recalculated from the census data. We also add a third, “intermediate” human capital to the two stocks whose constructions have been presented – first productive human capital ( $H_p$ ), and second total capital ( $H_T$ ). This third stock ( $H_I$ ) combines the number of years of studies *per capita* corresponding to the entire population and that of persons over 16 who are employed. By comparing our statistical database with those in the existing literature, we feel rather confident in suggesting that the original estimates of human capital stocks which we offer are substantially more reliable than the series provided by the PTW. Indeed, they are even improving in quality, frequency and/or length, compared to Cai and Du (2003) or Barro and Lee (2012), though remaining relatively close to the latter.

<sup>120</sup> World Population Prospects of United Nations, <https://esa.un.org/unpd/wpp/Download/Standard/Population/>

**Graph 4.8 Stocks of human capital for China: 1952-2014(in 10,000 persons x years)**



**Graph 4.9 Human Capital Index: Educational Attainment (years)**





## Chapter 5 EXPLAINING ECONOMIC GROWTH IN CHINA

### *New Time Series and Econometric Tests of Various Models*

Supported by new statistical series of physical capital stocks and of human capital, this chapter tries to improve the explanation of China's long-term economic growth. It offers econometric estimates performed within the framework of a broad range of theoretical models, going from standard specifications to more sophisticated endogenous models with R&D indicators. The author also proposes a method for designing a compressed dummy variable and tests to implement the quantitative analysis of institutional changes. The author provides a theoretical justification of the use of regressions in ordinary least squares on the first differences of logarithmic forms in levels. Finally, this chapter finds that productive physical capital and human capital stocks, R&D, as well as institutional changes, positively and significantly contribute to the Chinese GDP growth.

### 5.1 Introduction

It should be recognized that today the opportunities to perform, with all the rigor required, econometric estimates of long-term growth models on time series applied to the case of China are still hampered by the incomplete and/or unsatisfactory nature of the available statistical databases for two key variables for understanding the dynamics of accumulation, namely data on the stocks of physical and of human capital. This is true of the official yearbooks, especially those of the National Bureau of Statistics (NBS),<sup>121</sup> which to date do not provide series of physical capital stocks. But it is also true of databases which are publicly disseminated by researchers or research networks, such as those by the Penn World Tables (PWT)<sup>122</sup> for physical capital, or by Barro and Lee (1993) for human capital. These all generally exhibit some inadequacies.

Regarding physical capital, the problems mainly concern the scarcity of old data, or more recently the existence of statistical breaks, like the one that marked the transition from accounting according to the Material Products Balance System to the System of National Accounts in 1993. Such a change makes difficult comparisons of time-series in Chinese data, and even more across countries. Some economists, including Gregory C. Chow, have themselves rebuilt series of physical capital stocks at the national, regional or sectorial level. In our opinion, the most solidly designed series are those of Chow (1993) and his co-authors (see for example, Chow and Li [2002]); but they are no longer available after 1993, i.e., the date of interruption of the publication of the documents necessary for their construction. The PWT include China, but the explanations given by their statisticians are blurred on several sensitive issues, and do not distinguish the specificities of the country. As to the other available series, their calculation methods are frequently tainted with some estimation biases associated with an approximate interpretation of the perpetual inventory method (PIM) – which is the method we use here. Our criticism of this literature, as explained in an earlier article (Long and Herrera [2016a]), focuses on the questionable parameterization of initial physical capital stock levels or of the depreciation rates, on indeterminate contents of the investment series and, above all, on the inappropriate choice of price indices used by most authors.

---

<sup>121</sup> NBS (various years).

<sup>122</sup> See: <https://ptw-sas.upenn.edu>, and, for version 8.1, the latest one: [www.rug.nl/research/ggdc/data/ptw](http://www.rug.nl/research/ggdc/data/ptw).

The far fewer attempts at building databases on human capital stocks appear to be even more problematic. First, there are no official statistics measuring the average educational attainment level in China. PTW data were compiled from series of the average numbers of years of education by Barro and Lee (2012) and from returns to education by Psacharopoulos (1994); they suffer from serious deficiencies however and underestimate – very significantly in our opinion – the level of Chinese human capital. And if the database provided by Barro and Lee (2012) is of better quality, the fact that it begins only in 1970 and has a frequency of five years raises problems in econometrics. Consequently, we will have to build our own stocks, not only for physical capital, but also for human capital. Accordingly, drawing on new statistical series for these two fundamental variables, this chapter tries to address some of these shortcomings, and so contribute to improving explanations of Chinese economic growth over the long period.

Supported by new statistical series of physical capital stocks and of human capital over the period going from 1952 to 2014 estimated in Chapter 3 and 4, it offers econometric estimates taking into account the institutional changes that have occurred during China’s growth path, and carried out within the framework of a large range of theoretical models spanning from standard or augmented Solow specifications to more or less sophisticated linearized formalizations of endogenous growth, in order to shed light on how production factors have contributed to China’s GDP growth in the long run.

## 5.2 Quantifying Institutional Changes by Using Asymmetric Compressed Dummies

Chow and Li (2002)’s regressions are performed in least squares on the logarithmic forms in levels, and added a linear trend as a detrending method, like in many studies in the macroeconomic literature. However, Nelson and Kang (1981), following Chan, Hayya and Ord (1977), had showed that, in OLS estimates, the assimilation of a difference-stationary process (DS) – the most probable process for GDP, with that of unit root (Nelson and Plosser [1982]) – to a trend-stationary process (TS), as Chow and Li (2002) did it, can lead to a situation where the covariance of the residuals depends on the size of the sample, which artificially induces an autocorrelation of the residuals for the lags, and a cyclic movement into the series. Here, our unit root tests show that the log of China’s GDP has a unit root (see *Appendix 5.1*).

However, as indicated in chapter 2, using such an inappropriate detrending method, the OLS estimator of trend will converge to zero in probability and other OLS estimator will be divergent when the sample size tends to infinite (Long and Herrera [2016b]). Thus, we recommend performing the regressions of macro-dynamic growth models in the first differences of log-levels,<sup>123</sup> if the unit root tests indicate that the variables contain unit roots. It is supported by both theoretical and econometric foundations. From an econometric point of view, the logarithm might generally be useful in the case of heteroscedasticity problem, and difference operator<sup>124</sup> could avoid spurious regressions if there exists unit roots. From a macroeconomic theoretical point of view, regressions in first differences of logarithms are consistent with neoclassic as well as Keynesian frameworks. For example, in a neoclassic framework, if we test a Cobb-Douglas production function as follows:

$$Y_t = A_t K_t^\alpha H_t^\beta \quad (5.1)$$

<sup>123</sup> This specification is also suggested by Hamilton (1994, p. 110) for ARMA modelling.

<sup>124</sup> To avoid the over-differencing problem, we recommend to use the Inverse Autocorrelation Functions (IACF) to identify the order of integration together with unit root tests (Cleveland [1972], Chatfield [1980], Priestley [1981]).

In the first differences of logarithms, we have:

$$\Delta \log Y_t = \Delta \log A_t + \alpha \Delta \log K_t + \beta \Delta \log H_t \quad (5.2)$$

As:  $\Delta \log x_t = \log(x_t/x_{t-1}) = \log\left(1 + \frac{x_t - x_{t-1}}{x_{t-1}}\right) \approx \frac{x_t - x_{t-1}}{x_{t-1}}$ , such a regression could be interpreted in terms of growth rates – the constant being the average TFP growth rate, and the other coefficients the respective elasticities of the input factors.

Similarly, if we want to test a IS equation in a Keynesian framework, with:

$$Y_t = C_t + I_t + G_t + NX_t \quad (5.3)$$

As:  $\partial Y_t / \partial t = \partial C_t / \partial t + \partial I_t / \partial t + \partial G_t / \partial t + \partial NX_t / \partial t$ ,

$$(\partial Y_t / \partial t) / Y_t = \frac{C_t}{Y_t} \left( \frac{\partial C_t}{\partial t} / C_t \right) + \frac{I_t}{Y_t} \left( \frac{\partial I_t}{\partial t} / I_t \right) + \frac{G_t}{Y_t} \left( \frac{\partial G_t}{\partial t} / G_t \right) + \frac{\partial NX_t}{Y_t} \left( \frac{\partial NX_t}{\partial t} / NX_t \right) \quad (5.4)$$

and  $\frac{\partial x_t}{\partial t} / x_t$  is the growth rate of the variable  $x_t$  at time  $t$ ,<sup>125</sup> therefore:  $\frac{\partial x_t}{\partial t} = \frac{x_t - x_{t-1}}{x_{t-1}} \approx$

$\Delta \log x_t$ . Thus, such a regression can also be interpreted in terms of growth rates – the coefficients of each variable being here their proportions in GDP.

It is particularly difficult to quantitatively analyze intuitional changes in time series due to the fact that those changes are qualitative, and often asymmetric. Consequently, institutionalist economists generally prefer qualitative rather than quantitative analysis. Sometimes, dummy variables are introduced into regressions as qualitative indicators of institutional changes. But too many dummy variables involve over-fitting and multi-collinearity problems, or can even make the matrix of regressors singular. In this case, we propose a method to design compressed dummy variables, as well as a test to examine whether the *a priori* selected dummy variables are significant and should be included among the compressed dummy variables:

*Step 1:* we regress the simplest Solow model with a constant, but without any dummy variable, and get the residuals series.

*Step 2:* we test the residuals in order to know whether they are a white noise; if so, then we don't add any dummy variable. If there exists an autocorrelation problem in the residuals series, then we pass to the next step and create dummy variables. The autocorrelation problem is tested with the Lagrange Multiplier (LM) test and Ljung–Box (LB) test.

*Step 3:* we plot the residuals series and the approximated 95% confidence intervals of the null hypothesis of white noise. We observe if the residuals exceed the confidence intervals, then we denote a dummy variable for this point of time, i.e.: +1 for values superior to the confidence intervals and -1 for values inferior to the confidence intervals. As numerous dummy variables  $D_{1t}, D_{2t}, \dots, D_{nt}$  are probably generated, we have to test the collinearity and the singularity.

*Step 4:* Let us first test the singularity. With multiple dummy variables, if a pivot of a sweep operation is less than the critical value, then the matrix is deemed singular. This diagnostic will generally be automatically done by most econometric packages when we perform a regression. If the regressor matrix is singular, the econometric package will refuse to execute

<sup>125</sup> In addition to this demonstration in differential equations, another one can be provided in a perspective of difference operator, i.e.:

$$\begin{aligned} Y_t &= C_t + I_t + G_t + NX_t \\ \Delta Y_t &= \Delta C_t + \Delta I_t + \Delta G_t + \Delta NX_t \\ \Delta Y_t / Y_t &= \frac{C_t}{Y_t} \frac{\Delta C_t}{C_t} + \frac{I_t}{Y_t} \frac{\Delta I_t}{I_t} + \frac{G_t}{Y_t} \frac{\Delta G_t}{G_t} + \frac{NX_t}{Y_t} \frac{\Delta NX_t}{NX_t} \end{aligned}$$

As  $\Delta x_t / x_t$  is the growth rate of  $x_t$ , and  $\Delta x_t / x_t \approx \Delta \log x_t$ , the two demonstrations are thus equivalent.

the command. Thus, we have no need to write a particular program.<sup>126</sup> If there is no problem of singularity, then we directly pass to step 6; otherwise, we continue with step 5.

*Step 5:* if too many dummy variables have caused a singularity problem, then we do compress all the dummy variables into a single dummy, as follows:

$$D_t = D_{1t} + D_{2t} + \dots + D_{nt} \quad (5.5)$$

As the compressed dummy variable can probably be close to the constant term, we need to test the collinearity; so we pass to step 6.

*Step 6:* we test the multi-collinearity problem with the compressed dummy variable; to do that, various tests are available, such as the Variance Inflation Factor proposed by Belsley, Kuh and Welsch (1980). If a multi-collinearity problem appears, we delete the constant term,<sup>127</sup> and we don't recommend to use a "ridge regression."<sup>128</sup>

*Step 7:* then, we test the new residuals series from the regression with the compressed dummy variable (or with multiple dummy variables from *step 4*, if there is no singularity problem). If the series is already whited by the dummy, then we stop. If it cannot successfully pass the LM and LB tests, it can probably be caused by a symmetry between the positive and negative influences. As a consequence, we propose a scan method to deepen the values of certain points of time of the compressed dummy variable. For example, for a negative shock, we take the values ranging from -1 to  $-s$  ( $s > 1$ ), by small increments, until the residuals pass the LM and LB tests in a certain level of risk.

In a growth model, if  $\widehat{\alpha_D}$  is the estimated coefficient of the compressed dummy variable, and  $D_t \neq 0$ , the values of  $\frac{\widehat{\alpha_D}}{D_t}$  can be regarded as those of an impulse response function to a political or institutional shock at time  $t$ .

In step 3, it is arbitrary to select the *a priori* dummy variables just from the residuals graph. So, we propose here a Chi2 test (or Fisher test) to examine whether the dummies should be included or not. If the new dummy introduced is useful to explain the dependent variable, then it should be significant in the model, or the  $R^2$  is improved. In other words:  $H_0: \beta = 0$  vs  $H_1: \beta \neq 0$ ; or:  $H_0: R_0^2 = R_1^2$  vs  $H_1: R_0^2 < R_1^2$ , where  $\beta$  is the coefficient of the dummy variable; and  $R_0^2$  and  $R_1^2$  are the coefficients of determination of the null model and the alternative model, respectively.

The null model is:  $Y_t = \alpha_0 + \alpha_1 X_{1t} + \dots + \alpha_k X_{kt} + \varepsilon_t$ , where  $X_{1t} \dots X_{kt}$  are  $k$  explicative variables,  $\alpha_0, \alpha_1, \dots, \alpha_k$  their coefficients, and  $\varepsilon_t$  is the Gaussian innovations series with mean zero and variance  $\sigma^2$ .

The alternative model is written as follows:  $Y_t = \alpha_0 + \beta D_t + \alpha_1 X_{1t} + \dots + \alpha_k X_{kt} + \varepsilon_t$ , where  $D_t$  is a dummy variable. The dummy can be defined as instantaneous, permanent, or temporary. The instantaneous dummy variable takes the values +1 or -1 when a positive or a negative shock occurs, and 0 for any other point of time. The permanent dummy variable has the values +1 or -1 after a positive or negative shock, and 0 before. The temporary dummy

<sup>126</sup> For example, SAS suggest critical values at  $10^{-7}$  ([http://support.sas.com/documentation/cdl/en/etsug/63939/HTML/default/viewer.htm#etsug\\_arima\\_sect022.htm](http://support.sas.com/documentation/cdl/en/etsug/63939/HTML/default/viewer.htm#etsug_arima_sect022.htm)).

<sup>127</sup> In our estimations, the constant term always appears nonsignificant. In addition, in regressions in first differences of logs performed within a neoclassic framework, it can be interpreted as the constant growth rate of Hick-neutral TFP – which doesn't necessarily correspond to the reality, and is here observed to be nonsignificant.

<sup>128</sup> As a matter of fact, the multi-collinearity problem is caused here by the similarity between the intercept and the compressed dummy variable. So we just need to delete the constant in the regressions to avoid such a problem.

variable takes the values +1 or -1 when a positive or a negative shock occurs during a period, and 0 otherwise.

We note:  $N_t = \beta D_t + \varepsilon_t$ , with  $N_t = Y_t - (\alpha_1 X_{1t} + \dots + \alpha_k X_{kt})$ . Let  $D = (D_1, D_2, \dots, D_T)^T$  and  $N = (N_1, N_2, \dots, N_T)^T$  under null hypothesis,  $N$  is a zero mean Gaussian vector with variance covariance matrix  $\sigma^2 \Omega$ .

Therefore, the generalized least squares (GLS) will give:

$$\hat{\beta} = \frac{\delta}{\kappa} \quad \text{and} \quad \widehat{\text{var}}(\hat{\beta}) = \frac{\sigma^2}{\kappa} \quad (5.6)$$

where  $\delta = D^T \Omega^{-1} N$ , and  $\kappa = D^T \Omega^{-1} D$ . These estimators are efficient according to the method of Jong and Penzer (1998) – or to that of Ansley and Kohn (1985). And  $\sigma^2$  is obtained from the residuals series. The empirical estimators of  $\sigma^2$  is:

$$\widehat{\sigma^2} = \frac{1}{T} \sum_{t=1}^T \widehat{\varepsilon}_t^2 \quad (5.7)$$

When the sample size is small compared to the number of parameters  $k + 2$ , we recommend to use the unbiased estimator:

$$\widehat{\sigma^2} = \frac{1}{T - k - 2} \sum_{t=1}^T \widehat{\varepsilon}_t^2 \quad (5.8)$$

If there is a heteroscedasticity problem in the residuals series  $\varepsilon_t$ , we recommend to use the robust correction of Findley, Monsell, Bell, Otto and Chen (1998):<sup>129</sup>

$$\widehat{\sigma^2} = (1.49 * \text{Median}(|\varepsilon_t|))^2 \quad (5.9)$$

The Student statistics of  $\hat{\beta}$ ,  $\tau = \frac{\hat{\beta}}{\sqrt{\widehat{\text{var}}(\hat{\beta})}} = \frac{\delta/\kappa}{\sigma/\sqrt{\kappa}}$ , approximately obeys  $t(T - k - 2)$ , where

$T$  is the number of observations, and  $k$  the number of explicative variables in null model “2” with the dummy variables and constant term. We know that if  $T - k - 2 \geq 25$ , the distribution function of Student is close to Gaussian:

$$\tau \sim N(0,1) \text{ approximately, when } T - k - 2 \geq 25 \quad (5.10)$$

So  $\tau^2 \sim \chi(1)$ , and it is used to identify the significance of the dummy variable. If it is significant, then this dummy is selected in step 3.

We can also use alternative Wald forms of the Fisher test. Under  $H_0: R_0^2 = R_1^2$  vs  $H_1: R_0^2 < R_1^2$ ,

$$F = \frac{(RSS_0 - RSS_1)/1}{RSS_1/(T - k)} \sim F(1, T - k) \quad (5.11)$$

where  $RSS_1$  represents the residuals sum of squares of the alternative model (with dummy), and  $RSS_0$  the residuals sum of squares of the null model (without dummy).

The Chi2 and Fisher tests are essentially equivalent – even if many researchers prefer to use F (or  $t$ ) tables rather than Chi2 (or normal) ones because the former provide better approximations in small samples. However, we recommend to use the Chi2 test here, because generally, a single dummy doesn't increase much the  $R^2$ . If  $k$  is small, then the effects of explicative variables on the global significance of the model are more important than those of the dummies introduced, and we would probably get mislead conclusions about the efficiency of the dummy variables.

<sup>129</sup> Our test is similar to the outlier detection procedure in X-12-ARIMA, so we suggest here to use the method proposed by the Census Bureau's time series analysis program (Findley *et al.* [1998]).

### 5.3 Econometric Estimates within the Framework of Various Theoretical Growth Models

Thus, taken as a whole, these are four respective concepts of capital and of labour (or human capital) that we have selected, in an alternating or combined manner, as inputs of different production functions which we will now determine theoretically and test empirically, with:

Capital	{	<i>stricto sensu</i> productive physical capital stock (without land, without inventories)	$K_{Pe}$
		<i>lato sensu</i> productive physical capital stock (without land, with inventories)	$K_{Pl}$
		fixed physical capital stock (with land, without inventories)	$K_F$
		total physical capital stock (with land, with inventories)	$K_T$
and			
Labor	{	employed population (or number of employed persons)	L
		productive human capital stock	$H_P$
		total human capital stock	$H_T$
		intermediary human capital stock	$H_I$

In addition, it should be noted that the series of the Chinese GDP over the period 1952-2014 is taken from *China Statistical Yearbooks* of the NBS (various years).

To perform our econometric estimates, we choose several specifications derived from various growth models. The first of them, similar to a simple  $Y = AK$  version, mobilizes a production function linear into a single input that we limit only to the stock of physical capital. The second theoretical framework is a Solow model, represented as a Cobb-Douglass functional form with two production factors, estimated in a standard (physical capital and simple labour) or augmented way (physical capital and human capital). The third one integrates research-and-development (R&D), by using a traditional formalization of endogenous growth. Growth theory is one of the fields that experienced the most decisive advances over the last 30 years, especially under the influence of the “new growth theory,” or growth with endogenous technical progress. Standard theory in macro-dynamics, due to Solow and others in the 1950s, has been improved thanks to explanations of total factor productivity and the analysis of the specific contributions of human capital and R&D, among others.<sup>130</sup> These works have remobilized some issues already studied by microeconomics for a long time, such as non-convexities. Nevertheless, as Solow himself indicated it, and others with him, it would not really be fair to consider that the “new” growth models are very different from the “old” ones. Such is the case of the  $AK$  model (which revisits pioneer Keynesian dynamics); but this remark also applies to much more sophisticated nonlinear models, often resorting to increasing returns associated with the externalities of R&D or education. In fact, when they are empirically tested, the log-linearized specifications of these models are very close to extended Solowian formalizations. Herrera (1998) has given a mathematical proof that an endogenous growth can appear within an augmented Solowian framework by remaining a convexity in technology.<sup>131</sup> In order to apply econometrically our original statistical series of

<sup>130</sup> Concerning the role of infrastructures in economic growth, see, by instance: Dessus and Herrera (2000).

<sup>131</sup> Endogenous growth appears within an extended Solowian framework by keeping a concave production function, with constant returns to scale on all factors, be reproducible or not. For example, it would be the case with the following production function, combining two bifactorial symmetrical C.E.S. production functions for capital ( $K$ ) and labour ( $L$ ):

$$Y = K^\alpha (\Lambda L)^{1-\alpha} = \left( \mu_P K_P^{\sigma_K - 1/\sigma_K} + \mu_G K_G^{\sigma_K - 1/\sigma_K} \right)^\alpha \left( \phi_K \frac{\sigma_K}{\sigma_K - 1} \right) \cdot \left[ \Lambda^{\sigma_L - 1/\sigma_L} \left( \mu_N N_Y^{\sigma_L - 1/\sigma_L} + \mu_S S_Y^{\sigma_L - 1/\sigma_L} \right) \right]^{(1-\alpha)} \left( \phi_L \frac{\sigma_L}{\sigma_L - 1} \right)$$

where  $Y$  is the output,  $K_P$  and  $K_G$  are the stocks of private and public capital,  $S_Y$  and  $N_Y$  skilled labour (human capital) and unskilled labour, and  $\Lambda$  is technical progress, with  $0 < \alpha < 1$ , unitary scale parameters ( $\phi_K = \phi_L = 1$ ), the sums of intensity parameters normalized at 1 ( $\mu_N + \mu_S = 1$  and  $\mu_P + \mu_G = 1$ ), and elasticities of substitution between factors characterized by  $\sigma_K < 1$  and  $\sigma_L > 1$  (an inequality which is a condition for endogenous growth). See: Herrera (1998).

capital, we will use these three categories of models – precisely, Solow, AK and endogenous growth –, taking into consideration their formal compatibility.<sup>132</sup>

Our regressions are performed in OLS on the first differences of logarithmic forms in levels. The unit root tests show that the growth rates of our variables are all stationary (*Appendix 5.1*). The studied period is of 62 years: 1953-2014. Chow and Li (2002) excluded years with sharp fluctuations from their analysis, which we believe to be an unsatisfactory choice, because it is arbitrary and involves a loss of information. We decide instead to include them by introducing a qualitative variable,  $D$ , aimed at taking into account the institutional changes and their impact on economic growth using an original method proposed in section above.<sup>133</sup> The years with the dummy, which is unique to preserve the maximum of degrees of freedom, are those for which the residuals – of the estimate of the Solowian specification – exceed the confidence intervals. As a consequence,  $D$  is set to +1 in 1963-1965 (recovery), 1984 (tax reform), 1992 (Deng Xiaoping’s tour) and 2007 (overheating); but to the value -1 during the negative shocks of 1960-1962 (recession), 1967 (beginning of the Cultural Revolution), 1976 (death of Mao Zedong) and 1989-1990 (strong political agitation).

The first set in the econometric estimates *à la* AK is conducted using the following equation:

$$g_{Yt} = c + \theta D + \alpha g_{K_{it}} + \varepsilon_t \quad (5.12)$$

where  $g_{Yt}$  and  $g_{K_{it}}$  are the growth rates of GDP and of one of the physical capital stocks  $i$ , as defined according to our four different conceptions, with or without the constant  $c$  (*Table 5.1*). We can make several comments about the eight tests of AK-type models carried out in least squares (*Table 5.2*). The elasticities of the stock of physical capital are significant and range from 0.60 (for the narrowly-defined productive capital, with a constant) and 0.82 (for the fixed capital, without constant). Corresponding to the coefficients of the constants in the regressions that include them, the growth rates of technical progress – unchanged, in reference to a neutrality in the sense of Hicks – are between +0.72 and +2.09%, but without ever appearing as statistically significant. In general, there is no autocorrelation in these estimates, but the latter have a slight problem of heteroscedasticity, even after corrections (Newey and West [1994]).

**Table 5.1 Classification of the regressions of AK models according to the physical capital input**

Constant Capital		<i>with a constant</i>	<i>without a constant</i>
<i>Productive capital</i>	$K_{pe}$	[1]	[2]
<i>Productive capital</i>	$K_{pl}$	[3]	[4]
<i>Fixed capital</i>	$K_F$	[5]	[6]
<i>Total capital</i>	$K_T$	[7]	[8]

Notes: See Long and Herrera (2016a) for the details of the construction methods of the stocks of physical capital, with the following notations:  $K_{pe}$  = narrowly-defined physical capital stock (without land, without inventories);  $K_{pl}$  = largely-defined physical capital stock (without land, with inventories);  $K_F$  = fixed physical capital stock (with land, without inventories);  $K_T$  = total physical capital stock (with land, with inventories).

<sup>132</sup> The purpose of this chapter is not to examine in detail the theoretical problems related to the use of these models, discussed in depth by authors from diverse currents (DeLong and Summers [1991], Fine [2000], or Salvadori [2003]).

<sup>133</sup> As our compressed dummy already whited the residuals series, no need of the scan procedure for the asymmetry.

**Table 5.2 Results of eight regressions tested within the framework of AK models**

	<i>Constant</i>	<i>D</i>	<i>Capital</i>	<i>R</i> <sup>2</sup>	<i>Autocorrelation</i>	<i>Heteroscedasticity</i>	<i>Correction</i>
[1]	0.020920 (1.104416)	0.116240 (4.510076)	0.596416 (4.134000)	0.584202	0.8473 0.8355	0.0169 0.0182	Yes
[2]		0.115260 (4.2903065)	0.778377 (14.15365)	0.573710	0.5870 0.6342	0.0109 0.0123	Yes
[3]	0.019889 (1.123258)	0.116343 (5.033511)	0.746392 (3.974649)	0.604473	0.5192 0.4942	0.0346 0.0354	Yes
[4]		0.115453 (4.941431)	0.780895 (12.58536)	0.578234	0.3207 0.3347	0.0312 0.0322	Yes
[5]	0.007632 (0.345782)	0.113514 (4.687775)	0.766911 (4.198741)	0.608815	0.9639 0.9608	0.0111 0.0124	Yes
[6]		0.112960 (4.450500)	0.816090 (17.85223)	0.603317	0.9557 0.9631	0.0097 0.0110	Yes
[7]	0.007228 (0.372294)	0.114026 (5.154586)	0.749326 (4.511338)	0.608440	0.6107 0.5875	0.0187 0.0200	Yes
[8]		0.113549 (4.974455)	0.815049 (16.76032)	0.607383	0.5961 0.5839	0.0175 0.0188	Yes

*Notes: The first column gives the number of the regression using a physical capital stock with or without a constant (Table 5.1). In the next three columns, the numbers between parentheses are t-statistics. In the Autocorrelation column, the p-values are given (for the Fisher test, then the Chi<sup>2</sup> test) for the null hypothesis “no autocorrelation in the residuals series” with the Breusch-Godfrey LM test. In the Heteroscedasticity column, the p-values are given (Fisher and Chi<sup>2</sup> tests) for the null hypothesis “no heteroscedasticity in the residuals series” with the Breusch-Pagan-Godfrey Heteroskedasticity test. The last column indicates whether a correction of heteroscedasticity à la Newey-West is introduced or not.*

A second set of regressions is conducted on the basis of the following specifications:

$$g_{Yt} = \theta D + \alpha g_{Kt} + \beta g_{Hjt} + \varepsilon_t \quad (5.13)$$

with  $g_{Hjt}$  the growth rate of the stock of human capital  $j$ , as one of its possible three forms (Table 5.3) – when it is not the simple labour which is used instead. Also in OLS and over the period 1953-2014, 16 other regressions are carried out within this framework, numbered [9] to [24] according to the selected inputs (Table 5.4). We use a robust correction method (that is, the one giving the best econometric results)<sup>134</sup> if the regression does not exhibit white noises in the residuals series. The  $R^2$  is improved, and now often exceeds 0.60. The tests [9], [13], [17] and [21], using a simplified definition of labour, i.e., the number of employed persons, reveal very (excessively) high coefficients for this factor, varying from 0.87 in the estimate [9] to 0.80 in the [21], while those associated with physical capital stocks are in a range from 0.63 to 0.67, respectively. As GDP growth is much faster than population growth, the strong contribution of the labour input in economic growth is overestimated, due to the likely underestimation of the total factor productivity dynamics. Nevertheless, the assumption of constant returns to scale can no longer be defended. Therefore, it becomes relevant to use the stock of human capital, whose productivity is higher, as the labour factor.

<sup>134</sup> The Breusch-Pagan-Godfrey (BPG) and Glejser tests reveal a problem of heteroscedasticity in the regressions, but those of Harvey and ARCH say otherwise, while the White test is ambiguous. As a precaution, we only present the results which are the most unfavorable to us (i.e., BPG).



**Table 5.3 Classification of the regressions of Solow models according to the inputs of physical capital and of human capital (or labour)**

<b>Labour Capital</b>	<b>Employed population <math>L</math></b>	<b>Productive human capital <math>H_p</math></b>	<b>Total human capital <math>H_T</math></b>	<b>Intermediate human capital <math>H_I</math></b>
<b>Productive capital <math>K_{pe}</math></b>	[9]	[10]	[11]	[12]
<b>Productive capital <math>K_{pl}</math></b>	[13]	[14]	[15]	[16]
<b>Fixed capital <math>K_F</math></b>	[17]	[18]	[19]	[20]
<b>Total capital <math>K_T</math></b>	[21]	[22]	[23]	[24]

Notes:  $K_{pe}$  = narrowly-defined physical capital stock (without land, nor inventories);  $K_{pl}$  = largely-defined physical capital (without land, with inventories);  $K_F$  = fixed physical capital stock (with land, without inventories);  $K_T$  = total physical capital stock (with land and inventories);  $L$  = employed population (number of employees);  $H_p$  = productive human capital stock;  $H_T$  = total human capital stock;  $H_I$  = stock of intermediary human capital.

**Table 5.4 Results of 16 regressions tested within the framework of Solow models**

	<b>D</b>	<b>Capital</b>	<b>Labour</b>	<b>R<sup>2</sup></b>	<b>Autocorrelation</b>	<b>Heteroscedasticity</b>	<b>Correction</b>
[9]	0.118975 (6.271856)	0.630125 (9.739585)	0.875202 (5.557353)	0.668385	0.5002 0.4804	0.0360 0.0380	Yes
[10]	0.117687 (4.587090)	0.645203 (8.602465)	0.357933 (2.389076)	0.588909	0.7919 0.7818	0.0192 0.0215	Yes
[11]	0.114086 (4.306282)	0.825511 (12.00118)	-0.125379 (-0.713103)	0.576406	0.4481 0.5032	0.0263 0.0285	Yes
[12]	0.119781 (4.852476)	0.661599 (7.276215)	0.281701 (1.712719)	0.591847	0.7473 0.7367	0.0404 0.0422	Yes
[13]	0.118837 (9.140261)	0.636886 (9.303649)	0.810567 (3.652557)	0.656016	0.2191 0.2003	0.0567 0.0578	No
[14]	0.118051 (8.358487)	0.638595 (6.081470)	0.387116 (1.658947)	0.597031	0.4201 0.3951	0.0517 0.0530	No
[15]	0.118051 (8.358487)	0.638595 (6.081470)	-0.035032 (-0.179094)	0.578464	0.3006 0.3122	0.0744 0.0745	No
[16]	0.120267 (8.442043)	0.657526 (7.161307)	0.301414 (1.783127)	0.599801	0.4168 0.3925	0.0923 0.0913	No
[17]	0.117069 (6.464553)	0.666295 (13.57806)	0.865285 (6.570643)	0.696859	0.5392 0.5925	0.0107 0.0128	Yes
[18]	0.115066 (4.675375)	0.712260 (9.729585)	0.267190 (1.769894)	0.611447	0.8978 0.8933	0.0139 0.0162	Yes
[19]	0.111358 (4.502513)	0.875383 (10.32063)	-0.152962 (-0.793211)	0.607375	0.8692 0.8975	0.0237 0.0260	Yes
[20]	0.117399 (4.986434)	0.706400 (9.268862)	0.256905 (1.684053)	0.618606	0.8964 0.8986	0.0297 0.0318	Yes
[21]	0.117270 (6.971822)	0.669875 (11.43115)	0.806270 (5.821376)	0.685602	0.3462 0.3459	0.0182 0.0205	Yes
[22]	0.115733 (5.186720)	0.704728 (8.914253)	0.287051 (1.758287)	0.617113	0.4914 0.4702	0.0267 0.0289	Yes
[23]	0.112601 (5.070557)	0.850287 (10.47045)	-0.092945 (-0.515318)	0.608966	0.5783 0.5710	0.0420 0.0437	Yes
[24]	0.118026 (5.489480)	0.703472 (8.719675)	0.263691 (1.791969)	0.623754	0.5319 0.5153	0.0497 0.0511	Yes

Notes: The first column gives the number of the regression carried out by combining capital and labour inputs (Table 5.3). For the rest, see Table 5.2's Notes.

The estimates [10] and [14], selecting the productive versions of human capital and physical capital, in the narrowly- or broadly-defined conceptions of the latter, offer interesting results, after corrections à la Newey-West: the elasticities of both physical stocks are around 0.64, those of human capital are from 0.36 to 0.39. Consequently, their sums thus yield returns to scale which are almost exactly constant, without any constraint. The global returns also

appear constant in the estimates [18] and [22]<sup>135</sup>, but with elasticities for productive human capital that are notably smaller, and above all not significant. The stocks of fixed and total physical capital include too many unproductive elements, such as land, to match the strictly productive definitions of human capital. None of the coefficients of total human capital stock appears with the statistical significance required in [11], [15], [19] and [23]. In fact, they indicate far worse results – human capital even being negative, though not significant –, when the concepts of physical and human capital stocks are considered, these being furthest from their respective productive “core”. In contrast, the indicator of intermediate human capital integrated as an input of the Solow production function tested according to formulas [12], [16], [20] and [24], leads to elasticities of physical capital stocks ranging from 0.66 to 0.70 and of human capital stocks from 0.30 to 0.26. Both of these satisfy the thresholds of statistical significance – albeit by a narrow margin for  $H_I$  in equation [24]. In this last regression [24], the positive contribution of human capital can be explained by a productive impact, directly or not, of some of its components deemed to be “unproductive” (for example, the pensioners).

Finally, we test a third set of equations derived from linearized forms of endogenous growth models incorporating the expenditure on R&D, alongside the human capital stock, as shown in:

$$g_{Yt} = \theta D + \alpha g_{KIt} + \beta g_{Hjt} + \gamma g_{R\&Dt} + \varepsilon_t \quad (5.14)$$

where  $g_{R\&Dt}$  is the growth rate of spending on R&D<sup>136</sup>. Converted into constant prices of 1952, as well as being expressed in the first differences of the logarithmic forms in levels, as shown above with the other input variables, this series was previously found to have been stationary using the unit root tests (*Appendix 5.1*). The same principle of correction is also adopted: apart from cases where the residuals are white noises, we apply a correction as soon as at least one of the tests carried out reveals a risk of heteroscedasticity (at 5%), thanks to the method of White or that of Newey-West, in order to obtain robust regressions.

It should be observed that China has started to integrate into the international accounting system for R&D activities since 1986 only; before this date, it was not possible to get access to a homogeneous data series, as established by the OECD *Frascati Manual* (OECD [2015]). Given this constraint, we identified two indicators of R&D expenditure (*Table 5.5*): *i*)  $R\&D_1$ , constructed from Science and Technology budgets<sup>137</sup> (1952-1985), as given for the R&D of public entities and higher education (1986-1988), and the aggregated R&D of the *Statistical Yearbooks of Science and Technology* (1989-1994), then of the NBS (1995-2014); and *ii*)  $R\&D_2$ , a variable corresponding to the funding of the various fundamental or applied components of sciences and technologies (1952-1970), to which are also added those of the enterprises’ technical innovation (1971-1985), before that the profiles of the two series were joined in 1986<sup>138</sup>.

The calculation of the average growth rates of R&D expenditure (about 14.5% in our period from 1952 to 2014) gives much higher values than those we also get for expressions of the total factor productivity (TFP), regardless of how we define it as the Solow residual, with neutral technical progress in the sense of Hicks<sup>139</sup>. But the contribution of this TFP generally is not

<sup>135</sup> For these estimates and the previous ones, global constant returns are confirmed by the Wald tests.

<sup>136</sup> Expenditure on R&D are preferred to the scientific workforce, already incorporated into the stocks of human capital, or to the number of patents, intellectual property having been regulated in China only since 1986.

<sup>137</sup> Cf. Gu and Lundvall (2006). They used the database of the Chinese Academy of Science and Technology for Development (*Chinese Science and Technology Statistics Network*), an institution belonging to the Ministry of Science and Technology whose site (<http://www.sts.org.cn>) is no longer accessible since mid-2015.

<sup>138</sup> For the details of construction of R&D series, see *Appendix 5.3*

<sup>139</sup> For the details of TFP, See *Appendix 5.2*

shown to be statistically significant; this could support a result already highlighted by Su and Xu (2002). It is also much more than the growth rate of the TFP term (+2.5%) advanced by Chow and Li (2002), in a framework that followed the Solow model to the end, explaining in logarithms a GDP expressed in *per capita*, and incorporating a linear trend. Their sample is however more limited than ours,<sup>140</sup> and, what is more, divided into sub-periods. Nevertheless, it is mainly because we have doubts not only about the magnitude of this trend, underestimated in our view, but also about the relevance of its introduction into OLS estimates, in particular, due to the observation of the presence of breaks in the series used by Chow and Li (2002), even “cleaned” (i.e., without “problematic” years from 1958 to 1969), that we ultimately opted for regressions in first differences of logarithmic forms in levels applied to specifications which overflow the strict Solow framework to mobilize models with endogenous technical progress. The results of the regressions [25] to [32] (*Table 5.6*) show that R&D, as represented by our two indicators, positively contributed to China’s GDP growth, with coefficients located between 0.086 and 0.090 for  $R\&D_1$ , and between 0.039 and 0.048 for  $R\&D_2$ , being most frequently statistically significant. However, the coefficients of physical capital stocks are now clearly lower than those recorded in the previous tests, but remain within quite satisfactory ranges. This finding is even more interesting than the sum of the elasticities linked to the inputs of directly productive capital and labour proves to be – almost always – close to unity. Furthermore, the considering institutional variables improved the overall consistency of our estimates.

**Table 5.5 Classification of the regressions of endogenous growth models according to the indicator of R&D associated with productive human capital and physical capital**

Labour and R&D Capital	Productive human capital $H_p$ associated with variable $R\&D_1$	Productive human capital $H_p$ associated with variable $R\&D_2$
Productive capital $K_{pe}$	[25]	[26]
Productive capital $K_{pl}$	[27]	[28]
Fixed capital $K_F$	[29]	[30]
Total capital $K_T$	[31]	[32]

Note: See Long and Herrera (2015a) for the building of physical and human capital stocks.

**Table 5.6 Results of eight regressions tested within the framework of endogenous growth models**

	$D$	Capital	Labour	R&D	$R^2$	Autocorrelation	Heteroscedasticity	Correction
[25]	0.103105 (5.537157)	0.422057 (2.428350)	0.562009 (2.61545)	0.086067 (1.8014)	0.675554	0.0783 0.0675	0.0148 0.0181	Yes
[26]	0.111480 (5.026992)	0.525868 (3.932758)	0.462766 (2.76943)	0.042471 (1.1751)	0.640294	0.4143 0.3823	0.0360 0.0393	Yes
[27]	0.103005 (6.456074)	0.373844 (2.047401)	0.653300 (2.67512)	0.090289 (1.9497)	0.657143	0.0415 0.0365	0.0412 0.0443	Yes
[28]	0.112643 (7.771511)	0.494799 (3.734314)	0.544281 (2.211582)	0.039300 (1.4658)	0.615061	0.3207 0.2926	0.0920 0.0923	No
[29]	0.100431 (5.388878)	0.490519 (3.898327)	0.451932 (2.87184)	0.089195 (2.2201)	0.700799	0.2769 0.2518	0.0052 0.0075	Yes
[30]	0.108308 (5.021435)	0.578488 (5.705632)	0.377931 (2.83953)	0.048529 (1.4272)	0.662266	0.7615 0.7573	0.0175 0.0208	Yes
[31]	0.101340 (6.079767)	0.456553 (3.231333)	0.519503 (2.69692)	0.088922 (2.1688)	0.682849	0.1482 0.1293	0.0251 0.0285	Yes
[32]	0.110012 (5.604318)	0.558111 (4.815367)	0.435512 (2.66917)	0.043121 (1.1081)	0.640942	0.5399 0.5101	0.0463 0.0493	Yes

Notes: The first column gives the number of the regression combining stocks of productive physical and human capital with R&D (*Table 5.5*). For the rest, see *Table 5.2's* Notes.

<sup>140</sup> This is also the case of the study by Ding and Knight (2009), which only concerns the years 1980-2004.

One might be concerned that there may exist some feedback effects between the dependent and explicative variables: the output may also have an influence on the input factors. In such a case, the explicative variables associated with the residuals would be endogenous. Consequently, the estimations of the coefficients would be biased due to a simultaneous equation bias. We have examined the causality between dependent and explicative variables through pairwise Granger causality tests (bivariate and VAR) – expecting that the explicative variables do cause  $g_Y$ , but that  $g_Y$  does not cause the explicative variables. These tests show that all explicative variables are not endogenous – except technical progress (weakly endogenous). In addition, it should be observed that the institutional variable significantly improved the residuals and the exogeneity Wald test results in VAR models (*Appendix 5.4*).

## 5.4 Conclusion

Based on time series of stocks of physical capital and of human capital for China from 1952 to today (2014), which we have completely reconstructed for this work, we have estimated econometrically several specifications derived from a broad range of macro-dynamic models, spanning from simplified *AK*-type versions to more complex representations of endogenous growth with indicators of R&D, through the standard or augmented Solow formalizations. The best empirical results are achieved when we select the concepts of physical capital and human capital stocks which are the closest to their respective productive “core”. For, in our ultimate, most complete regressions, we clearly observe positive and significant contributions of *stricto sensu* productive physical capital ( $K_{Pe}$ ), of productive human capital ( $H_P$ ), but also of R&D to China’s GDP growth over a long period (i.e., 60 years); this is for theoretical frameworks where constant returns to scale are often accepted.

While capturing economic information related to institutional changes that have characterized the modern history of China, the introduction of our qualitative variable  $D$  strongly reduces the autocorrelation of the residuals, which (very probably) derives from disruptions caused by the presence of large fluctuations in the variables studied during some periods of this history (especially in the 1960s and 1990s), and improves the explanatory power of our econometric estimates. The persistence of a slight problem of heteroscedasticity at the end of this work, in several tests, suggests the need to analyze in greater depth the issue of the possible cycles in the growth trajectory of the Chinese economy, thus opening up new research perspectives.

## **Chapter 6 PIKETTY IN BEIJING**

### *The Laws of Capital in the Twenty-First Century in China*

This chapter builds a capital stock *à la* Piketty for China over 1952-2012, and estimate elasticities associated with it through specifications also integrating human capital, R&D, and institutional change. This chapter calculates an implicit rate of return of this capital to test the validity of what Piketty states as a “fundamental inequality”, comparing the rate of return on capital and the income growth rate in the long run. Then, Piketty’s “law” connects the coefficient of capital with the ratio between savings rate and income growth rate. These results are compared with estimates over 1978-2012, i.e., the sub-period of “capitalism with Chinese characteristics.”

#### **6.1 Introduction**

The success of *Capital in the Twenty-First Century* by the French economist Thomas Piketty has been staggering, including in China, where it was published in 2015, shortly after its French (2013) and English (2014) editions. In this book, the author defines “capital” in a very broad sense and makes a presentation of what constitutes, in his eyes, “fundamental laws” of the dynamic functioning of the capitalist system. The purpose of this chapter is to reconstruct, over a long period (1952-2012), statistical series of capital stocks as close as possible to the definition given by Piketty, and to test the validity of these laws in the case of the Chinese economy.

A preliminary question is whether the Chinese economic system can be assimilated or likened to capitalism or not. A vast majority of authors, both abroad and in China, argue that since it has opened to the world system in 1978, China’s economy has moved significantly closer capitalism; enough anyway to allow us, from a methodological point of view, to try to apply to this country the framework proposed by Piketty. Therefore, we will assume the generally accepted hypothesis according to which such a system constitutes one of the forms of today’s capitalism: in this case, the expression “state capitalism” might be the most appropriate. Moreover, the concept of capital used by Piketty could be able to applied, according to him, to any patrimonial system, as the suggested mode of regulation would correspond to any ownership system, even public (Piketty [2013], p. 83). As a consequence, it seems relevant to us to wonder about the scope and the limits of the analysis Piketty has applied to the developed capitalist countries concerning the very singular case of China.

This chapter offers the readers a statistical method for constructing data on capital for China, in the manner of Piketty, over a relatively long period, going (from 1952 to 2012). The methodology gradually expands the definition of stock from narrowly-defined productive physical capital (traditionally designated), in order to include the inventories necessary for production, but also the values of not-directly productive components, such as land and buildings (including housing), as well as monetary elements representative of the country’s net asset position vis-a-vis the rest of the world. We will call this capital *à la* Piketty, in other words, the “stock of general capital”, reasoning as he does that the economy is open (Part 1). Thereafter, the elasticities associated with this aggregate capital are estimated econometrically with specifications which integrate – alongside this general stock – human capital, R&D, and a variable of institutional change. These tests are performed within the framework of modern neoclassical macrodynamic models; an analytical framework that Piketty explicitly claims to be his, although not exclusively so. On this basis, we calculate an implicit rate of return on

such capital to verify, or to refute, what Piketty presents as a “fundamental inequality”, comparing the rate of return of capital and the income growth rate in the long run. Then, the “economic law” that Piketty states – connecting the coefficient of capital with the ratio of the savings rate to the income growth rate – is examined, by comparing several indicators of savings (Part 2). The results previously obtained are compared with a new set of estimates performed for a sub-period: 1978-2012. This period is shorter, but corresponds more clearly to what many authors consider to be that of “capitalism with Chinese characteristics” (Part 3). In conclusion, we touch on the issue of the inequalities in China today, which is a crucial but complex question that cannot be really examined in more detail in this chapter.

## 6.2 Construction of a time series of general capital *à la* Piketty for China

### *The concept of “capital” according to Piketty*

As it is understood by Piketty in his bestseller or in other publications signed or co-signed by him in the past,<sup>141</sup> “capital” is a particularly broad notion, expanded well beyond the usual physical capital. His conception is closer to notions of “assets” or “patrimony”, which in turn can be “simplify[ied]” (Piketty [2013], p. 54) as “wealth” (Piketty and Zucman [2014]). In fact, capital actually means everything (or almost everything) that can bring money to its owner, with the main exception being human capital. In other words, capital is any asset which allows the owner to earn a return. It thus corresponds to all the assets to which it is possible to give a price, whether material or not (intangible assets), be it of a physical or financial nature. In this definition, capital may or may not have a productive function (it may not be directly productive or may even be unproductive). Capital may also exist as private property, but it may also be public or collective. Capital therefore concerns non-human assets, owned and traded in markets (Piketty [2013], p. 82) by individuals or groups of individuals, including the state.<sup>142</sup> That is to say, it includes all furniture capital used for housing, as well as financial and professional capital (buildings, equipment, machinery, patents, etc.) used by the enterprises and government.<sup>143</sup> We call this general capital here  $K_G$ , and it is seen as a production factor which is thus remunerated at its marginal productivity. The latter depends on the substitutability between capital and labor, which would be superior to 1, according to Piketty. Hence, from the conceptual, methodological and analytical points of view, he can clearly be included within the neoclassical tradition – but also among other currents (Keynesian, institutionalist...)<sup>144</sup>

Therefore, from our point of view, the challenge will be for us to reconstruct a series of capital stock for China, defined *à la* Piketty. China is indeed incorporated in the databases made publicly available on Piketty’s website, but the curious visitor will not find any figures for capital stock there (see: [piketty.pse.ens.fr](http://piketty.pse.ens.fr)). Creating capital stock series is certainly a difficult task, in particular because of the specificities of this economy, which still retains some features of the socialist system even today. This is the case, for example, of the status of the agricultural land which has an original tenure system that is still considered as “public;” or of intellectual property, that has only been recognized and regulated in China since the second half of the 1980s. More generally, the values of capital goods to be calculated are influenced by changes in

---

<sup>141</sup> See, for example: Piketty (2003), Piketty and Saez (2003), Atkinson, Piketty and Saez (2011).

<sup>142</sup> In practice, capital may be owned either by private individuals (private capital), or by the state and the public administrations (public capital) (Piketty [2013], p. 83).

<sup>143</sup> In more detail, this capital represents the sum of the non-financial assets (housing, land, businesses, buildings, machinery, equipment, patents, business assets held directly...) and the financial assets (bank accounts, savings accounts, bonds, companies’ shares, other financial investments...), less the financial liabilities (all debts) (p. 86).

<sup>144</sup> Haight (2015).

prices set by markets in which the interventions of the state are very energetic, multifaceted, and almost permanent.

### *Method of construction of a Chinese capital stock à la Piketty*

While Piketty has abundant data resources at his disposal to build the wealth-capital series for developed countries, in the case of China, there are only two “National Economic Censuses” (2004 and 2007). Consequently, we cannot use the wealth survey method to compute such series and have to turn to the perpetual inventory method (PIM).<sup>145</sup>

To construct statistically-rigorous data on overall general capital à la Piketty  $K_G$ , our approach consists of expanding, step-by-step, a stock of productive physical capital, understood in a narrow ( $K_{Pe}$ ) or larger sense ( $K_{Pl}$ ), to obtain a value of fixed capital ( $K_F$ ), including land ( $L$ ), and then a total physical capital ( $K_T$ ), comprising also the inventories ( $V$ ), and finally the desired general stock, noted  $K_G$ . The latter is an extremely broad aggregate that brings together the various components of the previous overall physical capital stock (called “total”), stretching from equipment, machinery and tools to buildings, industrial facilities and residential housing, through to values of agricultural lands, livestock, raw materials and energy, but also intangible elements (e.g., software, in addition to hardware), as to domestic assets.<sup>146</sup> Finally, all foreign exchange currency and gold reserves ( $R$ ) owned by China’s authorities, and approximating the accumulated balances of trade with the rest of the world, are added to these assets:

$$\text{Stock of } \left\{ \begin{array}{ll} \text{productive physical capital } \textit{stricto sensu} \text{ (without land, without inventories)} & K_{Pe} \\ \text{productive physical capital } \textit{lato sensu} \text{ (without land, with inventories)} & K_{Pe} + V = K_{Pl} \\ \text{fixed physical capital (with land, without inventories)} & K_{Pe} + T = K_F \\ \text{total physical capital (with land, with inventories)} & K_{Pe} + L + V = K_T \\ \text{general capital (with foreign exchange currency and gold reserves)} & K_{Pe} + L + V + R = K_G \end{array} \right.$$

The first four kinds of capital stock are constructed in chapter 3. While, the stock of general capital  $K_G$  defined in this way, à la Piketty, for an open economy is thus obtained by adding to our total capital ( $K_T$ ) the net wealth that the country owns vis-a-vis the rest of the world, as represented by the stocks of reserves in gold<sup>147</sup> and foreign currency<sup>148</sup> accumulated by the monetary authorities. These reserves are then converted into national currency, at average annual official exchange rates and expressed at constant 1952 prices. Captured by the Central Bank (i.e., the People’s Bank of China) as part of its “Compulsory Foreign Exchange Settlement System” (a device remained in force until 2012), these gold and foreign currency reserves allow us to approximate the accumulated balances of exports and imports of China with foreign countries.<sup>149</sup> Our general capital is highly consistent with Piketty’s definition of wealth, which integrates productive as well as unproductive components.

This series of general capital stock,  $K_G$ , that we have rebuilt for China from 1952 to 2012, is provided for the reader in *Appendix 6.1*. Several factors lead us to argue that the quality of this time series is of quality: *i*) our initial stocks of capital are calculated with a capital-output ratio which is less approximate than those that are selected in the literature for China; *ii*) our

<sup>145</sup> See Long and Herrera (2016a) for the details of the construction of China’s physical capital stocks using the PIM.

<sup>146</sup> See: Xu (1999), who uses as sources the statistics of fixed assets by the NBS and other various ministries.

<sup>147</sup> Here, we select the annual average price of gold in US dollars on the London market since 1978 and, before this date, we use the historical tables of the price of gold by the World Gold Council (Green [1999]).

<sup>148</sup> See: NBS (various years). And, before 1985: People’s Bank of China (1992), p. 79.

<sup>149</sup> The incompleteness of Chinese data on foreign direct investments (available since 1983 only) has forced us to use the reserves of the monetary authorities to approximate the net asset position of the country.

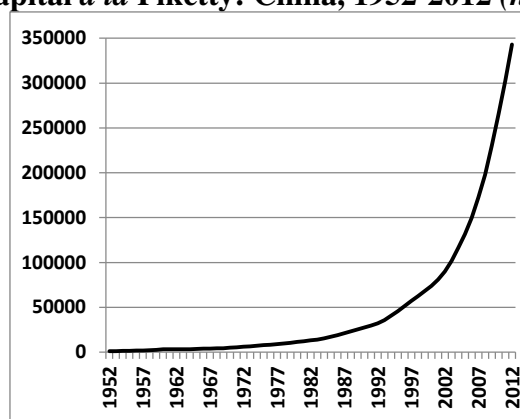
investment flows are consistent with the statistical scope of the initial stocks; *iii*) our investment price indices are well adapted to the respective contents of the stocks, and the unit root tests show that they are non-stationary and integrated in the order of 2 – so they cannot be used instead of others; *iv*) our depreciation rates are estimated by type of capital based on the compatible assumptions on age-efficiency and retirement, and the investment shares are then used to approximate the capital structure and calculate a total depreciation rate; and *v*) a parameter error analysis shows that these series of capital stock is solidly built.<sup>150</sup>

### 6.3 Piketty’s Dynamic “Laws” of Capital in China

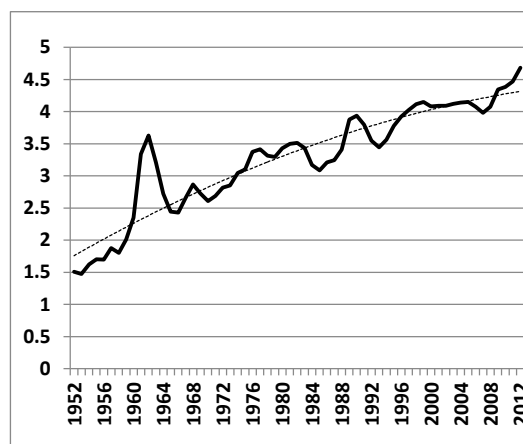
#### *The “Fundamental Inequality” Between the Return on Capital and Income Growth*

In *Capital in the Twenty-First Century*, Piketty (2013) argues that the return on capital, noted  $r_{KG}$ , as we have just defined it, must be higher than the income growth rate,  $g_R$ , i.e.,  $r_{KG} > g_R$ , in order to impulse needed by the dynamic mechanisms of (capitalist) economy. Otherwise, this would “kill” the engine of accumulation (p. 943), because the capitalists would see their profits shrink to the point that they no longer invest enough. The first “law” that he formulates – as an accounting relationship in fact – argues that the share of profits in national income is equal to the product of the profit rate and the capital-income ratio. Thus we calculate this ratio (*Figure 6.2*) on the basis of our series of general capital stock,  $K_G$  (*Figure 6.1*), and from data of gross national income (GNI),  $R$ , supplied by the *China Statistical Yearbooks* of the NBS (various years)

**Figure 6.1 General Capital à la Piketty: China, 1952-2012 (hundreds million yuans)**



**Figure 6.2 Ratio General Capital-National Income: China, 1952-2012 (coefficient of capital)**



<sup>150</sup> Long and Herrera (2016a).



To calculate the rate of return on general capital *à la* Piketty,  $r_{KG}$ , we use the formula:

$$r_{KG} = \alpha_{KG} \cdot \frac{R}{K_G}$$

where  $\alpha_{KG} = \partial R / \partial K_G \cdot K_G / R$  is the elasticity of income with respect to capital stock.

The elasticity of capital is equivalent to the share of capital in national income. We can use the “GDP with income approach” data provided by NBS to calculate the share of capital after 1978 at the provincial level. With the official data of NBS, the average share of capital is around 51% over 1978-2014 – a high value confirmed by most results in the current literature (*Table 6.2*).

To estimate this elasticity (i.e., share of capital), we need to test econometrically a production function in which this general capital is considered to be the production factor, or just one of the production factors. To do this, we choose to use various specifications derived from several theoretical neoclassical frameworks, i.e. from linearized functional forms of: i) simple models, *à la* AK, where the single input is general capital in Piketty’s sense; ii) standard ones, *à la* Solow, where the two factors considered are general capital and simple labor; and iii) more complex models, augmented to integrate, alongside general capital, an input of human capital, but also expenditure on R&D, in the manner of a formalization with endogenous growth. We therefore consider successively the following three equations:<sup>151</sup>

$$\text{Equation (1):} \quad g_{Rt} = \theta D + \alpha_{KG} g_{KGt} + \gamma g_{R\&Dt} + \varepsilon_t$$

$$\text{Equation (2):} \quad g_{Rt} = \theta D + \alpha_{KG} g_{KGt} + \beta g_{Lt} + \gamma g_{R\&Dt} + \varepsilon_t$$

$$\text{Equation (3):} \quad g_{Rt} = \theta D + \alpha_{KG} g_{KGt} + \beta g_{Ht} + \gamma g_{R\&Dt} + \varepsilon_t$$

where  $g_R$ ,  $g_{KG}$ ,  $g_L$ ,  $g_H$  and  $g_{R\&D}$  are respectively the growth rates of GNI, general capital stock *à la* Piketty, simple labor ( $L$ ), a stock of human capital ( $H$ ), and spending on R&D. The series of China’s national income over the period 1952-2012 is taken from the *China Statistical Yearbooks* of the NBS (various years). Moreover, a qualitative variable,  $D$ , destined to take account of the institutional changes and their impact on growth, is introduced. Distinguishing between positive and negative shocks, the dummy  $D$  takes the value +1 in 1963-65 (recovery), 1984 (tax reform), 1992 (Deng Xiaoping’s tour) and 2007 (overheating), but -1 in 1960-62 (recession), 1967 (beginning of the Cultural Revolution), 1976 (death of Mao) and 1989-90 (strong political unrest).<sup>152</sup>

The variable of simple labor corresponds to the workforce (active population), namely all employed persons aged over 16 years. The absence of official series of human capital stocks in China, as well as – in our view – the relatively unsatisfactory character of the available international databases, especially those of PWT (Penn World Tables [various years]), led us to reconstruct such an indicator ourselves, using a methodology we have detailed elsewhere.<sup>153</sup>

Let us limit ourselves to indicating here that “human capital” is supposed to accumulate in the manner of physical capital, and that it means the product of the average level of education

<sup>151</sup> The estimates are in the first differences of log levels in order to avoid spurious regressions because we have detected unit roots in the log levels of variables (Long and Herrera [2016b, 2017a]). Also: Nelson and Kang (1981).

<sup>152</sup> The design of this dummy variable is based on residuals analysis and econometric (significance, singularity and multi-collinearity) tests (Long and Herrera [2017a]). Even if the dummy could be asymmetric if needed, here a symmetric dummy has already whited the residuals series.

<sup>153</sup> Long and Herrera (2015a). Compared with the current literature, the original series of human capital that we provided are much more reliable than those of PWT. They improve in quality, in frequency and/or in length, those by Cai and Du (2003), or by Barro and Lee (2012), while remaining relatively close to them.

(number of years of studies leading to diplomas) by a specific population. For the year  $t$ , the stock of human capital is equal to that of the previous period (net of a rate of depreciation), plus the investment in human capital of  $t$ . The increase in the latter in year  $t$  is the sum of the products of the number of new graduates for each type of education and the number of cumulative years in the category. The stock of human capital used in our estimates is termed “productive”, since it is calculated for the workforce – and not for total population. We also build cautiously the series of expenditure in R&D,<sup>154</sup> according to the budget data of Science and Technology (1952-1985), R&D by public entities and higher education (1986-1988), and aggregated R&D from *Statistical Yearbooks of Science and Technology* (1989-1994), then from the NBS (1995-2012).

**Table 6.1 Results of the estimates of our three theoretical models: China, 1953-2012**

Equation	$D$	General Capital	Simple Labor	Human Capital	R&D	$R^2$	Autocorrelation	Heteroscedasticity	Correction
(1)	0.099596 (5.456165)	0.686832 (7.683111)	-	-	0.075111 (1.802472)	0.6654	0.1181 0.1135	0.0337 0.0358	Yes
(2)	0.104944 (8.195789)	0.571319 (7.587738)	0.725271 (3.525905)	-	0.064459 (2.604417)	0.7271	0.0729 0.0629	0.0555 0.0581	No
(3)	0.100767 (5.998232)	0.459334 (3.002002)	-	0.504085 (2.414623)	0.090485 (2.209519)	0.6908	0.1479 0.1286	0.0256 0.0292	Yes

Notes: In the first column is indicated the number of the equation tested, integrating the general capital stock à la Piketty and, possibly, the other variables, simple labor or human capital, and R&D. The  $t$ -statistics are given between parentheses in the following five columns. The  $p$ -values (of Fisher and Chi-square tests) are presented in the columns Autocorrelation (for the null hypothesis “there is no autocorrelation of the residuals” for the Breusch-Godfrey LM Test) and Heteroscedasticity (for the null hypothesis “there is no problem of heteroscedasticity of the residuals” for the Breusch-Pagan-Godfrey Test). The last column mentions whether a correction à la Newey-West for the heteroscedasticity was necessary or not.

**Table 6.2 Some estimates of the elasticity of the output with respect to capital in China**

Authors	Elasticity values	Comments
Zhang (1991)	0.70	Data taken from various sources
Guo and Jia (2005)	0.69	Data from 1979 to 2004, with cointegration methods
Jefferson (1990)	0.65	Data on the steel industry from 1980 to 1985
Su and Xu (2002)	$0.65 > \alpha_K > 0.40$	Estimates of AK models on data from 1952 to 1998
Chow and Li (2002)	0.61	Tests of a Solow model in the form of a Cobb-Douglas production function, with introduction of a linear trend
Zheng <i>et al.</i> (2009)	$0.60 > \alpha_K > 0.50$	Method inspired by Chow and Li (2002), with TFP
Chen <i>et al.</i> (1988)	0.54	Data relative to state-owned enterprises from 1953 to 1985
Jefferson <i>et al.</i> (2008)	0.38	Data on industrial sectors from 1998 to 2005
Zhang <i>et al.</i> (2003)	0.37	Estimates made with introduction of constraints
Perkins and Rawski (2008)	$0.13 < \alpha_K < 0.93$	Wide range (lowest point: 1952-57; highest point: 1957-65)

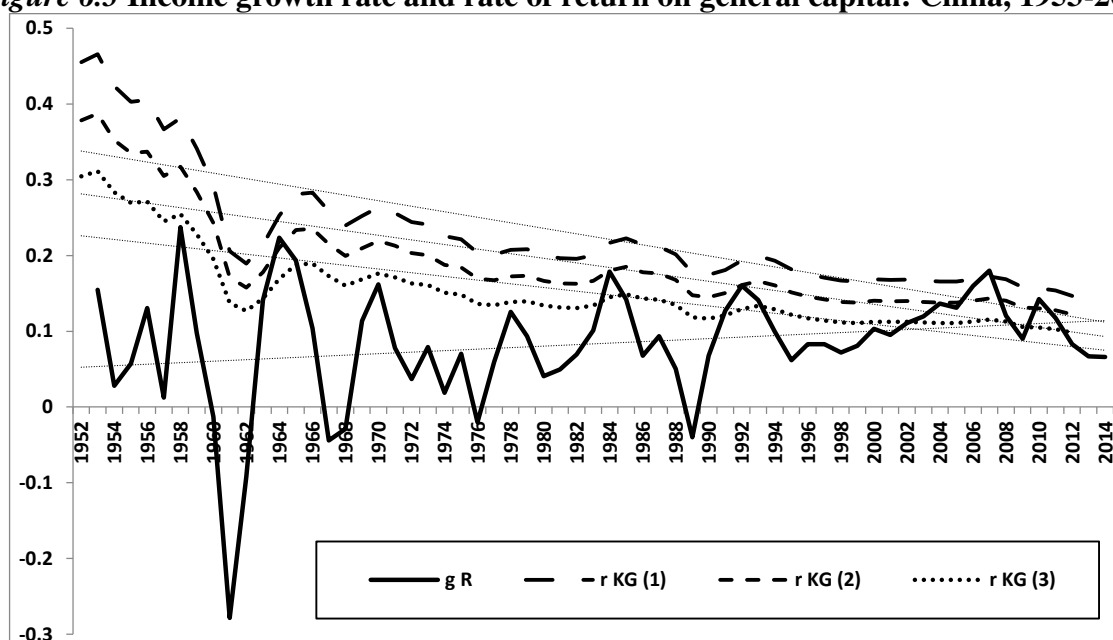
Our regressions are performed in ordinary least squares on first differences of the logarithmic forms in levels. Our time series cover the period 1953-2012, that is, 60 years of the economic history of China. The preliminary unit root tests indicate that the growth rates of all variables are stationary. If at least one of the tests revealed a risk of heteroscedasticity (at the 5% level), we introduce a correction by the White or Newey-West methods to obtain robust regressions. The coefficients associated with the different variables considered are presented in *Table 6.1*. The elasticities of national income with respect to general capital stock,  $\alpha_{KG}$ , are statistically significant, and found to be 0.69, 0.57 and 0.46 respectively, according to the choice of the

<sup>154</sup> See: Long and Herrera (2017a).

equation tested within models of *i*) AK-type, *ii*) Solowian, or *iii*) endogenous growth integrating R&D as an indicator of technical progress. As we can see, they are in the order of magnitude of the values proposed in the literature (*Table 6.2*). Based on these different elasticities, which are to be multiplied by the calculated values of the ratio national income / general capital ( $R/K_G$ ), now we are able to provide three separate estimates of the rate of return on general capital *à la* Piketty,  $r_{KG}$ , and then to compare their evolutions to the growth rate of national income,  $g_R$  (*Figure 6.3*).

As stated by Piketty, the “fundamental inequality” between the rate of return on capital and the income growth rate ( $r_{KG} > g_R$ ) seems apparently to be verified in our database for China over the 60 years considered.<sup>155</sup> However, we must nuance this result, for at least three main reasons. First, the more the model is complete and adjusted to consolidate theoretically the specification being tested empirically, the more the coefficient of capital conceived in Piketty’s sense tends to fall (0.46), and the less clearly so-called “inequality” is found to be validated (in this case, equation (3), which incorporates not only the stock of general capital, but also that of human capital, R&D, and a dummy for institutional changes). Then, even for lower values of the same coefficient – let’s say, inferior to 0.40, i.e., within the range of those suggested by authors such as Zhang *et al.* (2003), Jefferson *et al.* (2008), or Perkins and Rawski (2008) –, Piketty’s “law” is no longer valid. It should be mentioned, by the way, that we ourselves in a previous study (Long and Herrera [2015b]) provided elasticities associated with various capital stocks of between 0.35 and 0.40, by focusing on productive “cores” of physical capital compatible with the use of production functions. This *de facto* leads to challenging the relevance of Piketty’s definition of capital as a “patrimony”. Finally, we can observe that this “inequality” is beginning to be tendentially challenged over the last decade (*Figure 6.3*), even for higher values of the elasticity (0.57).<sup>156</sup>

**Figure 6.3 Income growth rate and rate of return on general capital: China, 1953-2012**



Note: These rates are to be understood in percentages (e.g., 0.1 = 10%).

<sup>155</sup> Bai, Hsieh and Qian (2006) found a return of capital of about 20% over 1978-2005, that is even much higher than ours (of about 15-18% over the 60 years studied, according to different elasticities). If we use their return of capital, Piketty’s relationship  $r > g$  would also be valid.

<sup>156</sup> It is close to the official NBS data for a share of capital of 0.51 over 1978-2014.

### ***Piketty's "Fundamental Law" in China: savings, growth and coefficient of capital***

According to Piketty, besides the relationship concerning the share of profits and “inequality”  $r_{KG} > g_R$  studied before, there is a “second law” on the dynamics of capitalist economies that is said to be “fundamental”. It occupies an important place in Piketty’s explanation of social inequalities, and it argues that the ratio of the general capital stock, or patrimony, to national income (a ratio noted  $\beta = K_G/R$ ) would tend asymptotically to the value of the quotient of the savings rate ( $s$ ) and the income growth rate ( $g_R$ ), the latter being close to that of production. This can be written as:  $\beta = K_G/R = s / g_R$ . In this section, we will thus attempt to empirically confirm or disprove this “law”.

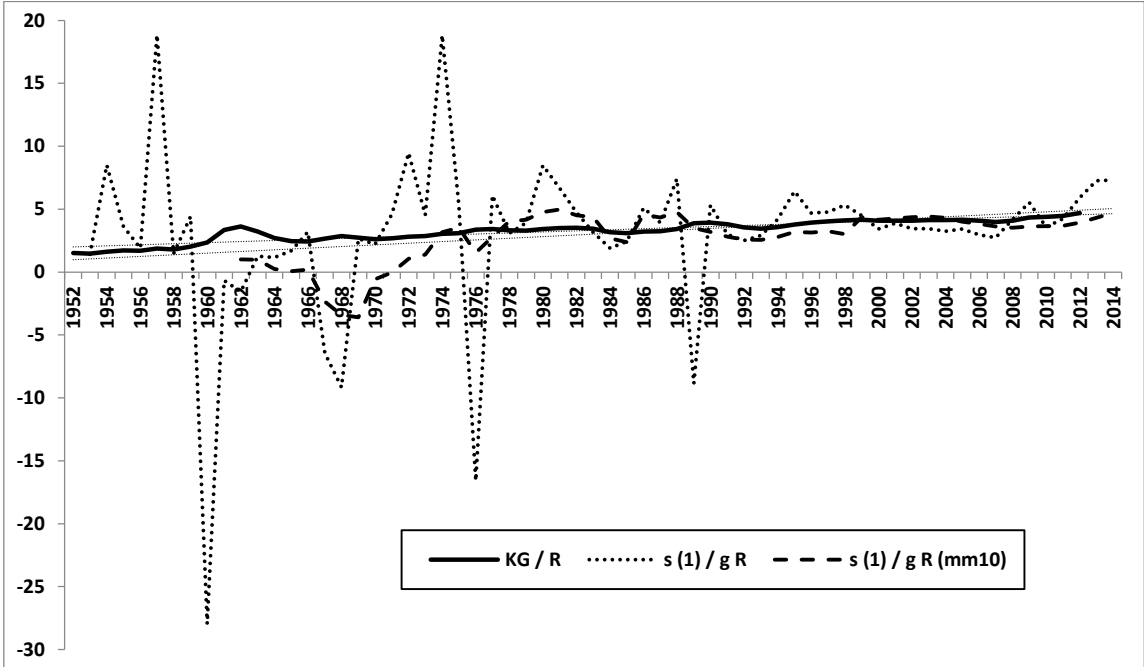
To do this, for China over the period studied, we must have a broadly-defined conception of the savings rate, encompassing all the different “economic agents.” Nevertheless, no series that corresponds to this variable exists for China, from 1952 to 2012. Several options are then available to us to reconstruct it. The best of them consists in considering savings as the difference between national income and total final consumption; the latter being the sum of public and private consumptions in the calculation of the output according to an expenditure approach, as established by the System of National Accounts (SNA):  $s_{(1)} = (1 - C)_G/R$ . Such a method has the advantage of consistency, since the construction of the general capital stock  $K_G$  also resorts to series of flows provided by the SNA (those of investment, or gross capital formation).

We have preferred to use this indicator  $s_{(1)}$  because of the disadvantages that have accompanied the elaboration of the other savings rates we were able to conceive. A second rate,  $s_{(2)}$ , considers the level of the households’ per capita consumption, divided by the rate of available income per head, from NBS source. As this series only starts in 1978, it is too short, especially since a recent alteration of the statistical methodology prevents extending it beyond 2012. A third series,  $s_{(3)}$ , was chosen to replace the available income by the national one. It too is expressed in per capita terms, in order to expand the previous series by extending it both backwards before 1978, and forwards after 2012. Doing so, however, has introduced a bias of overvaluation, because what is obtained is a savings rate of households, which is considerably higher than that of the Chinese economy taken as whole. A fourth indicator,  $s_{(4)}$ , can be designed from data published by the Central Bank, relative to the bank deposits. The annual variations of the latter, concerning not only households and enterprises, but also the various entities of the state, can be interpreted as corresponding to the flows of net savings of the year. But, this time, this new savings rate is underestimated, since all the savings do not take the form of money (in addition, there are physical reserves, including strategic raw materials, energy resources or agricultural stocks), and even money saved itself is not found only in bank deposits (such savings also exist partly in the form of household liquidity). Disaggregated data of financial accounts in flows are also available, allowing us to distinguish different savings rates between sectors (government, households, non-financial enterprises, financial institutions, the rest of the world). But this can only be done for figures since 2000.

All things considered, this is indeed the savings rate  $s_{(1)}$  we choose to be used for calculating the ratio  $s / g_R$ , by taking the GNI growth rate as the denominator. If we compare this ratio to the coefficient of general capital, we observe a certain tendency of  $s / g_R$  to converge towards  $\beta$ . Piketty describes this “law” as a long-term relationship, which would require at least 30 years to be assessed. As a result, we follow him by using a moving average (retroactive over several years: five, seven, 10, 15, 20, 25, or 30), in order to represent the rate of savings over the long

period, smoothing out strong fluctuations observed in the short term. A cursory view, omitting the sharp volatility of  $s_{(1)} / g_R$ , suggests that a convergence does in fact take place (Figure 6.4). In addition, the more extensive the length of the moving average, the more this convergence appears to be “obvious”.

**Figure 6.4 Coefficient of capital and ratio savings rate to income growth: China, 1953-2012**



Notes:  $K_G/R$  measures capital in years of national income;  $s_{(1)} / g_R$  is to be interpreted in percentages.

Nevertheless, we must go beyond appearances or intuition. As we are dealing with a long-run relationship, “equality” cannot be confirmed by a simple Wald test. Therefore, we need to examine whether a cointegration relationship exists between the series of  $\beta = K_G/R$  and of  $s/g_R$  with a moving average. We start by testing a univariate approach à la Engle and Granger (1987). This method consists in beginning with unit root tests on the variables considered. These tests reveal that the series of coefficient of capital and of ratio savings rates to income growth are non-stationary, regardless of the duration of the moving average. Moreover, the first differences of these series are stationary and integrated with an order of 1:  $\beta \sim I(1)$  and  $s_{(1)MM} / g_R \sim I(1)$ . Then, in a second step, we test the equation:  $s_{(1)MM} / g_R = c(0) + c(1) \beta$ . For it, the Wald test checks if  $c(1)$  is unitary. After that, the stationarity of the series of the residuals then obtained is estimated by an ADF test, using the critical values (with lags or not) proposed by Engle-Granger (1987) – those by MacKinnon (1991) are more precise, but require at least 50 observations, cannot be mobilized without a bias due to the insufficient size of the sample tested, when the chosen moving average exceeds 15 years.

**Table 6.3 Results of the tests made with Engle-Granger (1987) univariate approach for  $s/g_R$  and  $\beta$**

	Level	5 years	7 years	10 years	15 years	20 years	25 years	30 years
Sample size	60	56	54	51	46	41	35	31
c (1)	0,86191	0,81812	0,80357	0,80357	0,81090	0,81421	0,79775	0,79576
Wald Test								
<i>p</i> -value (Fisher)	0,5781	0,1118	0,0207	0,0067	0,0010	0,0000	0,0000	0,0000
<i>p</i> -value (Chi <sup>2</sup> )	0,5760	0,1060	0,0171	0,0047	0,0004	0,0000	0,0000	0,0000
<i>t</i> -statistics ([-1,68,1,68] at 10% Gauss.)	-0,5592	-1,6163	-2,3854	-2,8303	-3,5189	-4,7419	-6,3827	-7,4208
Coefficient Value	c (1) = 1	c (1) = 1	c (1) < 1	c (1) < 1	c (1) < 1	c (1) < 1	c (1) < 1	c (1) < 1
ADF Test	-7,20785	-3,75474	-3,64981	-5,70419	-1,84345	-1,91795	-1,71583	-1,78651
Lags	0	9	0	9	0	0	4	0
Models	None	None	Trend	Constant	None	None	None	None
Criterion	AIC	AIC	AIC	AIC	AIC	AIC	AIC	AIC
Critical Values	-3,37	-3,17	-3,37	-3,17	-3,37	-3,37	-3,17	-3,37
Relation of cointegration	Yes	Yes	Yes	Yes	No	No	No	No

While the graphical representations looked like indicating that the longer the moving average, the more “visible” the tendency of  $s_{(1)MM} / g_R$  to converge towards  $K_G/R$ , the econometric tests show the opposite: the cointegration relationship exists between the series of  $s_{(1)MM} / g_R$  and  $\beta$  when the savings rate is calculated in moving averages of five, seven, and 10 years. Beyond these durations, the residuals of our regressions are not stationary; which means that the cointegration relationship is rejected for terms of moving averages greater than 15 years. This – negative – result can be explained by the relatively small size of the samples studied, especially because the number of observations decreases as the length of moving average increases (46 points for 15 years, for example). This reduces the credibility of our tests, even by standards of Engle-Granger. Another reason for such rejection beyond 15 years might be related to the presence of a zero constant constraint ( $c(0) = 0$ ). Including a non-zero constant in our tests indeed brings results that allow us to accept the existence of a cointegration, with notably higher  $R^2$ , for all moving average durations of the ratio for the savings rate to income growth, for up to 30 years.<sup>157</sup> Then, however, the coefficient associated with  $c(1)$  is no longer found to be equal to 1 by the Wald test, since it exceeds unity almost always (except for five years) and rather widely so (1.90 for seven years, 2.36 for 10 years, 2.03 for 15 years, 1.68 for 20 years, 1.53 for 25 years, 1.57 for 30 years), in contrast to the values achieved with a null constant (Table 6.3). These remained close to 1, or just below. Thus, these results are relatively ambiguous, and this ambiguity is confirmed by the new results from the application of a multivariate approach *à la* Johansen (1988), with the advantage of allowing the introduction of deterministic components and qualitative variables (similar to the dummy we use to account for the institutional changes) into a Vector Error Correction Model (VECM), adapted to the study of long-term links. Once a VAR( $p$ ) which defines residuals as white noise is built, and the dummy appropriately integrated, we use the information criterion to select the optimal number of lags  $p$  and to estimate the cointegration through a VECM( $p-1$ ), with specific deterministic components. In agreement with the unit root tests made on  $\beta$  and  $s_{(1)MM} / g_R$ , we set a linear trend in the cointegration equation (long term), but not in the VAR (short run).

Finally, our conclusions are cautious: our results are mixed and lean in favor of the existence of cointegration relationships of an order of 1 between  $\beta$  and  $s_{(1)MM} / g_R$ , which are verified up to 10 years at least. Furthermore, the rejection of the cointegration relationships cannot be held

<sup>157</sup> For example, for a moving average calculated over 30 years, the ADF test statistic is -5.28, exceeding the critical value of -3.37, without trend and with a lag selected at zero according to the AIC information criterion.

as insured for lengths of moving average of more than 15 years, due to the small size of our samples. In other words, it is likely that Piketty’s “fundamental law” is *quasi* valid: i.e., it is to be viewed as a process of asymptotic convergence in the long term.

**Table 6.4 Results of the tests made with Johansen (1988) multivariate approach for  $s/g_R$  and  $\beta$**

	Level	5 years	7 years	10 years	15 years	20 years	25 years	30 years
Lags	3	3	2	1	1	1	1	1
Criteria	LR FPE AIC HQ	LR FPE AIC SIC HQ	SIC	LR SIC HQ	LR SIC HQ	LR SIC HQ	SIC	SIC
Dummy	With	Without	Without	Without	Without	Without	Without	Without
p-value (Jarque-Bera)	0.0206	0.0315	0.5967	0.2627	0.2627	0.3525	0.2736	0.3541
Trace Test	1	1	1	0	0	0	0	0
Max-Eig Test	1	1	1	0	0	0	0	0
Cointegration	Yes	Yes	Yes	No	No	No	No	No

Notes: Our criteria are: LR = Sequential Modified LR Test Statistic; FPE: Final Prediction Error; AIC: Akaike Information Criterion; SIC = Schwarz Information Criterion; and HQ = Hannan-Quinn Information Criterion. The critical values are those proposed by MacKinnon-Haug-Michelis, all used at the 5% level. For the p-values of the Jarque-Bera Test for residuals, we retain the Doornik-Hansen Orthogonalization.

## 6.4 Estimates for the sub-period 1978-2012

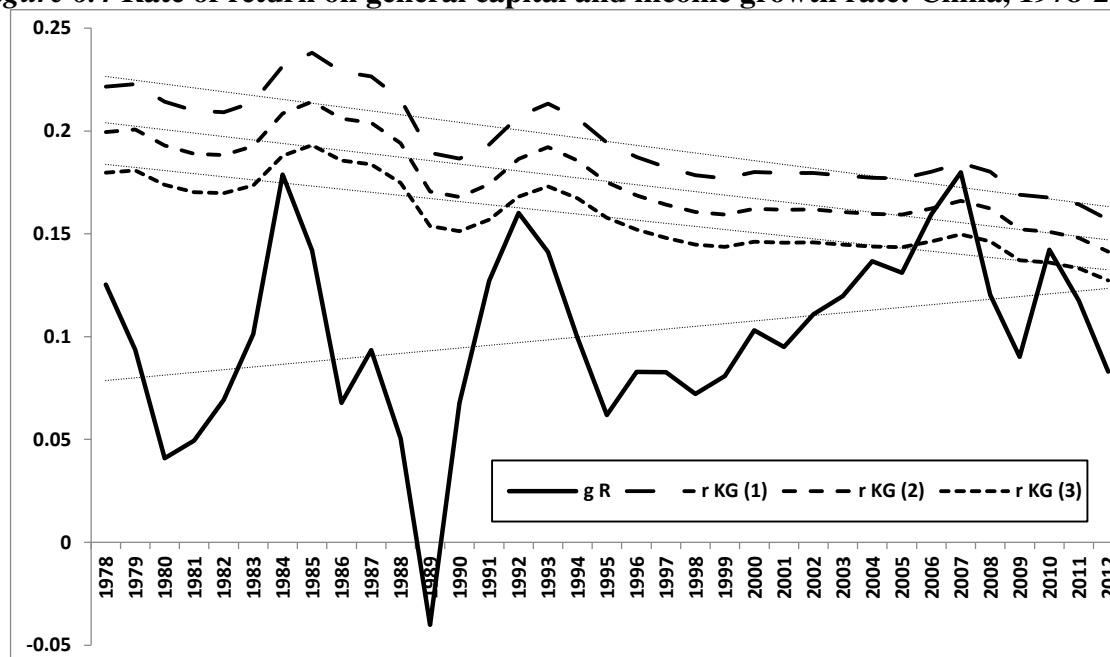
Obviously, our tests are problematic when considering the whole economic history of China since 1952. This is because after 1949 its political leaders tried specifically to break with the “laws of capitalism,” more or less successfully for several decades, by attempting to create a socialist economic system. As we know, a decisive orientation towards greater openness was put into practice after 1978, which a lot of authors in economics or other social sciences have analyzed as a shift towards “capitalism with Chinese characteristics.” If this hypothesis is accepted, then it is necessary to examine what happens to the results of our econometric estimates when applied only this recent period, i.e. for 1978-2012.

### *The Inequality* $r_{KG} > g_R$

The elasticities of national income with respect to general capital as defined by Piketty (Table 6.5) are estimated in the same way as before, according to the three growth models of AK-type, Solow, and endogenized technical progress derived from the R&D activities. As shown, the coefficients obtained for the sub-period 1978-2012 are all statistically significant, and those of the general capital stock are higher than over the entire period (1952- 2012). This is logical given the corresponding rates of return. In addition, the structure of the production function remains consistent, revealing roughly constant returns to scale, whether simple labor or human capital is retained. As the period studied is characterized by less political perturbation, it is not surprising to see a decline in the impact of institutional changes on the growth path after 1978. Almost perfectly Gaussian, the residuals of our regressions no longer present any problems of heteroscedasticity – due to the net reduction of economic fluctuations.<sup>158</sup> This reinforces the statistical robustness of our results, despite the relative smallness of the new samples: from 1978 to 2012, Piketty’s “fundamental inequality” is verified tendentiously.

<sup>158</sup> This is because of such disturbances that Chow and Li (2002) had decided to exclude the years 1959-1969.

**Figure 6.4 Rate of return on general capital and income growth rate: China, 1978-2012**



Note: These rates are to be understood in percentages (e.g., 0.1 = 10%).

**Table 6.5 Results of the estimates of various theoretical models: China, 1978-2012**

	<i>D</i>	<i>General Capital</i>	<i>Simple Labor</i>	<i>Human Capital</i>	<i>R&amp;D</i>	<i>R</i> <sup>2</sup>	<i>Autocorrelation</i>	<i>Heteroscedasticity</i>	<i>Correction</i>
(1)	0.056470 (4.932871)	0.734504 (13.39682)	-	-	0.143396 (3.721595)	0.643 515	0.2187 0.2023	0.4190 0.3907	No
(2)	0.069553 (6.313409)	0.661446 (12.21600)	0.449290 (3.089311)	-	0.143870 (4.202882)	0.727 430	0.3564 0.3026	0.7212 0.6859	No
(3)	0.059175 (5.447685)	0.596055 (7.384775)	-	0.363500 (2.233636)	0.139853 (3.845574)	0.692 934	0.3359 0.2826	0.1901 0.1792	No

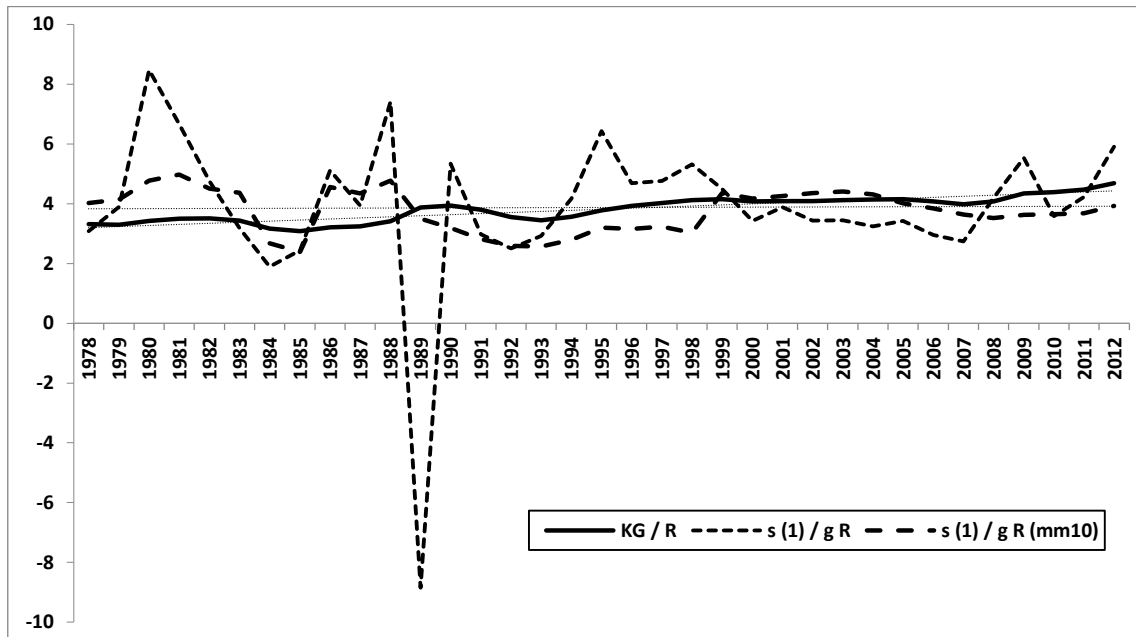
Notes: The first column contains the number of the equation tested, integrating the stock of general capital, simple labor or human capital, as well as R&D. The t-statistics are given between parentheses in the following five columns. The p-values (of Fisher and Chi-square tests) are indicated in the columns Autocorrelation (for the null hypothesis “no autocorrelation of the residuals” for the Breusch-Godfrey LM Test) and Heteroscedasticity (for the null hypothesis “no problem of heteroscedasticity of the residuals” for the Breusch-Pagan-Godfrey Test). The last column mentions whether a correction à la Newey-West for the heteroscedasticity was needed or not.

**The “Law”**  $\beta = s / g_R$

As regards the “fundamental law”, which states that the ratio of the general capital stock to national income converges asymptotically towards the quotient of the growth rates of savings and of income, its confirmation can only be assumed. That is to say, it is left to a “visual” interpretation (and hence to the discretion of each reader) about how the long-term tendencies in these two variables evolve in Figure 6.5. As already stressed, the ambiguity of the results of the cointegration tests between  $s/g_R$  and  $\beta$  is worsened over the sub-period 1978-2012, with the notable reduction (by 27 years) of the size of our samples, thus removing all statistical foundation of attempts for estimating cointegration relationships between the two series. Given our previous comments, and because the volatility of the ratio between the savings rate and the income growth rate has substantially dropped in conjunction with the reduction of fluctuations in the economy and the institutions, it does not seem to us unreasonable to suggest the validity of Piketty’s “fundamental law” for the years 1978-2012, albeit with necessary caution and the nuances specified above.



**Figure 6.5 Coefficient of capital and ratio savings rate to income growth rate: China, 1978-2012**



Notes:  $K_G/R$  measures capital in years of national income;  $s_{(1)}/g_R$  is to be interpreted in percentages.

## 6.5 Conclusion

While our empirical estimates of the verification of what the author of *Capital in the Twenty-First Century* states as “fundamental laws” in the long run leads to mixed results over the period 1952-2012, those performed for the sub-sample from 1978 to 2012, which numerous economists or social scientists called “capitalism with Chinese characteristics”, tend rather to validate them. Nevertheless, this conclusion can be put forward only with the reservations we have thought necessary to underline above. The latter concern, more particularly, the very broad definition of “capital” defended by Piketty; a definition questionable in itself and, additionally, hardly compatible with his own theoretical framework, which refers to a production function, but with “capital” input that was not constructed as a strictly “productive” factor. Our nuances also deal with the fragility of the results of the econometric tests that support the existence of cointegration relationships between the series of coefficient of capital and of the ratio of the savings rate / income growth rate, in the long run.

That said, the reader might feel – rightly – some frustration of not seeing us address the issue of inequality in China, which is crucial to Piketty, and others.<sup>159</sup> It is however not relevant, in our view, to formulate the problem of the inequalities which characterize China’s current development in the terms used by Piketty, due to the fact that he gives excessive importance to the transmission of patrimonies of wealth, through inheritance and donation. Indeed, the origins of these inequalities, as well as the mechanisms by which they operate, are different in the People’s Republic of China, and require explanations whose technical details cannot be dealt with in a few words. The same holds for the critical interpretation we have to give concerning the works that Thomas Piketty, in co-signing with Nancy Qian, devoted to this subject in China – and in other emerging countries,<sup>160</sup> as well as concerning the statistical data they used (specifically those drawn from the *China Yearbooks of Household Survey* by the

<sup>159</sup> Among many others: Bourguignon (1979), Lambert (1993), or Sen (1997).

<sup>160</sup> Piketty and Qian (2009, 2011).

NBS, which substantially underestimate the incomes of the top percentiles in the distribution tables). But this would require further search<sup>161</sup>...

---

<sup>161</sup> *Appendix 6.2* illustrates a brief discussion about the inequality via Gini coefficient. However we left this grand question in future research.

## Chapter 7

# SOME CONSIDERATIONS ON CHINA'S LONG-RUN ECONOMIC GROWTH: 1952-2014

### *From the Analysis of Factor Contributions to that of the profit rate*

This chapter offers to the readers some methodological considerations on the theme of China's economic growth in the long period. In previous chapters, using reworked Chinese official statistical data, we have first rebuild a time series of a stock of productive physical capital from 1952 to 2014, that is, the longest possible one, to go back close to the date of formation of the People's Republic and to extend this series to the present days, in order to take account of the very latest yearbooks published by the National Bureau of Statistics of China (NBS) at the beginning of 2016. Secondly, we test this new database for estimating the contributions of various factors of production to economic growth in China within a neoclassical theoretical framework. By this way, we underline several methodological limitations of such standard models – problematic, because, according to us, insurmountable. In a third step, an original framework is mobilized, in the spirit of the recent researches provided by Piketty (2013), as presented in his book, *Capital in the Twenty-First Century*, where this author combines mainstream references with components that borrow to well-known Keynesian as well as institutionalist formalizations. Some of the problems attached to Piketty's work are identified in this occasion. We finally choose to move the methodological reflection towards more clearly heterodox perspectives, by introducing a profit rate indicator, to enrich the study of China's economic growth.

### **7.1 Contribution of production factors to China's growth: measures and limits**

From the results of the econometric regressions in chapter 5 we see that, on a historical trajectory of China's long-run growth characterized by a much faster economic dynamic than changes in the population, the contribution of labour to GDP growth seems to be overstated, in spite of the demographic weight of this country. One of the main reasons for this result is the possible underestimation of the effect of total factor productivity in these regressions.<sup>162</sup> In addition, the expected improvement provided by the introduction of the R&D indicator is rather disappointing, because it did not highlight much significant positive impact of this variable on GDP growth and R&D is somewhat endogenous for the regression residuals. It should be also observed that, from a theoretical point of view, the integration of R&D is only a partial answer to the issues of identification and measurement of technical progress engines in these neoclassical models, even augmented (with endogenous growth). This difficulty is such that it drove some authors, such as Chow and Li (2002), to eliminate from their statistical samples the years with major perturbations and to introduce a simple linear trend – a solution which is, according to us, not satisfactory.<sup>163</sup>

More generally, our regressions do not exhibit any autocorrelation problem, but they do fail to prevent the apparition of a problem of heteroscedasticity, even after corrections. The principle that we have adopted in this matter – except for the situations where the residuals are white noises – was to introduce a correction by the methods provided by White or by Newey-West if

---

<sup>162</sup> For example, instead of simple labour, using a stock of human capital, with a much higher productivity, significantly improves the empirical results, bringing the elasticity of the augmented labour factor to more "reasonable" values.

<sup>163</sup> On the criticisms about Chow and Li (2002)'s studies, and some answers to them: Long and Herrera (2015c).

at least one of the tests was indicating a risk of heteroscedasticity (at 5%), in order to make our regressions robust. The integration of the qualitative variable  $D$ , capturing economic information relating to the successive institutional changes occurred between 1952 and 2014, reduced the autocorrelation of the residuals – the latter very probably coming from disruptions caused by the fluctuations of the variables recorded during certain periods (such as in the 1960s and 1990s) –, and then improved the explanatory power of the econometric estimates by strengthening their overall coherence. Nevertheless, and in addition to rather unsatisfactory empirical results, the persistence of the heteroscedasticity problem made it clear that we need to address the question of the possible existence of cycles in China’s growth trajectory.

For this, a choice is ultimately made for an exit of the mainstream. The purpose of this chapter is not to revisit the theoretical critics of the neoclassical macrodynamic corpus, up to its most sophisticated formalizations endogenizing technical progress. We consider that this criticism was conducted thoroughly enough<sup>164</sup> to justify the invitation made here by the readers to follow us towards some “heterodox” reflections on growth and cycles – which disqualify at the same time the use of real business cycles models, whose foundations (Frisch-Slutsky paradigm) are in our opinion as fragile as those of the orthodox representations of the long term.

## 7.2 Piketty’s “laws” in the case of China: attempts of verification and their limits

Before examining the issue of cycles in the Chinese economy, we have proposed an intermediary analysis which will allow us to highlight and study several relationships between key variables for further reasoning in Chapter 6. This second step returns to Piketty (2013)’s recent researches exposed in his *Capital in the Twenty-First Century*. As in other previous publications by this author,<sup>165</sup> a particularly large definition of capital is suggested, close to that of “patrimony” or of “wealth,”<sup>166</sup> and corresponding to all assets (excluding human capital) that allow their owner to earn a return on them, whether real or financial, productive or not, private or of state or collective ownership (p. 82)... As capital is seen as a production factor, remunerated at its marginal productivity depending on the substitutability between capital and labour (by assumption superior to 1), such a conception can be considered to be close to the neoclassical framework – even if Piketty also borrows from the Keynesian and institutionalist currents. Our efforts in Chapter 6 was to rebuild for China a series of capital stock within the meaning of Piketty, and to try to verify the “laws” of the dynamics of capitalism that he evoked.<sup>167</sup> This implies accepting the hypothesis that the Chinese economy, while retaining lots of features of the socialist system (such as land tenure, intellectual property, state interventionism, etc.) can be assimilated – at least since it opened in 1978 – to one of the variants of contemporary capitalism. This is in fact the view, as it seems, of a fairly large majority of the observers in the literature.<sup>168</sup>

As a consequence, we rebuilt a series of capital stock *à la* Piketty for China since 1952 in Chapter 6, in order to estimate it over the period often called “capitalism with Chinese characteristics:” 1978-2014. To do this, we expanded our previous stock of productive physical capital ( $K_p$ ), which already incorporated the inventories required for production, to add the values of non-productive components, such as lands and buildings – including residential housing – as well as monetary items representing the net asset position of China vis-à-vis

---

<sup>164</sup> Read here, among others: Fine (2000), Herrera (2000, 2006), Parente (2001), Salvadori (2003), and Krugman (2013).

<sup>165</sup> Piketty (2013). And before that: Piketty (2003), Piketty and Saez (2003), Atkinson, Piketty and Saez (2011).

<sup>166</sup> For the first concept, see: Piketty (2013), p. 54. And for the second one: Piketty and Zucman (2014).

<sup>167</sup> There is no series of China’s capital stock in the database provided by Piketty. See: [piketty.pse.ens.fr](http://piketty.pse.ens.fr).

<sup>168</sup> See, for example, the book written by Aglietta and Bai (2012). For its criticism: Andreani and Herrera (2014).

outside countries., here called “overall capital,” which gathered together assets as diverse as equipment, machines and tools, constructions, industrial facilities and residential housing, agricultural lands, raw materials and energy, intangible elements (software...), but also the reserves in gold and foreign currency accumulated by the monetary authorities.<sup>169</sup>

On this basis, we try to verify (or disprove) the “fundamental inequality” described by Piketty (2013), who argued that the return on capital ( $r_{KG}$ ) must exceed the income growth rate ( $g_R$ ), to impulse the (capitalist) economy’s dynamics; without which profits would be insufficient and do not incite entrepreneurs to invest. The first “economic law” – or accounting relationship in reality – that Piketty formulated suggests that the share of profits in national income is equal to the product of the profit rate and capital-income ratio. So we calculate an “implicit” rate of return on the overall capital ( $r_{KG}$ ), by multiplying the elasticity of income with regard to capital stock  $\alpha_{KG}$  (with  $\alpha_{KG} = \partial R / \partial K_G \cdot K_G / R$ ) by the inverse of the coefficient of capital; that is,  $r_{KG} = \alpha_{KG} \cdot R / K_G$ . We obtained the ratio between national income  $R$  and capital  $K_G$  respectively from the data given by the *China Statistical Yearbooks* (NBS [various years]) and from our own series of capital, while the elasticity of the latter is estimated, through the three equations exposed above, according to the same method, by substituting physical capital ( $K_P$ ) by that defined *à la* Piketty ( $K_G$ ). *Table 6.5* already presents those regressions.

The definition of capital defined *à la* Piketty ( $K_G$ ) and the analytical framework of production function are contradictory. Underlying the difficulty associated with the use of a not strictly productive capital as an input of the production function. Then, and as a consequence, the values of the coefficients associated with production factors (with simple labour especially) become very sensitive to changes in specifications, even moderated.

### 7.3 Growth and cycles in China: some elements for a methodological reflection

It is quite clear that the analysis of capital accumulation in China cannot be conducted without risk of confusion in the same terms as those of a “developed” capitalist country. Nevertheless, we believe that the theoretical basis of such an examination cannot rely, as Piketty did it, on the concept of marginal productivity of capital. We therefore propose to move the discussion towards the reflection on the evolutions of the profit rate variable, in our view more important to ask the issue that interests us. As a matter of fact, unlike the too quick reading of Marx that Piketty seems to have made, capital does not accumulate “unlimitedly”;<sup>170</sup> it could see its rate of profit decline along with accumulation, thus slow down the latter, even in the peculiar case (that of a “state capitalism”?) of the Chinese economy. This was what the trend in the rate of return on capital also seemed to indicate in *Graph 6.4*. But in an attempt to verify this hypothesis of the tendency of the rate of profit to fall, it is necessary first to abandon Piketty’s notion of a capital-patrimony, far too broad and ambiguous, to go back to the definition of a capital stock closer to a productive “heart”, with which we started this chapter.

Consequently, in this third and final step of the reasoning, we calculate for China from 1952 to 2014 a profit rate ( $r$ ) of the stock of physical capital as originally defined ( $K_P$ ), according to a formula interpreting, in rather free terms, the Marxist ratio of a “surplus” ( $P$ ) to the sum of constant capital and variable capital, as follows:

$$r = \Pi / K \quad (7.1)$$

where the surplus, or “profit” ( $\Pi$ ), can be written:

$$\Pi = Y - (Z + T + B) \quad (7.2)$$

<sup>169</sup> For the details of the methodology of construction of this overall capital stock, see: Long and Herrera (2015b).

<sup>170</sup> Piketty (2013), p. 27.

that is to say, as the product ( $Y$ ) minus the sum of the direct remunerations of the employees ( $R$ ), of their indirect income ( $B$ ), such as social welfare compensations, and of taxations ( $T$ ). Advanced total capital  $K$  is determined by:

$$K = K_p + R + B \quad (7.3)$$

To calculate  $r$ , we use data from different, but homogeneous sources. We first have recourse, as before, to the series of GDP, defined according to the production approach, as published in the *China Statistical Yearbooks* (NBS [various years]).

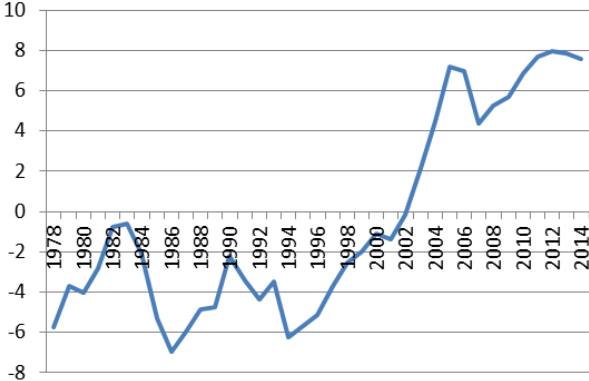
**Remunerations**

The remunerations of the employees also come from these same NBS yearbooks, but with a breakdown of GDP by the income approach. They contain all incomes received by the employees, including bonuses and other payments received in kind. We retain the series of “total wage bills of employed persons in urban units” and rural income before 1978

The remuneration data used is collected from GDP data by income approach that has 4 components: compensation of employees, net taxes on production, depreciation of fixed assets and operating surplus. NBS does not publish the national GDP data by income approach but the local bureaus of statistics (LBS) publish the GDP data by income approach in provincial level (data available since 1978). And NBS also doesn’t use the data provided by LBS as the source of calculation of national GDP, it uses the data provided by the “directly-under survey teams” of NBS.

Consequently, the gap exists between the different GDP series (of about 5% on average between the national aggregate and the sum of the provincial GDPs). NBS explains such errors as “due to different data resources and estimating methods.”(*Data of Gross Domestic Products of China (1996-2002)* NOTES FROM EDITORS) and suggested using “net outflow” as balance term. We argue that such a balance term could not exclude the error because there is evidence of manipulation of data from LBS. It is interesting to observe from *Graph 7.1* that before 2002, the percentage of errors are negative (that is to say the sum of provincial GDP is inferior to the national GDP) and becomes smaller and smaller. It seems that before 2002, the errors are probably caused by the statistical errors and alongside the amelioration of SNA of China, the errors reduced. However since 2002, the sum of provincial GDP was superior to national GDP and the errors grows. This indicates that after 2002, the local government probably “inflated” their GDP under the background that the GDP growth rate becomes the most important evaluation criterion for local leaders. Under the pressure of promotion competition, local government has the incentive to manipulate data in order to make the GDP data “grosser”.

**Graph 7.1 Gap between the national aggregate and the sum of the provincial GDPs (%)**



In order to reduce those errors (statistical errors and data manipulation), as the “compensation of employees” is a component of GDP by income approach, so we might assume that it should have the same proportion of error as the sum of provincial GDP by income approach. Then the following correction factor is proposed:

$$f = \frac{\sum GDP_j}{GDP_{national\ level}} \quad (7.4)$$

$GDP_{national\ level}$  is the official national GDP data by production approach of NBS, and  $\sum GDP_j$  is the sum of GDP by income approach provided by each LBS. and then we use the sum of provincial “compensation of employees” divides the correction factor so that we get the corrected “compensation of employees” in national level.

$$R_{corrected} = \frac{\sum R_j}{f} \quad (7.5)$$

The second correction should be made is that, in order to take into account various changes in the administrative map of China’s regions (in particular, those implied by the division of Sichuan – separated from Chongqing – [1997] or by the creation of Hainan – previously belonging to Guangdong – [1998]). So we integrate Sichuan and Chongqing together as “Sichuan”, Hainan and Guangdong integrate together as “Guangdong”. The data of Tibet is not available until 1990. As Tibet only occupies a very small proportion throughout the national economic system; the missing data before 1990 of Tibet makes insignificant errors.

For the “compensation of employees” before 1978, we use the sum of “total wage bill of employed persons in urban units<sup>171</sup>” and “total rural agriculture income after agricultural tax” to approximate. The “total wage bill of employed persons in urban units” data comes from NBS, it is the pre-tax wages (even before 1978 there is no income tax), including the room charges, utility bills, housing funds and social insurance contribution paid by employees. According to the definition of NBS, it contains all the direct and indirect wages, no matter it is in the name of wage or not, no matter it is in the monetary form or physical form, they are all included in the “total wages”. So the “total wage bill of employed persons in urban units” is a very good approximation of “compensation of employees” as direct and indirect wage (except some insurance should be added, see *infra*). Before 1978, under the background of strict segmentation between urban and rural, the rural residents almost have only the agriculture income, so we use the agricultural tax to estimate the rural incomes.

## Rural incomes and agricultural tax

The Chinese agricultural tax has 4 grand categories: agriculture and husbandry tax (the official translation was agriculture and animal husbandry tax before 1988), contract tax, tax on special agriculture (the official translation was agriculture specialty tax before 1988) and tax on use of arable land. Since 1<sup>st</sup> January 2006, the agriculture and husbandry tax and the tax on special agriculture have been canceled and a new tobacco tax has been added.

The levying method of agricultural tax is based on the normal yields of current year (not the actual yields), the unit is “100 million kg flour and rice”, and there is no tax threshold or exemption. As a consequence, China’s agricultural tax is rather unfair: firstly, taxing on normal yields not on actual yields makes the burden of farmers become particularly heavy in the bad years. Secondly, there is no exemption threshold for agricultural tax; contrast to the personal income tax of urban employed persons, even a very low rural income must pay tax. The

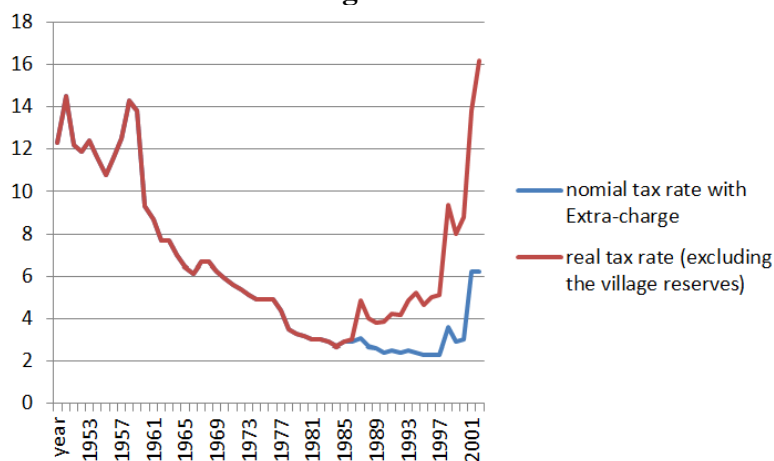
---

<sup>171</sup> In Chinese: 城镇就业人员工资总额

purchase price of flour and rice is the planned price of Supply and Marketing Cooperatives, the planned price is generally lower than the market price (commodity grain prices) that aggravated the inequality. The surplus transferred from rural to urban. This also why we argue that, we cannot exclude the rural when we calculate the profit rate with a Marxist approach. Because the particularity of China is that: the surplus is not just only transferred from workers to capitalists but also is transferred from rural to urban. At last, the tax rate of agricultural tax is not fixed. The local governments have the right to levy an “extra-charge” apart from the formal tax. The village collective organizations can also levy the so called “village reserve”<sup>172</sup>. As a consequence the burden of farmers becomes more and more heavy. Even the central government has set several reforms in order to prevent the local authorities’ arbitrary increase of tax. But the reforms had little positive effects. The rural tax-fee reform of 2002 didn’t get the expected consequences. After the reform the nominal tax rate has increased more than 100% in the next year (see *Graph 7.2*). Entering into the 21<sup>st</sup> century, as the agriculture burden has become more and more heavy, but the agriculture income is so low compared to the earning of migrant workers. Alongside the increasing mobility between urban-rural, the farmers have more opportunity to work in the cities as a migrant worker. As a consequence, the farmers have no more incentive to undertake the agriculture work. The tax base of agricultural tax also becomes smaller and smaller that even gradually threaten the food sovereignty. Finally the central government determined to cancel the agricultural tax in 2006<sup>173</sup>.

We estimate the agriculture income based on the agriculture tax data (formal tax and extra-charge) provided by the “*China Finance Yearbook 2012*”<sup>174</sup> and “*China Finance Yearbook 1999*”<sup>175</sup>. After we have get the total agriculture income before tax, we minus all the 4 types agriculture tax (formal and extra-charge, but without consideration of “village reserve” due to lack of data<sup>176</sup>) to get the series  $R_{agriculture}$ . We see that, after 1986, even without consideration of “village reserve”, the real rural tax rate is much higher than the nominal rate (including extra-charge).

**Graph 7.2 Real and Nominal Agriculture Tax before the Reform (%)**



<sup>172</sup> It has various terms, generally it has 8 famous grand categories: 3 reserves and 5 “plan as a whole”(“三提五统”). 3 reserves are: provident fund, public welfare fund and management fees; 5 “plan as a whole” are: rural education expenditures, birth control expenditures, special care expenditures, militia training expenditures and rural roads expenditures.

<sup>173</sup> Concerning the problem of farmer’s burden and “San Nong” problem (三农问题), we ask readers to check related works of Wen Tiejun and Li Cangping since several years. Limited to the topic of this thesis, we didn’t discuss more details in this paper.

<sup>174</sup> Page 466

<sup>175</sup> Table 2-6 and table 2-10

<sup>176</sup> There were almost 1 million administrative villages in 1992 and more than 3 million nature villages in that time (according to Ministry of Civil Affairs), we have no official data in village level to estimate those village reserves.



So we get the total remuneration of labors over 1952-2014:

$$R = \begin{cases} W + R_{agriculture}; before 1978 \\ \frac{\sum R_j}{f}; after 1978 \end{cases} \quad (7.6)$$

Where  $W$  is the “total wage bill of employed persons in urban units”,  $R_{agriculture}$  is the rural agriculture income after the four agriculture tax.

## Tax

As we have pointed out in the beginning, the wages and compensations of employees are both pre-tax income, we need to exclude the personal income tax in the total tax if we have already the total tax in the formula. But agriculture income is income after tax, while the agriculture tax is contained in the total tax, so we have no need to exclude this part. As the GDP data also contains the importation, so that the import tariff should also be included in the total tax and regarded as a part of production cost. The incomes tax of China began in 1980. But the data of NBS database has many missing term before 1999, we have founded those missing data in the “*China yearbook 1999*”.

## Welfare

The wages and compensations of employees have not covered all welfare expenditures and labor protection cost. Those parts are also production cost. China’s social security system has experienced a tortuous evolution and there is huge difference between rural and urban.

The urban pension insurance system was established in 1951 that covered employees of urban. According to the “*Labor Insurance Regulations of the People's Republic of China*<sup>177</sup>” in 1951: 3% of total wages were extracted as subscription of labor insurance fund. In 1955 and 1958 the pension insurance system has been established and adjusted for staffs of authorities and public institutions. This system functions until 1978. But for rural, there is no pension insurance system until most recent years.

The characteristics of social insurance over 1951-1978 are: all the personal welfares are undertaken by (public) enterprises from birth to death. It has played a supporting role of security under the planned economy system. It has great contribution to the industrialization of new China. At the meantime, the rural cooperative medical system (RCMS<sup>178</sup>) including the famous “barefoot doctor” during Mao’s period have covered more than 90% rural population in 1970s. That reflects the spirit of that peasants resist risk of illness together through mutual help under the background of socialist public ownership.

However the Social Security System of this period gradually disintegrated along with the reform and opening up. Especially the micro foundation of RCMS didn’t exist anymore after the “household responsibility system” reform (the “barefoot doctor” cannot survive after such a reform without the support of “collective work points”). The medical burden of farmers becomes heavier day after day. In the side of urban employed persons, the expensive welfare expenditures made that the state-owned enterprise was in an unfavorable situation in the

<sup>177</sup> In Chinese: 《中华人民共和国劳动保险条例》

<sup>178</sup> That is farmers pay a certain amount of money each year for CMS, and collective and government also invest a portion to form a dedicated fund so that the farmers could be reimbursed according to a certain percentage when they meet medical treatment.

concurrence of market economy. So that over 1978-1991, the social welfare spending was gradually supported by state, enterprises and individuals.

Over 1991-2000, there were experimental reforms in each provinces. One of the most important is that the state council has determined the social insurance criterions in 1997<sup>179</sup>. Those criterions are stable (only slight adjustments in particular years) and been applied for a long period. China has also founded the National Social Security Fund (NSSF) to manage and operate the assets of NSSF.

*“NSSF serves as the social security strategic reserve centralized by the central government to supplement and adjust the social security spending during the peak time period of the aging of population. The funding sources of NSSF include fiscal allocation from the central government, the transfer of state-owned capital and the fund investment proceeds, capital raised by other methods approved by the State Council.”*<sup>180</sup>

From 2001 to now, the current social security system has gradually been formed. Due to the successful experience of RCMS in 1970s, the Central Committee of CPC decided to rebuild the new RCMS in 2002. They have also carried out new rural social pension insurance pilot in 2009 that tries to cover the social welfare for the total population. Furthermore, the pension reform of 2015 has canceled the privilege of the staffs of authorities and public institutions that they didn't pay the premium of social assurances before.

The current China's Social Security System or welfare are consisted by “5 assurances and 1 funds”: Pension insurance, medical insurance, unemployment insurance, work injury insurance, maternity insurance and housing fund, summarized in *table 7.1*:

**Table 7.1 Tariff of Social Insurance of China (Until 2016)**

	Units	Individuals	Notes
Pension insurance	20%	8%	Before 2015, National fiscal pays the totality insurance for staffs of authorities and public institutions; the insured persons at their own expense (including unemployed) pay 100%.
Medical insurance	6%	2%	
Unemployment insurance	2%		The partition between units and individuals is determined by each province.
Work injury insurance	0.75% in average	0%	-
Maternity insurance	Less than 0.5%	0%	-
Housing fund	At least 5%, at most 12%		The premium for individuals and units are equal and the tariff is determined by each province.

*Note 1: Generally, if the individual's wage exceeded 300% of average annual wage of provincial level in last year then the exceeded part is not accounted as the basis of insurance; if the individuals' wages are less than 60% of this average annual wage, the basis is accounted as 60% of average annual wage.*

*Note 2: Housing fund is a welfare system with typical Chinese characteristic. It is firstly proposed in Shanghai in 1991 and promoted to the whole country in 1994 and in 1999 it has become a statutory system.*

*Note 3: According to the plan of 13<sup>th</sup> five years plan, the maternity insurance will be canceled and incorporated into the medical insurance.*

<sup>179</sup> “The decision of establishing consolidated corporation employee pension system” In Chinese: 《关于建立统一的企业职工基本养老保险制度的决定》.

<sup>180</sup> [http://www.ssf.gov.cn/Eng\\_Introduction/201206/t20120620\\_5603.html](http://www.ssf.gov.cn/Eng_Introduction/201206/t20120620_5603.html)

We see that as the evolution of social security system involves the essential differences between planned economy and market economy. It is extreme difficult to find an indicator that has consistent statistical scopes in long run. The revenue and expenditures data of Social Insurance Fund of NBS database are only available since 1989. Before the reform 1978, during the transition period and after those institutional changes, the statistical scopes and criterions are different.

So for data before 1978, as most welfare have already been including in the total wages, we only take 3% of total wages as the total welfare expenditure according to the labor protection regulation of 1951. For the transition period over 1978-1985, we use the indicator of “total cost of labor protection and welfares<sup>181</sup>”. The definition of this indicator comes from page 272 of “*China labor and wage statistics 1952-1985*<sup>182</sup>” and data comes from page 185. According to its definition, this indicator including: (1) pensions for vacant, retired and severances. (2) Medical and health expenses (3) Funeral expenses and death gratuity of employees (4) Allowance for the employees in difficult living condition (5) Subsidies on production of agricultural and sideline (6) Cultural and sports promotion expenses (7) Collective welfare subsidy (8) Collective welfare facilities cost (8) Others such as transportation expenses of visiting relative and subsidies of birth control *etc.*

We could clearly see that this indicator in transition period contains the retired wages. We argue the wages of retired persons also consist the operating costs of enterprises then it should also be excluded from profit. So the indicator of welfare constructed after 1985 should also including retired wages. So that the data of total welfare expenditure over 1989-2014 contains two parts: the first is the “Revenue of Social Insurance Fund” *i.e.* “5 insurances and 1 fund” paid by units (the housing funds and insurances paid by individuals have already been included in the total wages.); the second is the wages of retired persons. According to the *Table 7.1* we know that the total tariff of five insurances are about 37% and units pay 28% (we assume that units and individuals share equally the cost of unemployment insurance that is 1% respectively) that is to say we multiple the “Revenue of Social Insurance Fund” by 75.67% (28/37) to get the first part and plus the retired wages so that we have the total welfare expenditures.

The retired wages contains five aspects: (1) pensions for vacant (2) pensions for retired (3) pensions for severances (4) medical and health expenses of those three kinds of retirements. (5) Others. Retired wages over 1990-2002 comes from “*China labor yearbook 2003*”(page 529), data over 2002-2005 comes from “*China labor yearbook 2003*”(table 11-10). Data of 1989 is calculated from the growth rate provided by the labor yearbook. After 2006, as the Urban Pension Insurance System is relatively completed, so NBS didn’t published the retired wages anymore, we use “urban employees’ pension payments” as instead.

Data over 1986-1989 are missing. For the total welfare expenditures of those three years, we firstly calculate the total retied wages according to the numbers of retired persons and the average growth rate of retied wages. And then we assume that the growth rate of the proportion of (retied wage/ total welfare expenditures) is constant that is to say we use the geometric average growth rate to estimate the total welfare expenditures of those 3 years. Finally we get the total welfare expenditures over 1952-2014 with keeping consistent statistical criterions as possible as we can.

---

<sup>181</sup> In Chinese: 劳保福利费用总额.

<sup>182</sup>In Chinese: 《中国劳动工资统计资料 1952-1985》

$$B = \begin{cases} 3\% * W; \text{ data before 1978, according to the laws of 1951, 1955 and 1958} \\ B_T; & 1978 - 1985 \\ \text{estimated } B_T; & 1986 - 1988 \text{ missing data estimated by average growth rate} \\ 75.67\% * A_s + W_r; & 1989 - 2005 \\ 75.67\% * A_s + E_p; & 2006 - 2014 \end{cases} \quad (7.7)$$

Where  $B_T$  is the total cost of labor protection and welfares,  $A_s$  is the Revenue of Social Insurance Fund,  $W_r$  is the retired wages and  $E_p$  is urban employees' pension payments.

All these data are expressed at 1952 constant prices, using the consumer price index for their conversion. *Graph 7.5* shows the evolutions of the profit rate  $r$  in China from 1952 to 2014<sup>183</sup>. As we can see, this indicator is trending down, apparently with three distinct periods: first, a sharp decline throughout the 1950s, and until the early 1960s, corresponding to the times of the formation of the People's Republic and the break with the Soviet Union; secondly, a decrease in the rate of profit, rather clear, but significantly less pronounced in the 1960s and the 1970s; and thirdly, a relative stabilization at a lower level after the reforms adopted in 1978, going from 1980 to the present. The Chinese profit rate is 17.8% on average between 1952 and 2014, with three stages recorded around 40%, 20% and (less than) 10% for the sub-periods identified: 1952-1962, 1963-1978, and 1979- 2014.

#### 7.4 Econometric Methodologies for Trend and Cycles: Spectral Analysis and Filters

Following Nelson and Plosser (1982), an implicit suggestion of Chapter 2 is that the economic growth and fluctuations should be studied together. And the heteroscedasticity problems in the regression of Chapter 5 also suggest that the economic cycles and even crisis should not be ignored. To identify the economic cycles and potential trend in long-run, we might turn our analysis from time domain to frequency domain.

According to the Fourier's transform, each time series has a presentation in frequency domain and its population spectrum  $s_Y(\omega)$  is equivalent to its autocorrelation functions. For a stationary series  $\{Y_t\}_{t=-\infty}^{\infty}$ , the population spectrum could be written as:

$$s_Y(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_j [\cos(\omega j) - i \sin(\omega j)] \quad (7.8)$$

Where  $\gamma_j$  is the population autocorrelation function.

Then the sample spectrum could be written as:

$$\hat{s}_Y(\omega) = \frac{1}{2\pi} \sum_{j=-T+1}^{T-1} \hat{\gamma}_j [\cos(\omega j) - i \sin(\omega j)] \quad (7.9)$$

Where  $\hat{\gamma}_j$  is the sample autocorrelation function.

As  $\hat{s}_Y(\omega)$  is a sine periodic function, then the sample periodogram provides information about the cycles:

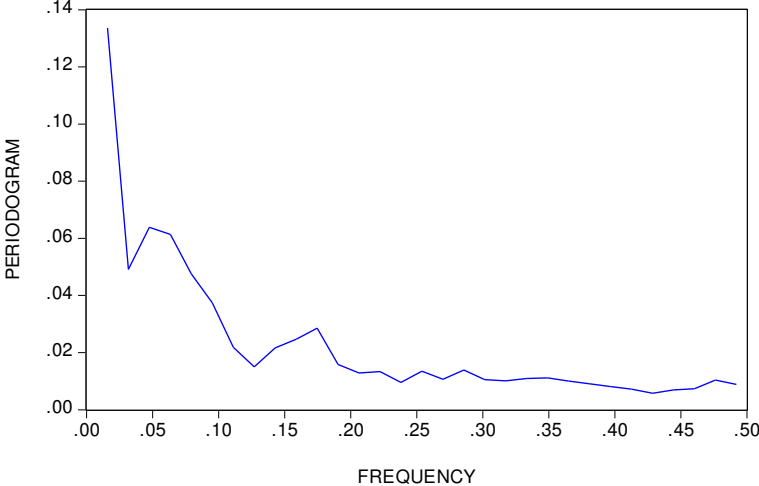
$$T_n = \frac{2\pi}{\omega_n} \quad (7.10)$$

Where  $\omega_n$  is the  $n^{\text{th}}$  sample frequency in the sample periodogram. *Graph 7.3* illustrates the sample periodogram. The high values of low frequencies indicate that the profit rate has a

<sup>183</sup> The details of database are presented in *Appendix 7*.

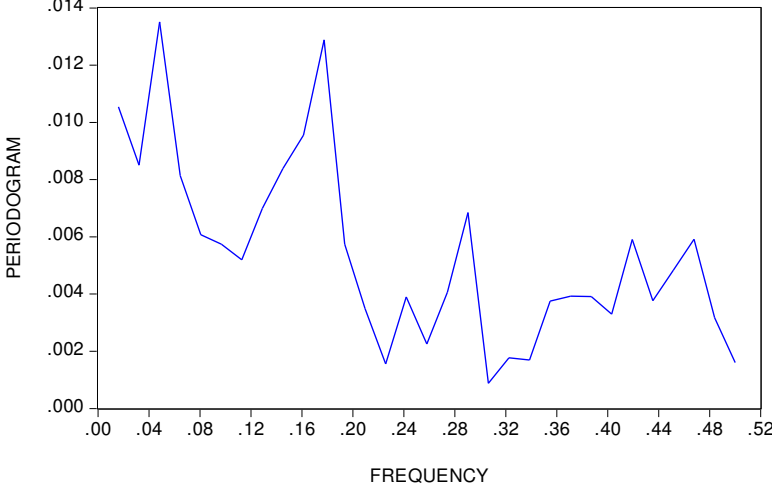
long run trend that is nonstationary (see also *graph 7.5*). The second peak point corresponds a frequency of  $\omega_n = 0.175$  that is to say a cycle of 35 years. As the sample size is 63 years, it seems that the periodogram has found a trend in long run and that the economic reform of 1978 divides PRC's economic trajectory into two stages.

**Graph 7.3 Sample Periodogram of Profit Rate**



If we apply a difference filter to eliminate the long run trend, that is to say, we illustrate the sample periodogram of the changes of profit rate in *table 7.4*:

**Graph 7.3 Sample Periodogram of Changes of Profit Rate**



The peak points and their corresponding cycles are:

**Table 7.2 Cycles of Changes of Profit Rate**

$n$	1	2	3	4	5	6
$\omega_n$	0.048	0.177	0.242	0.29	0.419	0.468
$T_n(\text{years})$	130	35	25.9	21.67	15	13.4

As we see that after a simple filter, the new periodogram in fact does not provide any useful new information. There is still a long run cycle (130 years that exceeds the sample size) and we re-obtained the dichotomy of economic trajectory by the reform of 1978. For the other cycles, it is difficult to give an economic explanation that also suggests the economic cycles are complicated in China or the periodogram is insufficient.

Indeed there are many insufficiencies of periodogram. One of the most is that even the sample periodogram provides an unbiased estimation for population spectrum if the sample size is sufficient large<sup>184</sup>:

$$\frac{2\hat{s}_Y(\omega)}{s_Y(\omega)} \approx \chi^2(2) \quad (7.11)$$

And a  $\chi^2(2)$  variable has an expectation of 2.

However, as the 95% interval of confidence of a  $\chi^2(2)$  variable is (0.05, 7.4) that is to say  $\hat{s}_Y(\omega)$  has a so large interval of confidence that  $\hat{s}_Y(\omega)$  is not a satisfactory estimator of  $s_Y(\omega)$ . In this situation, a nonparametric method of kernel regression might be help to smooth the periodogram. For example, if we use Bartlett kernel, equation (7.10) becomes:

$$\hat{s}_Y(\omega) = \frac{1}{2\pi} \left\{ \hat{\gamma}_0 \sum_{j=1}^{T-1} \kappa_j^* \hat{\gamma}_j \cos(\omega j) \right\} \quad (7.12)$$

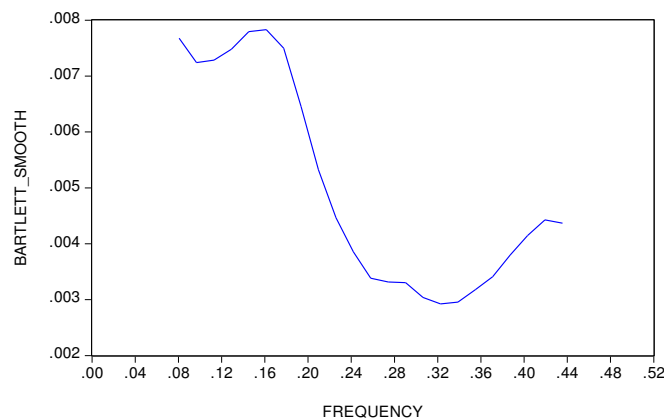
And

$$\kappa_j^* = \begin{cases} 1 - \frac{j}{q+1} & \text{for } j = 1, 2, \dots, q \\ 0 & \text{for } j > q \end{cases} \quad (7.13)$$

Where  $q$  is the Bartlett kernel parameter. If we treat the changes of profit rate as a MA(5) series<sup>185</sup>, the periodogram becomes:

#### Graph 7.4 Sample Periodogram of Changes of Profit Rate with Kernel Regression

Kernel Density on DRKPL | Bartlett Window (Bandwidth: 5)



We see that, as usual only the cycle of 35 years has been filtered out. The initial application of spectral analysis and simple filter suggests that we might need other filter tools to explore the complicated behaviors of China's economic cycles.

The early researchers decomposed the economic time series into trend and cycles with the methods such as Beveridge-Nelson -Nelson (1981), Harvey (1985), Watson (1986), Clark (1987), Quah (1992), and Morley (2002). For recent years, the Hodrick-Prescott (1997) filter becomes more and more popular in the analysis for example especially in the behavior equilibrium exchange rate analysis (BEER approaches<sup>186</sup>). Inspired of BEER, we apply Hodrick-Prescott filter to separate the cyclical component of profit rate<sup>187</sup>. An advantage is that

<sup>184</sup> Fuller (1976, p280)

<sup>185</sup> 5 is a sufficient high order of MA to obtain a white noise residual series from MA model.

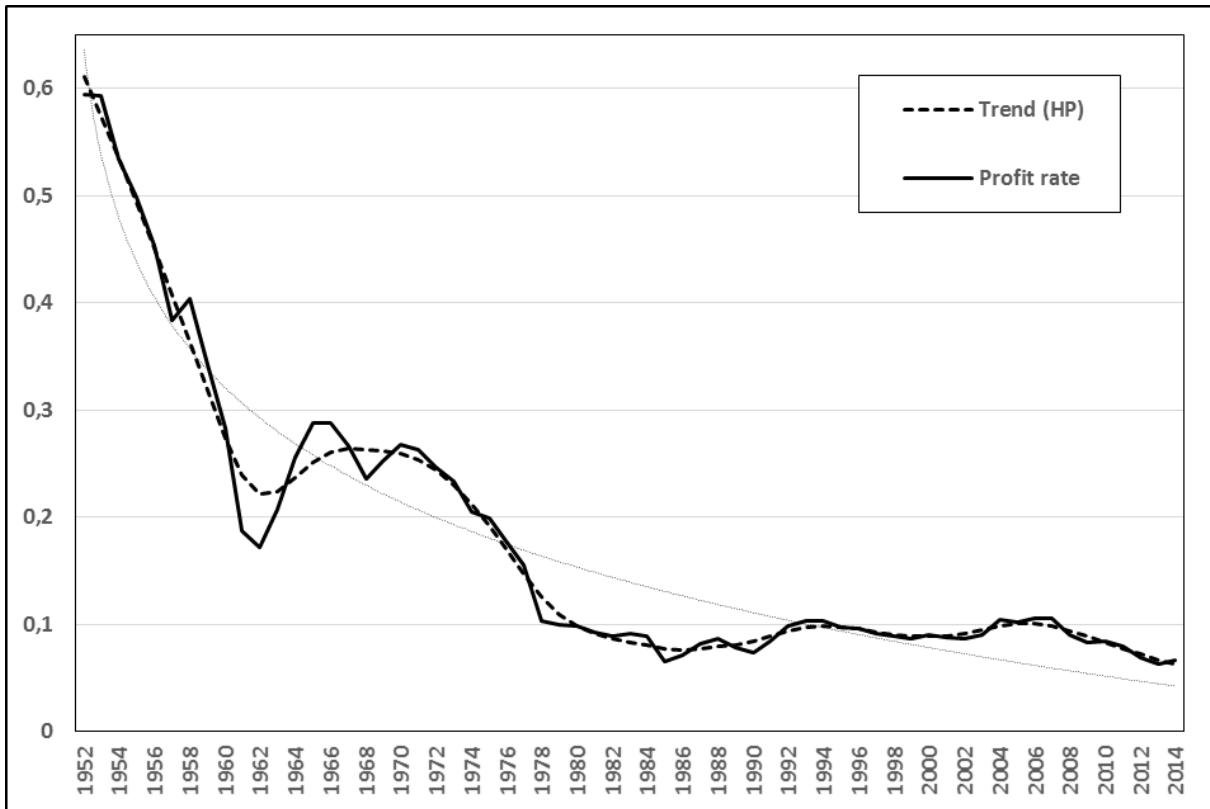
<sup>186</sup> BEER decomposes the real efficient exchange rate as two parts: a long run trend and a short run random fluctuations, see Clark and MacDonald (1997 and 1999)

<sup>187</sup> The parameter is used as the proposition of Ravn and Uhlig (2002) for the yearly data.

the trend component is more intuitive and the cycles are not fixed years anymore. The latter provides an opportunity to introduce multiple cycles with nonstandard periods (*Graph 7.6*).

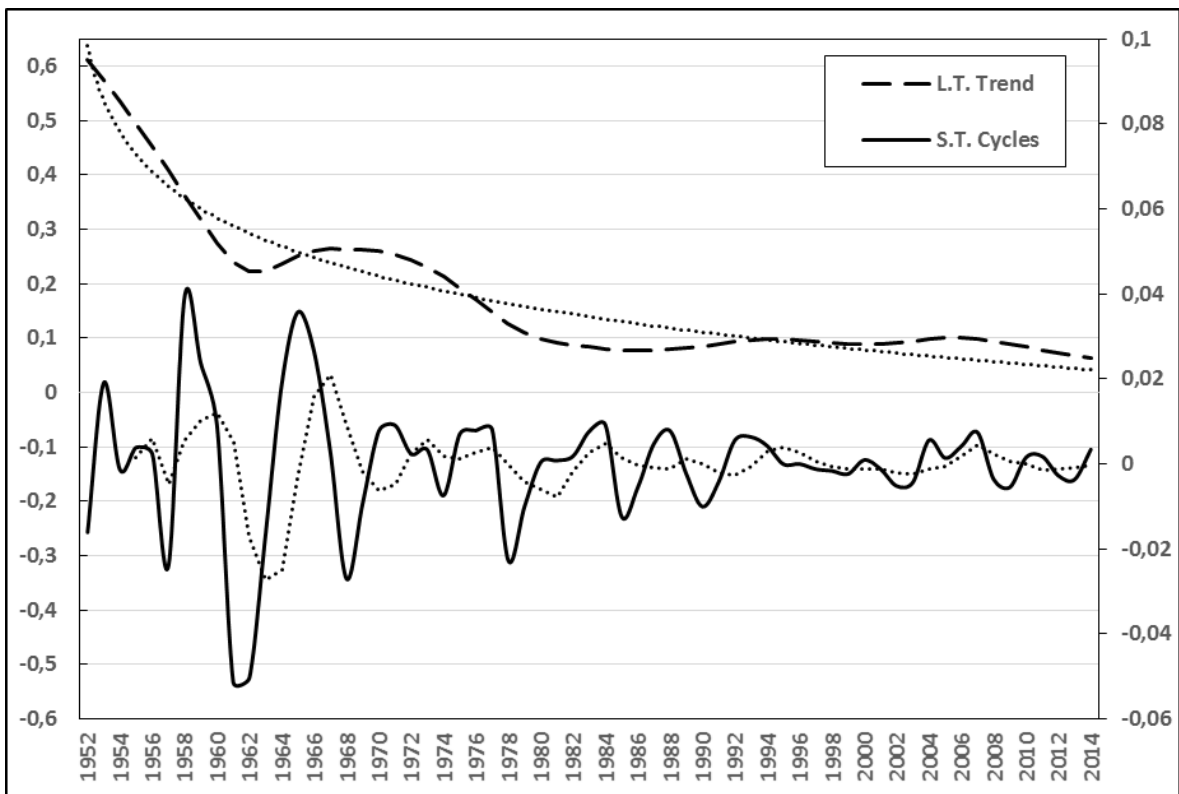
This decomposition of the profit rate reveals recurrent oscillations with some regularity, looking like economic cycles. The magnitude of the latter tends to decrease with time, while the frequency of their recurrence is accelerating. The years for which the component of the profit rate attributable to cycles – component expressed in first difference – records a negative value are the following: 1954, 1957, 1961-63, 1968-69, 1974, 1978-79, 1985-86, 1989-91, 1995, 1997-99, 2001-03, 2008-09, 2012-13. These situations correspond approximately to half the number of years of the total period studied (i.e., 27 out of 60), with 13 successive historical moments. The largest negative variations of the profit rate occurred in the years: 1957, 1961-63, 1968-69, 1974, 1978-79, 1985-86, 1990-91, 1999, 2002 and 2009. Is the use of the term “recession” appropriate to characterize such moments, in contexts where GDP growth rates are often still very high?

**Graph 7.5 Evolutions of the profit rate and its trend: China, 1952-2014**



*Note: The trend of the profit rate is that obtained after its breakdown by the Hodrick-Prescott (HP) filter.*

**Graph 7.6 Decomposition of the profit rate between trend and cycles: China, 1952-2014**



*Note: The trend is accompanied with a logarithmic trend, and the cycles with their (5-year) moving average.*



## 7.5 Conclusion

This chapter is based on the construction of an original database in which the stock of physical capital occupies the central place, in order to expose to the readers several methodologies of analysis of the growth of the Chinese economy over the period from 1952 to the present days. It maintains the consistency of the same statistical time series from the beginning to the end of the discussion. By doing so, we suggest the need for an “exit” from the usual framework of the neoclassical mainstream as well as – after having tried to apply Piketty (2013)’s “laws” to the case of post-1978 China – the relevance of more heterodox reflections, using the profit rate as a key indicator. By observing the changes in this variable over the past six decades, we realize that China’s economic growth trajectory – exceptional for its force and its scale – did not operate smoothly, or without difficulties.

We also suggest that the need for an “exit” from the usual framework of the time domain and turn to the spectral analysis and filter analysis in econometric. This work is still at a preliminary and explorative stage, but it already provides a number of interesting results. For sure, much remains to be done, in various directions. The explanations for the observed trends of the profit rate in the long term are to be examined in depth, in terms of labour productivity, share of profits in value added, or compositions of capital. The same is true for the interpretations of the short-term fluctuations or cycles, their turning points, their amplitude, their frequency... Are the moments of negative changes in the cyclical component of the profit rate always “recessions”? And in which specific cases would it be possible to talk of “crises”? To sketch the answers to these complex issues – in addition to those related to the mathematical and statistical tools to be used to break down the profit rate –, the institutions and anti-crisis policies successively conducted on 60 years of the history of this country would certainly need to be examined in greater depth. And probably also in terms of non-quantitative economics, that could be informed and helped by other social sciences...

## Chapter 8 CAPITAL ACCUMULATION AND CYCLES IN CHINA'S ECONOMY FROM 1952 TO 2014

### *Two Methods of Analysis through Industrial Profit Rates*

Based on various originally-constructed statistical series of stocks of productive physical capital and of enterprises' fixed assets, and on a definition – as rigorous as possible – of the scope of the industrial sector, we calculate several indicators of profit rates at the micro and macroeconomic levels for China from 1952 to 2014. The results obtained by these two methods (micro and macro) are quite similar and can be summarized as follows: *i*) a tendency of the profit rate to fall is observed over the long period, for the two levels of analysis. *ii*) At the macro level, the short-term fluctuations in the profit rates show a succession of (rarely complete) cycles whose amplitude decreases with time. *iii*) More than a third of the period is affected by recessive years for the cyclical component of the profit rates. The largest declines are recorded, in descending order, after the rupture between China and the Soviet Union (1961-63), during the Cultural Revolution (1968), in the course of the 1950s, during the post-Mao transition (1976-77), when a neoliberal experiment has been tempted (1989-91), and with the spread of the globalization crises (which affected China in 1998, 2001, 2009, then since 2012). *iv*) It is mainly the increasing organic composition of capital that tendentially pushes down the macro rate of profit.

### 8.1 Introduction

Remarkable for its strength as well as for its relative stability in recent years, the growth path of the Chinese economy raises many questions, along with numerous academic studies.<sup>188</sup> These questions concern not only the causes, mechanisms and engines of such a dynamism, but also its sustainability and the likely consequences of the rise (or so-called “emergence”) of China in the hierarchy of the countries in the capitalist world system. Most of these issues related to the *sui generis* – and singularly complex – nature of this economy which has adopted many features of capitalism since its opening in 1978, while it retained some characteristics of socialism, particularly in terms of land tenure, intellectual property, or massive investments and proactive state interventions – a state which stayed itself under the authority of a powerful Communist Party. In the case of China, our interpretation encourages us to speak of a “state capitalism,” but under conditions which remain those of a transition to socialism.<sup>189</sup>

This chapter does not attempt to define the nature of the current Chinese economic system; and still less to deal with all facets that such a definition would require. It will aim more modestly to offer some thoughts on the role played by the rates of profit in the dynamics of capital accumulation in China's economy over the long period. As a matter of fact, our premise is that today, the functioning of this economic system shares sufficiently (and more and more) common features with capitalism to allow us methodologically to use the concept of “profit rate” in order to study it. Such a research will be conducted within a Marxist framework, quite original in this current indeed, because it is performed through two methods; more precisely by “microeconomic” and “macroeconomic” analyses. Here, we conceive these two levels of analysis very simply: “micro” means led by using statistical data taken from the accounts of the enterprises, and “macro” by using data from series characterizing the national economy. These two methods meet at the level of the industrial sector, which is thus studied from two distinctive angles. We chose such an approach after having written a series of

---

<sup>188</sup> Read, for example: Chow (1993), Maddison (1995), Chow and Li (2002), or Ding and Knight (2009).

<sup>189</sup> See: Andreani and Herrera (2013, 2015).

researches to China's economic growth in which we emphasized the limits – insurmountable, according to us – of the tools provided by the neoclassical mainstream, or its dependencies.<sup>190</sup>

First, it should be stressed that the different indicators of profit rates that we will build, by putting in relation a surplus or “profit”, and a stock of capital or of fixed assets, cannot be interpreted in the same terms than in the cases of developed capitalist countries. However, the attention devoted to profit rate indicators is important if we are to explain the reproduction dynamics of the Chinese economy in the long term, even over the time it was largely planned. As a consequence, once clearly identified the core of our subject – the industry – (Part 1), our efforts will be focused on the calculations of profit rates of the industrial enterprises at the microeconomic level (Part 2), and of profit rates of the industrial sector at the macro level (Part 3). Then, we will study the changes in these indicators, as well as those in their technical and economic decompositions, shedding light on a succession of cycles which punctuates the capital accumulation process of this economy over the last six decades (Part 4).

---

<sup>190</sup> Here, the reader is invited to consult our previous works on China's economy: Long and Herrera (2015, 2016 and 2017). For a theoretical critique of the so-called “new” neoclassical growth, published in *Research in Political Economy*: Herrera (2011).

## 8.2 The industrial sector in the Chinese accounting systems

The contours of the “industrial sector” should be defined carefully, because this concept was apprehended in different ways in the accounting systems that have succeeded in China (Table 8.1). Similar to the Soviet planning model, the balances of the Material Product System (MPS) remained in force from 1952 to 1992. It recognized the productive contributions of agriculture and industry, but not services – whose value added was then not included in the calculation of the national income. Therefore, all non-agricultural activities identified in the classification of the time could be considered as “industrial”. Following the reforms of the late 1970s, the MPS was gradually replaced by the System of National Accounts (SNA), which introduced a distinction between three economic sectors: primary for agriculture, secondary for industries and construction, tertiary for everything else (among other activities, transport, post-telecommunications, commerce, social services, etc.).

The complete transition from the MPS to the SNA was achieved in 1993 and, the following year, the National Bureau of Statistics of China (NBS) released an “Industry Classification of National Economy”, called “GB/T4754-1994” (国民经济行业分类). The secondary sector had been divided into four sections under the titles “B” for mining and extractive industries, “C” for manufacturing industries, “D” for the production and distribution of electricity, gas and water, and “E” for construction. Thus, the aggregation of the sections B, C and D fit well to the traditional concept of “industry”. In 2004, the “GB/T4754-2002” classification was adopted, leaning on the typology of the “2003 Three-Sector Classification Rules” (三次产业划分规定).<sup>191</sup> The modifications then introduced (with new delimitations of sub-sections, or “divisions”, within the secondary sector, or between the latter and the tertiary sector) did not call into question the previous definition of industry. The same applies to the changes which accompanied the new “GB/T4754-2011”,<sup>192</sup> in application since 2012, and mostly concern the agricultural activities (section “A”) and services (strictly identified to the tertiary sector, and including additional divisions transferred from the secondary sector).

**Table 8.1 Evolutions in the scope and classification criteria of the industrial activities**

Period	Scope	Criteria	Comments
1952-1992	All activities, except agriculture	Material Product System (MPS)	Non-recognition of the productive contribution of the activities in the tertiary sector by the NBS
1993-2003	Sections B + C + D, excluding construction	System of National Accounts (SNA) “GB/T4754-1994”	Recognition of the productive contribution of the activities in the tertiary sector by the NBS
2004-2011	Sections B + C + D, excluding construction	“GB/T4754-2002” and “2003 Three-Sector Classification Rules”	Redistribution of the divisions in the secondary sector, significant changes in the tertiary sector
2012-Present	Sections B + C + D, excluding construction	“GB/T4754-2011” and “2012 Three-Sector Classification Rules”	Some divisions in the secondary sector moved to the tertiary sector, more identified to services

The statistical consistency of the “GB / T4754” Classifications and the relative stability of the scope of industry in the different periods of their elaboration led us to define the “industrial enterprises” as those belonging to all sections B + C + D, as the NBS conceives them. Clearly, we retain here the productive entities whose activities are primarily performed within the sections of “mines” (B), “manufacturing industries” (C) and “production and distribution of electricity, gas and water” (D), that is, all the secondary components, except construction. This is an interpretation relatively close to that of the 2008 International Standard Industrial Classification (ISIC). Finally, we see that the successive adjustments recorded in the Chinese

<sup>191</sup> [http://www.stats.gov.cn/tjgz/tjdt/200305/t20030519\\_16460.html](http://www.stats.gov.cn/tjgz/tjdt/200305/t20030519_16460.html).

<sup>192</sup> [http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114\\_8675.html](http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114_8675.html).

accounting systems have had only limited impacts on the contours of the fundamental concept of industry.

### 8.3 Calculation of industrial profit rates at the microeconomic level

First of all, we will calculate microeconomic profit rates from data collected at the level of the enterprises of the industrial sector, as defined above. This calculation requires the availability of two types of variables: the profits of these enterprises, and the value of their capital stocks. Regarding these capital stocks, we follow the approach proposed by Gregory C. Chow (1993), which used cumulated data in order to determine the stocks of fixed assets of the industrial enterprises. The aim of this author was to evaluate stocks at the national scale. Nevertheless, the series that he used are no longer put at the disposal of the public by the NBS since the transition from the MPS to the SNA in 1993; so, it is not possible to extend them beyond that date. But, thanks to the existence of *Enterprise Accounting Standards* (standardized business accounting balances), continuous data on cumulated depreciations allow us to reconstruct the stocks of fixed assets of the industrial enterprises, as Chow did it. The *Enterprise Accounting Standards* that we use are those established for 2006 (会计准则 2006). All productive entities are indeed supposed to comply with this accounting system, but a significant part of them is still registered with reference to the 1992 standards in the documents of the NBS, as well as in those of the Ministry of Finance.

The capital stocks which are considered here are those of tangible assets with a serving life of more than one fiscal year. These are, among others, buildings, equipment, machinery, tools, means of transport, which are held by enterprises for their production of goods and services, rental or administrative purposes. Concerning the total value of fixed assets of the industrial enterprises, noted  $K_{AT}$  and recorded at year-end values in the *Tables of Assets and Liability of Enterprises*,<sup>193</sup> the *Enterprise Accounting Standards 2006* adopt the following definition:

$$K_{AT} = K_{AO} - A_C - L_A$$

with  $K_{AO}$  the original value of fixed assets,<sup>194</sup> corresponding to their initial cost, that is to say, to the total expenditures spent by the enterprises through the purchase, construction, installation, transformation, expansion or technical upgrading of these tangible assets. From this value are deduced the cumulated depreciations during the years of functioning<sup>195</sup> and the impairments of assets recorded in the accounts over the period. When the NBS did not provide data on these impairment losses, these were recalculated for the missing years.<sup>196</sup>

The total profits realized during the accounting period,<sup>197</sup> noted  $P_T$ , are given by the following formula:

$$P_T = B_E + R_E - D_E$$

where  $R_E$  and  $D_E$  represent the operating revenues and expenses respectively, while  $B_E$  corresponds to the operating benefits, to be interpreted themselves as corporate income (including those earned from investments), less the sum of the charges, various taxes, other expenses of the exercise and impairment losses of the assets.

<sup>193</sup> For the *Enterprise Accounting Standards*, the data come from the *Tables of Assets and Liability of Enterprises*.

<sup>194</sup> This value is reported according to the year-end debit balance of fixed assets in the accounting records.

<sup>195</sup> Value reported according to the year-end credit balance of cumulated depreciations in the accounting records.

<sup>196</sup> In most cases, the NBS provided the data of “total value of fixed assets” and “original value of fixed assets”.

<sup>197</sup> The amounts of total profits are found in the “*Profit Tables*” in the accounting records of the enterprises.

**Table 8.2 Definitions of the four microeconomic profit rates of the industrial enterprises**

<i>Criterion 1: Depreciation</i>	<i>Criterion 2: Taxation</i>	Taxes not deducted from profits	Taxes deducted from profits
Cumulated depreciations included in the capital of fixed assets		Nominal profit rate before taxation: $r_1$	Nominal profit rate after taxation: $r_2$
Cumulated depreciations excluded from the capital of fixed assets		Real profit rate before taxation: $r_3$	Real profit rate after taxation: $r_4$

We are thus able to calculate four profit rates for the industrial enterprises at the micro level. Two criteria are retained here (Table 8.2): *i*) whether the cumulated depreciations are included in the capital of fixed assets (nominal rate of profit) or not (real rate of profit), and *ii*) whether taxes are deducted from the profits (profit rate after taxation) or not (before taxation rate). These four profit rates are written:

$$\text{Micro} \left\{ \begin{array}{l} \text{nominal profit rate of the industrial enterprises before taxation:} \\ \text{nominal profit rate of the industrial enterprises after taxation:} \\ \text{real profit rate of the industrial enterprises before taxation:} \\ \text{real profit rate of the industrial enterprises after taxation:} \end{array} \right. \begin{array}{l} r_1 = \frac{P_T}{K_{AO}} \\ r_2 = \frac{P_T - T_E}{K_{AO}} \\ r_3 = \frac{P_T}{K_{AT}} \\ r_4 = \frac{P_T - T_E}{K_{AT}} \end{array}$$

where  $T_E$  represents the income taxes on the industrial enterprises.

In China, tax regulation has undergone significant changes since the founding of the People's Republic. These changes have accompanied those of the ownership structure of the whole economy. The "Great Socialist Transformations" were launched in 1952; they consisted more notably in expanding the scope of the state and collective enterprises, which extended to almost all of the productive entities of the country (more than 99%) as soon as the end of 1956. A major tax reform was decided in 1984; it was implemented in parallel to the Chinese government's decision to allow again private property in the industrial sector. We will use as indicator of taxation the "industrial" component of the industrial and commercial tax between 1952 and 1984. From 1985 on, i.e., just after the instauration of the tax on corporate income, levied on the state and collective enterprises,<sup>198</sup> it is this last tax that we chose. Nevertheless, after 2001, all national companies were subject to this tax.<sup>199</sup>

In a large majority of the cases, the statistical series provided by the NBS are incomplete and allowed calculating rates of profit since 1978 only. Thus, we had to complement ourselves all the missing data. For those of the "total value of fixed assets" prior to 2000, we used instead of it the "net value of fixed assets", which is a very similar series. The latter is recorded at year-end value in the yearbooks of the NBS anterior to 1993 – as is also recorded the "total value of fixed assets". However, between 1994 and 1999, the "net value of fixed assets" is presented as an average annual indicator. To correct the bias that characterizes this period and be able to recalculate "net values of fixed assets" at the end of the year, we assume here that the growth rate of a half-year is equal to half the growth rate of the year.

<sup>198</sup> See the "Notes" of the *China Finance Yearbook 2012* (p. 452).

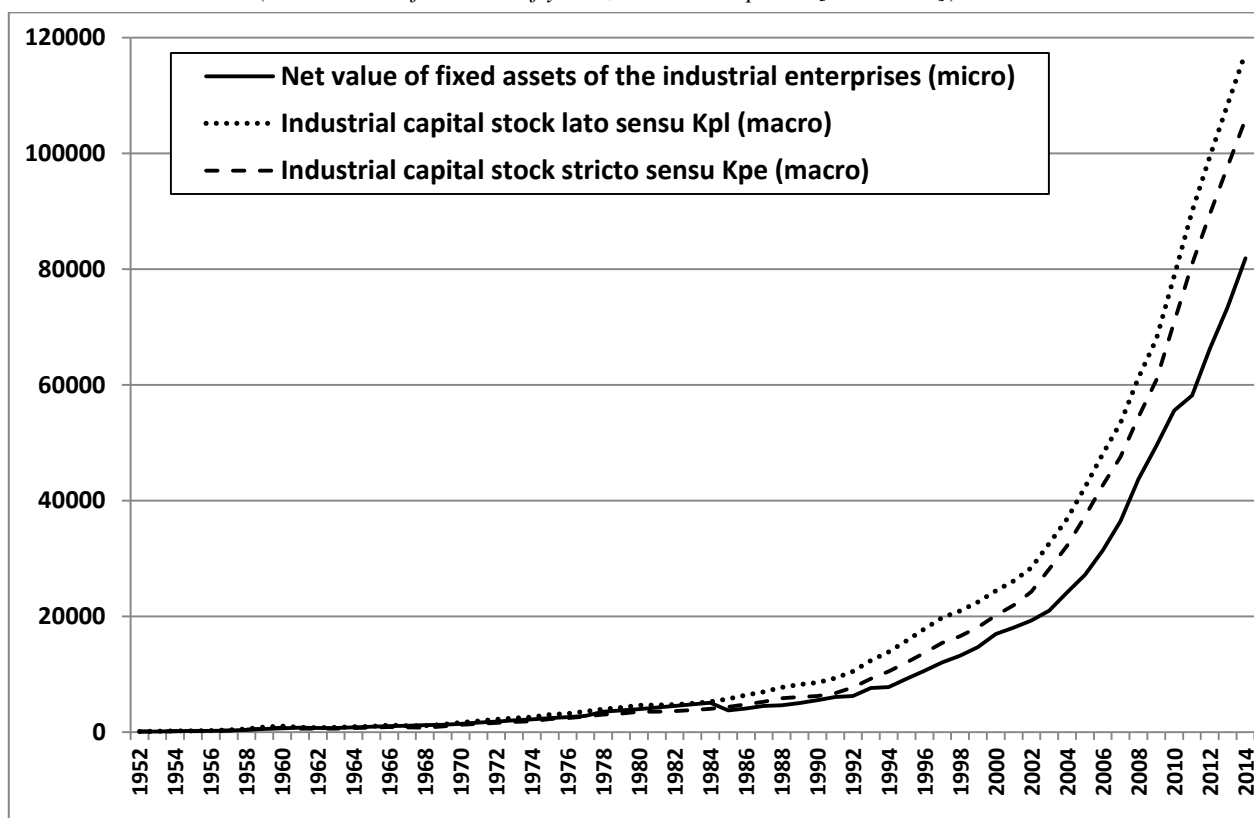
<sup>199</sup> Cf. the *China Finance Yearbook 2000* (p. 401).

**Table 8.3 Types of enterprises taken into account for the calculation of the profit rates by period**

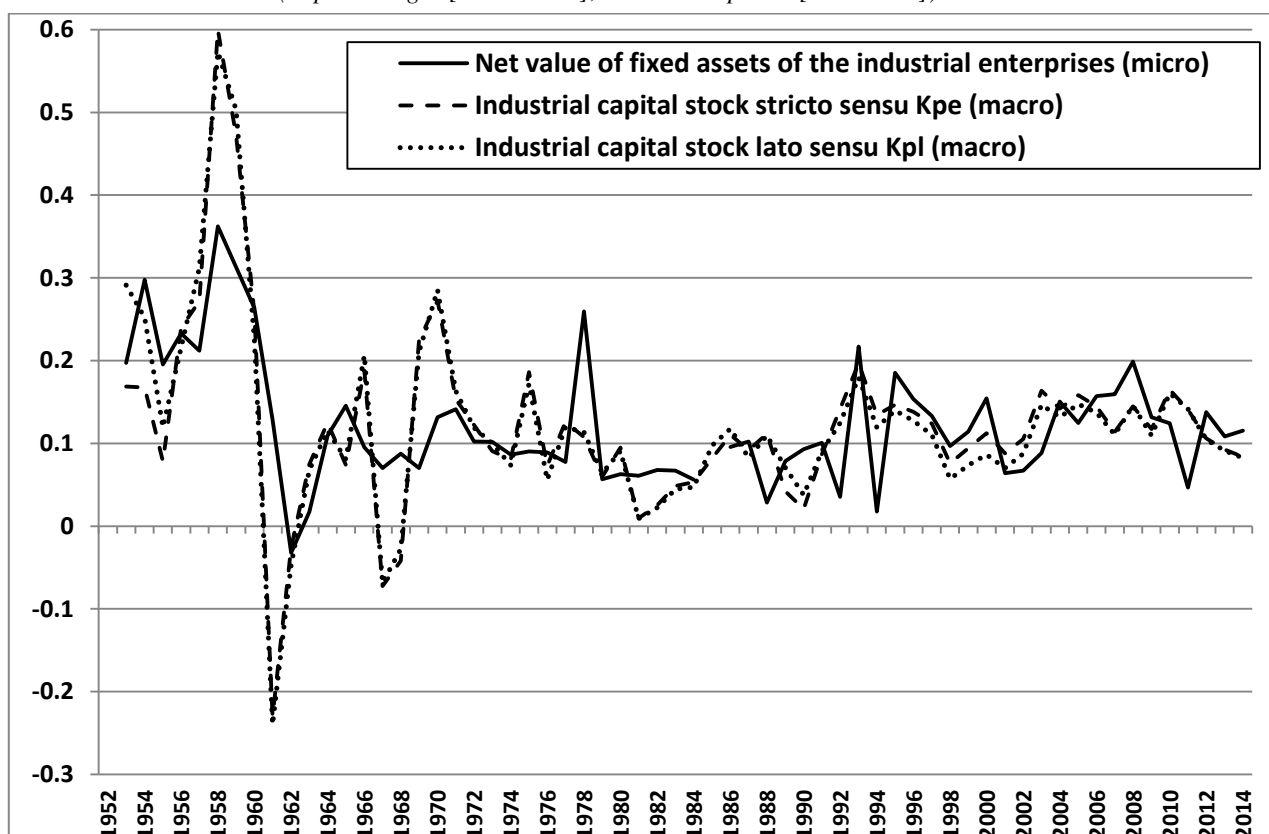
	$r_1$	$r_2$	$r_3$	$r_4$
1952-1978	All industrial enterprises owned by the state			
1979-1984	All industrial enterprises	All industrial enterprises owned by the state		
1985-1997	All industrial enterprises, whatever their accounting system			
1998-2006	All state-owned enterprises with annual revenues from their main business exceeding 5 million yuans			
2007-2010	All enterprises with annual revenues from their main business exceeding 5 million yuans			
2011-2014	All enterprises with annual revenues from their main business exceeding 20 million yuans			

As indicated in *Table 8.3*, the accounting documents which were available to build our original series of micro capital stocks do not include the enterprises with a size smaller than a certain threshold of assets. The weight of these small production units being limited, our calculations can be seen as acceptable approximations of the profit rates of the industrial enterprises as a whole. But this omission is probably sufficiently significant to induce a bias in our results.

**Graph 8.1 Levels of the micro and macroeconomic industrial capital stocks: China, 1952-2014**  
(in hundreds of millions of yuans, at constant prices [base 1952])



**Graph 8.2 Growth rates of the micro and macro industrial capital stocks: China, 1952-2014:**  
(in percentages [0.1 = 10 %], at constant prices [base 1952])



#### 8.4 Calculation of industrial profit rates at the macroeconomic level

In a second step, we will calculate macroeconomic profit rates, for the industrial sector again, in order to compare them to the microeconomic results previously obtained. Such rates are ratios which put in relation a numerator representing the aggregate surplus of the industrial sector or “profit”, and a denominator corresponding to the capital stock of the same sector. Regarding this stock, we rely on new statistical series of physical capital reconstructed by us for China over the long period: 1952-2014. Rebuilt on the basis of official data, especially those of the NBS, our series use original (and complex) methods of elaboration – involving modern techniques of cointegration for the determination of capital stock price indices. It will not be possible to present extensively here these methods; their detail is available to the reader in an article recently published in the *China Economic Review* (Long and Herrera [2016a]). Our database includes various time series of physical capital stocks called “productive” – that is, without residential buildings and the value of their land –, stocks conceived according to more or less broad definitions; in particular, there are: a *lato sensu* productive capital,  $K_{Pl}$ , including the inventories, and a *stricto sensu* productive capital,  $K_{Pe}$ , which does not include them.

Let us mention that several arguments allow us to support that our series are of good quality compared to those currently available in the literature. First, our initial stocks of capital are calculated through an iterative process which converges towards a capital-output ratio less approximate (and lower)<sup>200</sup> than those generally advanced. In addition, our investment flows are consistent with the statistical scopes of these initial stocks. Then, the depreciation rates are

<sup>200</sup> See, for example: Zhang (1991) and He, Chen and He (2003).



estimated by type of capital, under consistent assumptions on age-efficiency and retirement, in order to deduce the calculation of a total depreciation rate from the overall structure of the capital. Our efforts have focused on constructing price indices of investments strictly tailored on the content of these capital stocks. The unit root tests that we performed have shown that, contrary to what many authors think,<sup>201</sup> with very rare exceptions,<sup>202</sup> the price index of capital investment – index that does not appear continuously and homogeneously from 1952 to 2014 for the entire China in the yearbooks of the NBS) – cannot be replaced by another price index. This issue is indeed fundamental to the extent that the price indices are the components that determine the most decisively the level and the structure of the stocks of capital. Their careful construction is therefore crucial.

Thus, four industrial profit rates are calculated at the macroeconomical level, as follows:

$$\text{Macro} \left\{ \begin{array}{l} \text{profit rate of the } \textit{stricto sensu} \text{ productive industrial capital before taxes: } r_5 = \frac{Y_{(I)} - R_{(I)}}{K_{Pe(I)}} \\ \text{profit rate of the } \textit{stricto sensu} \text{ productive industrial capital after taxes: } r_6 = \frac{Y_{(I)} - R_{(I)} - T_{(I)}}{K_{Pe(I)}} \\ \text{profit rate of the } \textit{lato sensu} \text{ productive industrial capital before taxes: } r_7 = \frac{Y_{(I)} - R_{(I)}}{K_{Pl(I)}} \\ \text{profit rate of the } \textit{lato sensu} \text{ productive industrial capital after taxes: } r_8 = \frac{Y_{(I)} - R_{(I)} - T_{(I)}}{K_{Pl(I)}} \end{array} \right.$$

where  $Y_{(I)}$  represents the product of the industrial sector,  $R_{(I)}$  the income of the workers of this sector,  $T_{(I)}$  the taxes on corresponding companies,  $K_{Pe(I)}$  and  $K_{Pl(I)}$  the industrial components of the respectively narrow or broad stocks of productive physical capital (*Graphs 8.1 and 8.2*).

In the same way that, at the microeconomic level, we have defined the industrial sector as all enterprises of the sections “B + C + D”, excluding construction (section “E”), taken as a whole, it is logically a productive capital stock without residential buildings and the value of their land that we use in addressing the macro level. We assume here that the proportion of the industrial capital stock  $K_{(I)}$  in the total productive capital stock ( $K$ ) is equal to that of the industrial production  $Y_{(I)}$  (i.e., the sum of the industrial value added) in the gross domestic product (GDP), minus the value added of the construction sector, noted  $Y^*$ , that is to say:

$$K_{(I)t} = \frac{Y_{(I)t}}{Y^*} \cdot K_t = \alpha_t \cdot K_t$$

where  $K_t$  is the total stock of productive physical capital respectively conceived *stricto sensu*  $K_{Pe}$ , or *lato sensu*  $K_{Pl}$ .

Therefore, we associate to the trajectory of  $\alpha_t$  an assumption of constant returns to scale in production.<sup>203</sup> The calculation of this variable is allowed through the online series of the NBS after 1978 and, before 1978, thanks to the “Comprehensive Statistical Data and Materials on 50 Years of New China” (新中国 50 年五十年统计资料汇编).

<sup>201</sup> Among others: Jefferson, Rawski and Zheng (1996), Wu (1999), Zhang and Zhang (2003), Shan (2008)...

<sup>202</sup> Let us quote here: He (1992) and Chow (1993).

<sup>203</sup> Although carried out under a very different methodology to that developed in the present article, one of our previous studies on China’s economic growth has shown that such an assumption of constant returns to scale in production is defensible under certain conditions. On this point, see: Long and Herrera (2015c).

China's GDP comes from the calculations performed by the NBS according to the production approach, aggregating the value added of the three economic sectors, primary, secondary and tertiary. Total incomes (both direct and indirect, including premiums and specific allocations) received by the workers of all industrial sections,  $R_{(I)}$ , and expressed before taxation, are also extracted from the NBS's databases. However, only the data after 2003 are provided. So, for those prior to that date, we recalculate them by multiplying the remunerations of the urban (i.e., non-rural) employees by the proportion  $\beta_t$  of the industrial value added  $Y_{(I)t}$  in those of the secondary  $Y_{(S)t}$  and tertiary  $Y_{(T)t}$  sectors, as follows:  $\beta_t = Y_{(I)t}/(Y_{(S)t} + Y_{(T)t})$ ; the sources being here identical to those of  $\alpha_t$ .

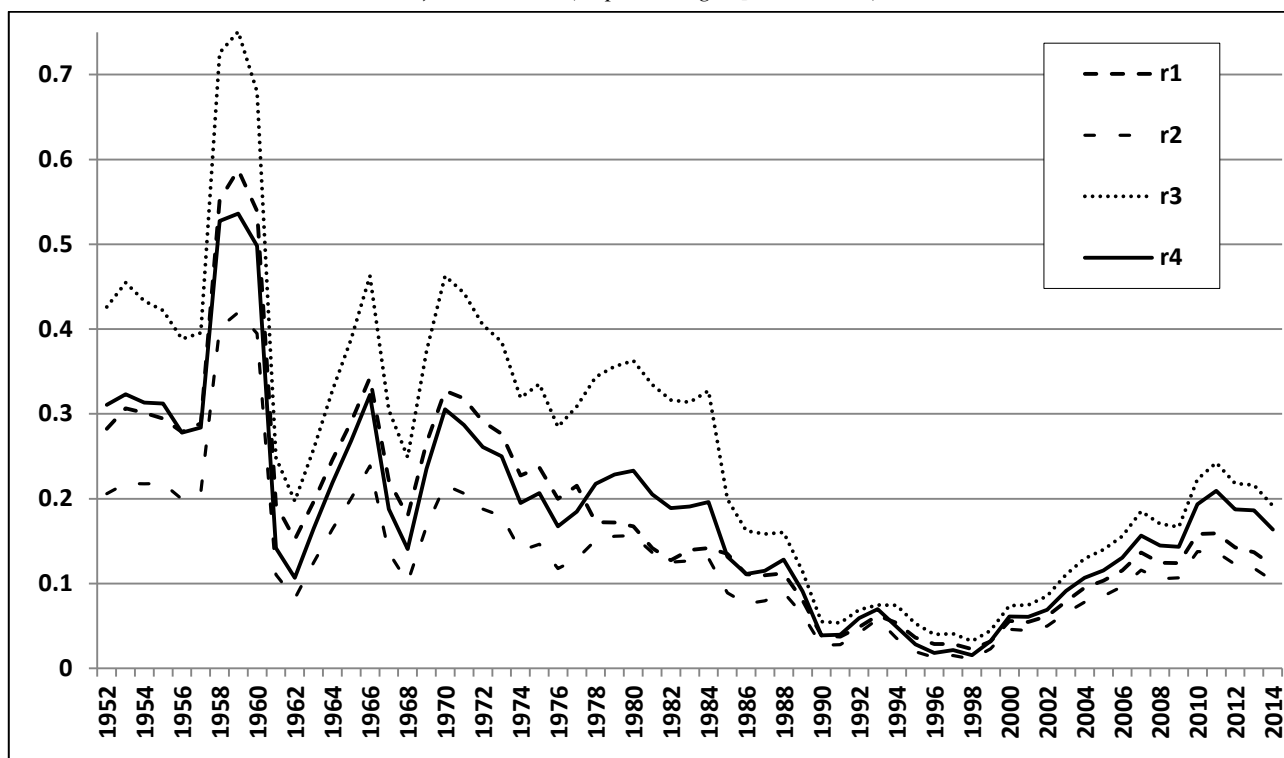
The series related to these remunerations after 2000 come from the NBS's online database, and, before that date, from the "Comprehensive Statistical Data and Materials on 50 Years of New China". The comparison of actual and estimated income of the industrial workers over the period after 2003 shows a gap of around +35 % between the latter and the former; this leads to correct downward the remunerations before 2003. The consumer price index is used to convert current income in constant income (base 1952).

Data on taxes of the industrial enterprises,  $T_{(I)}$ , were much more difficult to get, especially because the NBS disseminates little statistical information about them. Published by the State Administration of Taxation, the *Tax Yearbook of China* (中国税务年鉴) provides data on such taxation by economic sections since 2001 only. Before the tax reform in 1993, the first fiscal yearbook (or *Tax Yearbook of China 1993*) gives data on the "industrial and commercial tax" of the industrial sections for the period 1952-1993, while the *Tax Yearbook of China 2001* indicates income taxes on enterprises by sections since 2000 only. Consequently, the series of  $T_{(I)}$  is incomplete between 1993 and 1999. Over those years, it is assumed that there is a proportional relationship between the taxation of the industrial sections and the total product,  $\gamma_t = Y_{(I)t}/Y_t$ . This assumption is acceptable for the taxes on sales (or VAT), but not for those on the enterprises' incomes, because of the existence of various tax incentives implemented by the Chinese authorities in favor of foreign firms.<sup>204</sup> It was therefore necessary to distinguish the years of application of this policy to take them into account, by using the table of "Taxes on corporate revenues by section and by nature of the enterprises for the whole country" in the corresponding yearbooks (全国企业分项目分企业类型所得税情况).

---

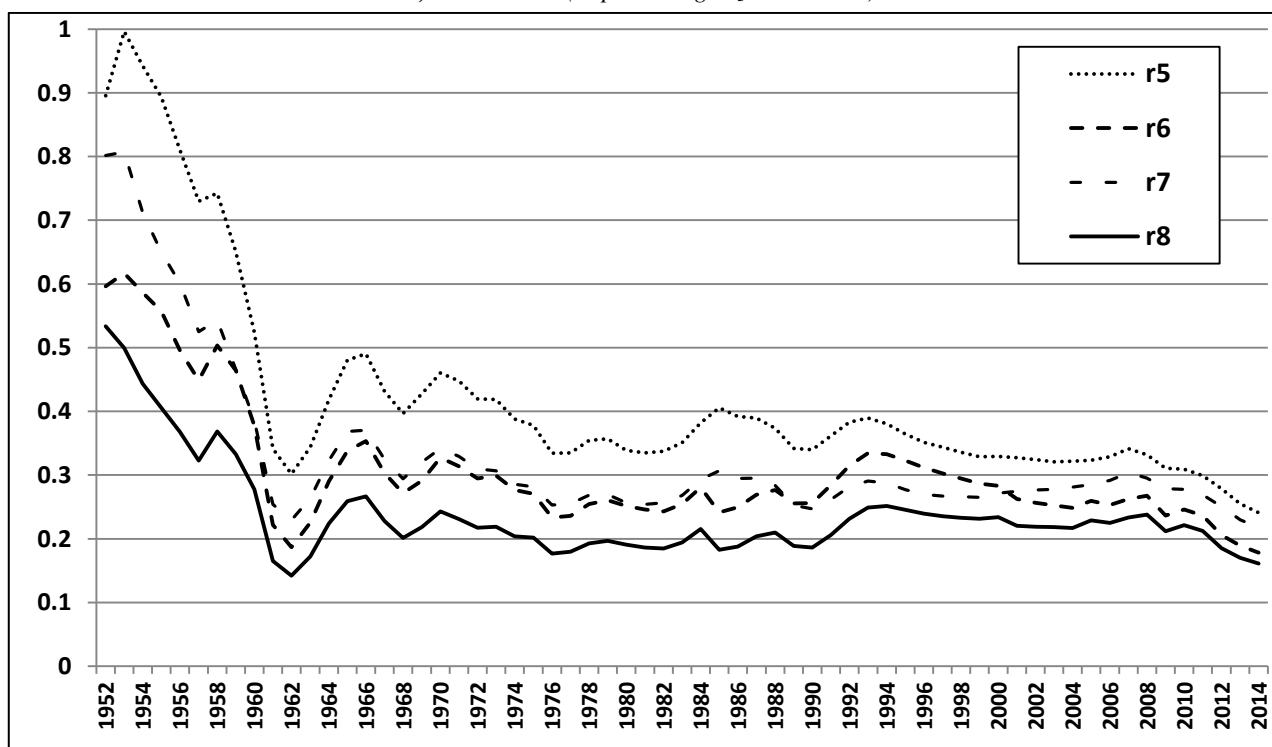
<sup>204</sup> Cf. Article 8 of the Act of 1991 on the tax revenues of the companies with foreign investment and foreign enterprises (中华人民共和国外商投资企业和外国企业所得税法 1991).

**Graph 8.3 Changes in the profit rates of the industrial enterprises at the microeconomic level:  
China, 1952-2014 (in percentages [0.1 = 10 %])**



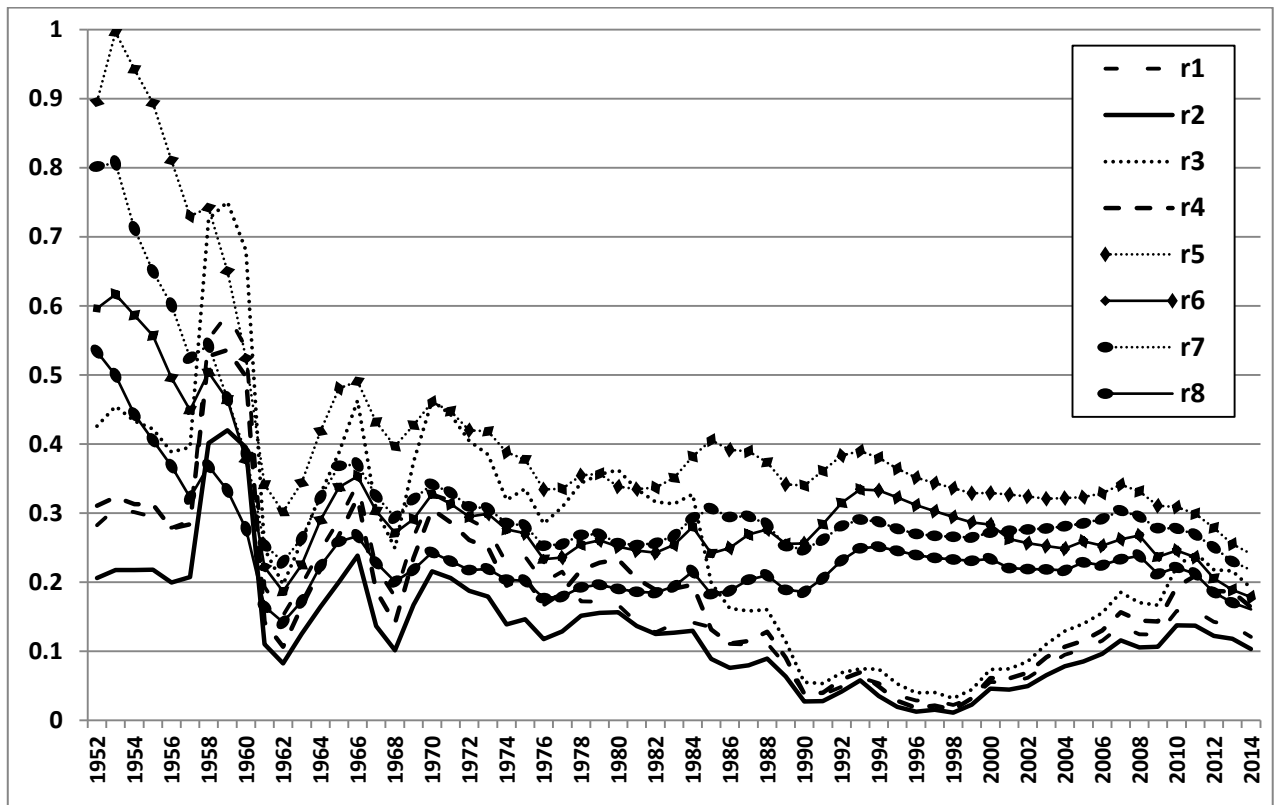
Notes:  $r_1$  = nominal profit rate before taxes;  $r_2$  = nominal profit rate after taxes;  $r_3$  = real profit rate before taxes;  $r_4$  = real profit rate after taxes of the industrial enterprises at the micro level.

**Graph 8.4 Changes in the profit rates of the industrial sector at the macroeconomic level:  
China, 1952-2014 (in percentages [0.1 = 10 %])**

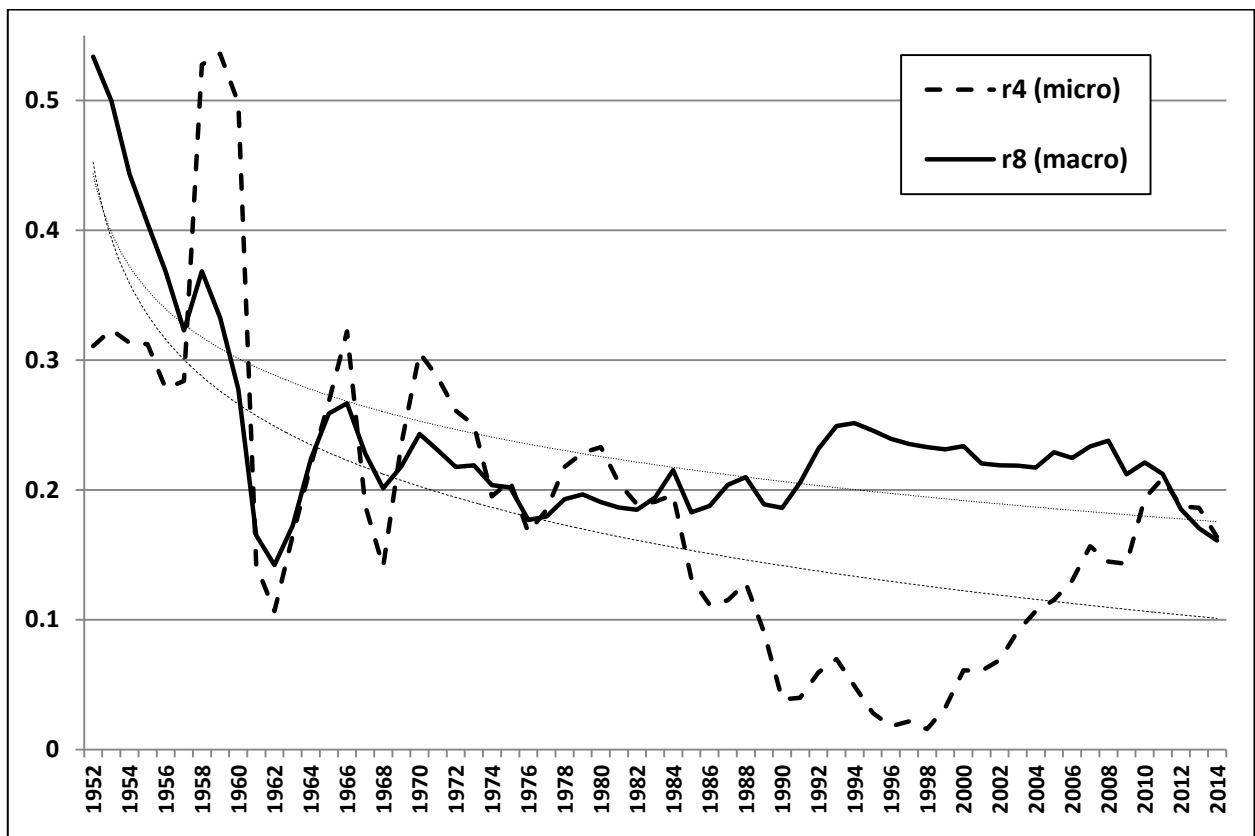


Notes:  $r_5$  = profit rate of narrowly-defined capital before taxes;  $r_6$  = profit rate of narrowly-defined capital after taxes;  $r_7$  = profit rate of broadly-defined capital before taxes;  $r_8$  = profit rate of broadly-defined capital after taxes for the industrial sector at the macro level.

**Graph 8.5 Comparison of the changes in the profit rates at the micro and macroeconomic levels:  
China, 1952-2014 (in percentages [0.1 = 10 %])**



**Graph 8.6 Comparison of the trends of the profit rates at the micro and macroeconomic levels:  
China, 1952-2014 (in percentages [0.1 = 10 %])**



## 8.5 Changes in the micro and macroeconomic rates of profit: a comparison

The evolutions of the industrial profit rates calculated at the micro and macroeconomic levels are presented in *Graphs 8.3* and *8.4*. The results obtained at the macro level are higher than those found microeconomically. Indeed, in average, the micro profit rates are respectively 17.9% for  $r_1$  (pre-tax nominal profit rate of the industrial enterprises), 13.0% for  $r_2$  (nominal rate after taxes), 26.2% for  $r_3$  (real rate before taxes) and 18.2% for  $r_4$  (real rate after taxes) over the entire period from 1952 to 2014. The average macro profit rates are found at 42.2% for  $r_5$  (profit rate of the narrowly-conceived productive industrial capital before taxes), 30.4% for  $r_6$  (profit rate of the *stricto sensu* productive capital after taxes), 32.9% for  $r_7$  (profit rate of the *lato sensu* capital before taxes) and 23.7% for  $r_8$  (profit rate of the capital defined in a broad sense after taxes) during the same period 1952-2014. As we see it, the averages of the two profit rates which are the most representative of the effective activity of the Chinese industry, that is to say,  $r_4$  at the micro level (calculated by subtracting the taxes and excluding the cumulated depreciations of fixed assets of the industrial enterprises) and  $r_8$  at the macro level (calculated from the productive capital stock of the industrial sector including inventories, but not residential buildings and the value of their land), are of the same order of magnitude: 18.2% for the first profit rate, and 23.7% for the second one. Both profit rates remain still rather close to one another over the sub-period 1978-2014, that is, after the reforms: 12.0% and 21.2% respectively.

In general, the overall profiles of the micro and macroeconomic profit rates are quite similar; they are basically characterized by a downward tendency over the long period (*Graph 8.5*). Very marked fluctuations are observable for the two levels of analysis during a first step, going from the founding of the People's Republic to the break with the Soviet Union (1952-1961). Following a downtrend, the oscillations of the profit rates continue, albeit in a much less harsh way, until 1978, and even until the 1990s, but gradually diminishing. It was from there that things seem to have changed somewhat. Indeed, the trajectory of the macro profit rate appears to move upward, slightly, from the early 1990s, while that of the micro profit rate continues its descent, before rising more strongly at the end of the decade. The micro and macro curves meet again in the first years of the 2010s, and move together downward. These sequences are clearly visible in the case of the indicators  $r_4$  and  $r_8$  (*Graph 8.6*). Beyond the “reassuring” or “safe” result – at least, for a Marxist economist – brought by setting light on a falling profit rate trend over the long period (a trend which is measured in logarithmic terms for  $r_4$  and  $r_8$  in *Graph 8.6*), however, the findings of a sharp rise in the trajectory of  $r_4$  from 1999 until 2007 (or rather until 2011), on the one hand, and, on the other hand, of a relative stability for that of  $r_8$ , extended over fifty years (from 1962 to 2011 approximately), require to introduce some complexity in these too intuitive interpretations.

Consequently, for further analysis, we perform a technical decomposition of the rates of profit in order to distinguish their long-term trends and their cyclical components capturing short-term fluctuations. Such a breakdown can be obtained by writing these profit rates, as follows:

$$r_t = \Psi_t + \theta_t + \varepsilon_t$$

where  $\Psi_t$  represents the trend – which is decreasing and can take a polynomial form –,  $\theta_t$  the cyclical component – that is to say, a stationary process (of sinusoidal type, for example) –

and  $\varepsilon_t$  an error term – for example random walk or white noise. A simple formulation of this breakdown is, among many other possibilities<sup>205</sup>:

$$r_t = [a_1 t + \dots + a_n t^n] + [a_0 + A \sin(\omega t + \varphi)] + [b_1 r_{t-1} + \dots + b_p r_{t-p} + u_t]$$

with  $a_1 < 0$ , and where the three components (polynomial trend, sinusoidal functional form of the cycle, and error term) are shown in brackets.

Here, we present the application of the technical decomposition to the cases of the macro rates of profit  $r_6$  and  $r_8$ . For this, the breakdown is performed by using the method of the Hodrick-Prescott filter (*Graph 8.7*); the setting of its own parameters being completed by those suggested by Ravn-Uhlig (*Graph 8.8*).<sup>206</sup> Other breakdowns into trend and cycles have also been tried in time series;<sup>207</sup> they give similar results and confirm the solidity of findings.

*Graph 8.8* shows that the short-term cycles of the macro profit rates see the magnitude of their fluctuations diminish with time, from the early 1950s until the end of the 2000s – however, they seem to widen again from hence. Thus, these fluctuations make alternate fairly regularly up and down periods. For the profit rates  $r_6$  and  $r_8$ , with two parameter settings for the filters (Hodrick-Prescott and Ravn-Uhlig parameters), the years of common recession, marked by first differences of the cyclical components recording a negative sign, are observed 24 times. Such a negative sign happen specifically in 1957, 1961-63, 1968, 1976-77, 1981-82, 1985-86, 1989-91, 1998-99, 2001-04, 2009 and 2012-14. This corresponds to more than a third of the 63 years of the total period from 1952 to 2014 – even if the GDP growth rate can sometimes simultaneously achieve a quite high rate.

Through these 11 sequences of recession, we readily recognize the successive slowdowns that have characterized China’s economic history since the founding of the People’s Republic. After the huge difficulties experienced in the early times (1949-1952), mainly due to the wars and convulsions through which the country has gone during the decades before the revolution, we find traces of the recessionary period that began in 1954 and whose low point was in 1957. The crisis of the early 1960s, the worst ever for China, has resulted from the combined effects – clearly visible in 1961-62 – of the interruption of the USSR’s aid after the Sino-Soviet conflict, the failure of the “Great Leap Forward”, and disasters occurred on the Yellow River. Another low point, 1968 coincides with the hardening of the Cultural Revolution, launched two years earlier. The serious problems encountered in 1976-77 reveal those of the transition following the death of Chairman Mao Zedong. 1981-82 were years of implementation of the structural reforms of “openness” adopted after the XI Congress of the Communist Party, and 1985-86 those of application of the 1984 tax reform – one of the turning points towards China’s market economy. Amid the collapse of the USSR, a brief “neoliberal” experiment was attempted and resulted in a sharp slowdown in the economy (1989-91) – accompanied by corruption. In a (quite paradoxical) context of strong dynamism of China’s GDP, the declines recorded from 1998 on are largely attributable to exogenous (or imported) shocks, linked to the spread of regional or global crises: the Asian crisis (1998-99), then the “new economy”

<sup>205</sup> We propose such a form because for the stationary part, according to the Fourier’s transform, given any T observations on a process  $(y_1, y_2, \dots, y_T)$  there exist frequencies  $\omega_1, \omega_2, \dots, \omega_M$  and coefficients such that the values of  $y_t$  could be expressed as:  $y_t = \mu + \sum_{j=1}^M \{\alpha_j \cos[\omega_j(t-1)] + \delta_j \sin[\omega_j(t-1)]\}$ . If the highest values of frequency  $\omega$  has been filtered out (the second term in the equation), then the rest  $M-1$  weighted sum of periodic functions present an even more “stationary” process; when  $M \rightarrow \infty$  that might be approximated by an ARMA process (third term).

<sup>206</sup> See: Hodrick-Prescott (1981), then Ravn and Uhlig (2002).

<sup>207</sup> Alternative techniques are those with – fixed length – symmetrical filters (Baxter and King [1995], Christiano and Fitzgerald [1999]) or – time-varying – asymmetric filters. The other methods that we used are those given by Beveridge-Nelson (1981), Harvey (1985), Watson (1986), Clark (1987), Quah (1992), and Morley (2002).

and “post-September 11” crises (2001-04), and the so-called “financial” crisis of 2008 (whose global effects have been felt in China in two times: in 2009, and from 2012 to present).

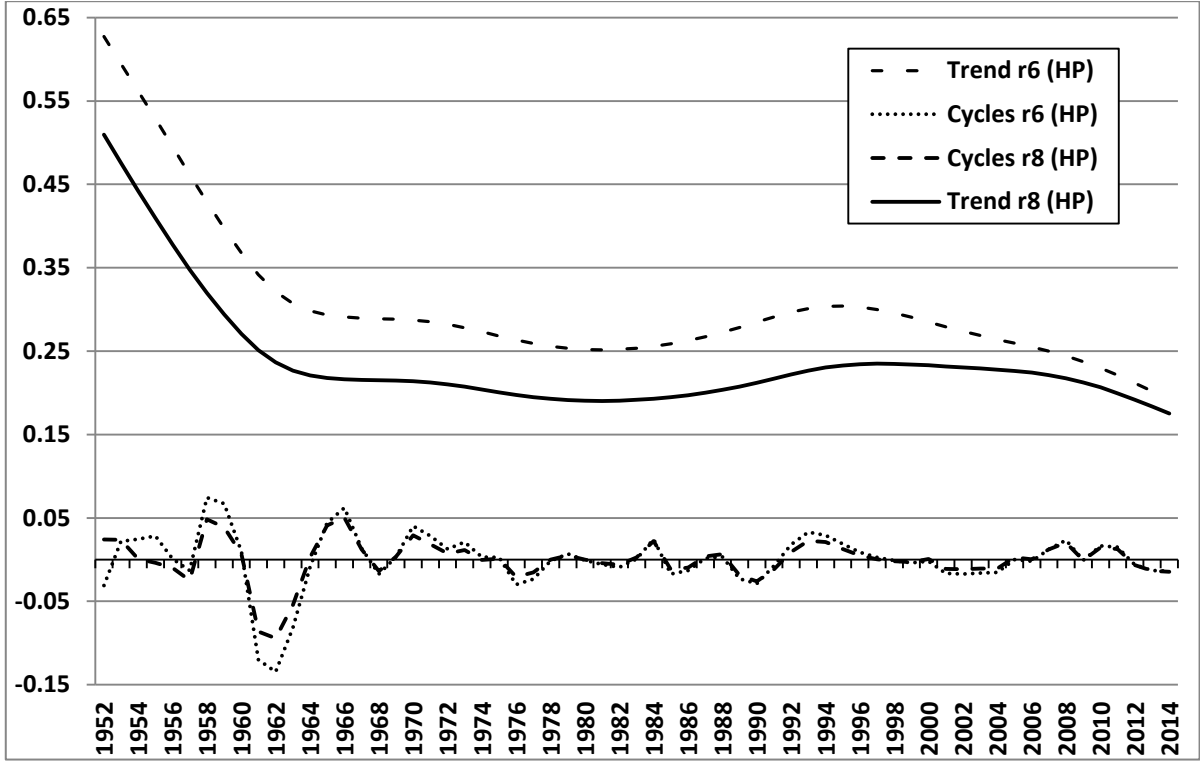
Finally, we proceed to an economic decomposition of the macro profit rate (here  $r_8$ ) in order to distinguish the respective changes in the organic composition of capital (i.e., the inverse of  $R_{(t)}^*/K_{Pl(t)}$ ), the productivity of the labor cost unit ( $Y_{(t)}/R_{(t)}^*$ ), and the share of profits ( $\Pi_{(t)}/Y_{(t)}$ ), using the following simple formula,:

$$r = \Pi_{(t)}/Y_{(t)} \cdot Y_{(t)}/R_{(t)}^* \cdot R_{(t)}^*/K_{Pl(t)}$$

where  $\Pi_{(t)}$  is profit, with  $\Pi_{(t)} = Y_{(t)} - R_{(t)} - T_{(t)}$ ; and  $R_{(t)}^*$  the cost of labor in the industrial sector (without taxes), approached by the product of the number of employees and average earnings. Theoretically, this formula is close to that suggested by Weisskopf (1979).

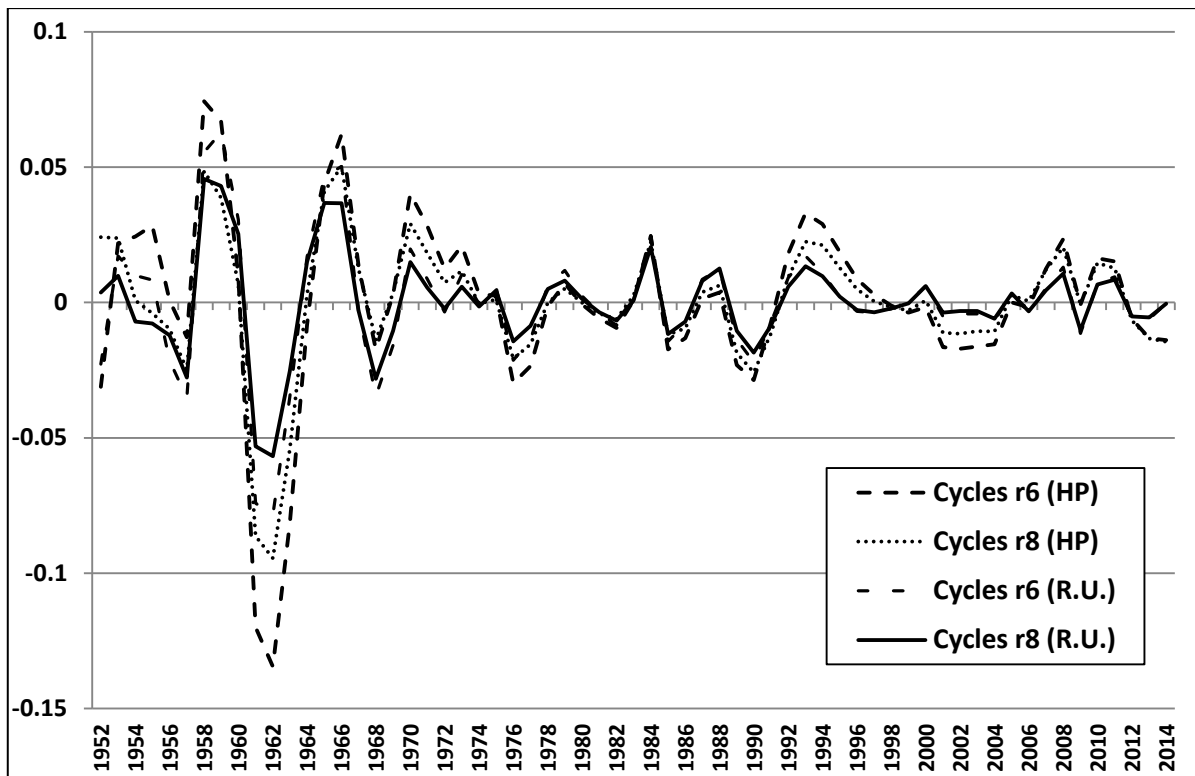
Graph 8.10 indicates that it is mostly the strong increase in the organic composition of capital that contributes to explain in large proportions the downward trend of the long-run profit rate. If the profit share remains relatively stable, the upward trend of the productivity of labor cost unit is slightly more pronounced – but the latter begins to decline over the last decade.

**Graph 8.7 Technical decomposition of the macro profit rates  $r_6$  and  $r_8$  into trend and cycles: China, 1952-2014 (in percentages [0.1 = 10 %])**



Note: The technical breakdown is performed using the method of the Hodrick-Prescott filter (HP filter).

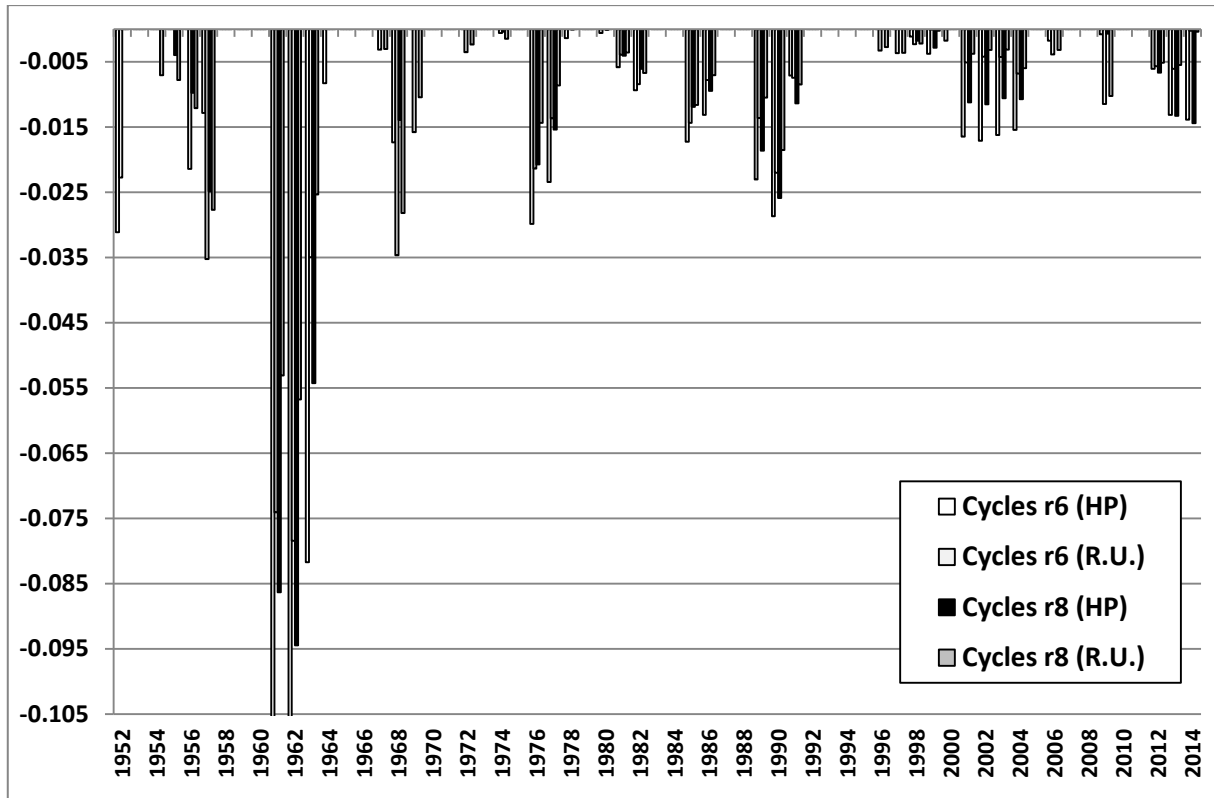
**Graph 8.8 Changes in the cyclical components of the macro profit rates  $r_6$  and  $r_8$  according to several methods of technical decomposition: China, 1952-2014 (in percentages)**



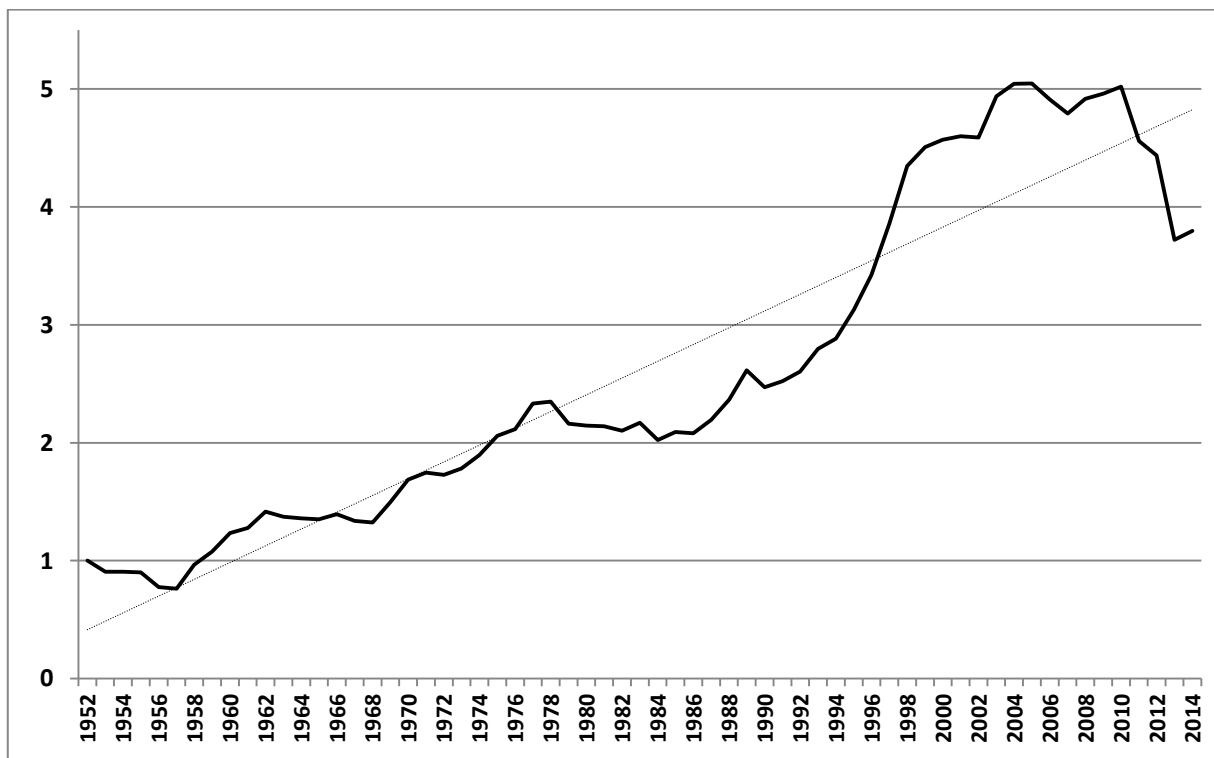
*Note: The technical breakdown is performed by using the method of the Hodrick-Prescott filter with its own parameters (power = 2, lambda = 100) or those suggested by Ravn and Uhlig, R.U. (power = 4, lambda = 6.25).*



Graph 8.9 Negative values of the cyclical components of the macro profit rates  $r_6$  and  $r_8$ :  
China, 1952-2014 (in percentages [1 = 1952])



Graph 8.10 Organic composition of capital obtained by an economic decomposition of  $r_8$ :  
China, 1952-2014 (in indices [1 = 1952])



Note: Variable presented with its linear trend.

## 8.6 Conclusion

Based on a definition – as rigorous as possible – of the scope of the industrial sector, and the construction of original stocks of fixed assets of enterprises and productive physical capital (*Appendix 8.1*), we have calculated profit rate indicators at the micro and macro levels for China from 1952 to 2014. The results obtained using the two selected methods (micro-macro), are quite similar, and can be summarized as follows: *i*) a tendency of the rate of profit to fall is observed over a long period, for the two levels of analysis. *ii*) The short-term fluctuations in profit rates show, at the macro level, a succession of cycles – rarely completely achieved – whose amplitude is decreasing with time. *iii*) More than a third of the total period (1952-2014) is concerned with recessive years of the profit rate cyclical components. The largest declines are recorded, in descending order, after the rupture between China and the Soviet Union (1961-63), during the Cultural Revolution (1968), in the course of the 1950s (especially in 1957), for the post-Mao transition (1976-77), when a neoliberal experiment was attempted (1989-91), and finally with the dissemination of the crises of capitalist globalization (which affected China in 1998, 2001 and 2009, then again after 2012). And *iv*) it is essentially – much more than the evolutions of the profit share in value added and of the productivity of the labor cost unit – the increasing organic composition of capital that pushes down, tendentially, the macro profit rate.

However, a number of difficulties of interpretation persist at the end of this exercise. First, it is the analysis of this decline of the profit rate itself that raises a problem, to the extent that this long-term trend finds indeed a part of its explanation in the extreme scarcity of physical capital that has characterized China at the beginning of the revolution. In addition, over rather long periods of time, at the macro level, we can very distinctly observe intervals of relative stability of the industrial profit rates, or even phases of increases of these rates, as in the first half of the 1990s. The micro analysis also highlights a clear recovery in the profit rates, but from the end of the 1990s – until the moment when the country suffered the effects of the 2008 “financial” crisis. Thus, our conclusion of a long-term downward tendency in the profit rate must tolerate some nuances. Secondly, and apart from the disturbances of the first times of the revolution, the most notable gap between the trajectories of the micro and macro profit rates can be observed after the adoption of the structural reforms (1978) – and of the taxation reform (1984). The deep causes of such a discrepancy, which lasted until the late 2000s (i.e., until the burst of the most recent stage of the “systemic” crisis in 2008),<sup>208</sup> are to be found in differences in our studying angles – that is, in the statistical sources too –, in the perimeters and contents of the industrial sector (for example, the scope of the small industrial enterprises is changing at the micro level, and it does not integrate the small productive units, generally with higher rentability rates than those of big state-owned enterprises which are registered), but also in the indicators related to taxation. Furthermore, even if the gap previously noted between the micro and macro levels seems to narrow when the effects of the systemic crisis stroke the Chinese economy at the end of the 2000 decade, orientating down again both the micro and macro profit rates, the question remains of how to qualify recessive phenomena that negatively affect the rate of profit in overall contexts where very high GDP growth rates are recorded, as it is still the case in China at the present time – even in 2015. The answers to these questions, as well as to those, among others, related to the functional forms able to translate the most pertinently possible the long-term trends and short-term fluctuations, thus call for further research.

---

<sup>208</sup> For a theoretical and political interpretation of the current systemic crisis (which is not only “financial”), in a Marxist perspective, see: Herrera (2014).

## Chapter 9 ECONOMIC STRUCTURE, CYCLES AND CRISES IN CHINA'S ECONOMY FROM 1952 TO 2014

### *Methods of Analysis through Reviewed Marxist Point of View*

Chapter 7 provides a preliminary discussion that suggests the need for an “exit” from the usual framework of the neoclassical mainstream and also suggests that the need for an “exit” from the usual framework of the time domain and turn to the spectral analysis and filter analysis in econometrics. Chapter 7 has calculated the profit rate associated with the productive in broader sense, however in a classic Marxist point of view, the analysis of profit rate should be concentrated in the industry. So Chapter 8 has calculated the industrial profit rates in both macro and microeconomic levels. However, the industrial profit rates calculated in Chapter 8 have some insufficiencies to analyze the economic cycles of all sectors in China. As we have underlined, we should calculate the total profit rate of all economic sectors to identify the economic cycles and potential crises as the cycles and crises will affect all economic sectors not only industries. Besides, how the profit rates influence the key economic variables is still unknown in the analysis of Chapter 8. That is to say, the economic structure of China rests unknown.

### 9.1 Introduction

In this Chapter, we have first calculated 4 different total profit rates of all economic sectors over 1952-2014 from a reviewed Marxist point of view. The profit rates have a long-run decline trend and present cyclical fluctuations. We then use the structural vector autoregressive models (SVARs) to analyze China's economic structure. We examined the influences of profit rates on several key economic variables such as investment growth, capital accumulation and economic growth by impulse responses functions. Based on *a priori* restrictions hypotheses, through two different approaches of short run restrictions and long run restrictions, we have prudently tested those *a priori* economic structures under the background of market economy. We find that China's economy didn't necessarily satisfy those hypotheses in all periods.

Contrary to the dichotomy suggested by the spectral analysis in Chapter 8, the tests show that the economic trajectory of PRC should at least be distinguished into 3 different periods: 1) 1952-1977, it was the Soviet-style planned economy period. The specific characteristics are that the economy fluctuates up and down drastically; the growth rate of profit rate has contemporaneous co-movement with other macro-economic variables; the economic fluctuations and crises are more politically motivated while the profit rate is not the main factor that determinates the investment growth, capital accumulation and economic growth. 2) 1978-1992, it was the planned economy with Chinese characteristics period. Even though China began its opening reform since 1978, the nature of this period should still be contributed to planned economy rather than market economy. The characteristics present as: economic fluctuations began to ease up; while the variations of economic growth precede the variations of profit rate; the economic structure of this transitory period is relative complex and cannot be simply classified, just as called by Deng Xiaoping (1979, 1984, 1992) himself<sup>209</sup>, it was “planned economy with market as supplement” or “socialism can also have the existence of market economy”. 3) 1993-present, it is the so called market economy with

---

<sup>209</sup> See *Selected Works Of Deng Xiaoping, Vol. 2 and Vol. 3*

Chinese characteristics period. After the fiscal reform (a Tax-sharing system reform) of former Prime Minister Zhu Rongji, China also turns from MPS to SNA; the political volatility still plays an important role for economic fluctuations but it has gradually dropped to a relative subordinate factor. In the same time, as China has been gradually integrated into the world economy deeply, it benefits a further decline in economic volatility grace to external market as a buffer. It is also because of the background of China's integration into the world economy, the China's economic fluctuations and crises gradually present characteristics of imported crises.

Our econometric empirical tests show that, the *a priori* restrictions imposed in order to analyze China's economic structure are difficult to valid in the first and second periods, while it is quasi valid in the third period. Therefore, the second period was more close to the planned economy. However, the sample size of the third period is small that leads statistical uncertain in quantitative analysis. We try to improve the precision of econometric estimations of this period by Bayesian approaches. But practice shows that Bayesian approaches didn't ameliorate the estimation of this period, the calculated impulse responses functions have not too much difference from the traditional statistical methods. This is because, firstly, just as we have underlined, before and after 1993, they are two periods with totally different economic natures. It is worth to wonder that whether it is suitable to use the information over the planned economy period 1952-1992 as the pre-sample *a priori* information of market economy period 1993-2014. Secondly, the *a priori* distribution assumptions in BVARs estimation are not necessarily valid for China. For example, Litterman's prior requires that we should believe the changes of variables are impossible to forecast, that it is to say the first difference of a variable is a white noise (plus a constant). This is equivalent to assuming that the capital market is in perfect competition: China's growth rate of profit rate, growth rate of investment, growth rate of capital accumulation and economic growth are random walks. Obviously, it is hard to believe that such strong assumptions are true in China, even after 1993. Thus, we are not surprised that the Bayesian analysis is not necessarily better than traditional statistical methods here.

However, the impulse responses functions given by Bayesian analysis are very similar to that given by traditional SVARs. This suggests that even we are in a small sample; the economic structure given by traditional econometric methods should be stable and reliable to a certain extent. In the last, as NBS has recently published some part of the macro economic data of 2015, so we have predicted the economic data of 2015 using the above SVARs with data over 1952-2014. This one-step ahead out-of-sample forecast result matches well with the data released by NBS. In the meantime, it seems that we have successfully predicted the 2015 Chinese stock market turbulence which could be regarded as a local financial crisis; despite we are unclearly that the crisis will occur in the financial sector when we made the prevision with data over 1952-2014. This implies that although we are very aware that the real economic structure may be much more complex than our simplified quaternary model, but our models indeed have a quite good out-of-sample prediction capability. It has a value of application, which is very rare in modeling experience. Besides, the prediction results of full sample models are better than predictions of subsample models. This implies that though the arguments of validation of *a priori* restrictions are weak over 1952-1992, but it still provides useful additional information. It also reflects that the local financial crisis 2015 might be the consequences of accumulated factors in long run, it worth a further discussion.

## 9.2 Framework of Data

Even the traditional Marxist economists use the profit rate of industrial sectors to analyze the economic crisis, while in this chapter, we use the total profit rate of all economic sectors (similar to chapter 7 but with a strict productive capital stock) to analyze China's economic crisis. This is because:

1) The macro economic variables generally used to analyze the economic cycles and crises, such as monetary supply, exchange rate, unemployment rate or interest rate are indicators for entire economy. It is not enough to use only the industrial profit rate to measure those overall macroeconomic variables, we should consider the total profit rate of all sectors.

2) Although we have defined the "industrial sectors" as rigorous as possible and calculated industrial profit rate from macro and micro levels. However, the drawbacks of those profit rates are also obvious. For example, when we calculate the wages industrial enterprises, due to lack of detailed data before 2003, we have introduced some hypotheses that will lead some biases for the macro industrial profit rate. And due to the changes of statistic scopes of NBS, the micro data ignored small industrial enterprises.

3) The real problem is that when we calculate the macro industrial profit rate, due to lack of investment series of industrial sectors, we have assumed that the proportion of industrial capital in the total capital  $\alpha$  equals to the proportion of industrial output in the total GDP. Under such assumption, the influence of industrial profit rate (macro) on the industrial investment is equivalent to the influence of total profit rate of whole economy on the total investment.

Thus, we use the total profit rate of all economic sectors not the industrial profit rate to analyze China's economic cycles and crises.

The data are the same data in previous chapters, we distinguish two kinds of capital stock: the productive capital in strict sense  $K_{pe}$  and total capital  $K_T$ . And we distinguished two methods of calculations: a profit rate  $r$  that its denominator contains the remuneration of laborers  $R$ , that is to say, we regard variable capital also as initial cost of capital proliferation. A profit rate  $r_c$  in classic Marxist views, that its denominator does not contain the remuneration of laborers  $R$ , that is to say, the capital proliferation only refers to the capital proliferation of constant capital its own, summarized in *table 9.1*:

**Table 9.1 Profit Rates with Reviewed Marxist Point of View**

	$K_{pe}$ is constant capital	$K_T$ is constant capital
$R$ is regarded as initial cost of capital proliferation	$r_{pe}$	$r_T$
Capital proliferation only refers to constant capital	$r_{pec}$	$r_{Tc}$

The formulas of calculation are as follow:

$$r_{pe} = \frac{Y - R - (T - T_i) - B}{K_{pe} + (R + B)} \quad (9.1)$$

$$r_{pec} = \frac{Y - R - (T - T_i) - B}{K_{pe}} \quad (9.2)$$

$$r_T = \frac{Y - R - (T - T_i) - B}{K_T + (R + B)} \quad (9.3)$$

$$r_{Tc} = \frac{Y - R - (T - T_i) - B}{K_T} \quad (9.4)$$

Where  $Y$  is total input, i.e. GDP.  $R$  is remuneration of laborers (income before the income tax) that also includes the rural laborers income.  $T$  is total tax (including import tax),  $T_i$  is the total personal income tax.  $B$  is the total welfares expenditures of whole society (including the wages of retired persons and Social Security Fund Expenditure) that is regarded as an indirect production cost.

Note that we also regard welfare expenditures as a part of variable capital. This is because, even  $B$  contains retired persons' wages and social security expenditures, and they didn't purchase the labor at current period directly but when enterprises decide to employ workers, they will anticipate this indirect production cost. Thus, the welfare expenditures are also the cost of labor reproduction process. Such an opinion has no influence on  $r_c$  but decreased  $r$ .

From above we see that, the difference between  $r_{pe}$  and  $r_T$  (also the difference between  $r_{pec}$  and  $r_{Tc}$ ) is whether we regard "residential investment" as purchase of constant capital. The difference between  $r_{pe}$  and  $r_{pec}$  (also the difference between  $r_T$  and  $r_{Tc}$ ) is whether we regard expenditures of variable capital as cost of capital proliferation.

### 9.3 Framework of Analysis

#### Problems and solutions

Our purpose is to establish an economic system to analyze the influences of profit rate on other macroeconomic variables (such as growth rate of investment, capital accumulation, and economic growth) in the system. For this purpose VAR provides a good analytical framework. Through calculating the impulse response functions, we can easily analyze the consequences of an external shock of profit rate on the other variables in the system. However, a pure statistical VAR lacks theoretical foundations and due to the presence of simultaneous equations bias, the coefficients of atheoretical VAR are biased estimators. We need to restrict the structures of VAR according to the identification conditions so that makes the system be identifiable.

As  $K_T$  contains the capital of all economic sectors (including the financial capital and agricultural capital) the corresponding profit rate  $r_T$  (or  $r_{Tc}$ ) might provide some useful information about the analysis of financial crisis. So we firstly use  $r_T$  as the example to describe the process of analysis<sup>210</sup>.

More specifically, our purpose is to examine the influences of profit rate  $r_t$  on investment growth rate  $gI_t$ , capital accumulation rate  $gK_t$  and economic growth  $gY_t$ . We need to establish a SVAR and correctly explore the economic structures between them that also should satisfy the identifiable conditions. We explore the structural relationships between the variables in the system by following steps:

---

<sup>210</sup> In fact, the analysis *infra* shows that different profit rates have the same structures of structural matrix  $B_0$ . This suggests that no matter which profit rate we used to analyze the problem in hand, it doesn't affect the conclusions. The four profit rates conduct similar conclusions.

1) We establish a multivariate atheoretical VAR model, test the coefficients we restricted and calculate the impulse functions of endogenous variables to  $r_t$  in order to summary the influences of profit rate on other variables.

2) We establish bivariate VARs respectively, in those systems, one variable is profit rate  $r_t$ , another is the variable to be analyzed. We test the Granger causality two by two and calculate the impulse response functions in order to explore the relations between the two variables.

The null hypothesis of Granger causality test is a strong assumption to verify the economic structure because it assumes that one variable is totally exogenous. If it is verified, then we can impose many restrictions on the VARs. However, the results of Granger test are very sensible to the order of lags and the assumption is generally too strong, the results might not be the same as expectation.

3) Evidently, from above steps, we will find out some structural relations between variables. Based on those results and assumptions in line with economic theory and logic, we might impose some restrictions on the structure of VARs so that makes the system be identifiable. And then we could estimate one or several SVARs models, we get the economic structures among those macroeconomic variables and we can finally calculate the orthogonal impulse response functions of variables to the  $r_t$ 's innovations. By doing this, we will get more reliable conclusions about the influences of profit rate on other variables.

The first difficult problem is that the profit rate  $r_T$  is obviously nonlinear and nonstationary series. We need to choose appropriate detrending methods in order to get stationary series. From the graphs and correlogram,  $r_T$  is nonlinear and nonstationary and we have three alternative methods to transform it into stationary time series: 1) from the graph,  $r_T$  contains a decreasing trend in long run, we could filter out this long run trend by HP filter and the rest cycle component seems to be mean stationary, while the heteroskedasticity could be treated by Box-Cox transformation (Box and Cox 1964). 2) The first difference of  $r_T$  is stationary that is, the variations of profit rate is stationary. 3) The first difference of log of  $r_T$  is stationary that is, the growth rate of profit rate is stationary.

We further analyze which de-trended profit rate series is the best alternative. We cite the example of influence of profit rate on investment.

Firstly even in chapters 7 and 8, we use HP filter to identifier the economic cycles, however here HP filter seems not to be a very good detrending method here. This is because, if we use the cycle component of  $r_T$ , the conclusions we get will be the "influence of periodic movements of profit rates on the investment". However, we also hope that the information of the long run decline trend will be included in the analysis and this is fundamental for Marxist. Only using the cycle component, we will miss much information. Besides, even the cycle component is stationary in average, but from graph, the cyclical fluctuations present characteristics of harmonic motion. This suggests that there is heteroscedasticity in the cycle component. We need to further use other tools such as Box-Cox transformation to treat this problem, this will further distorted information.

Secondly, compared to the variations, the growth rate of profit rate will bring more information. For example, considering two situations that the first is that the profit rate increased from 10% to 11%, and the second is that the profit rate increased from -1% to 0%. The variations are the same, 1%. But the same variations will have significant different

influences on enterprises' investment behaviors. The former one just has some impacts that enterprise might increase the investment while the latter will have a more important impact that determines whether enterprise will continue to invest to product or not.

Thus we use the first difference of log of  $r_T$  that is the growth rate of profit rate GRT to analyze the influences of profit rate on the economic variables. Note that the real total profit rate of whole economy is always positive in the sample, thus its log always exists.

## Models

Econometrically, our purpose is to identifier and estimate the following model, in order to analyze the influences of profit rate on the behaviors of other economic variables in the system:

$$\mathbf{B}_0 \mathbf{y}_t = \mathbf{c} + \mathbf{B}_1 \mathbf{y}_{t-1} + \mathbf{B}_2 \mathbf{y}_{t-2} + \cdots + \mathbf{B}_p \mathbf{y}_{t-p} + \mathbf{u}_t \quad (9.5)$$

where

$$\mathbf{y}_t = (GRT_t, GIT_t, GKT_t, GY_t)' \quad (9.6)$$

$$\mathbf{u}_t = (u_t^r, u_t^I, u_t^K, u_t^Y)' \quad (9.7)$$

$$\mathbf{B}_0 = \begin{bmatrix} 1 & -\beta_{12}^{(0)} & -\beta_{13}^{(0)} & -\beta_{14}^{(0)} \\ -\beta_{21}^{(0)} & 1 & -\beta_{23}^{(0)} & -\beta_{24}^{(0)} \\ -\beta_{31}^{(0)} & -\beta_{32}^{(0)} & 1 & -\beta_{34}^{(0)} \\ -\beta_{41}^{(0)} & -\beta_{42}^{(0)} & -\beta_{43}^{(0)} & 1 \end{bmatrix} \quad (9.8)$$

$$\mathbf{c} = (c_1, c_2, c_3, c_4)' \quad (9.9)$$

$\mathbf{B}_p$  is a  $(4 \times 4)$  matrix, its row  $i$ , column  $j$  element is noted as  $\beta_{ij}^{(s)}$   $s=1,2,\dots,p$ .

We assume that the lag  $p$  is sufficient large so that  $\mathbf{u}_t$  is vector white noise:

$$E(\mathbf{u}_t \mathbf{u}_\tau') = \begin{cases} \mathbf{D}, & \text{for } t = \tau \\ \mathbf{0}, & \text{otherwise} \end{cases} \quad (9.10)$$

Our purpose is to calculate the impulse response functions

$$\frac{\partial \mathbf{y}_{t+s}}{\partial u_t^r} \quad (9.11)$$

It describes the consequences of one unit increase in the growth rate of profit rate's innovations at date  $t$  ( $u_t^r$ ), for the values of the variable in the system at time  $t+s$  ( $\mathbf{y}_{t+s}$ ), holding all other innovations at all dates constant.

Write the above dynamic structural model as its reduced-form, that is the following VAR model:

$$\mathbf{y}_t = \mathbf{\Pi}' \mathbf{x}_t + \boldsymbol{\varepsilon}_t \quad (9.12)$$

where

$$\mathbf{\Pi}' \equiv -\mathbf{B}_0^{-1} [\mathbf{c} \quad \mathbf{B}_1 \quad \mathbf{B}_2 \quad \cdots \quad \mathbf{B}_p] \quad (9.13)$$

$$\mathbf{x}_t \equiv (1 \quad \mathbf{y}_{t-1}' \quad \mathbf{y}_{t-2}' \quad \cdots \quad \mathbf{y}_{t-p}')' \quad (9.14)$$

$$\boldsymbol{\varepsilon}_t \equiv -\mathbf{B}_0^{-1} \mathbf{u}_t \quad (9.15)$$

$$\boldsymbol{\Omega} = E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t') \quad (9.16)$$

The identification conditions of SVAR are relatively complicated. Collect the parameters to be estimated in  $\mathbf{B}_0$  as a  $(n_B \times 1)$  vector  $\boldsymbol{\theta}_B$ , and collect the parameters to be estimated in  $\mathbf{D}$  as a  $(n_D \times 1)$   $\boldsymbol{\theta}_D$ . If the following two conditions are verified, then the system is identifiable:



1) Order condition,  $n(n + 1)/2 \geq n_B + n_D$ , where  $n$  is the number of variables in the system. It assumes that the number of restrictions is at least as greater as the number of parameters in structural matrix.

2) Rank condition,  $\text{rank}(J'J) = n_B + n_D$ . Where  $J = \begin{pmatrix} \frac{\partial \text{vech}(\Omega)}{\partial \theta_B'} & \frac{\partial \text{vech}(\Omega)}{\partial \theta_D'} \end{pmatrix}$ , that is to say  $J$  is linearly independent of column. It assumes the MLE is a unique maximum (local maximum).

Giannini (1992) provided the numerical method to verify the rank condition about  $J$ . Realizing the identification through short-run restrictions is the commonly used method, that is to say we impose restrictions on the structure of  $B_0$ . While Blanchard and Quah (1989), Blanchard and Diamond (1989, 1990) used the long-run restrictions to realize the identifications<sup>211</sup>. However those *a priori* restrictions are also the points that SAVR model has been most criticized. In order to reach the identification conditions, those assumptions are generally difficult to defense, they lack solid theoretical foundations. In additional, our purpose is to calculate the impulse responses functions, so we also need to calculate the standard errors of those impulse responses functions. However, the researches of Runkle (1987), Lutkepohl (1990) show that the precisions of standard errors of impulse responses functions based on VARs are poor. Therefore, we hope to realize two aims in our modelling:

1) The restrictions should be as simple and reliable as possible. 2) The number of parameters in the system should be as few as possible in order to increase the precision of estimation of standard errors<sup>212</sup>.

One ideal situation is that if we can order the variables in  $y_t$  to make  $B_0$  being a lower triangular matrix, then the system will be just-identified. We have only need to firstly estimate the MLE of unrestricted VAR, and then decompose the covariance matrix of VAR residuals  $\Omega$  with unique orthogonal decomposition:

$$\Omega = ADA' \quad (9.17)$$

As such an orthogonal decomposition is unique<sup>213</sup>, thus  $A \equiv B_0^{-1}$ .

Then we get the estimators of dynamic structural model.

*A priori*, such an ordering seems to be possible. Note at time  $t$ , all the past available useful information until a lag of  $p$  as

$$I_t = \{GRT_{t-1}, \dots, GRT_{t-p}; GIT_{t-1}, \dots, GIT_{t-p}; GKT_{t-1}, \dots, GKT_{t-p}; GYT_{t-1}, \dots, GYT_{t-p}\}$$

We assume that:

$H_I$ : Enterprise expects the profit rate in the future based on the information of past. That is to say,  $GRT_t$  could be written as a linear projection on the past information.

$$\begin{aligned} GRT_t &\equiv \hat{E}(GRT_t|I_t) \\ &= c_1 + \beta_{11}^{(1)} GRT_{t-1} + \beta_{11}^{(2)} GRT_{t-2} + \dots + \beta_{11}^{(p)} GRT_{t-p} \\ &\quad + \beta_{12}^{(1)} GIT_{t-1} + \beta_{12}^{(2)} GIT_{t-2} + \dots + \beta_{12}^{(p)} GIT_{t-p} \\ &\quad + \beta_{13}^{(1)} GKT_{t-1} + \beta_{13}^{(2)} GKT_{t-2} + \dots + \beta_{13}^{(p)} GKT_{t-p} \\ &\quad + \beta_{14}^{(1)} GYT_{t-1} + \beta_{14}^{(2)} GYT_{t-2} + \dots + \beta_{14}^{(p)} GYT_{t-p} + u_t^r \quad (9.18) \end{aligned}$$

That is to say we have restricted  $-\beta_{12}^{(0)} = -\beta_{13}^{(0)} = -\beta_{14}^{(0)} = 0$  (9.19)

<sup>211</sup> We will discuss the long run restrictions in details later.

<sup>212</sup> In this case, the Bayesian approach might be very useful, we will discuss in detail later.

<sup>213</sup> Amisano and Giannini (1997) use Cholesky decomposition  $\Omega = PP'$

**H<sub>2</sub>**: Enterprise determinates its investment behavior based on the expectation on the future profit rate and the past information:

$$\begin{aligned}
GIT_t &\equiv \hat{E}(GIT_t|GRT_t, I_t) \\
&= c_2 + \beta_{21}^{(0)}GRT_t + \beta_{21}^{(1)}GRT_{t-1} + \beta_{21}^{(2)}GRT_{t-2} + \cdots + \beta_{21}^{(p)}GRT_{t-p} \\
&\quad + \beta_{22}^{(1)}GIT_{t-1} + \beta_{22}^{(2)}GIT_{t-2} + \cdots + \beta_{22}^{(p)}GIT_{t-p} \\
&\quad + \beta_{23}^{(1)}GKT_{t-1} + \beta_{23}^{(2)}GKT_{t-2} + \cdots + \beta_{23}^{(p)}GKT_{t-p} \\
&\quad + \beta_{24}^{(1)}GYT_{t-1} + \beta_{24}^{(2)}GYT_{t-2} + \cdots + \beta_{24}^{(p)}GYT_{t-p} + u_t^I \quad (9.20)
\end{aligned}$$

That is to say we have restriction:  $-\beta_{23}^{(0)} = -\beta_{24}^{(0)} = 0$  (9.21)

**H<sub>3</sub>**: according to the PIM equation, the investment in year  $t$  will determinate the capital stock level of year  $t$ :

$$\begin{aligned}
GKT_t &\equiv \hat{E}(GKT_t|GIT_t, GRT_t, I_t) \\
&= c_3 + \beta_{31}^{(0)}GRT_t + \beta_{31}^{(1)}GRT_{t-1} + \beta_{31}^{(2)}GRT_{t-2} + \cdots + \beta_{31}^{(p)}GRT_{t-p} \\
&\quad + \beta_{32}^{(0)}GIT_t + \beta_{32}^{(1)}GIT_{t-1} + \beta_{32}^{(2)}GIT_{t-2} + \cdots + \beta_{32}^{(p)}GIT_{t-p} \\
&\quad + \beta_{33}^{(1)}GKT_{t-1} + \beta_{33}^{(2)}GKT_{t-2} + \cdots + \beta_{33}^{(p)}GKT_{t-p} \\
&\quad + \beta_{34}^{(1)}GYT_{t-1} + \beta_{34}^{(2)}GYT_{t-2} + \cdots + \beta_{34}^{(p)}GYT_{t-p} + u_t^K \quad (9.22)
\end{aligned}$$

That is to say, we restricted that  $-\beta_{34}^{(0)} = 0$  (9.23)

**H<sub>4</sub>**: The capital stock level will determinate the level of output. This equation could be interpreted as production function from endogenous economic theory or neoclassic point of views. From Marxist point of views, if the supply of labor is sufficient, more capital stock means that more labor could create more values with that physical capital.

$$\begin{aligned}
GYT_t &\equiv \hat{E}(GYT_t|GKT_t, GIT_t, GRT_t, I_t) \\
&= c_4 + \beta_{41}^{(0)}GRT_t + \beta_{41}^{(1)}GRT_{t-1} + \beta_{41}^{(2)}GRT_{t-2} + \cdots + \beta_{41}^{(p)}GRT_{t-p} \\
&\quad + \beta_{42}^{(0)}GIT_t + \beta_{42}^{(1)}GIT_{t-1} + \beta_{42}^{(2)}GIT_{t-2} + \cdots + \beta_{42}^{(p)}GIT_{t-p} \\
&\quad + \beta_{43}^{(0)}GKT_t + \beta_{43}^{(1)}GKT_{t-1} + \beta_{43}^{(2)}GKT_{t-2} + \cdots + \beta_{43}^{(p)}GKT_{t-p} \\
&\quad + \beta_{44}^{(1)}GYT_{t-1} + \beta_{44}^{(2)}GYT_{t-2} + \cdots + \beta_{44}^{(p)}GYT_{t-p} + u_t^Y \quad (9.24)
\end{aligned}$$

Thus, we have assumed a set of identifiable restrictions in a **recursive manner**.

Even we have a confident theoretical foundations and realistic logic for the restrictions in the above four equations, and the restrictions are as few as possible. We might be better to test those restrictions before we apply them in order to strengthen the arguments of using those restrictions. That is to say, it is better to estimate firstly a general unrestricted dynamic system and test those restrictions before applying them in the SVAR models.

Therefore, we firstly estimate the unrestricted dynamic system (9.5):

$$\mathbf{B}_0\mathbf{y}_t = \mathbf{c} + \mathbf{B}_1\mathbf{y}_{t-1} + \mathbf{B}_2\mathbf{y}_{t-2} + \cdots + \mathbf{B}_p\mathbf{y}_{t-p} + \mathbf{u}_t$$

Or its reduced-form, i.e. an unrestricted atheoretical VAR model (9.12):

$$\mathbf{y}_t = \mathbf{\Pi}'\mathbf{x}_t + \boldsymbol{\varepsilon}_t$$

And then test if

$$-\beta_{12}^{(0)} = -\beta_{13}^{(0)} = -\beta_{14}^{(0)} = -\beta_{23}^{(0)} = -\beta_{24}^{(0)} = -\beta_{34}^{(0)} = 0 \quad (9.25)$$

are valid or not.

## 9.4 Econometric Estimations: SVARs and BVARs

### Wald Test in Unrestricted Dynamic System

As pointed above, we want to firstly estimate (9.5) and then test the null hypothesis (9.25). Obviously this could be realized by a Wald test.

We need to firstly determinate the order of lags of its reduced-form that is the  $p$  of the unrestricted VAR( $p$ ) model. Assume that the maximum lag is an election political cycle, that is to say, 5 years, and then different information criterions report the optimal lags in *table 9.2*:

**Table 9.2 Optimal lags selected by information criterions for unrestricted VAR( $p$ )**

	LR	FPE	AIC	SC	HQ
Lag	3	3	5	1	1

*LR: sequential modified LR test statistic (each test at 5% level)*

*FPE: Final prediction error*

*AIC: Akaike information criterion*

*SC: Schwarz information criterion*

*HQ: Hannan-Quinn information criterion*

The VAR Residual Serial Correlation LM Tests show that until  $p=3$ , there is no correlation in the residuals.

**Table 9.3 Residual Serial Correlation LM Tests for unrestricted VAR( $p$ )**

Prob of Null Hypothesis: no serial correlation at lag order  $h$

<b>h</b>	<b>VAR(1)</b>	<b>VAR(2)</b>	<b>VAR(3)</b>
1	0.0106	0.0751	0.8019
2	0.0380	0.0479	0.4998
3	0.0402	0.1098	0.3946
4	0.5528	0.6092	0.4983
5	0.0867	0.2855	0.3588
6	0.8125	0.2641	0.1022
7	0.4149	0.0861	0.0688
8	0.6191	0.7269	0.8652
9	0.2566	0.5209	0.4917
10	0.9123	0.4376	0.9075

Thus,  $p=3$  and we then get the estimates of unrestricted dynamic system. However, the Wald test rejected null hypothesis:

**Table 9.3 Wald test for restrictions in VAR(3)**

$$H_0: -\beta_{12}^{(0)} = -\beta_{13}^{(0)} = -\beta_{14}^{(0)} = -\beta_{23}^{(0)} = -\beta_{24}^{(0)} = -\beta_{34}^{(0)} = 0$$

Test Statistic	Value	df	Probability
Chi-square	470.4833	6	0.0000

We are not surprised that the short-run restrictions assumptions are rejected by Wald test. Firstly, the unrestricted dynamic system is atheoretical statistical model, the potential endogenous problem will lead that the coefficients such as  $\beta_{12}^{(0)}$  are biased. So the conclusions about the restrictions from Wald test might not be necessarily confident.

Secondly, the system only contains 4 variables. Evidently, the real economic system will be much complicated than this. The innovations will contain the influences of other omitted

variables. The real economic structure is more complicated as well. In the real world, a complete economic system will obviously not only contain those 4 variables. Hence, the quaternary system here is simply a subsystem of a larger unknown system. If we believe that the restrictions are valid in the quaternary system under a background of a larger and more complicated unknown system; then the same, under the background of known quaternary system, it might be more reliable to test corresponding restrictions in respective bivariate system.

So here we have two methods to improve the ways to explore the economic structural: one is still based on the unrestricted quaternary dynamic system, we change the order of the variables in  $\mathbf{y}_t$ , to make the new  $\mathbf{B}_0$  being a lower triangular matrix and look for economic theoretical foundations for new system. Alternatively, we still based on the same restrictions assumptions, but we test in the bivariate VARs that excluding the influences of other variables, that considers the relations between two variables alone and to find the arguments gradually.

We firstly consider the first method. Despite the fact that we believe that the coefficients in unrestricted system are biased, the  $t$  tests show that the following structural of  $\mathbf{B}_0$ <sup>214</sup>:

$$\mathbf{B}_0 = \begin{pmatrix} 1 & 0 & 0 & X \\ 0 & 1 & X & 0 \\ 0 & X & 1 & 0 \\ X & 0 & 0 & 1 \end{pmatrix} \quad (9.26)$$

$X$  presents that the coefficients are significant (in 5% level). 0 presents that we cannot reject the null hypothesis that the coefficient in this position is zero.

Even we don't use the numerical algorithm provided by Giannini (1992) but we can immediately know that this structure presents an unidentifiable system in analytical way. This is because, if we assume that the MLE has already been founded, then the maximum value of log likelihood function should be:

$$\begin{aligned} \mathcal{L}(\mathbf{B}_0, \mathbf{D}, \hat{\boldsymbol{\Pi}}) = & -(T/2) \log(2\pi) + (T/2) \log|\mathbf{B}_0|^2 - (T/2) \log|\mathbf{D}| \\ & - (T/2) \text{trace}\{(\mathbf{B}'_0 \mathbf{D}^{-1} \mathbf{B}_0) \hat{\boldsymbol{\Omega}}\} \end{aligned} \quad (9.27)$$

Where  $\hat{\boldsymbol{\Pi}}$  is the MLE.

Assume

$$\mathbf{B}_0 = \begin{pmatrix} 1 & 0 & 0 & a \\ 0 & 1 & b & 0 \\ 0 & c & 1 & 0 \\ d & 0 & 0 & 1 \end{pmatrix} \quad (9.28)$$

Then

$$|\mathbf{B}_0| = abcd - ad \quad (9.29)$$

We notice that elements  $a$  and  $d$  are totally equivalent, that is, if we change the positions of  $a$  and  $d$ , the determinant of  $\mathbf{B}_0$  is unchanged. That means, there exists at least two different  $\mathbf{B}_0$  that makes  $\mathcal{L}(\mathbf{B}_0, \mathbf{D}, \hat{\boldsymbol{\Pi}})$  have the same maximum value. And we have no way to distinguish the two models with the same probability distribution of data. Thus, the model is unidentifiable.

Thus, we next try to test those short-run restrictions in bivariate system.

### Granger causality test and Wald Test in bivariate VARs

---

<sup>214</sup> We also attempt to use DRT and GRPE to replace GRT, and we get the same structure for the structural matrix.

As we pointed out in the beginning, it might be not appropriate to test the exclusions with Granger causality test. Because the short-run restrictions only require that  $B_0$  is lower triangular matrix. But the null hypothesis in Granger causality test will assume that in a certain bivariate VAR,  $B_0, B_1 \dots B_p$  are all lower triangular. Evidently, Granger causality test is a stronger form of exclusion restrictions. Meanwhile, the Granger causality test is very sensible to the order of lags. Different lags probably give totally contradictory conclusions. In fact, the results of tests are indeed so:

**Table 9.4 P-values of Bivariate Pairwise Granger Causality Tests**

Null Hypothesis	Lag=1	Lag=2	Lag=3	Lag=4	Lag=5	Conclusion
GIT does not Granger Cause GRT	0.273	0.165	0.0442	0.0102	0.0279	Reject H0
GRT does not Granger Cause GIT	0.0101	0.0826	0.6387	0.6632	0.7155	Accept H0
GKT does not Granger Cause GRT	0.004	0.0139	0.0321	0.0171	0.0303	Reject H0
GRT does not Granger Cause GKT	0.0047	0.3755	0.1914	0.3536	0.3251	Accept H0
GY does not Granger Cause GRT	0.2796	0.5077	0.0706	0.0917	0.1458	Accept H0
GRT does not Granger Cause GY	0.1864	0.7499	0.9188	0.5913	0.7224	Accept H0
GKT does not Granger Cause GIT	0.0013	0.0004	0.1587	0.2605	0.0138	Accept H0
GIT does not Granger Cause GKT	0.0006	0.2018	0.0014	0.0015	0.0001	Reject H0
GY does not Granger Cause GIT	0.0018	0.0031	0.4328	0.1628	0.1848	Accept H0
GIT does not Granger Cause GY	0.2484	0.1335	0.1019	0.0055	0.0156	Accept H0
GY does not Granger Cause GKT	2.00E-05	0.2145	0.0051	0.005	0.0162	Reject H0
GKT does not Granger Cause GY	0.0007	0.0481	0.0441	0.017	0.0703	Reject H0

We see that Granger Causality Tests generally didn't give any useful information. Thus we try to test (9.25) respectively in each corresponding bivariate VARs. With 4 variables, we have established  $C_4^2 = 6$  bivariate unrestricted dynamic systems and then test corresponding restrictions in each system with Wald test. Summarized in *table 9.5*:

**Table 9.5 Wald test for restrictions in bivariate VARs**

Null Hypothesis	Bivariate System variables	Lags								p-values of Wald test
		Information criterions					Lag exclusion test	LM Tests	Final P used	
		LR	FPE	AIC	SC	HQ				
$-\beta_{12}^{(0)} = 0$	GRT GIT	2	3	3	1	2	1	2	2	0.0281
$-\beta_{13}^{(0)} = 0$	GRT GKT	2	2	2	1	2	1	2	2	0.1283
$-\beta_{14}^{(0)} = 0$	GRT GYT	1	2	2	1	2	1	2	2	0.0000
$-\beta_{23}^{(0)} = 0$	GIT GKT	5	5	5	3	3	3	3	3	0.0000
$-\beta_{24}^{(0)} = 0$	GIT GY	2	3	3	2	2	3	3	3	0.0000
$-\beta_{34}^{(0)} = 0$	GKT GY	3	3	4	1	1	1	3	3	0.0000

Note: 1) The results of lag exclusion test reserve the minimum common significant lag and the maximum lag is set to be 5.

2) The results of LM tests reserve the minimum lag that there is no correlation in the residuals until lag=12.

The structures of bivariate dynamic systems seem to be further away from expectation. And introducing the institutional indicator variables didn't ameliorate the results of Wald test either. This implies that GRT and GY influence each other at date  $t$ , they have contemporaneous effects on each other. GIT and GKT also influence each other at date  $t$ .

Even it could be interpreted superficially from the PIM equation<sup>215</sup>, but it does not mean the  $K_t$  determines  $I_t$ . Because from logic, it is the investment determines the capital stock level not inversely. In this situation, the accumulation rate of capital should be regarded as a forward-looking indicator of growth rate of investment. Because, if we anticipate that a faster accumulation rate of capital, then we might have more saving to use as investment, thus we will also anticipate a faster investment growth rate. That is to say we should say that the current capital accumulation rate might be helpful to forecast the current growth rate of investment (not “determinate”).

The above attempt suggests that we cannot use short-run exclusion restrictions to realize the identifications. So we turn to the long-run restrictions of Blanchard and Quah (1989)

### Long-run restrictions conditions

The above analysis shows that it is difficult and even impossible to use the short-run exclusion restrictions to realize the identification of system. Blanchard and Quah (1989) proposed an alternative identification method based on restrictions on the long-run properties of the impulse responses. The basic idea is the (accumulated) response of the  $i$ -th variable to the  $j$ -th structural shock is zero in the long-run. That means we test  $c_{i,j} = 0$  where  $c_{i,j}$  is row  $i$ , column  $j$  element of matrix  $\mathbf{C}$ . And  $\mathbf{C}$  is defined as<sup>216</sup>:

$$\mathbf{C} = \Psi_{\infty} \mathbf{B}_0^{-1} \mathbf{D}^{1/2} \quad (9.30)$$

When we use Cholesky decomposition, the long-run restrictions  $\mathbf{C}$  is lower triangular matrix and short-run restrictions  $\mathbf{B}_0$  is lower triangular matrix will give the same impulse response functions. Thus testing the above *a priori* restrictions is equivalent to test:

$$c_{1,2} = c_{1,3} = c_{1,4} = c_{2,3} = c_{2,4} = c_{3,4} = 0 \quad (9.31)$$

Here is a problem that what does mean “long-run”? 10 year? 15 year? 20 or 30 years? Our sample size is 63 years. We define as long as possible period as “long-run”. We calculate the impulse response functions until 30 years to observe the long-run restrictions conditions. If 0 is always contained in the 95% interval of confidence for the impulse response functions over 10-30 years, then we conclude that the long-run restrictions are valid.

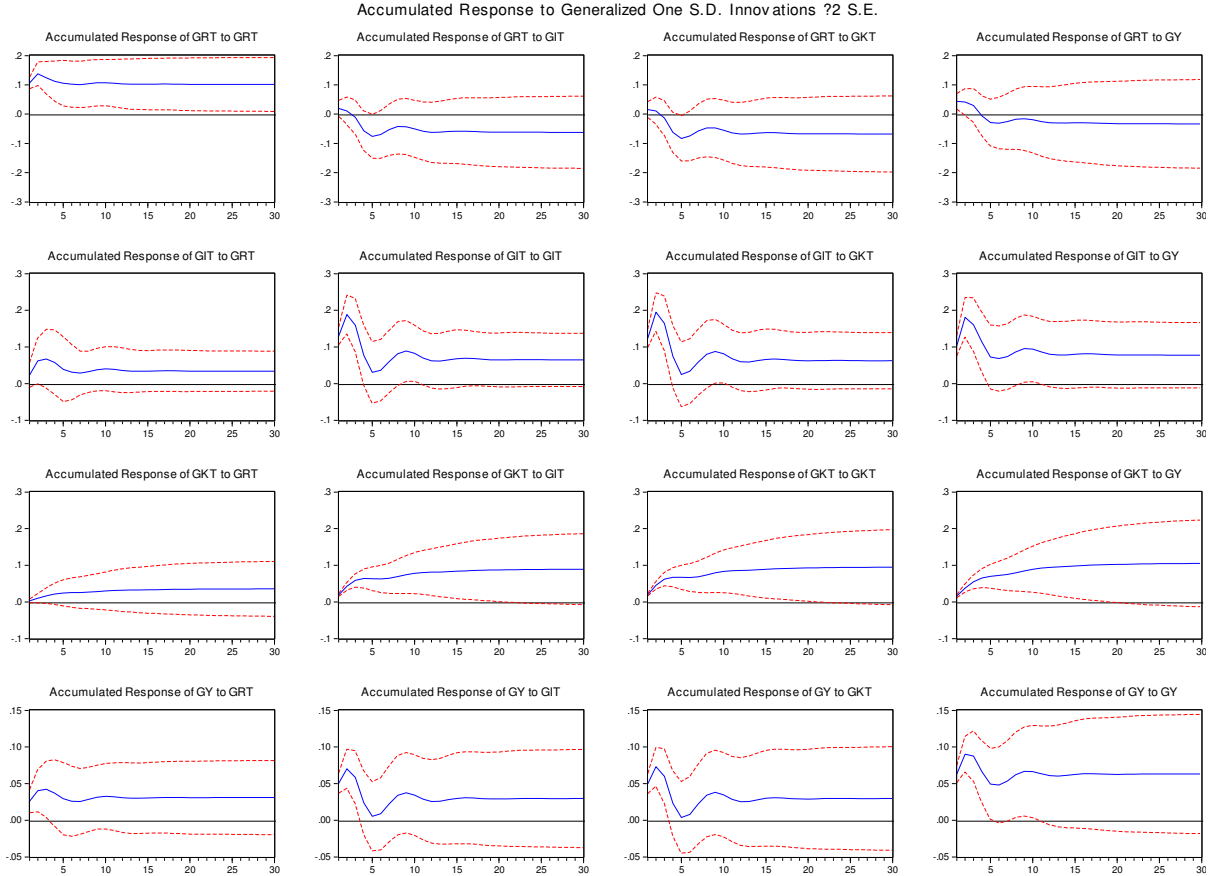
Besides, here we use the generalized impulses proposed by Pesaran and Shin (1998) to calculate those impulses because the advantage of this method is that the innovations does not depend on the VAR ordering.

---

<sup>215</sup> We might also write PIM equation inversely as  $\frac{I_t}{P_t} = K_t - (1 - \sigma)K_{t-1}$  so  $K_t$  “determinates”  $I_t$  in the same date, of course the logic is not true, but we have such a representation.

<sup>216</sup> Or we use Cholesky decomposition:  $\mathbf{C} = \Psi_{\infty} \mathbf{P}$

**Graph 9.1 Accumulated responses to generalized one standard deviation of innovations**



Thus we get the following structure of **C**:

$$C = \begin{pmatrix} X & 0 & 0 & a \\ 0 & X & ? & ? \\ 0 & X & X & X \\ 0 & 0 & 0 & X \end{pmatrix} \quad (9.32)$$

? presents that even in the interval of 10-30 years, 0 is contained in the 95% interval of confidence, but the horizontal axis zero is very closed to the boundary of interval of confidence. Considering the fact that the standard errors of impulses are relative large, so  $c_{2,3} = c_{2,4} = 0$  has larger uncertainty. If we restrict those two elements to zero, then the model is over-identified (because we have only need to restrict 6 elements to zero that could satisfy the order condition.). In this case, the model has the same Cholesky decomposition impulses with restricted **C** as lower triangular. But if we relax restriction of  $c_{2,3} = 0$ , then the model become unidentifiable (rank condition not satisfied, with the same analytical method in equations (26)-(29)). But  $c_{2,3} = 0$  has a solid theoretical foundation due to PIM equation. It is the investment determinate the capital, not inversely.

Therefore, according to the long-run restrictions the model is over-identified. Over-identification is also what we wanted. Because, a just-identified model means the system has only solution. Such a situation generally has little probability and over-identification could increase the precision of estimation. Even this over-identified model gives us some useful information, but LR test show that the exceed restrictions are not valid.

**Table 9.6 LR test for over-identification**

Null hypothesis that the restrictions are valid

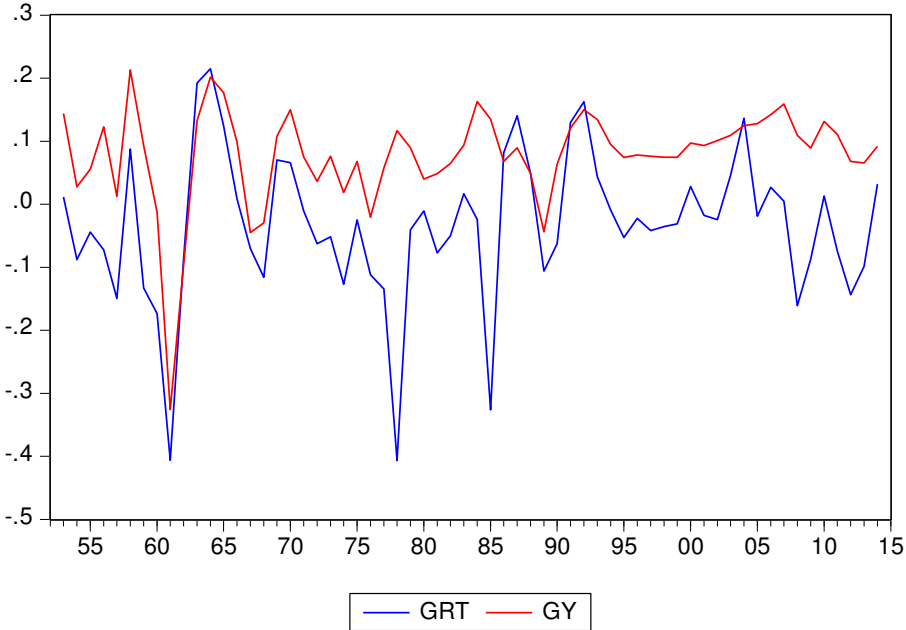
Chi-square(3)	22.17044	Probability	0.0001
---------------	----------	-------------	--------

We argue that the essential cause of that the restrictions are difficult to valid is that the economic structure is time variant. That is to say  $B_0$  or  $C$  is not stable. Alongside the opening reform and institutional changes, the economic nature of China has undergone a fundamental change. The *a priori* restrictions seem to be true in the background of market economy, however, under the background of planned economy, the restrictions are not necessarily valid. For example, we assume in the  $H_2$  that, enterprises determinate their investment behaviors according to their expectation on profit rate. In a context of market economy, it is clearly a reasonable assumption. But in the planned economy period, investment behaviors of firms are not only driven by profit rate but contrarily, it depends largely on the political choices of policymakers. For example, if the policymakers have observed a relative lower economic growth, then they might subjectively increase the investment in order to simulate the economy. If the decision-making thinking of the national leaders is like this, then the profit rate might not be the main argument of investment decision temporarily. On the contrary, the economic growth rate might be a forward-looking indicator of growth rate of investment, that is to say,  $\beta_{24}^{(0)} \neq 0$ . Therefore we should model China's economy period by period or introduce institutional indicative variables to consider the problem that the economic structure changes over time.

**Institutional dummy variables and divisions of periods**

From the *graph 9.2*, we see that before 1978 the extremums of GRT and GY situated in the same date; this indicates that they have the contemporaneous influences during this period. And after the opening reform 1978, and before the fiscal reform 1993, the extremums of GY preceded GRT. While after the reform 1993, the extremums and movement of GRT preceded GY. In the last period, those characteristics match better the *a priori* assumptions under the background of the market economy. The *graph 9.2* suggests that China's economic structure changes over time. Alongside the institutional changes, the economic structure becomes totally different. We should consider economic structures period by period. Besides, the *graph 9.2* also suggests that even the opening reform began 1978, but 1978-1992 was still some kind of planned economy. Only after the fiscal reform 1993, China started a real transformation of turning to market economy gradually.

**Graph 9.2 GRT and GY over 1952-2014**





Firstly, we consider whether one (or several) exogenous dummy could help improving the economic structure problems so that the systems more satisfy the restriction assumptions under the market economy background.

$$\mathbf{B}_0 \mathbf{y}_t = \mathbf{c} + \mathbf{d}_t + \mathbf{B}_1 \mathbf{y}_{t-1} + \mathbf{B}_2 \mathbf{y}_{t-2} + \cdots + \mathbf{B}_p \mathbf{y}_{t-p} + \mathbf{u}_t \quad (9.33)$$

From the econometric tests below, the answer is yes. But if we want to consider the problem of that  $\mathbf{B}_0$  varies over time, the exogenous dummy might not be sufficient to explain this question. We should estimate the following model:

$$[\mathbf{B}_0^{(1)}(\mathbf{I} - \mathbf{D}) + \mathbf{B}_0^{(2)}\mathbf{D}]\mathbf{y}_t = \mathbf{\Gamma}\mathbf{y}_t + \mathbf{u}_t \quad (9.34)$$

Where  $\mathbf{D} = \begin{cases} \mathbf{0}, & \text{over period 1} \\ \mathbf{I}, & \text{over period 2} \end{cases} \quad (9.35)$

Of course we can define 3 or more periods as long as the sample has sufficient observations.

That is to say we argue that the structural matrix  $\mathbf{B}_0$  has certain structure in the planned economy and has another structure in market economy period:

$$\mathbf{B}_0 = \begin{cases} [\mathbf{B}_0^{(1)} & \text{over period 1} \\ \mathbf{B}_0^{(2)} & \text{over period 2} \end{cases} \quad (9.36)$$

Obviously, we have no reason to think that  $\mathbf{B}_0$  changes over time but  $\mathbf{\Gamma}$  remains constant. So  $\mathbf{\Gamma}$  should also have corresponding matrix form for each period. This is equivalent to that we estimate respectively SVARs for each period.

The new problems arise. If the number of sub-periods is many and  $p$  is big, then the number of parameters to be estimated will raise sharply. We are in a small sample, the number of observations might not sufficient to estimate so many parameters. Therefore, we deal with this problem from several aspects:

- 1) In accordance with the reality, the number of sub-periods should be as few as possible.
- 2) Satisfying that the residuals are white noise, the lags should be as few as possible.
- 3) In the sub sample estimation, we might use Bayesian approach to increase the precision of estimators.

Let us firstly consider the exogenous dummy. A primary question is that how many dummies we should define and whether we use them in the same time.

We firstly define 3 dummies:

- d1 equals to 1 over 1952-1977, equals zero otherwise. This dummy indicates the period of planned economy period.
- d2 equals to 1 over 1978-1992, equals zero otherwise. This dummy indicates the period of planned economy period with Chinese characteristics (with market as commentary).
- d3 equals to 1 over 1993-2014, equals zero otherwise. This dummy indicates the period of market economy period with Chinese characteristics.

Evidently those 3 dummies are linearly dependent and cannot used in the same regression. Either we use two of them either we delete the constant term.

Or we define two dummies:

- Du1: equals to 0 over 1952-1977 and 1 otherwise. This dummy indicates that before and after the opening reform 1978, they are two different periods.

Du2: equals to 0 over 1952-1992 and 1 otherwise. This dummy indicates that before and after the fiscal reform 1993, they are two different periods.

Here those two new dummies could be used in the same regression. Evidently, according to the definition of those dummies, some combinations are equivalent, merged and summarized in *table 9.7*.

We use the stepwise method to look for the combination with maximum  $R^2$  in VAR(3)<sup>217</sup>, and test whether the long-run restrictions are valid.

**Table 9.7 Estimations of VAR(3) with Exogenous Dummy Variables**

Exogenous terms	C	(C d1) / (C Du1)	(C d2)	(C d3) / (C Du2)	(C d2 d3) / (C Du1 Du2) / (C du1 du2) / (d1 d2 d3) / (C d1 d3)
Average $R^2$	0.5634555	0.57515425	0.56480125	0.5861405	0.59039075
Lowest $R^2$	0.381709	0.393851	0.383569	0.418169	0.42046
Determinant resid covariance (dof adj.)	7.07E-12	6.15E-12	7.45E-12	6.37E-12	6.02E-12
Log likelihood	451.9258	458.6055	452.9472	457.5917	461.9242
AIC	-13.55681	-13.64764	-13.45584	-13.61328	-13.62455
SIC	-11.72576	-11.67574	-11.48394	-11.64138	-11.51180
LM test	Accepted	Accepted	Accepted	Accepted	Accepted
Structural of matrix C	X 0 0 0 0 X ?? 0 X X X 0 0 0 X	X 0 0 0 0 X ?? 0 X X X ? 0 0 X	X 0 0 0 0 X ?? 0 X X X 0 0 0 X	X 0 0 0 0 X ?? 0 X X X 0 0 0 X	X 0 0 0 0 X ?? 0 X X X 0 0 0 X
Identification	over-identified if c24=0 Un-identified otherwise	over-identified if c24=0 Un-identified otherwise	over-identified if c24=0 Un-identified otherwise	over-identified if c24=0 Un-identified otherwise	over-identified if c24=0 Un-identified otherwise

*Null hypothesis of LM test: No autocorrelation of residuals until lag 12*

We expect that after introducing the dummies,  $R^2$  and log likelihood will increase, determinant of residuals covariance will decrease and we might have smaller AIC and SIC. If it is the case, then we could say that the exogenous dummies have ameliorated the models.

The *table 9.7* gives much useful information. Firstly, compared to the system without dummy, the  $R^2$  of all systems contained dummies (no matter how many dummies and no matter what kind of combination between them) become larger. This suggests that the institutional indicative variables indeed have ameliorated the models. Secondly, the more dummies we have, higher increment of  $R^2$ ; this suggests that each period is relative independent period and has its own characteristics. It also suggests that our division of periods is relatively successful. However, introducing d2 didn't improve too much the models; this implies that even the second period 1978-1992 is different from previous and next periods, but it is more closed to the former planned economy period. According to our principle above that we should have as few as possible periods, we could combine 1952-1992 as the "planned economy period with

<sup>217</sup>Average  $R^2$  of 4 equations in the system.

Chinese characteristics” in order to reduce the number of parameters. Thirdly, from the structure of matrix C, the economic structure is relative stable but the key identification condition of systems is that whether  $c_{24}=0$ . This indicates that our previous concerns are justified. That is, if the Chinese leaders have observed the changes of economic growth, then they subjectively changes the growth rate of investment. Then the *a priori* restriction assumptions under the market economy is not valid;  $c_{24}$  does not equal to zero; the influence of economic growth on the investment growth rate is not zero in long run; the system is unidentifiable. **So we can only apply the *a priori* assumptions for the period 1993-2014 which is more close to market economy.**

We see that if we only consider this period. The sample size decrease sharply, from 61 to 22. In such a small sample, if the model is just-identified, we will using those 88 points to estimate  $4*(4p+1)+10$  parameters. Then the lags should not exceed 4. Luckily, we have pointed out above that the optimal lag is 3 that satisfy this condition. Even so, due to so many parameters, the precision of estimations is questioned. As pointed out above, we try to use the Bayesian analysis to improve the precision of estimations.

### **Bayesian analysis and sub estimation of period 1993-2014**

Bayesian analysis requires the prior probability distribution of parameters. We have two different choices: the first one is that we directly use information of 1952-1992 as pre-sample, and then estimate the BVAR over 1993-2014. The second is using some kind of prior specification such as Litterman (1986) and Sims and Zha (1998) etc.

However, both methods have their own disadvantages here. As we try to underlined, before and after 1993 they are two periods with different economic natures. So it seems not very reasonable to use the information during planned economy as pre-sample to estimate the economic structure during market economy (or almost market economy). Secondly, the prior specifications require that we believe the parameters have certain specific probability distribution. The success of Bayesian analysis depends on whether the distribution we have chosen is indeed close to the real situation. However, it remains space for manipulation; this is also the disadvantages of Bayesian approaches. For example, the basic idea of Litterman prior specification is that we believe the changes of variables are impossible to forecast:

$$y_t - y_{t-1} = c + \varepsilon_t \quad (9.37)$$

$\varepsilon_t$  is uncorrelated with lagged values of any variables.

If the market is in perfect competition, the changes of GRT seem indeed impossible to be forecasted. Such a belief is obviously too strong for China. Even after 1993, the intervention of government is still everywhere. The market is not in perfect competition evidently. Besides, we must believe the standard errors of the parameters of lagged variables decay towards to zero in certain way. Econometricians argue a lot about this decay. For example, Litterman (1986) himself proposed decay hyperbolically<sup>218</sup>, Kadiyala and Karlsson (1997) preferred linear decline that is the relative tightness parameter  $L_3$  equals to 1 and Koop and Korobilis (2009) suggested 2 for  $L_3$ .

We attempt to use different Bayesian specifications to improve estimation. Summarized in *table 9.8*:

---

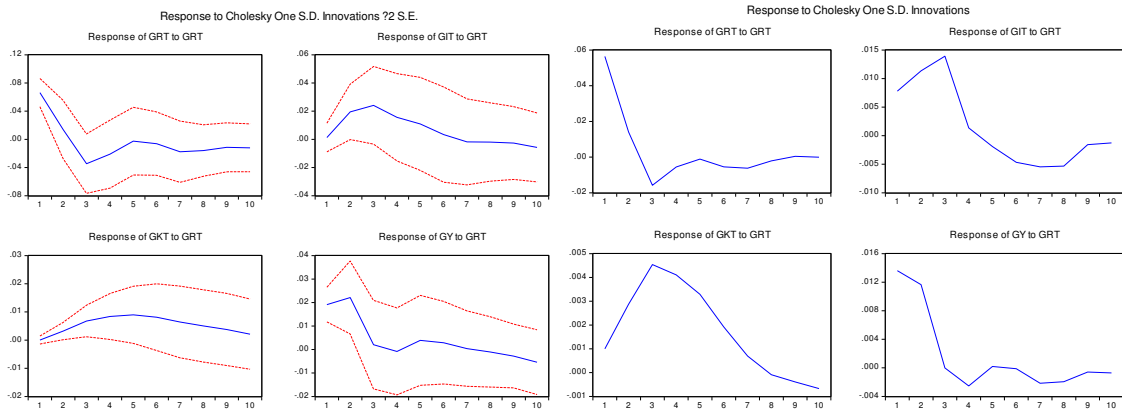
<sup>218</sup> That is to say the standard errors are  $\gamma/1, \gamma/2, \dots, \gamma/p$

**Table 9.8 Comparison of BVARs Estimations for period 1993-2014**

	1952-1992 as pre-sample	Litterman/Minnesota	Sims-Zha	Traditional VAR 1993-2014
Priors	Coef. matrix: $\theta_0^{219}$ , Cov. matrix: variance 0	Mu: 0, L1: 0.1, L2: 0.99, L3: 1	L0: 1, L1: 0.1, L3: 1	N.A.
Average $R^2$	0.6676465	0.468692	0.446659	0.793736
LM test	Rejected	Rejected	Rejected	Accepted

We see that the Bayesian approaches didn't improve the results of estimations here. This implies that the *a priori* distributions are indeed too strong hypotheses. The information provided by the pre-sample 1952-2014 is better than other priors but not as good as the sub sample itself. This indicates that although the information over 1952-1992 are useful (because it's the same economy even the nature has changed) but the information during planned economy is not suitable as prior distribution information of market economy period. In the meantime, from the *Graph 9.4* (left block is the traditional VAR, right block is the BVAR (with pre-sample as prior), we see that the impulse response functions calculated from BVAR are very similar to that calculated from subsample 1993-2014. So we finally use the results of traditional VAR with subsample 1993-2014 even the sample size is small.

**Graph 9.4 Impulse Response Functions of Traditional VAR and BVAR for Period 1993-2014**



We see from *Graph 9.5* that in the subsample, (9.31) is valid<sup>220</sup>:

$$c_{1,2} = c_{1,3} = c_{1,4} = c_{2,3} = c_{2,4} = c_{3,4} = 0$$

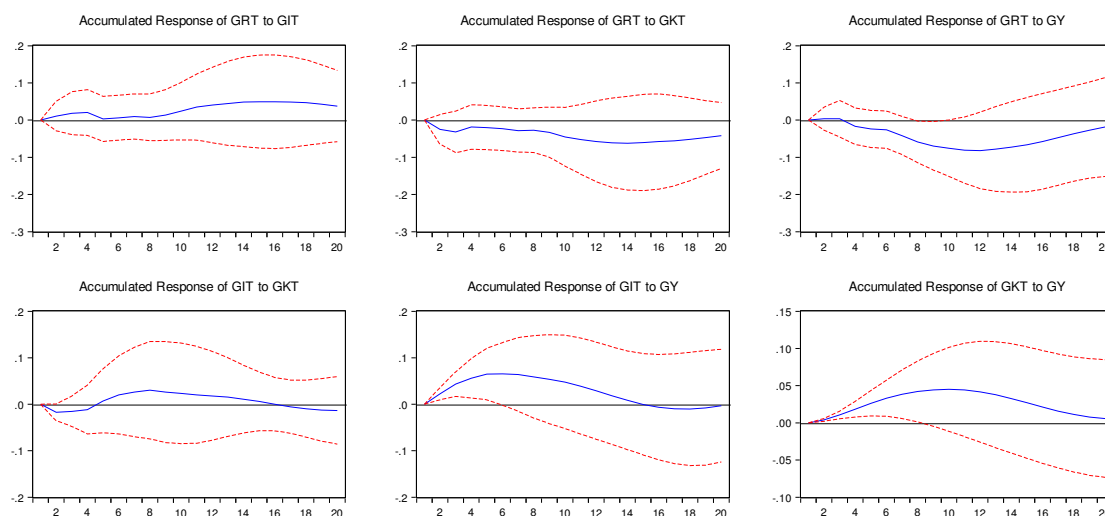
Thus the system is identifiable.

<sup>219</sup> We firstly estimate a VAR with data 1952-1992, and then use the pre-sample information as priors. The details of parameterization are in the *Appendix 9.2*.

<sup>220</sup> Here the sample size is only 22, so we calculate impulses until 20 years.

### Graph 9.5 Accumulated Responses for the model with period 1993-2014

Accumulated Response to Cholesky One S.D. Innovations ?2 S.E.

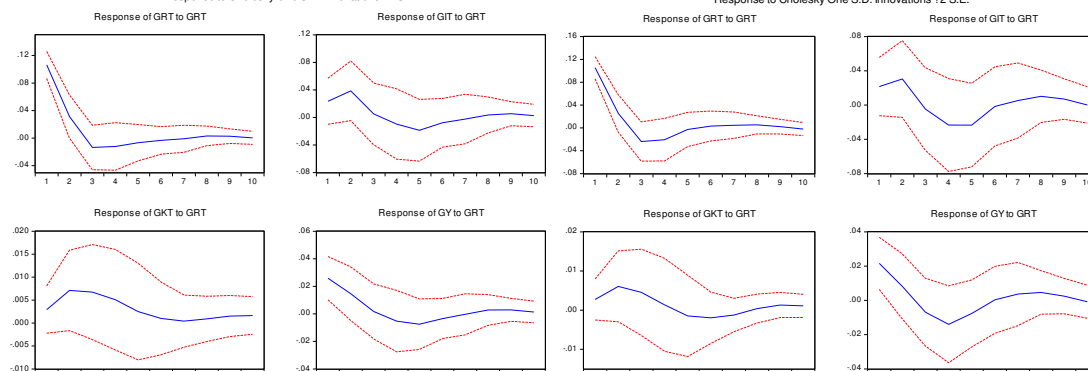


### Results and Previsions

From above analysis process, we see that: China’s economic structure is time variant, and could roughly be divided into 3 periods. 1952-1977 was a period of Soviet-style planned economy; 1978-1992 was a period of planned economy with Chinese characteristics, *i.e.* planned economy with market economy as complement; after 1993, it is a period of market economy with Chinese characteristics, that is, market economy with planned economy as complement. The short-run *a priori* restriction assumptions are difficult to valid and the long-run restrictions are valid only in the subsample 1993-2014. Bayesian approaches fails to improve the estimation; this is because the information of planned economy periods before 1993 is not suitable as prior information of market economy; as well as the assumptions on the prior probability distribution of Bayesian analysis is too strong hypothesis. Even the sample size is small so that the standard errors of impulses might be large. But from *graph 9.5*, the accumulated impulses we would like to test are all tend to zero, thus, the model is identifiable. The sample 1952-1992 also provided much useful information; therefore we also report the impulse response functions of full sample SVAR:

### Graph 9.6 Impulse Response Functions of Full Sample SVAR

Response to Cholesky One S.D. Innovations ?2 S.E.



Note: left block is SVAR with 3 dummies, right block is SVAR without dummy.

The key identifiable condition for full sample model is whether C24 equals zero. But this condition is ambiguous. This implies that if Chinese leaders observed economic crisis, they might subjectively increase the investment as an anti-crisis policy rather than let the profit rate

determining whether we investment more or less. This is also one of the most important characteristics of China's economy: very powerful governmental intervention for anti-crisis.

The last step of Box-Jenkins (1976) modeling philosophy is prevision. Now we try to use the full sample and subsample models to predict the economic situation of 2015. NBS has published some initially data of 2015 in the year 2016 recently;<sup>221</sup> so we can verify our prevision:

**Table 9.8 Forecast the Economic Growth Rate of 2015 with Data over 1952-2014**

		GRT	GIT	GKT	GY
NBS <sup>222</sup> data		N.A.	3.4%	N.A.	6.9%
Forecast by full sample model without dummy	Value	-4.8%	4.4%	10.9%	6.6%
	RMSE	0.158432	0.049955	0.165162	0.031903
	MAE	0.137710	0.042965	0.156112	0.024935
	MAPE	165.2387	39.37974	2500.854	0.945150
	Theil	0.031903	0.024935	34.42076	0.162895
Forecast by full sample model with dummy <sup>1,2,3</sup>	Value	-2.3%	5.6%	11%.	8.6%
	RMSE	0.164466	0.050130	0.149755	0.029137
	MAE	0.146229	0.043092	0.137604	0.023604
	MAPE	146.7758	39.07008	1248.364	24.69899
	Theil	0.793943	0.200322	0.903595	0.139841
Forecast by subsample model	Value	-2.7%	9.9%	11.2%	9.7%
	RMSE	0.166674	0.048038	0.150943	0.014060
	MAE	0.145566	0.040314	0.13760	0.012375
	MAPE	121.7106	37.32195	5941.033	12.69810
	Theil	0.826713	0.191456	0.883610	0.067614

*Note: The data are in constant price.*

*RMSE: Root Mean Square Error*

*MAE: Mean Absolute Error*

*MAPE: Mean Absolute Percentage Error*

*Theil: Theil inequality coefficient*

We see that all the three models give a negative prevision for the growth rate of total profit rate of whole society, it means that the profit rate will continue to fall even it is already rather low (5% in 2014). If the profit rate continues to fall, the Marxists might argue that there will be a crisis in the future. Considering that the corresponding capital of GRT is the total capital that also contains the financial capital, such a prevision is reasonable. Because during 2015 Chinese stock market turbulence, the Shanghai index fall from the highest point 5178.19 in 12 June 2015 to its lowest point 2638.3 in 27 January 2016 – a drop as much as 49%. In one year (from 12/6/2015 to 12/06/2016) the investors suffered a total loss about 25.69 trillion Yuan<sup>223</sup>. That approximately corresponds to the GDP of Germany in 2015.

<sup>221</sup> Those data are primary and generally will be revised before the formal publication of *China yearbook 2016*.

<sup>222</sup> [http://www.stats.gov.cn/tjsj/zxfb/201601/t20160120\\_1306759.html](http://www.stats.gov.cn/tjsj/zxfb/201601/t20160120_1306759.html)

<sup>223</sup> Data source: Shanghai Stock Exchange and Shenzhen Stock Exchange.

**Graph 9.7 2015/2016 Chinese stock market turbulence: index of Shanghai**



As GRT is the profit rate containing financial capital, considering the huge loss of financial capital during the financial crisis. It is not difficult to understand that there will be a negative growth rate of total capital profit rate. Though we didn't know the crisis will occur in the financial sector in the next year with our models. However it could still be considered as a successful out-of-sample prevision with data before 2015.

On the other hand, the forecast for economic growth is also very successful. The initial data published by NBS is that the GDP growth rate of 2015 is 6.9% in constant price. While the full sample model forecasts that the GDP growth rate in 2015 will be 6.6% in constant price. It is very close to the data released by NBS. This suggests that even the condition  $c_{24}=0$  is ambiguous, but full sample model indeed provided more information. This is why we insist to reserve the results of full sample model (*graph 9.6*). At the meantime, the prevision results of full sample also suggests that the financial crisis 2015 in China might be endogenous and might be caused by accumulated factors in long-run.

Many econometric models have good in-sample prevision capacity that is a high  $R^2$ . But their out-of-sample previsions are generally very poor. Here we have provided an economic model with good capacity in one step ahead out-of-sample forecasting. That means our modelling is rather successful.

## 9.5 Decompositions of Profit Rates

To identifier the economic cycles and crises of China's economy, we firstly deepen the economic decomposition of profit rates in Chapter 8 and proposed the following three decompositions and then apply the filters to the economic components of profit rates.

**Table 9.9 Economic decompositions of profit rates**

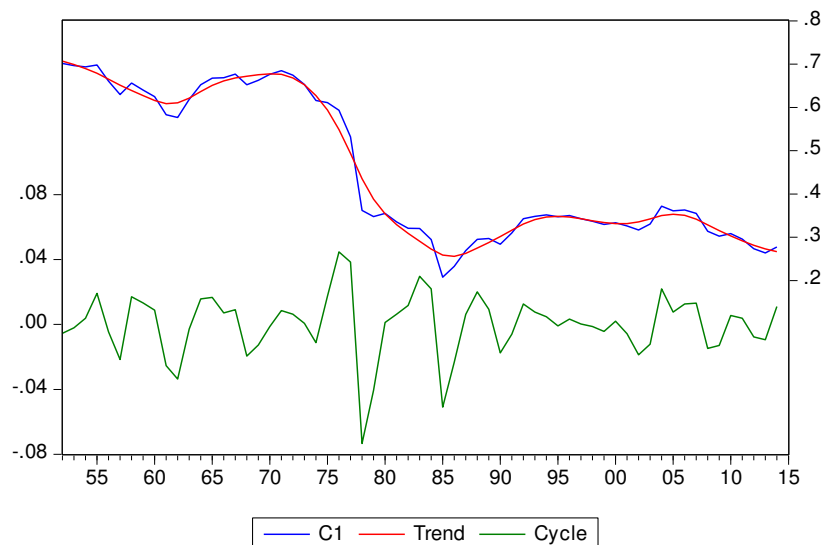
	Decomposition 1	Decomposition 2	Decomposition 3
$r_T$	$r_T = \frac{\frac{\Pi}{\bar{Y}} * \frac{Y}{wL}}{1 + c:v} \quad (9.38)$	$r_T = \frac{\Pi}{Y} * \frac{1}{\frac{K_T}{Y} + \frac{wL}{Y}} \quad (9.39)$	$r_T = \frac{\Pi}{wL} * \frac{1}{1 + \frac{K_T}{wL}} \quad (9.40)$
$r_{Tc}$	$r_{Tc} = \frac{\left(\frac{\Pi}{\bar{Y}} * \frac{Y}{wL}\right)}{c:v} \quad (9.41)$	$r_{Tc} = \frac{\Pi}{Y} * \frac{Y}{K_T} \quad (9.42)$	$r_{Tc} = \frac{\Pi}{wL} * \frac{wL}{K_T} \quad (9.43)$
$r_{pe}$	$r_{pe} \frac{\left(\frac{\Pi}{\bar{Y}} * \frac{Y}{wL}\right)}{1 + c2:v} \quad (9.44)$	$r_{pe} = \frac{\Pi}{Y} * \frac{1}{\frac{K_{pe}}{Y} + \frac{wL}{Y}} \quad (9.45)$	$r_{pe} = \frac{\Pi}{wL} * \frac{1}{1 + \frac{K_{pe}}{wL}} \quad (9.46)$
$r_{pec}$	$r_{pec} = \frac{\left(\frac{\Pi}{\bar{Y}} * \frac{Y}{wL}\right)}{c2:v} \quad (9.47)$	$r_{pec} = \frac{\Pi}{Y} * \frac{Y}{K_{pe}} \quad (9.48)$	$r_{pec} = \frac{\Pi}{wL} * \frac{wL}{K_{pe}} \quad (9.49)$

Where  $\frac{\Pi}{\bar{Y}}$  is the part of profit noted as C1,  $\frac{Y}{wL}$  is the productivity of labor cost unit noted as C2,  $c:v$  is the organic component of total capital noted as C3T,  $\frac{Y}{K_T}$  is the productivity of total capital noted as C4T,  $\frac{\Pi}{wL}$  is the rate of surplus value noted as C5,  $c2:v$  is the organic component of productive capital noted as C3PE,  $\frac{Y}{K_{pe}}$  is the productivity of productive capital noted as C4PE. The data are presented in *Appendix 9.1*.

We then apply HP filter to those components and we get same cycles and crises in chapter 8 that applies the filter to the industrial profit rates. That is to say, the economic cycles and crises in chapter 8 have been confirmed by the economic indicators of all economic sectors with a reviewed Marxist point of view.

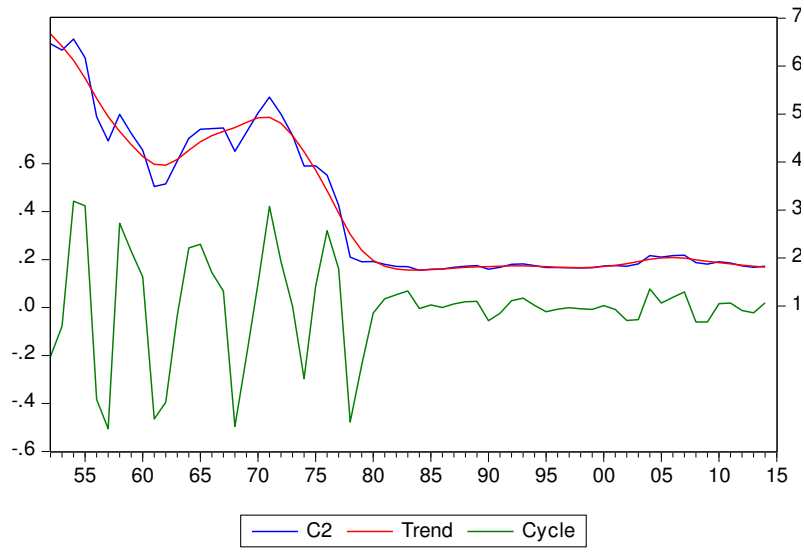
**Graph 9.8 Econometric Decomposition of Total and Productive Profit Rates**

Hodrick-Prescott Filter (lambda=6.25)

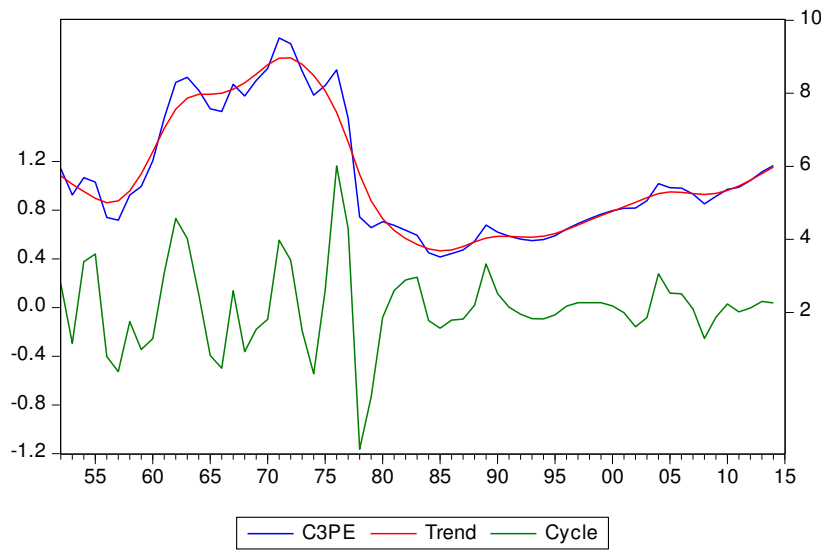




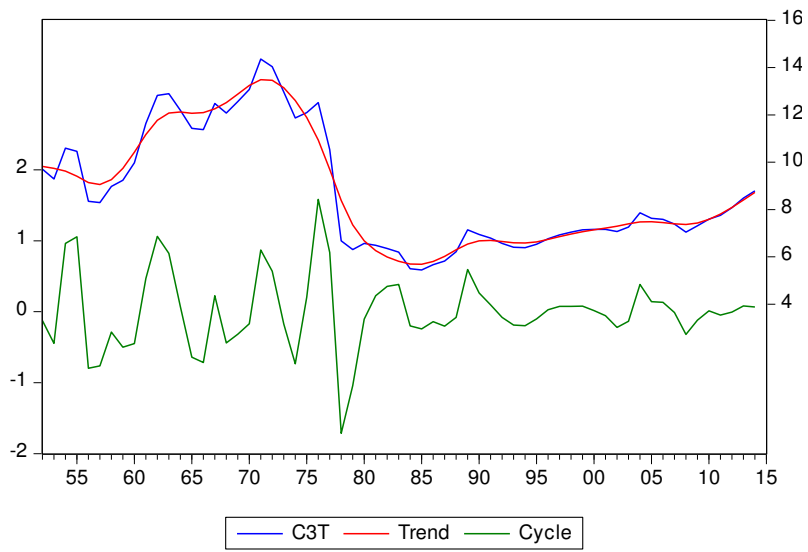
Hodrick-Prescott Filter (lambda=6.25)



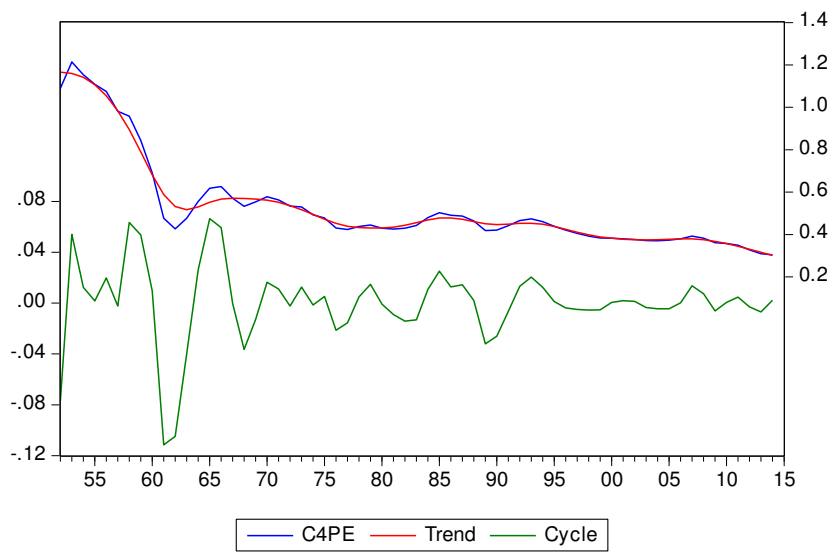
Hodrick-Prescott Filter (lambda=6.25)



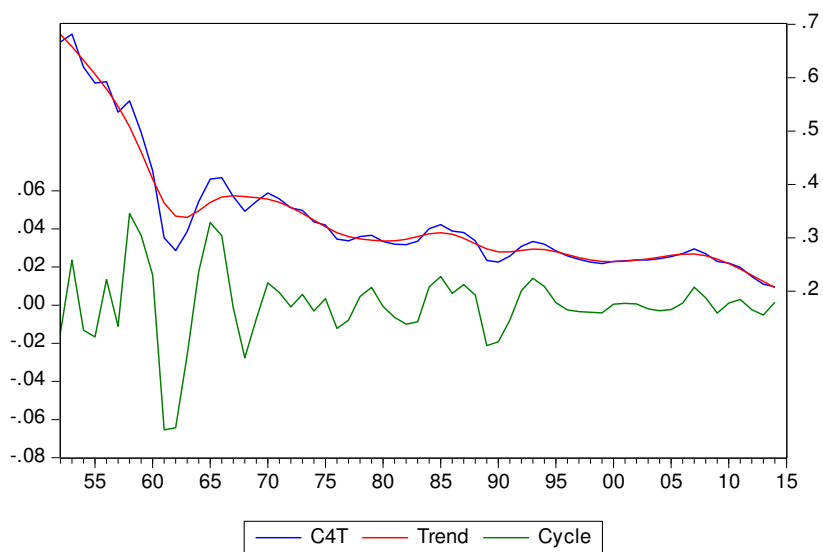
Hodrick-Prescott Filter (lambda=6.25)



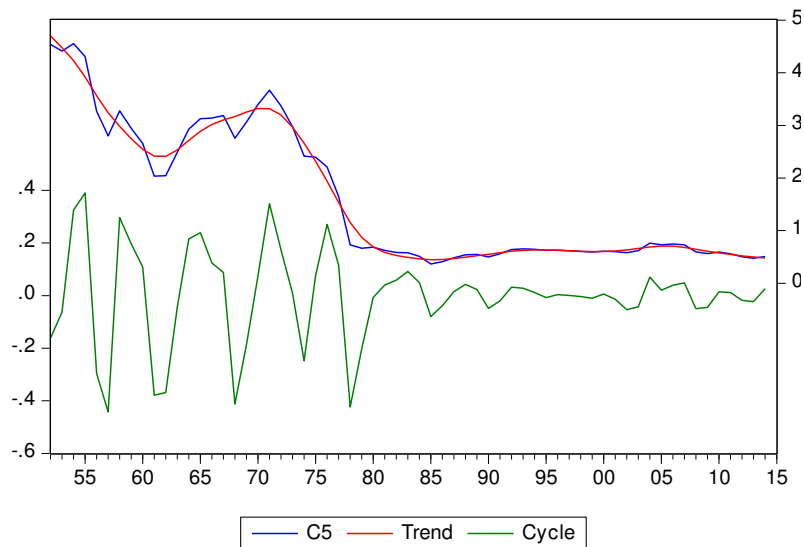
Hodrick-Prescott Filter (lambda=6.25)



Hodrick-Prescott Filter (lambda=6.25)



Hodrick-Prescott Filter (lambda=6.25)



## 9.6 Conclusions

In this Chapter, we have first calculated 4 different total profit rates of all economic sectors over 1952-2014 from reviewed Marxist point of view. The profit rates have a long-run decline trend and present cyclical fluctuations. We then use the structural vector autoregressive models (SVARs) to analyze China's economic structure. We examined the influences of profit rates on several key economic variables such as investment growth, capital accumulation and economic growth by impulse responses functions. The short-run *a priori* restriction assumptions are difficult to valid and the long-run restrictions are valid only in the subsample 1993-2014. Bayesian approaches fails to improve the estimation. The key identifiable condition for full sample model is whether C24 equals zero. But this condition is ambiguous. This implies that if Chinese leaders observed economic crisis, they might subjectively increase the investment as an anti-crisis policy rather than letting the profit rate determinate whether we investment more or less. This is also one of the most important characteristics of China's economy: very powerful governmental intervention for anti-crisis. We have used the full sample and subsample models to predict the values of some economic variables of 2015. We predict that the profit rate will continue to fall even it is already rather low (5% in 2014). If the profit rate continues to fall, the Marxists might argue that there will be a crisis in the future however it is consistent with the facts that there is a financial crisis in the stock market in the year 2015/2016. On the other hand, the forecast for economic growth is also very successful. The initial data published by NBS is that the GDP growth rate of 2015 is 6.9% in constant price. While the full sample model forecasts that the GDP growth rate in 2015 will be 6.6% in constant price. The prevision results of full sample also suggest that the financial crisis 2015 in China might be endogenous and might be caused by accumulated factors in long-run. In a word, we have provided an economic model with good capacity in one step ahead out-of-sample forecasting. In addition, we have also extended the economic decomposition of profit rates of Chapter 8. We proposed three different decompositions and then apply filter to those components. The economic cycles and crises in chapter 8 have been confirmed by the economic indicators of all economic sectors with a reviewed Marxist point of view.

## Chapter 10 Conclusions and Future Researches

From this thesis, the author perceived that in analyzing China's economy, researchers face two difficulties: the first difficulty is the particularity of China that is also classified as "socialism with Chinese characteristics," which includes the unique cultural background and language, nature of the economy, lack of data, and frequent institutional changes. The second difficulty is the insufficiency of modern economic growth models suffered from by researchers, such as the criticism of Romer (2015), who stated that "For the last two decades, growth theory has made no scientific progress toward a consensus." In addition, researchers also suffer from the general econometric problem for macroeconomic modeling, for example, the small sample problem, weak identification, and sensible estimation for the stationarity of series and truncate parameters.

Faced with so many difficulties, the author tries to find the possible solutions. In Chapter 2, the author followed Nelson and Kang (1981, 1984) and provided a mathematical proof to show that OLS estimators of detrending method with a linear trend in difference-stationary processes are spurious. The OLS estimator of the trend converges toward zero in probability, and the other OLS estimator is divergent when the sample size tends to infinity. The demonstration is realized by Chebyshev's inequality. However, the author also pointed out that if disturbance term is a martingale difference sequence, then conclusions are still held using the law of large numbers for  $L^1$ -Mixingale sequence proposed by Andrews (1988). That is, spurious regression exists in a broader sense in reality. The author then designs a statistical series through Monte Carlo simulation to verify it, with a sample size of a million points as an approximation of infinity. The seed values used correspond to the true random numbers generated by a hardware random number generator to avoid the pseudo-randomness of random numbers given by software. The author repeats such an experiment 100 times and obtains results consistent with the mathematical proof provided. The author then provides a justification to use the first difference of log in the economic growth models in Chapter 5.

Chinese policymakers contribute the rapid economic growth to the success of the foundation of "socialism with Chinese characteristics." For instance, Hu Jintao's report at the 17th Party Congress (2007) has the following assertion: "To sum up, the fundamental reason behind all our achievements and progress since the reform and opening up policy was introduced is that we have blazed a path of socialism with Chinese characteristics and established a system of theories of socialism with Chinese characteristics." The most important point of "Chinese characteristics" is that this economy is not a "pure" market economic system. Many hypotheses of sophisticated economic growth models are not valid in China. Consequently, those models cannot be tested. In fact, for this point, Chinese economists and their foreign colleagues have difficulty in fully communicating with each other.

Consequently, this thesis has only tested a relatively reliable and simple production function within the neoclassic and endogenous framework. Even if we have not included the theoretical criticism of such models, the insufficiency of mainstream economic growth theory becomes evident when we attempt to explain China's economic growth. For example, heteroscedasticity suggests that we have to pay attention to the economic cycles and even crises.

The frequent institutional changes cause heteroscedasticity problems and bring difficulty when attempting to introduce dummy variables for those changes. Having excessive dummies will cause a multicollinearity problem. Sometimes, qualitative descriptions must be used for

the institutional analysis. Inspired from the outlier tests and scan method in ridge regression, the author proposed a method in Chapter 5 to design a compressed dummy variable for the quantitative analysis in this case.

Another important institutional change is the transition from the Chinese accounting system established according to balances in the MPS to the implementation of the SNA. This change has made comparisons involving both chronological and transversal series risky. Such a transition occurred in a considerably late time. Thus, to date, no official Chinese statistics relating to physical capital stocks and human capital stock have been made.

This lack of data hinders econometric studies of growth in this country. A series of such stocks are proposed in the literature, but most available empirical work on this topic suffers from multiple deficiencies. Chapter 3 has built the most reliable and longest possible statistical series of capital stocks for China. The initial capital stocks are calculated by an iteration procedure. The investment flows are consistent with the perimeters of the initial stocks. The investment price indices are strictly tailored to the content of these stocks, and the unit root tests show that all the indices are non-stationary and integrated to the order of 2, which means that they cannot be substitutes, as supposed in many other studies. The depreciation rates are estimated by type of capital, under assumptions consistent with age efficiency and retirement. Investment shares are used to approximate an overall capital structure and to calculate the total depreciation rate. Built from 1952 to 2014, the original series are available to econometricians seeking to conduct new long-term empirical studies on China.

As regards human capital, Chapter 4 has distinguished the difference between total human capital and productive human capital in employed persons. The author has considered the influences of education reforms in the 1950s and Cultural Revolution on the human capital level. By comparing the new statistical database with those in the existing literature, the author feels confident in suggesting that the original estimates of human capital stocks, which the author offers, are substantially more reliable than the series provided by PTW. The stocks are improving in terms of quality, frequency, and/or length, compared with those of Cai and Du (2003) or Barro and Lee (2012), although remaining relatively close to the latter. The author also has proposed a new human capital indicator with the method of Kendrick (1976) as an effort to avoid the limitation of “educational attainment” of Barro–Lee framework.

Supported by new statistical series of physical capital stocks and of human capital, Chapter 5 attempts to improve the explanation of China’s long-term economic growth and offers econometric estimates performed within the framework of a broad range of theoretical models, going from standard specifications to more sophisticated endogenous models with *R&D* indicators. Finally, this chapter finds that productive physical capital and human capital stocks, *R&D*, and institutional changes positively and significantly contribute to the Chinese GDP growth. However, the TFP is nonsignificant to economic growth.

However, the persistence of a heteroscedasticity problem at the end of this work, in several tests, suggests the need to further analyze the issue of the possible cycles in the growth trajectory of the Chinese economy, thus opening up new research perspectives.

Before doing this, Chapter 6 builds a capital stock à la Piketty for China over 1952–2012 and estimates elasticities associated with it through specifications also integrating human capital, *R&D*, and institutional change. This chapter calculates an implicit rate of return of this capital to test the validity of what Piketty states as a “fundamental inequality,” comparing the rate of

return on capital and the income growth rate in the long run. Piketty's "law" then connects the coefficient of capital with the ratio between savings rate and income growth rate. These results are compared with estimates in 1978–2012, i.e., the sub-period of "capitalism with Chinese characteristics." While our empirical estimates of the verification of what the author of *Capital in the Twenty-First Century* states as "fundamental laws" in the long run lead to mixed results in 1952–2012, those performed for the sub-sample from 1978 to 2012, which numerous economists or social scientists called "capitalism with Chinese characteristics," tend to validate them. Nevertheless, this conclusion can be put forward only with the reservations the author has thought necessary to highlight above. The latter concern, that is, the broad definition of "capital" proposed by Piketty, a definition questionable in itself and hardly compatible with his own theoretical framework, refers to a production function, but with "capital" input that was not constructed as a strictly "productive" factor. Our nuances also deal with the fragility of the econometric test results that support the existence of cointegration relationships between the series of coefficient of capital and of the ratio of the savings rate/income growth rate, in the long run.

The author finally chooses to move the methodological reflection toward clearer heterodox perspectives, by introducing a profit rate indicator, to enrich the study of China's economic growth in Chapter 7. Chapter 7 has calculated a profit rate associated with productive capital stock with inventories. By observing the changes in this variable over the past six decades, the author realizes that China's economic growth trajectory—exceptional for its force and its scale—did not operate smoothly or without difficulties.

Those fluctuations imply the potential economic cycles and crises. To filter those cycles, the author also suggests the need for an "exit" from the usual framework of the time domain and turning to the spectral analysis and filter analysis in an econometric perspective. This preliminary and explorative work provides several interesting results.

Chapter 8 concentrated in the profit rate of industrial sectors, that is, a traditional Marxist analytical view. Based on various originally constructed statistical series of stocks of productive physical capital and of enterprises' fixed assets, and on a rigorous definition of the scope of the industrial sector, the author calculated several indicators of profit rates at the micro- and macroeconomic levels for China from 1952 to 2014. The results obtained by these two methods (micro and macro) are similar and can be summarized as follows: 1) A tendency of the profit rate to fall is observed over the long period, for the two levels of analysis. 2) At the macro level, the short-term fluctuations in the profit rates show a succession of (rarely complete) cycles whose amplitude decreases with time. 3) More than a third of the period is affected by recessive years for the cyclical component of the profit rates. The largest declines are recorded, in descending order, after the separation between China and the Soviet Union (1961–1963), during the Cultural Revolution (1968), in the course of the 1950s, during the post-Mao transition (1976–1977), when a neoliberal experiment has been tempted (1989–1991), and with the spread of the globalization crises (which affected China in 1998, 2001, 2009, and 2012). 4) The increasing organic composition of capital tendentially pushes down the macro rate of profit.

However, the industrial profit rates calculated in Chapter 8 are insufficient to analyze the economic cycles of all economic sectors in China. As the author has highlighted, the total profit rate of all economic sectors should be calculated to identify the economic cycles and potential crises as the cycles and crises will affect not only industries, but all economic sectors. Chapter 9 then deepens the analysis of Chapter 8 from a reviewed Marxist perspective.

Chapter 9 first calculated four different total profit rates of all economic sectors over 1952–2014. The author then uses the SVARs to analyze China's economic structure. The author examined the influences of profit rates on several key economic variables, such as investment growth, capital accumulation, and economic growth by impulse response functions. Based on *a priori* restrictions hypotheses, through two different approaches of short-run and long-run restrictions, the author has tested those *a priori* economic structures under the background of market economy. Contrary to the dichotomy suggested by the spectral analysis in Chapter 8, the tests show that the economic trajectory of PRC should at least be distinguished into three different periods: 1) 1952–1977 (Soviet-style planned economy period), 2) 1978–1992 (period of planned economy with Chinese characteristics), and 3) 1993–present (period of market economy with Chinese characteristics). After the fiscal reform in 1993, China has been gradually and deeply integrated into the world economy, leading to a further decline in economic volatility grace to external market. Considering the background of China's integration into the world economy, China's economic fluctuations and crisis gradually present characteristics of imported crisis.

Our econometric empirical tests show that the short-run *a priori* restriction assumptions are difficult to validate, and the long-run restrictions are valid only in the subsample over 1993–2014. Bayesian approaches fail to improve the estimation. The key identifiable condition is ambiguous, which implies that if Chinese leaders observed economic crisis, then they might subjectively increase the investment as an anti-crisis policy rather than let the profit rate determine whether the investment should be more or less. This implication is also one of the most important characteristics of China's economy: highly powerful governmental intervention for anti-crisis.

The author has used the full sample and sub-sample models to predict the values of some economic variables of 2015. The author predicts that the profit rate will continue to fall even if it is already low (5% in 2014). If the profit rate continues to fall, then the Marxists might argue that a crisis will occur in the future. However, this argument is consistent with the facts that a financial crisis in the stock market will happen in 2015 or 2016. The forecast for economic growth is also highly successful. The initial data published by NBS is that the GDP growth rate of 2015 is 6.9% in constant price. While the full sample model forecasts that the GDP growth rate in 2015 will be 6.6% in constant price, the prevision results of full sample also suggest that the financial crisis in 2015 in China might be endogenous and might be caused by accumulated factors in the long run. Essentially, the author has provided an economic model with good capacity, which is one step ahead of out-of-sample forecasting. In addition, the author has also extended the economic decomposition of profit rates of Chapter 8. The author proposed three different decompositions and then applied filter to those components. The economic cycles and crises presented in Chapter 8 have been confirmed by the economic indicators of all economic sectors with a reviewed Marxist perspective.

This thesis remains a preliminary and explorative work in studying China's economic growth trajectory and its institutional transition. Many promising research works are left to be done. For example, the crises in the beginning years seem to be caused by political variations. After the opening-up reform, the economic fluctuations and crises seem to be increasingly associated with the world economy's fluctuations. However, for the recent crisis, the behaviors of profit rate indicate that the crises and cycles are caused more by endogenous problems. The mechanism of such an endogeneity is an interesting topic. Moreover, how did each crisis emerge? What was the anti-crisis policy that the Chinese government carried out for those crises? What lesson can we learn from the cost of those policies of anti-crisis? The

discussion about the inequality of China is another important topic even though that might displease the Chinese government. And for example, the iteration procedure of initial capital in Chapter 3 is based on an assumption of ergodicity. Although the author has an idea about the ergodicity test, the efficient and power of this test should be simulated. The analysis from an open macroeconomy might be a promising way to explain China's economic growth. For example, the misalignment between real exchange rate and equilibrium exchange rate seems to play an important role in China's macroeconomy. In Chapter 9, the SVAR used to analyze the economic structure is a model with small number of variables. The real economic system should be more complicated than the current one. Although the large-scale macro-econometric models are critiqued by Lucas (1976) and their out-of-sample forecasting is not better than the small model (Nelson, 1972; Ashley, 1988), the dynamic factor models seem to provide an alternative method that makes use of available information. In addition, although the Bayesian approaches did not ameliorate the estimation in the work of this thesis, recent work by Chang, Chen, Waggoner, and Zha (2016) indicates that Bayesian analysis has a promising application if we can find a good prior.



## References:

- Acemoglu, D., Johnson, S., & Robinson, J. A. (2005), Institutions as a fundamental cause of long-run growth, *Handbook of economic growth*, 1, 385-472.
- Aglietta, M., and G. Bai (2012), *La Voie chinoise : capitalisme et empire*, Paris: Odile Jacob.
- Amisano, G., & Giannini, C. (1997), Identification analysis and FIML estimation for the AB-Model, In *Topics in Structural VAR Econometrics* (pp. 48-59), Springer Berlin Heidelberg.
- Andreani, T., and R. Herrera (2013), “Système financier et socialisme de marché ‘à la chinoise’,” *La Pensée*, n° 373, p. 65-76 (published in *Chinese in Marxism and Reality* [Beijing], n° 2-2013, p. 22-28).
- Andreani, T., and R. Herrera (2015), “Which Economic Model for China?,” *International Critical Thought – A Journal of the China’s Academy of Social Sciences*, n° 21, p. 163-183.
- Andreani, T. and R. Herrera (2014), “Quel Modèle économique pour la Chine ? Analyse critique sur La Voie chinoise de Michel Aglietta et Guo Bai”, *Marché & Organisations*, 21, 163-183.
- Andrews, D. W. (1988), Laws of large numbers for dependent non-identically distributed random variables, *Econometric theory*, 4(03), 458-467.
- Ansley, C.F., and R. Kohn (1985), “Estimation, Filtering, and Smoothing in State Space Models with Incompletely Specified Initial Conditions,” *The Annals of Statistics*, vol. 13, n° 4, p. 1286-1316.
- Atkinson, A.B., T. Piketty and E. Saez (2011), “Top Incomes in the Long Run of History”, in Atkinson A.B. and T. Piketty (eds.), *Top Incomes: A Global Perspective*, p. 664-759, New York: Oxford University Press.
- Bai, E.-C., C.-T. Hsieh and Y. Qian (2006), “The Return to Capital in China,” *NBER Working Paper*, n° 12755, Cambridge, MA.
- Bai, P., (2012), Human Capital Estimating in China and Its Provinces, *Journal of Xiamen University (Arts & Social Sciences)*, 4 (2012): 82-89. (in Chinese: 柏培文. (2012). 全国及省际人力资本水平存量估算. *厦门大学学报: 哲学社会科学版*, (4), 82-89.)
- Barro, R.J., and J.W. Lee (1993), “International Comparisons of Educational Attainment,” *Journal of Monetary Economics*, vol. 32, n° 3, p. 363-394.
- Barro, R.J., and J.W. Lee (2012), *Educational attainment dataset*. Available online: <http://www.barrolee.com/>
- Baumol, W. J., Litan, R. E., & Schramm, C. J. (2007), *Good Capitalism, Bad Capitalism, and the Economics of Growth and Prosperity*, Yale University Press.
- Baxter, M., and R.G. King (1995), “Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series,” *NBER Working Paper Series*, n° 5022, Cambridge MA.
- Belsley D.A., E. Kuh and R.E. Welsch (1980), *Regression Diagnostics – Identifying Influential Data and Sources of Collinearity*, New York: Wiley Series in *Probability and Mathematical Statistics*.

Beveridge S. and C.R. Nelson (1981), "A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the 'Business Cycle'," *Journal of Monetary Economics*, vol. 7, n° 2, p. 151-174.

Blanchard, O., & Quah, D. (1988). *The Dynamic Effects of Aggregate Demand and Supply Disturbances* (No. 2737). National Bureau of Economic Research, Inc.

Blanchard, O. J., Diamond, P., Hall, R. E., & Yellen, J. (1989). The beveridge curve. *Brookings papers on economic activity*, 1989(1), 1-76.

Blanchard, O. J., Diamond, P., Hall, R. E., & Murphy, K. (1990). The cyclical behavior of the gross flows of US workers. *Brookings Papers on Economic Activity*, 1990(2), 85-155.

Bourguignon F. (1979), "Decomposable Income Inequality Measures", *Econometrica*, vol. 47, n° 4, pp. 901-920.

Box, G. E. P., & Jenkins, G. M. (1970). *Time series analysis: forecasting and control*, 1976. ISBN: 0-8162-1104-3.

Box, G. E., & Draper, N. R. (1987). *Empirical model-building and response surfaces* (Vol. 424). New York: Wiley.

Box, G. E., & Jenkins, G. M. (1976). *Time series analysis: forecasting and control*, revised ed. Holden-Day.

Cai F. and Y. Du (2003), "Destructive Effects of Cultural Revolution on Physical and Human Capital", *China Economic Quarterly*, vol. 2, n° 4, p. 795-806 (in Chinese: 蔡昉, & 都阳. (2003). "文化大革命"对物质资本和人力资本的破坏. *经济学*, 2(4), 795-806.)

Cai, F., et al. (1999) China 's Economic Growth: Labor Force, Human Capital and Employment Structure. Chapter of "*Sustainability of China 's Economic Growth: Review and Prospect in the New Century*" *Economic Science Press*. (in Chinese: 蔡昉, 王德文, 王小鲁, & 樊纲. (1999). 中国经济增长: 劳动力, 人力资本和就业结构. 载王小鲁, 樊纲: 《中国经济增长的可持续性: 跨世纪的回顾与展望》, 经济科学出版社.)

Caselli, F. (2005). Accounting for cross-country income differences. *Handbook of economic growth*, 1, 679-741.

Chan, K. H., Hayya, J. C., & Ord, J. K. (1977). A note on trend removal methods: the case of polynomial regression versus variate differencing. *Econometrica: Journal of the Econometric Society*, 737-744.

Chang, C., Chen, K., Waggoner, D. F., & Zha, T. (2016). Trends and cycles in China's macroeconomy. *NBER Macroeconomics Annual*, 30(1), 1-84.

Chatfield, C. (1979). Inverse autocorrelations. *Journal of the Royal Statistical Society. Series A (General)*, 363-377.

Chebyshev, P. L. (1867). On mean values. *J. Math. Pures Appl*, 12, 177-184.

Chen K., H. Wang, Y. Zheng, G.H. Jefferson and T.G. Rawski (1988), "Productivity Change in Chinese Industry: 1953-1985", *Journal of Comparative Economics*, vol. 12, n° 4, pp. 570-591.

Chen, Y., (2007) China's Overall Gini Coefficient since Reform and Its Decomposition by Rural and Urban Areas since Reform and Opening up. *Social Sciences in China*, 4, 45-60. (in Chinese: 程永宏. (2007). 改革以来全国总体基尼系数的演变及其城乡分解 Ⅲ. *中国社会科学*, (4).)

Chinese Service Center for Scholarly Exchange (Various years), *Chinese Returned Overseas Students Employment Blue Book*. People's Education Press. (title in Chinese: *中国留学回国就业蓝皮书*)

Chotikapanich, D., Rao, D. S., & Tang, K. K. (2007). Estimating income inequality in China using grouped data and the generalized beta distribution. *Review of Income and Wealth*, 53(1), 127-147.

Chow, G. C. (1993). Capital formation and economic growth in China. *The Quarterly Journal of Economics*, 108(3), 809-842.

Chow, G. C., & Li, K. W. (2002). China's economic growth: 1952–2010. *Economic Development and Cultural Change*, 51(1), 247-256.

Christiano L.J. and T.J. Fitzgerald (1999), "The Band Pass Filter," *NBER Working Paper Series*, n° 7257, Cambridge MA.

Clark P.K. (1987), "The Cyclical Component of U.S. Economic Activity," *Quarterly Journal of Economics*, vol. 102, n° 4, p. 797-814.

Clark, P. B., & MacDonald, R. (1997). What Determines Real Exchange Rates? The Long and Short of It. *IMF Work-ing Paper N*.

Clark, P. B., & MacDonald, R. (1999). Exchange rates and economic fundamentals: a methodological comparison of BEERs and FEERs. In *Equilibrium exchange rates* (pp. 285-322). Springer Netherlands.

Cleveland, W. S. (1972). The inverse autocorrelations of a time series and their applications. *Technometrics*, 14(2), 277-293.

Cui, Y. (1999), A Review on the Estimation methods of Contribution Rate of Education to Economic Growth, *Research On Education Tsinghua University*,(01):74-81. (in Chinese: 崔玉平. (1999). 教育对经济增长贡献率的估算方法综述. *清华大学教育研究*,20(1), 71-78.)

Darné, O. (2009). The uncertain unit root in real GNP: A re-examination. *Journal of Macroeconomics*, 31(1), 153-166.

Davidson, R., & MacKinnon, J. (1993). *Estimation and Inference in Econometrics*. Oxford University Press.

De Jong P. and J. Penzer (1998), "Diagnosing Shocks in Time Series," *Journal of the American Statistical Association*, vol. 93, n° 442, p. 796-806.

DeJong D.N., J.C. Nankervis, N.E. Savin and C.H. Whiteman (1992), "The Power Problems of Unit Root Test in Time Series with Autoregressive Errors," *Journal of Econometrics*, vol. 53, n° 1-3, p. 323-343.

DeLong J.B. and L.H. Summers (1991), "Equipment Investment and Economic Growth," *Quarterly Journal of Economics*, vol. 106, n° 2, p. 445-502.

Deng, Xiaoping. "Main points of speeches made in Wuchang, Shengzhen, Zhuhai and Shanghai." *Selected works of Deng Xiaoping* 3 (1994): 370-383.

- Deng, Xiaoping. "Selected Works Volume III (1982–1992)." Beijing: Foreign Languages Press, 1994.
- Deng, Xiaoping. "There is no fundamental contradiction between socialism and a market economy." *Collections of Deng Xiaoping's articles* (1985): 148-151.
- Deng, Xiaoping. "We Can Develop a Market Economy under Socialism, interview with Frank B." Gibney, Nov 26 (1979).
- Deng, Xiaoping. *Selected Works of Deng Xiaoping, 1975-1982*. Vol. 2. China Books & Periodicals, 1984.
- Department of Comprehensive statistics of NBS (1999). *Comprehensive Statistical Data and Materials on 50 Years of New China 1949-1998*. China Statistics Press, Beijing (title in Chinese: 新中国50年统计资料汇编)
- Department of Comprehensive statistics of NBS (2005). *Comprehensive Statistical Data and Materials on 55 Years of New China 1949-2004*. China Statistics Press, Beijing (title in Chinese: 新中国五十五年统计资料汇编).
- Department of Comprehensive statistics of NBS (2010). *China Compendium of Statistics 1949-2008*. China Statistics Press, Beijing (title in Chinese: 新中国六十年统计资料汇编)
- Department of Population and Employment Statistics of NBS (Various years), *China Population and Employment Statistics Yearbook*, China Statistics Press, Beijing (title in Chinese: 中国人口和就业统计年鉴)
- Department of Population and Employment Statistics of NBS (Various years), *China Population Statistics Yearbook*. China Statistics Press, Beijing (title in Chinese: 中国人口统计年鉴)
- Department of Population Statistics of NBS and the Third Department of Ministry of Public Security (1988), *China Population Statistics Collection 1949-1985*, Chinese Financial & Economic Publishing House (title in Chinese: 中华人民共和国人口统计资料汇编 1949-1985)
- Department of Science and Technology Statistics of NBS.(1989). *Statistics on Science and Technology of China 1949-1989*. China Statistics Press, Beijing (title in Chinese: 中国科学技术四十年)
- Department of Social Statistics of NBS (1986), *China labor and wage statistics 1952-1985*, China Statistics Press, Beijing (title in Chinese: 中国劳动工资统计资料 1952-1985)
- DeSA, U. N. (2015). *World population prospects: the 2015 revision*. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, New York.
- Dessus S. and R. Herrera (2000), "Public Capital and Growth: A Panel Data Assessment," *Economic Development and Cultural Change*, vol. 48, n° 2, pp. 407-418.
- Dickey D.A. and W.A. Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, vol. 74, n° 366, p. 427-431.
- Ding S. and J. Knight (2009), "Can the Augmented Solow Model Explain China's Remarkable Economic Growth? A Cross-Country Panel Data Analysis," *Journal of Comparative Economics*, vol. 37, n° 3, p. 432-452.
- Editorial department of China Education Yearbook (1984), *China Education Yearbook 1949-1981*, Encyclopedia of China Publishing House. (title in Chinese: 中国教育年鉴 1949-1981)

Editorial department of China Education Yearbook (1985), *China Education Yearbook 1982-1984*, Encyclopedia of China Publishing House. (title in Chinese: 中国教育年鉴1982-1984)

Elliott G., T.J. Rothenberg and J.H. Stock (1996), "Efficient Tests for an Autoregressive Unit Root," *Econometrica*, vol. 64, n° 4, p. 813-836.

Engle, R. F., & Granger, C. W. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica: journal of the Econometric Society*, 251-276.

Farrugia, C. A. (Various years). *Open Doors* (Various years): Report on International Educational Exchange. Inst of International Education.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *The American Economic Review*, 105(10), 3150-3182.

Feuerwerker A. (1977), *Economic Trends in the Republic of China: 1912-1949*, Michigan Papers in Chinese Studies, Ann Arbor.

Findley D.F., B.C. Monsell, W.R. Bell, M.C. Otto and B.-C. Chen (1998), "New Capabilities and Methods of the X-12-ARIMA Seasonal-Adjustment Program," *Journal of Business and Economic Statistics*, vol. 16, n° 2, p. 27-152.

Fine B. (2000), "Endogenous Growth Theory: A Critical Assessment," *Cambridge Journal of Economics*, vol. 24, n° 2, p. 245-265.

Fischer, H. (2010). *A history of the central limit theorem: From classical to modern probability theory*. Springer Science & Business Media.

Fraumeni, B. (1997). The measurement of depreciation in the US national income and product accounts. *SURVEY OF CURRENT BUSINESS-UNITED STATES DEPARTMENT OF COMMERCE*, 77, 7-23. Available on: [https://www.bea.gov/scb/account\\_articles/national/0797fr/maintext.htm](https://www.bea.gov/scb/account_articles/national/0797fr/maintext.htm).

Fuller, Wayne A., 1976, *Introduction to Statistical Time Series*, New York: John Wiley and Sons.

GIANNINI, C. (1992): *Topics in Structural VAR Econometrics*. Springer-Verlag, New York, NY

Goldsmith R.W. (1951), "A Perpetual Inventory of National Wealth," Conference on Research in Income and Wealth, Studies in Income and Wealth, National Bureau of Economic Research, vol. 14, p. 5-73.

Government Administration Council of the Central People's Government of the P.R.C. (1951). *Decision on Reform of Educational System*. People's Daily. Available online: <http://cpc.people.com.cn/GB/64184/64186/66656/4492689.html>

Government Administration Council of the Central People's Government of the P.R.C. (1953). *Labor Insurance Regulations of the People's Republic of China*. (title in Chinese: 中华人民共和国劳动保险条例). Available online: [http://www.mohrss.gov.cn/gkml/xxgk/201308/t20130808\\_109736.html](http://www.mohrss.gov.cn/gkml/xxgk/201308/t20130808_109736.html)

Government of India (various years), First Five-Year Plan (1951-56), *India's Five Year Plans Complete Documents*, Planning Commission, New Delhi.

Granger, C. W., & Newbold, P. (1974). Spurious regressions in econometrics. *Journal of econometrics*, 2(2), 111-120.

Green T. (1999), *Central Bank Gold Reserves: an Historical Perspective Since 1845*, London: World Gold Council.

Gu S. and B.-Å. Lundvall (2006), “China’s Innovation System and the Move Towards Harmonious Growth and Endogenous Innovation,” *Innovation, Management, Policy and Practice*, vol. 8, n° 1-2, p. 1-26.

Guo Q. and J. Jia (2005), “Estimating Total Factor Productivity in China”, *Economic Research Journal*, n° 6, pp. 51-60. (in Chinese: 郭庆旺, & 贾俊雪. (2005). 中国全要素生产率的估算: 1979—2004. *经济研究*,6(5), 1-60.)

Haight A.D. (2015), “Piketty’s Paradox: A Comparison to the Keynesian Paradox of Thrift”, *Journal of Post Keynesian Economics*, vol. 37, n° 4, pp. 533-544.

Hamilton, J. D. (1994). *Time series analysis*. Princeton: Princeton university press.

Han, X. (2015), *History of Chinese Patent*, Intellectual Property Publishing House. (title in Chinese: 专利史话)

Han, Z. (1990) An Analysis of the Economic Benefits of Educational Investment in China, *Educational Research*, 1: 23-33. (in Chinese: 韩宗礼. (1990). 我国教育投资的经济效益探析. *教育研究*, (1), 23-33.)

Hao F. (2006), “Estimates of Provincial Capital Stock in China: 1952-2004,” *Journal of Data Analysis*, vol. 6, n° 1, p. 6-13. (in Chinese: 郝枫. (2006). 中国省区资本存量估算: 1952-2004. *Journal of Data Analysis*,1(6), 11-29.)

Harberger A. (1978), “Perspectives on Capital and Technology in Less-Developed Countries”, in Artis L.J. and A.R. Nobay (eds.), *Contemporary Economic Analysis*, London: Croom Helm.

Harvey, A. C. (1985). Trends and cycles in macroeconomic time series. *Journal of Business & Economic Statistics*, 3(3), 216-227.

He F., R. Chen and L. He (2003), “The Estimation and Correlation Analysis on Our Country’s Cumulative Amount of Capital,” *Economist*, n° 5, p. 29-35 (in Chinese: 何枫, 陈荣 & 何林, “我国资本存量的估算及其相关分析”, *经济学家*).

He J.H. (1992), “Estimation of Assets in China,” *Journal of Quantitative and Technical Economics*, n° 8, p. 24-27 (in Chinese: 贺菊煌, “我国资产的估算”, *数量经济技术经济研究*).

Herrera R. (1998), “Dépenses publiques d’éducation et capital humain dans un modèle convexe de croissance endogène,” (Educational Public Expenditure and Human Capital in a Convex Model of Endogenous Growth), *Revue économique*, vol. 49, n° 3, p. 831-844.

Herrera, R. (2014), “A Marxist Interpretation of the Current Crisis,” *World Review of Political Economy – Journal of the World Association for Political Economy*, vol. 5, n° 2, p. 128-148.

Herrera, R. (2000), “Por uma critica da nova teorianeoclasica do crescimento”, *Revista da Sociedade Brasileira de Economia Politica*, 7, 55-73.

Herrera, R. (2006), “The Hidden Face of Endogenous Growth Theory”, *Review of Radical Political Economics*, 38(2), 243-257.

Herrera, R. (2011), “A Critique of Mainstream Growth Theory: Ways out of the Neoclassical Science(-Fiction) and Towards Marxism,” *Research in Political Economy*, vol. 27, n° 1, pp. 3-64.

- Hodrick R. and E.C. Prescott (1981), “*Postwar U.S. Business Cycles: An Empirical Investigation*,” Carnegie Mellon University Discussion Paper, n° 451 ([1997], *Journal of Money, Credit, and Banking*).
- Holz C.A. (2006), “New Capital Estimates for China,” *China Economic Review*, vol. 17, n° 2, p. 142-185.
- Hosking, J. R. (1981). Fractional differencing. *Biometrika*, 165-176.
- Hu Z.F. and M.S. Khan (1997), “Why is China Growing so Fast?,” *International Monetary Fund Staff Papers*, vol. 44, n° 1, p. 103-131.
- Hu, J. (2007). *Report at the 17th national congress of the communist party of China*. Beijing: National Congress of the Communist Party of China.
- Hu, Z., (2012). Estimation for Gini Coefficients Based on Grouped Data and the Social Welfare: 1985-2009. *The Journal of Quantitative & Technical Economics*. 9, 111-121. (in Chinese: 胡志军. (2012). 基于分组数据的基尼系数估计与社会福利: 1985~2009 年 ①. *数量经济技术经济研究*, (9).)
- Huang Y., R.E. Ren and X. Liu (2002), “Capital Stock Estimates in Chinese Manufacturing by Perpetual Inventory Approach,” *China Economic Quarterly*, vol. 1, n° 2, p. 377-396 (in Chinese: 黄勇峰 & 任若恩, “中国制造业资本存量永续盘存法估计”, *经济学 (季刊)*).
- Huang, Y. (2008). *Capitalism with Chinese characteristics: Entrepreneurship and the state*. Cambridge University Press.
- Hulten C.R. and F.C. Wycoff (1995), “Issues in the Measurement of Economic Depreciation,” *Economic Inquiry*, vol. 24, n° 1, p. 31-40.
- Hulten, C. R., Robertson, J. W., & Wykoff, F. (1987). *Energy, obsolescence, and the productivity slowdown*.
- Inklaar, R., & Timmer, M. (2013). Capital, Labor and TFP in PWT8.0. University of Groningen (unpublished).
- Jefferson G.H. (1990), “China’s Iron and Steel Industry: Sources of Enterprise Efficiency and the Impact of Reform”, *Journal of Development Economics*, vol. 33, n° 2, pp. 329-355.
- Jefferson G.H., T.G. Rawski and Y. Zhang (2008), “Productivity Growth and Convergence Across China’s Industrial Economy”, *Journal of Chinese Economic and Business Studies*, vol. 6, n° 2, pp. 121-140.
- Jefferson G.H., T.G. Rawski and Y. Zheng (1996), “Chinese Industrial Productivity: Trends, Measurement Issues, and Recent Developments,” *Journal of Comparative Economics*, vol. 23, n° 2, p. 146-180.
- Jiao, B., and Jiao, Z., Estimation of Human Capital in China: 1978-2007, *Economist*, 9.9 (2010): 27-33. (in Chinese: 焦斌龙, & 焦志明. (2010). 中国人力资本 存量估算: 1978—2007. *经济学家*, 9(9), 27-33.)
- Jiao, J. (1990). A Quantitative Analysis of the Economic Efficiency of Education in China, *Education & Economy*, 1: 18-21. (in Chinese: 焦季才. (1990). 关于我国教育经济效益的定量分析. *教育与经济*, (1), 18-21.)
- Jin G. (2012), “The Estimation of China’s Infrastructure Capital Stock,” *Economic Research Journal*, vol. 47, n° 4, p. 4-14 (in Chinese: 金戈, “中国基础设施资本存量估算”, *经济研究*).

- Johansen S. (1988), "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, vol. 12, n° 2, p. 231-254.
- Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: Journal of the Econometric Society*, 1551-1580.
- Jorgenson D. (1996), "Empirical Studies of Depreciation," *Economic Inquiry*, vol. 34, n° 1, p. 24-42.
- Jorgenson, D. W., & Fraumeni, B. M. (1989). *Investment in education. Educational Researcher*, 18(4), 35-44.
- Jorgenson, D. W., & Fraumeni, B. M. (1992). Investment in education and US economic growth. *The Scandinavian Journal of Economics*, S51-S70.
- Kadiyala, K. Rao, and Sune Karlsson. "Numerical methods for estimation and inference in Bayesian VAR-models." *Journal of Applied Econometrics* (1997): 99-132.
- Katz, A. J., & Herman, S. W. (1997). Improved estimates of fixed reproducible tangible wealth. *Survey of Current Business*, 77(5), 69-92.
- Kendrick, J. W. (1976). The Formation and Stocks of Total Capital. *National Bureau of Economic Research, Inc.*
- Knuth, D. E. (1997). *The Art of Computer Programming: Fundamental Algorithms*. Redwood City.
- Koop, G., & Korobilis, D. (2009). Manual to accompany MATLAB package for Bayesian VAR models. Retrieved, 10, 2012.
- Krugman, P. (2013), "The New Growth Fizzle", *New York Times*, August 18, available on: [http://krugman.blogs.nytimes.com/2013/08/18/the-new-growth-fizzle/?\\_r=1](http://krugman.blogs.nytimes.com/2013/08/18/the-new-growth-fizzle/?_r=1).
- Kwiatkowski, D., Phillips, P. C., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?. *Journal of econometrics*,54(1-3), 159-178.
- Lambert P.J. (1993), *The Distribution and Redistribution of Income – A Mathematical Analysis*, New York: Manchester University Press.
- Lardic S. and V. Mignon (2002), *Économétrie des séries temporelles macroéconomiques et financières*, Paris: Economica.
- Layard, R., & Psacharopoulos, G. (1974). The screening hypothesis and the returns to education. *Journal of political economy*, 82(5), 985-998.
- Li Z.G. and G.X. Tang (2003), "The Capital Formation and The Capital Adjustment Model During the China's Transition," *Economic Research Journal*, n° 2, p. 12-21 (in Chinese: 李治国 & 唐国兴, "资本形成路径与资本存量调整模型", *经济研究*).
- Li, H., Liang, Y., Fraumeni, B. M., Liu, Z., & Wang, X. (2013). Human capital in China, 1985–2008. *Review of Income and Wealth*, 59(2), 212-234.
- Li, Y., (2007). New theory of Gini Coefficients. *Economic Observer*. 5-8. (in Chinese: 厉以宁. (2007). 新基尼系数理论 [N]. *经济观察报*, 5-8.)



- Li, C., (2001), *A Study on the Difference of Human Capital and Economic Development in Different Regions of China*, Dissertation, Beijing, Tsinghua University School of Public Administration. (in Chinese: 李春波. (2001). 中国各地区人力资本与经济发展差距研究. 北京, 清华大学公共管理学院.)
- Li. S. (Income Distribution Team of Chinese Academy of Social Sciences) (2003). A Review of Income Inequality of China. *China Economic Quarterly*. 2(2), 379-403 (in Chinese: 李实. (2003). 中国个人收入分配研究回顾与展望. *经济学 (季刊)*, 2(2), 379-403.)
- Litterman, Robert B. "Forecasting with Bayesian vector autoregressions—five years of experience." *Journal of Business & Economic Statistics* 4.1 (1986): 25-38.
- Liu T.-C. and Yeh K.-C. (1965), *Economy of the Chinese Mainland: National Income and Economic Development: 1933-1959*, Princeton
- Liu, T. C., & Yeh, K. C. (1973). Chinese and other Asian economies: A quantitative evaluation. *The American Economic Review*, 63(2), 215-223.
- Long, Z., & Herrera, R. (2015a), "Construction de séries de stocks de capital humain pour l'économie chinoise", *mimeo*, UMR 8174 CNRS - Centre d'Économie de la Sorbonne (CES), October, Paris.
- Long, Z., & Herrera, R. (2015b), "Piketty in Beijing: The Laws of Capital in the Twenty-First Century Facing China," *mimeo*, UMR 8174 CNRS - Centre d'Économie de la Sorbonne (CES), December, Paris.
- Long, Z., & Herrera, R. (2016a), "Building Original Series of Physical Capital Stocks for China's Economy: Methodological Problems, Proposals of Solutions and a New Database," *China Economic Review*, vol. 40, n° 9, pp. 33-53.
- Long, Z., & Herrera, R. (2016b), "Spurious OLS Estimators of Detrending Method by Adding a Linear Trend in Difference Stationary Process: Mathematical Proof and Statistical Simulation," *mimeo*, CNRS – UMR 8174 Centre d'Économie de la Sorbonne at the University of Paris 1, June, Paris.
- Long, Z., & Herrera, R. (2017a), Una contribución a la explicación del crecimiento económico en China. Nuevas series temporales y pruebas econométricas de varios modelos. *Journal of Economics and Finance (Cuadernos de Economía*, in Spanish, Elsevier, London and Amsterdam) .
- Long, Z., & Herrera, R. (2017b), CAPITAL ACCUMULATION, PROFIT RATES AND CYCLES IN CHINA FROM 1952 TO 2014: LESSONS FROM THE EVOLUTION OF CHINESE INDUSTRY. *Journal of Innovation Economics & Management*. (Accepted paper, forthcoming).
- Long, Z., & Herrera, R. (2017c), "SOBRE O CRESCIMENTO ECONÔMICO CHINÊS NO LONGO PERÍODO: 1952-2014 Para uma passagem da análise da contribuição dos fatores até a da taxa de lucro" *Argumentum – Revista Brasileira da Universidade de Espírito Santo*, to be published in the first issue of 2017, Vitoria, Brazil.
- Lu. D., (1960). *Report of Education must be reformed* in the Second Session of the Second National People's Congress. (title in Chinese: 教育必须改革)
- Lütkepohl, Helmut. "Asymptotic distributions of impulse response functions and forecast error variance decompositions of vector autoregressive models." *The review of economics and statistics* (1990): 116-125.
- MacKinnon, J. G. (1991). Critical values for cointegration tests, Chapter 13 in *Long-Run Economic Relationships: Readings in Cointegration*, ed. RF Engle and CW J. Granger. Oxford, Oxford University Press

MacKinnon, J.G. (1996), "Numerical Distribution Functions for Unit Root and Cointegration Tests," *Journal of Applied Econometrics*, vol. 11, n° 6, p. 601-618.

Maddison A. (1995), *Monitoring the World Economy: 1820-1992*, OECD Development Centre, Paris.

Maddison, A. (1994). *Standardised estimates of fixed capital stock: a six country comparison*. Institute of Economic Research, Faculty of Economics, University of Groningen. on: [www.ggdc.net/publications/memorandum/gd9.pdf](http://www.ggdc.net/publications/memorandum/gd9.pdf).

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The quarterly journal of economics*, 107(2), 407-437.

Mao J. (2005), "Comparison and Refinement on the Studies of Estimating Capital Stock," *Henan Social Sciences*, n° 2, p. 75-78 (in Chinese: 毛军, "我国资本存量估算方法比较与重估", *河南社会科学*).

Marx, K. (1867). *Das Kapital: kritik der politischen ökonomie*. Verlag von Otto Meisner, Germany, 1885, 1894.

Ministry of Education of the People's Republic of China (Various years), *EDUCATIONAL STATISTICS YEARBOOK OF CHINA*, People's Education Press. (title in Chinese: *中国教育统计年鉴*)

Ministry of Education. (2011). *Compulsory Education Curriculum Standards 2011*. People's Education Press. (title in Chinese: 2011 年义务教育课程标准). Available online: <http://old.pep.com.cn/xiaoyu/jiaoshi/tbjx/kbjd/kb2011/>

Ministry of Finance - P.R. of China (various years), *Finance Yearbook of China*, Financial Magazine of China, Ministry of Finance of the People's Republic of China, Beijing (title in Chinese: *中国财政年鉴*).

Ministry of Finance - P.R. of China. (2006). *Enterprise Accounting Standards 2006*. (title in Chinese: 会计准则 2006) Available online: [http://www.mof.gov.cn/zhengwuxinxi/caizhengwengao/caizhengwengao2006/caizhengwengao2006/200805/t20080519\\_23593.html](http://www.mof.gov.cn/zhengwuxinxi/caizhengwengao/caizhengwengao2006/caizhengwengao2006/200805/t20080519_23593.html)

Montinola, G., Qian, Y., & Weingast, B. R. (1995). Federalism, Chinese style: the political basis for economic success in China. *World politics*, 48(01), 50-81.

Morley J. (2002), "A State-Space Approach to Calculating the Beveridge-Nelson Decomposition," *Economics Letters*, vol. 75, n° 1, p. 123-127.

Mulligan, C. B., & Sala-i-Martin, X. (1995). Measuring aggregate human capital (No. w5016). *National Bureau of Economic Research*.

National People's Congress of the People's Republic of China, Fifth Congress, Fifth Session., (1982). *Constitution of the People's Republic of China*. Adopted on December, 4. Available online: [http://www.npc.gov.cn/englishnpc/Constitution/node\\_2825.htm](http://www.npc.gov.cn/englishnpc/Constitution/node_2825.htm)

National People's Congress of the People's Republic of China. (1986). *Compulsory Education Law*. Available online: [http://www.npc.gov.cn/wxzl/gongbao/2000-12/06/content\\_5004469.htm](http://www.npc.gov.cn/wxzl/gongbao/2000-12/06/content_5004469.htm)

National People's Congress of the People's Republic of China. (1991). *Law of the P.R.C. on the Protection of Minors*. Available online: [http://www.npc.gov.cn/npc/zfjc/zfjcelys/2014-05/08/content\\_1862530.htm](http://www.npc.gov.cn/npc/zfjc/zfjcelys/2014-05/08/content_1862530.htm)

National People's Congress of the People's Republic of China. (1991). *Law of the People's Republic of China on the tax revenues of the companies with foreign investment and foreign enterprises*. Available online: [http://www.npc.gov.cn/wxzl/wxzl/2000-12/05/content\\_4550.htm](http://www.npc.gov.cn/wxzl/wxzl/2000-12/05/content_4550.htm)

National People's Congress of the People's Republic of China. (1994). *Labour Law of the P.R.C.* Available online: [http://www.npc.gov.cn/wxzl/gongbao/2000-12/05/content\\_5004622.htm](http://www.npc.gov.cn/wxzl/gongbao/2000-12/05/content_5004622.htm)

National People's Congress of the People's Republic of China (2004), *Regulations of the People's Republic of China on Academic Degrees*. (title in Chinese: 中华人民共和国学位条例)

NBS (1997a), *Data of Gross Domestic Product of China 1952-1995*, China Statistics Press, National Bureau of Statistics of China, Beijing (title in Chinese: 中国国内生产总值核算历史资料 1952-1995).

NBS (1997b), *China Statistical Yearbook on Investment in Fixed Assets: 1950-1995*, National Bureau of Statistics of China, Beijing (title in Chinese: 中国固定资产投资统计年鉴 1950-1995).

NBS (2000), *Fifth Population Census Data*, China Statistics Press, National Bureau of Statistics of China, Beijing (title in Chinese: 第五次人口普查数据). Available online: <http://www.stats.gov.cn/tjsj/pcsj/rkpc/5rp/index.htm>

NBS (2004), *Data of Gross Domestic Product of China 1996-2002*, China Statistics Press, National Bureau of Statistics of China, Beijing (title in Chinese: 中国国内生产总值核算历史资料 1996-2002).

NBS (2007), *Data of Gross Domestic Product of China 1952-2004*, China Statistics Press, National Bureau of Statistics of China, Beijing (title in Chinese: 中国国内生产总值核算历史资料 1952-2004).

NBS (2010), *Sixth Population Census Data*, China Statistics Press, National Bureau of Statistics of China, Beijing (title in Chinese: 第六次人口普查数据). Available online: <http://www.stats.gov.cn/tjsj/pcsj/rkpc/6rp/indexch.htm>

NBS (various years), *China Labour Statistical Yearbook*, China Statistics Press, Beijing (title in Chinese: 中国劳动统计年鉴).

NBS (various years), *China Statistical Yearbook*, Chinese-English Edition, National Bureau of Statistics of China, Beijing (title in Chinese: 中国统计年鉴).

NBS (Various years, since 2011). *CHINA YEARBOOK OF HOUSEHOLD SURVEY*. China Statistics Press, Beijing (title in Chinese: 中国住户调查年鉴)

NBS (Various years, since 1992). *China Yearbook Rural Household Survey*. China Statistics Press, Beijing (title in Chinese: 中国农村住户调查年鉴)

NBS and Ministry of Science and Technology of P.R.C. (Various years). *China Statistical Yearbook on Science and Technology*. China Statistics Press, Beijing (title in Chinese: 中国科技统计年鉴)

NBS. (various years). *GB/T4754-(Various years)*. (title in Chinese: 国民经济行业分类) Available online: <http://www.stats.gov.cn/tjsj/tjbz/hyflbz/>

NBS. (various years). *Three-Sector Classification Rules -(Various years)*. (title in Chinese: 三次产业划分规定) Available online: [http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114\\_8675.html](http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114_8675.html)

Nehru V. and A. Dhareshwar (1993), "A New Database on Physical Capital Stock: Sources, Methodologies and Results", *Revista de Análisis Económico*, vol. 8, n° 1, pp. 37-59.

- Nelson, C. R., & Kang, H. (1981). Spurious periodicity in inappropriately detrended time series. *Econometrica: Journal of the Econometric Society*, 741-751.
- Nelson, C. R., & Kang, H. (1984). Pitfalls in the Use of Time as an Explanatory Variable in Regression. *Journal of Business & Economic Statistics*, 2(1), 73-82.
- Nelson, C. R., & Plosser, C. R. (1982). Trends and random walks in macroeconomic time series: some evidence and implications. *Journal of monetary economics*, 10(2), 139-162.
- Newey W.K. and K.D. West (1994), "Automatic Lag Selection in Covariance Matrix Estimation", *Review of Economic Studies*, vol. 61, n° 4, p. 631-653.
- Ng S. and P. Perron (1995), "Unit Root Tests in ARMA Models with Data-Dependent Methods for the Selection of Truncation Lag," *Journal of the American Statistical Association*, vol. 90, n° 429, p. 268-281.
- Ng S. and P. Perron (2001), "Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power Lag," *Econometrica*, vol. 69, n° 6, p. 1519-1554.
- OECD (1993), *Methods Used by OECD Countries to Measure Stocks of Fixed Capital*, National Accounts: Sources and Methods, Organisation for Economic Cooperation and Development, Paris.
- OECD (2001), *Measuring Capital OECD Manual – Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services*, Statistics, Organisation for Economic Co-operation and Development, Paris.
- Penn World Tables (various years), PWT, <https://ptw-sas.upenn.edu>, for the 8.1 version: [www.rug.nl/research/ggdc/data/ptw](http://www.rug.nl/research/ggdc/data/ptw).
- People's Bank of China (1992), *China Financial Statistics 1952-1991*, Beijing: Research and Statistics Department. (title in Chinese: 中国金融统计1952-1991)
- Perkins D.H. (1988), "Reforming China's Economic System", *Journal of Economic Literature*, vol. 26, n° 2, pp. 601-645.
- Perkins D.H. and T.G. Rawski (2008), "Forecasting China's Economic Growth to 2025", in Brandt L. and T.G. Rawski (eds.), *China's Great Economic Transformation*, pp. 829-886, Cambridge: Cambridge University Press.
- Phelps, E. S. (1966). Models of technical progress and the golden rule of research. *The Review of Economic Studies*, 33(2), 133-145.
- Phillips P.C.B. and P. Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biomètrika*, vol. 75, n° 2, p. 335-346.
- Phillips, P. C. (1986). Understanding spurious regressions in econometrics. *Journal of econometrics*, 33(3), 311-340.
- Piketty T. (2003), "Income Inequality in France, 1901-1998", *Journal of Political Economy*, vol. 111, n° 5, pp. 1004-1042.
- Piketty T. (2014), *Capital in the Twenty-First Century*, Cambridge MA: Harvard University Press.
- Piketty T. and E. Saez (2003), "Income Inequality in the United States, 1913-1998", *Quarterly Journal of Economics*, vol. 118, n° 1, pp. 1-39.

Piketty T. and G. Zucman (2014), "Capital is Back: Wealth-Income Ratios in Rich Countries 1700-2010", *Quarterly Journal of Economics*, vol. 129, n° 3, pp. 1255-1310.

Piketty T. and N. Qian (2011), "Income Inequality and Progressive Income Taxation in China and India, 1986-2015", in Atkinson A.B. and T. Piketty (eds.), *Top Incomes: A Global Perspective*, pp. 40-75, New York: Oxford University Press.

Piketty, T. (2013). *Le capital au XXIe siècle*. Le Seuil.

Piketty, T., & Qian, N. (2009). Income inequality and progressive income taxation in China and India, 1986–2015. *American economic journal: applied economics*, 1(2), 53-63.

President of the Republic of China. (1922). *Renxu Educational System*. (title in Chinese: 壬戌学制)

Priestley, Maurice B. (1981), *Spectral Analysis and Time Series, vol. 1: Univariate Series, Probability and Mathematical Statistics*, London: Academic Press.

Psacharopoulos, G. (1981). Returns to education: an updated international comparison. *Comparative education*, 17(3), 321-341.

Psacharopoulos, G. (1985). Returns to education: a further international update and implications. *Journal of Human resources*, 583-604.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. *World development*, 22(9), 1325-1343.

Qian, Y., Wang, Q., and Liu, H. (2008) Re-estimate of China 's Human Capital: 1995-2005, *Statistical Research*, 25.12: 000003-10. (in Chinese: 钱雪亚, 王秋实, & 刘辉. (2008). 中国人力资本水平再估算: 1995—2005. *统计研究*, 25(12), 3-10.)

Qiao, H., and Shen, L., (2015) Re-estimate of China 's Human Capital: 1978-2011, *Shanghai journal of Economics*, 7: 36-45. (in Chinese: 乔红芳, & 沈利生. (2015). 中国人力资本存量的再估算: 1978-2011 年. *上海经济研究*, (7), 36-45.)

Quah D. (1992), "The Relative Importance of Permanent and Transitory Components: Identifications and Some Theoretical Bounds," *Econometrica*, vol. 60, n° 1, p. 107-118.

Ramey V.A. and K.D. West (1999), "Inventories," chapter 13, *Handbook of Macroeconomics*, vol. 1, part B, p. 863-923, Elsevier, Amsterdam.

Rand Corporation (Ed.). (2001). *A million random digits with 100,000 normal deviates*. Minnesota Historical Society.

Ravn M.O. and H. Uhlig (2002), "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations," *Review of Economics and Statistics*, vol. 84, n° 2, p. 371-376.

Romer, Paul M. "Mathiness in the theory of economic growth." *The American Economic Review* 105.5 (2015): 89-93.

Runkle, David E. "Vector autoregressions and reality." *Journal of Business & Economic Statistics* 5.4 (1987): 437-442.

Salvadori, N. (ed.) (2003), *The Theory of Economic Growth: A Classical Perspective*, Cheltenham: Edward Elgar.

- Schultz, T. W. (1961). Investment in human capital. *The American economic review*, 1-17.
- Schwert G.W. (1989), "Tests for Unit Roots: A Monte Carlo Investigation", *Journal of Business & Economic Statistics*, vol. 7, n° 2, p. 147-159.
- Sen A. (1997), *On Economic Inequality*, edition with J. Foster, Clarendon Press, Oxford.
- Shan H. (2008), "Re-estimating the Aggregate Capital Stock K of China: 1952-2006," *Journal of Quantitative and Technical Economics*, n° 10, p. 17-31 (in Chinese: 单豪杰, "中国资本存量 K 的再估算: 1952~2006 年", *数量经济技术经济研究*).
- Shanghai Municipal Bureau of Statistics (various years), *Shanghai Statistical Database Yearbook*, Wang Zhixiong, China Statistics Press, Shanghai (title in Chinese: 上海统计年鉴).
- Shorrocks, A. F. (1980). The class of additively decomposable inequality measures. *Econometrica: Journal of the Econometric Society*, 613-625.
- Sims, Christopher A., and Tao Zha. "Bayesian methods for dynamic multivariate models." *International Economic Review* (1998): 949-968.
- Song H., Z. Liu and P. Jiang (2001), "Analyzing the Determinants of China's Aggregate Investment in the Reform Period," *China Economic Review*, vol. 12, n° 2, p. 227-242.
- State Administration of Taxation (Various years). *Tax Yearbook of China*. China Taxation Publishing House (title in Chinese: 中国税务年鉴)
- State Council of the P.R.C. (1959). *Provisions relating to the experimental reforms of the school system*. (title in Chinese: 关于试验改革学制的决定)
- State Council of the P.R.C. (1991). *The decision of establishing consolidated corporation employee pension system*. (title in Chinese: 国务院关于建立统一的企业职工基本养老保险制度的决定). Available online: <http://www.people.com.cn/GB/shizheng/252/7486/7498/20020228/675965.html>
- Stock, J. H. (1987). Asymptotic properties of least squares estimators of cointegrating vectors. *Econometrica: Journal of the Econometric Society*, 1035-1056.
- Strumilin, S. (1962). The Economics of Education in the USSR. *International Social Science Journal*, 14(4), 633-646.
- Su Y. and X. Xu (2002), "The Specification of China's Economic Growth Model: 1952-1998," *Economic Research Journal*, n° 11, p. 3-11 (in Chinese: 舒元, & 徐现祥. (2002). 中国经济增长模型的设定: 1952—1998. *经济研究*, (11), 3-11.).
- Sun L.L. and R.E. Ren (2005), "Capital Input Measurement: a Survey," *China Economic Quarterly*, vol. 4, n° 4, p. 823 (in Chinese: 孙琳琳 & 任若恩, "中国资本投入和全要素生产率的估算", *世界经济*).
- Wang L. and A. Szirmai (2012), "Capital Inputs in the Chinese Economy: Estimates for the Total Economy, Industry and Manufacturing," *China Economic Review*, vol. 23, n° 1, p 81-104.
- Wang X. and G. Fan (eds.) (2000), *The Sustainability of China's Economic Growth*, Economic Sciences Press, Beijing. (in Chinese: 王小鲁, & 樊纲. (2000). *中国经济增长的可持续性: 跨世纪的回顾与展望*. 经济科学出版社.)

- Wang Y.X. and Y. Wu (2003), "Preliminary Estimates of Fixed Capital Stock in China's State Economy," *Statistical Research*, n° 5, p. 40-45 (in Chinese: 王益焯 & 吴优, "中国国有经济固定资本存量初步测算", *统计研究*).
- Wang, J., (2002), China's Economic Growth and Total Factor Productivity and human capital needs, *Chinese Journal of Population Science*, 2: 13-19 (in Chinese: 王金营. "中国经济增长与综合要素生产率和人力资本需求." *中国人口科学* 2 (2002): 13-19.)
- Wang, X., (2010) Gray Income and National Income Distribution. *Comparative Studies*. 3, 1-29. (in Chinese: 王小鲁. (2010). 灰色收入与国民收入分配. *比较*, 3, 1-29.)
- Wang,X., Fan,G., and Liu,P. (2009) Transformation of Growth Pattern and Growth Sustainability in China, *Economic Research Journal*, 1.1. (in Chinese:王小鲁, 樊纲, & 刘鹏. (2009). 中国经济增长方式转换和增长可持续性. *经济研究*, 1(1).)
- Wang., X., and Fan, G., (2005). Income Inequality in China and Its Influential Factors. *Economic Research Journal*, n° 10, p. 24-36 (in Chinese: 王小鲁, & 樊纲. (2005). 中国收入差距的走势和影响因素分析. *经济研究*, 10, 24-36.)
- Ward M. (1976), *The Measurement of Capital – The Methodology of Capital Stock Estimates in OECD Countries*, OECD, Paris.
- Watson M.W. (1986), "Univariate Detrending Methods and Stochastic Trends," *Journal of Monetary Economics*, vol. 18, n° 1, p. 49-75.
- Wold, H. (1954). Causality and econometrics. *Econometrica: Journal of the Econometric Society*, 162-177.
- World Bank (1995), *India Country Economic Memorandum – Recent Economic Developments: Achievements and Challenges*, Washington D.C.
- World Bank (2005). *World Development Report-A Better Investment Climate for Everyone*.
- Wu F.W. (1999), "Estimates of China's Agricultural Capital Stock," *Journal of Agrotechnical*, n° 6, p. 34-38 (in Chinese: 吴方卫, "我国农业资本存量的估计", *农业技术经济*).
- Wu H.X. (1993), "The 'Real' Chinese Gross Domestic Product for the Pre - reform Period: 1952-1977," *Review of Income and Wealth*, vol. 39, n° 1, p. 63-87.
- Wu, H. X. (2014, January). China's Growth and Productivity Performance Debate Revisited. *The conference board working papers*, EPWP1401.
- Xianchun, X. U. (2004). China's gross domestic product estimation. *China Economic Review*, 15(3), 302-322.
- Xiaoping, Deng (1984). "Building a socialism with a specifically Chinese character." *The People's Daily*.
- Xinhua News Agency (2005): [http://news.xinhuanet.com/life/2006-08/31/content\\_5029534.htm](http://news.xinhuanet.com/life/2006-08/31/content_5029534.htm)
- Xinhua News Agency (2006) <http://cpc.people.com.cn/GB/64093/64387/4740043.html>
- Xu, X. (1999), "Evaluation and Adjustments of China's Official GDP by the World Bank and Prof. Maddison", *Journal of Econometric Study of Northeast Asia*, vol. 1, n° 2, pp. 52-58.

- Xu, X. (2004). China's gross domestic product estimation. *China Economic Review*, 15(3), 302-322.
- Xue J. and Z. Wang (2007), "A Research on the Capital Calculation of 17 Industries of China," *Statistical Research*, vol. 7, p. 10-14 (in Chinese: 薛俊波 & 王铮, "中国 17 部门资本存量的核算研究", *统计研究*).
- Yang, G.,(2006), Estimation of Human Capital in China: 1952-2004, *Rural Economy*, 12 (2006): 54-57. (in Chinese: 杨国涛. (2006). 中国人力资本存量的估算: 1952—2004 年. *乡镇经济*, (12), 54-57.)
- Yang, J., et al. (2006), Human Capital Formation and Its Impact on Economic Growth: An Endogenous Growth Model Including Education and Health Input, *Management World*, 5: 10-18. (in Chinese: 杨建芳, 龚六堂, & 张庆华. (2006). 人力资本形成及其对经济增长的影响——一个包含教育和健康投入的内生增长模型及其检验. *管理世界*, (5), 10-18.)
- Yao, Y. and Lin, X. (2005) Contribution of Education on Economic Growth: International Comparison Based on the Multi-variable VAR Model, *The Journal of World Economy*. 10: 26-32. (in Chinese: 姚益龙, and 林相立. "教育对经济增长贡献的国际比较: 基于多变量 VAR 方法的经验研究." *世界经济* 10 (2005): 003.)
- Young A. (2000), "Gold into Base Metals: Productivity Growth in the People's Republic of China During the Reform Period", *National Bureau of Economic Research Working Papers*, n° 7856, Cambridge Ma.
- Yue, S., and Liu, C., (2006), Human Capital Accumulation and Regional Total Factor Productivity, *Economic Research Journal*, 4.1. (in Chinese: 岳书敬, & 刘朝明. (2006). 人力资本与区域全要素生产率分析. *经济研究*, 4(1).)
- Zhang Jun and Y. Zhang (2003), "Recalculating the Capital of China and a Review of Li and Tang's Article," *Economic Research Journal*, n° 7, p. 35-43 (in Chinese: 张军 & 章元, "对中国资本存量 K 的再估计", *经济研究*).
- Zhang Jun, S. Shi and S. Chen (2003), "Industrial Reform and Efficiency Change in China: Method, Data, Literatures and Present Results", *Economics Quarterly*, vol. 2, n° 1, pp. 1-38. (in Chinese: 张军, 施少华, & 陈诗一. (2003). 中国的工业改革与效率变化. *经济学 (季刊)*, 3(1), 1-38.)
- Zhang Jun, Wu G. and Zhang Ji. (2004), "The Estimation of China's Provincial Capital Stock: 1952-2000," *Economic Research Journal*, n° 10, p. 35-44 (in Chinese: 张军, 吴桂英 & 张吉鹏, "中国省际物质资本存量估算: 1952-2000", *经济研究*).
- Zhang Junk. (1991), "Systemic Analysis of Economic Efficiency During the 7th Five Year Plan," *Journal of Economic Research*, n° 4, p. 8-17 (in Chinese: 张军扩, "七五 期间经济效益的综合分析", *经济研究*).
- Zhang, F. (2000), China's physical and human capital estimates, *Economic Research Journal*, 8.1: 65-71. (in Chinese: 张帆. (2000). 中国的物质资本和人力资本估算. *经济研究*, 8(1), 65-71.)
- Zheng J., A. Bigsten and A. Hu (2009), "Can China's growth be sustained? A Productivity Perspective", *World Development*, vol. 37, n° 4, pp. 874-888.
- ZHU, P., and XU, D., (2007) Estimation of Urban Human Capital in China, *Economic Research Journal*, 9: 84-95. (in Chinese: 朱平芳, & 徐大丰. (2007). 中国城市人力资本的估算. *经济研究*, 9, 84-95.)



## Appendices

### Appendix 2.1 Simulation program by SAS, with explanation annotations

```
data simulation1;
  call streaminit(77381); *The number in parenthesis is the seed value in Appendix 2.2;
  do t=1 to 1000000;      *The sample size is one million;
    v1=rand("normal");  *Set the white noises series as Gaussian;
  output; *Repeat the simulation 100 times and respectively obtain the white noises v1,v2...v100;
end; *Use a different seed value in Appendix 2.2 for each replication;
run; *Use the true random numbers generated by hardware random number generator in order to
      avoid the pseudo-randomness of random numbers given by software.;
```

```
data simulation; *Merge the white noises into a single dataset;
  merge simulation1-simulation100;
run;
data simulation0; *Generate 100 random walks by setting all the initial values equal to 0;
  set simulation;
  array randomwalk(*) v1-v100; *Define an array with do loop in order to reduce the code;
  array y(100);
    do i=1 to 100; *The random walk is the accumulated sum of white noise;
      y(i) + randomwalk(i);
    end;
run;
```

```
proc reg data=simulation0 outest=reg;
  model y1-y100=t/RSQUARE; *Get 100 regressions and store the  $R^2$ ;
run;
quit;
```

```
proc reg data=simulation0 outest=reg0 TABLEOUT;
  model y1-y100=t/RSQUARE;
run; *Create another dataset in order to store the student statistics of OLS estimators;
quit;
```

```
data reg1;
  set reg0;
  if _TYPE_="T";
  rename Intercept=t_alpha t=beta;
  drop _MODEL_ _TYPE_ _RMSE_ y1-y100 _IN_ _P_ _EDF_ _RSQ_;
run; *Only reserve the student statistics of OLS estimators;
```

```
data reg;
  merge reg1 reg;
  by _DEPVAR_;
run; *Merge the datasets;
```

```
data reg;
  set reg;
  rename t=beta;
  rename Intercept=Alpha;
  rename _DEPVAR_=bootstrap;
  drop _MODEL_ _TYPE_ _IN_ _P_ _EDF_ _RMSE_ y1-y100;
run; *Rename the variables from automatic SAS names to specific names and drop all information we
```

don't need;

```
data reg;*As the variable bootstrap is character it will sort in order y1 y10 y100 y2 y21 y3....y99 in graphs. We change them into numeric.;  
set reg; *We can also correct this problem in the array statement step by adding a leading zero such as y01 y02....y09 y10...y100.;  
bootstrap=substr(bootstrap,2,3);  
run;
```

```
data reg;  
set reg(rename=(bootstrap=bootstrap_char)) ;  
bootstrap = input(bootstrap_char,best.);  
drop bootstrap_char _MODEL_ _TYPE_ y1-y100;  
run; *Change the variable bootstrap from character to numeric;
```

```
proc univariate data=reg;  
var alpha beta t_alpha t_beta;  
histogram alpha beta t_alpha t_beta / kernel normal;  
run; *Calculate some elements in table 2.1;
```

```
proc gplot data=reg;  
plot beta*bootstrap alpha*bootstrap/overlay;  
symboli=join;  
run;*Represent graph 2.3 and 2.4 ;
```

```
%macro reg(size);*Define a macro program to consider the behaviors of OLS estimators when sample size increases from 100 to 1000000 ;  
%do i=100 %to &size %by 10000;  
%let j= %sysevalf((&i-100)/10000);  
proc reg data=simulation0(where=(t<=&i))  
outest=out&j(keep=intercept t) noprint;  
model y1=t;  
run;  
quit;  
%end;  
%mend;
```

```
%reg(1000000) *Invoke the macro reg(size) and let size=1000000;
```

```
data reg1; *merge the datasets;  
set out0-out99;  
run;
```

```
%macro rename;*Define a new macro program in order to rename variables because SAS automatically creates the same names in each regression;  
%do i=1 %to 10;  
data reg&i;  
set reg&i;  
rename intercept=intercept&i t=t&i;  
run;  
%end;  
%mend;
```

```
%rename *Invoke the macro program;
```

```

data order(keep=size); *Create an index variable;
  do n=0 to 99;
    size=100+10000*n;
  output;
  end;
run;

data reg0; *Merge the datasets;
  merge order reg1-reg10;
run;

proc gplot data=reg0; *Represent graph 2.1 and 2.2;
  plot (intercept1-intercept10)*size/ overlay;
  symboli=join;
  plot (t1-t10)*size / overlay;
  symboli=join;
run;
quit;

```

### Appendix 2.2 Table of seed values

#### TABLE OF RANDOM DIGITS

365

18200	77381	59443	87430	77462	41440	75496	49906	09823	81293	89793
18201	79729	86526	22633	99540	23354	55930	37734	97861	68270	33174
18202	82377	53502	13615	21230	25741	59935	60282	90430	66251	75758
18203	31592	30957	14458	77037	10777	45252	69494	74509	16031	80045
18204	33553	07210	29127	18634	71052	35182	89048	04978	00451	46072
18205	59326	45916	55698	08330	92541	10196	37699	81162	65562	24792
18206	61082	83586	98989	78927	68800	44882	96851	79167	92786	82529
18207	14373	76009	65876	29319	63212	22002	57795	28772	74823	95093
18208	90754	76767	81309	32874	61792	63659	10851	29106	84988	63128
18209	33936	11659	56754	48332	08687	41299	31220	37709	28335	91985

Source: Rand Corporation (2001), p. 365. Online:  
[http://www.rand.org/pubs/monograph\\_reports/MR1418.html](http://www.rand.org/pubs/monograph_reports/MR1418.html).

Note: Here, the computer operating system used is Windows7-32 bits Home premium, with the 9.3 version of SAS. The results might be a little bit different in another operating environment – most programming languages use the IEEE 754 international standard. With this standard, a 32-bits computer can use a 23-bits precision when decimal numbers have no accurate representation in binary. However, for a 64-bits computer, it can use a 52-bits precision.

**Appendix 2.3 Simulation results using a sample size of a million points**

<b>Bootstrap</b>	<b>Alpha</b>	<b>T_Alpha</b>	<b>Beta</b>	<b>T_Beta</b>	<b>_RSQ_</b>
1	-516.428	-994.213	0.001478	1642.975	0.729684
2	-197.89	-454.435	0.001673	2218.098	0.83108
3	-270.459	-441.39	-0.00137	-1293.6	0.625945
4	-319.191	-499.053	0.00172	1552.42	0.706746
5	59.65598	147.5	-0.0021	-3001.91	0.900115
6	128.2268	303.2709	0.000895	1222.664	0.599184
7	340.0485	723.4509	-0.00085	-1049.39	0.524084
8	106.5433	173.9056	-0.0005	-473.332	0.183036
9	312.9737	707.3468	-0.00201	-2623.79	0.873166
10	706.1975	1119.959	-0.00064	-587.675	0.256706
11	-127.036	-339.147	0.000358	552.4023	0.233804
12	543.8749	1136.501	0.001163	1402.911	0.663091
13	588.8941	1529.704	-0.00052	-783.353	0.380284
14	-648.32	-813.506	-0.00027	-192.58	0.035761
15	656.4477	765.2626	-0.00222	-1496.84	0.69141
16	11.84133	27.68874	0.000893	1205.204	0.592256
17	488.6455	598.7078	-4.9E-05	-34.3688	0.00118
18	-465.545	-725.822	0.000631	568.3724	0.244169
19	-248.422	-564.73	0.000643	844.1401	0.416084
20	48.52915	105.5969	-0.00044	-549.449	0.231889
21	-101.445	-287.474	0.000207	338.1793	0.102628
22	127.0612	299.2239	0.002335	3175.413	0.909774
23	-33.161	-99.9226	-1.3E-05	-22.9001	0.000524
24	-453.84	-745.754	0.001144	1085.507	0.540932
25	235.6821	619.602	-0.00118	-1797.21	0.763592
26	-218.546	-584.063	-0.00084	-1290.12	0.624682
27	-440.194	-973.892	6.51E-05	83.11338	0.00686
28	-449.678	-1043.2	0.000493	660.5926	0.303807
29	112.1348	289.5755	-0.00141	-2105.15	0.815894
30	581.1902	1689.905	-0.00215	-3604.9	0.928548
31	-587.032	-1501.88	0.002193	3239.642	0.913008
32	-369.762	-1367.25	-0.00042	-889.29	0.441602
33	-389.217	-555.687	0.000312	256.8726	0.061899
34	867.6485	1281.799	-0.00091	-772.52	0.373743
35	436.7767	1145.472	0.000166	251.6912	0.059575
36	270.2492	565.8382	-0.0021	-2537.89	0.865607
37	216.3166	600.8799	-0.00052	-837.362	0.412172
38	-231.201	-467.153	-0.00027	-319.307	0.092524
39	91.05972	183.4367	-0.00069	-798.691	0.389465
40	-311.184	-661.038	0.000234	287.2567	0.076227
41	88.70737	226.1573	0.000826	1216.426	0.596725
42	-418.93	-845.305	0.00045	523.9499	0.215393
43	139.4184	556.7029	0.000388	895.4936	0.445033
44	131.9699	299.7307	0.001769	2319.397	0.843251
45	235.8081	671.6881	-8.7E-05	-143.432	0.020158
46	-183.356	-385.223	0.001201	1457.079	0.679804
47	-450.714	-849.624	-0.00025	-270.624	0.06824
48	-102.254	-255.019	-0.00238	-3433.09	0.92179
49	-639.041	-1252.14	0.000926	1047.677	0.523272
50	362.1756	950.0575	-0.00026	-398.336	0.136943

51	210.3742	444.9447	-0.00122	-1484.72	0.687928
52	421.0867	909.9346	0.000898	1120.044	0.556443
53	-455.699	-1037.49	-0.00086	-1129.1	0.560416
54	421.7283	649.61	-0.00237	-2104.8	0.815844
55	521.1628	1052.502	-0.0014	-1628.74	0.726237
56	-470.648	-899.902	-0.00035	-387.837	0.130751
57	30.66679	83.32206	6.79E-06	10.65426	0.000114
58	-299.44	-621.459	-0.00184	-2199.16	0.828659
59	83.65093	193.0325	-0.00104	-1381.63	0.656228
60	-144.012	-384.873	0.002268	3500.093	0.924532
61	831.9241	1056.377	0.000812	595.4674	0.261765
62	-261.051	-540.941	0.001855	2219.531	0.831261
63	-98.1186	-153.397	-0.00042	-382.35	0.127545
64	858.1653	1707.158	-0.00167	-1919.83	0.786587
65	-4.99706	-16.7538	0.001905	3686.877	0.931474
66	82.03943	203.1585	-0.00132	-1889.56	0.781203
67	-79.6881	-179.748	0.001974	2570.223	0.868526
68	-144.75	-270.425	0.000239	257.2805	0.062084
69	106.8698	344.2261	-0.00147	-2741.72	0.882588
70	224.7479	457.0921	0.001897	2227.121	0.832217
71	-531.303	-700.132	0.001526	1160.838	0.574023
72	-431.824	-1038.13	0.000284	393.6544	0.134172
73	-209.465	-398.03	0.000603	661.8163	0.304591
74	304.19	458.4119	-0.00137	-1195.68	0.588419
75	406.7961	471.6883	0.000832	556.7575	0.236629
76	-275.16	-545.632	-4.3E-05	-49.7171	0.002466
77	-149.003	-351.097	0.000263	357.8227	0.113505
78	-743.237	-1276.95	0.001326	1315.394	0.633735
79	-562.356	-967.819	0.002533	2516.59	0.863635
80	426.6258	808.3939	-0.00093	-1012.77	0.506345
81	620.8599	946.9761	-0.00246	-2161.95	0.823759
82	206.2948	509.1332	0.001018	1449.979	0.677673
83	658.6789	1399.053	2.77E-06	3.396448	1.15E-05
84	-183.309	-454.236	-0.00093	-1326.52	0.637638
85	-12.3161	-31.8307	-2.7E-05	-40.1805	0.001612
86	-218.468	-581.44	3.37E-05	51.82376	0.002679
87	-183.216	-381.86	0.000529	636.5787	0.288374
88	-286.844	-549.021	0.000599	662.0088	0.304714
89	374.423	746.4409	-0.00154	-1775.53	0.759183
90	418.4504	492.2846	0.00037	251.4381	0.059462
91	-159.337	-361.947	-2.9E-05	-37.6401	0.001415
92	-229.543	-385.27	-0.00095	-915.922	0.456201
93	149.2659	379.5512	0.002918	4283.706	0.948321
94	124.2723	235.9754	-0.00066	-726.347	0.34537
95	-542.8	-1029.7	0.000313	342.646	0.105071
96	335.8	459.1723	9.31E-05	73.50074	0.005373
97	230.6743	753.4047	0.003076	5799.956	0.971131
98	-450.053	-1081.94	0.000144	199.1844	0.038161
99	180.6602	451.0257	-0.00037	-535.181	0.222649
100	-206.238	-370.228	-0.00059	-609.264	0.270714

### Appendix 3.1 Deviation of PIM Equation

We should firstly distinguish the richness of capital stock (or the value of capital goods, see chapter 6), capital stock, productive capital and input of capital (or capital services, see chapter 5). For example, suppose the price of capital goods  $K_0$  in  $t = 0$  is  $P_0$ , so the value of capital goods in this time is:

$$V_0 = P_0 K_0 \quad (A3.1.1)$$

At  $t = \tau$  the price is supposed to be  $P_\tau$ , the value becomes:

$$V_\tau = P_\tau K_\tau = (1 - \sigma)^\tau V_0 \quad (A3.1.2)$$

Where  $\sigma$  is depreciation rate. After a period of use, the efficiency of capital goods falls; if we use  $d_\tau$  to present the relative efficiency of capital goods bought  $\tau$  years ago, then when  $t = \tau$  the capital stock is:

$$K_\tau = d_\tau K_0 \quad (A3.1.3)$$

We can see that the richness of capital stock  $V_\tau$  and capital stock  $K_\tau$  are different notions. Combining the equations above, it is easy to get:

$$d_\tau = \frac{P_0}{P_\tau} (1 - \sigma)^\tau \quad (A3.1.4)$$

That is to say, under the assumption of constant value of depreciation rate and no new investment, the age-efficiency of capital goods declines geometrically and it is proportional to price index (*i.e.* constant price). It is similarly to get the inverse proposition: if age-efficiency of capital goods declines geometrically, then the depreciation rate is constant. That is to say, we conclude that geometrical decline of age-efficiency is equivalent to constant value of depreciation rate.

Next we assume that all the investments of past years are in constant price so that we can simplify the deduction process. With the definition of PIM, the capital stock  $K_t$  at time  $t$  should be the weighted sum of infinite past investment series with the age-efficiency as weights:

$$K_t = \sum_{\tau=0}^{\infty} d_\tau I_{t-\tau} \quad (A3.1.5)$$

Where  $I_{t-\tau}$  is the investment of  $\tau$  years ago in constant price.  $d_\tau$  is the age-efficiency of capital goods with age  $\tau$ . That is to say after  $\tau$  years of use, the capital goods' ability of production is  $d_\tau$  portion to the new capital goods in  $\tau$  years ago. Generally we normalize the age-efficiency of new capital goods to 1, and suppose that asset loses efficiency of assets as they age and the efficiency of retired capital goods is 0:

$$d_t = \begin{cases} 1, & t = 0 \\ 0, & t > L \\ \text{other cas and } d_\tau < d_{\tau-1} < 1, & t = 2, 3 \dots L \end{cases} \quad (A3.1.6)$$

Where  $L$  is the maximum capital service life, this implies that we have also supposed that the mortality pattern is "simultaneous exit".

We note that the loss ratio of age-efficiency of capital goods (mortality rate) is:

$$m_\tau = d_{\tau-1} - d_\tau \quad (A3.1.7)$$

To make equation (A3.1.5) operable, we introduce the notion of replacement of capital. As capital goods lose efficiency as they age, in order to keep capital stock constant we must replace certain quantity of capital  $R_\tau$  in year  $\tau$ . We note  $\phi_\tau$  the rate of replacement of capital:

$$\phi_\tau = \frac{R_\tau}{K_{\tau-1}} \quad (A3.1.8)$$

Now we expand equation (A3.1.5), and write the expression of  $K_{t-1}$ :

$$K_t = d_0 I_t + d_1 I_{t-1} + \dots + d_\tau I_{t-\tau} + \dots \quad (A3.1.9)$$

$$K_{t-1} = d_0 I_{t-1} + d_1 I_{t-2} + \dots + d_{\tau-1} I_{t-\tau} + \dots \quad (A3.1.10)$$

Equation (A3.1.9) minus equation (A3.1.10) we get:

$$K_t - K_{t-1} = d_0 I_t - (d_0 - d_1) I_{t-1} - (d_{\tau-1} - d_\tau) I_{t-\tau} - \dots \quad (A3.1.11)$$

From equation (A3.1.6) we know that  $d_0 = 1$  and from equation (A3.1.7) we have:

$$K_t - K_{t-1} = I_t - \sum_{\tau=1}^{\infty} m_{\tau} I_{t-\tau} \quad (\text{A3.1.12})$$

The replacement of capital  $R_{\tau}$  should satisfy  $K_t - K_{t-1} = 0$ , with equation (A3.1.8), we have:

$$I_t = \sum_{\tau=1}^{\infty} m_{\tau} I_{t-\tau} = \phi_t K_{t-1} \quad (\text{A3.1.13})$$

Expanding equation (A3.1.13):

$$I_t = m_1 I_{t-1} + m_2 I_{t-2} + \dots + m_{\tau} I_{t-\tau} + \dots \quad (\text{A3.1.14})$$

And because  $I_t = \phi_t K_t$ , here  $K_t = K_{t-1}$  is constant, substituted in equation (A3.1.14) we have:

$$\phi_t = m_1 \phi_{t-1} + m_2 \phi_{t-2} + \dots + m_{\tau} \phi_{t-\tau} + \dots \quad (\text{A3.1.15})$$

If the oldest capital goods is  $\tau$ <sup>224</sup> years old, then equation (A3.1.15) could be written in a recursive equations with finite terms:

$$\phi_{\tau} = m_1 \phi_{\tau-1} + m_2 \phi_{\tau-2} + \dots + m_{\tau} \phi_0 \quad (\text{A3.1.16})$$

From equations (A3.1.12) and (A3.1.13) we know that:

$$K_t = K_{t-1} - \phi_t K_{t-1} + I_t \quad (\text{A3.1.17})$$

Hypothesis: age-efficiency of capital goods declines geometrically, namely:

$$d_{\tau} = (1 - \sigma)^{\tau} \quad (\text{A3.1.18})$$

Combining equations (A3.1.7), (A3.1.16) and (A3.1.18) we have:

$$\phi_t = \sigma \quad (\text{A3.1.19})$$

Finally the equation (A3.1.17) becomes the usually form:

$$K_t = (1 - \sigma)K_{t-1} + I_t \quad (\text{A3.1.20})$$

The above procedures have proved that if age-efficiency of capital goods declines geometrically, the constant rate of replacement of capital could be regarded as depreciation rate. The capital stock in year  $t$  is calculated by the depreciated capital stock of last year plus the new investment of this year in constant price.

Excepting the geometric decline of age-efficiency, there are also “Sum-of-the-years-digits decline” and “Straight-line decline”. In those cases, the equation (A3.1.20) is no longer valid. With equation (A3.1.4), we see that “age-efficiency declines geometrically” and “depreciation rate is constant” are necessary and sufficient conditions for each other. In fact, if only we assume that the depreciation rate is constant, we have an equivalent hypothesis of “age-efficiency declines geometrically”. A lot of empirical analyses indicate that geometrical decline is reasonable. For example: Hulten et.al (1987), Hulten (1995), Jorgenson (1996), Fraumeni (1997), Katz and Herman (1997). Thus we suppose the depreciation rate is constant.

The above demonstration also suggests that the PIM equation is an AR(1) equation. This conclusion will simply some calculation in *Appendix 3.2*.

---

<sup>224</sup> The oldest year  $\tau$  is not the maximum service life  $L$ .

### Appendix 3.2 Convergence and stability of the iterative procedure for initial capital stock

The hypothesis imposed by Nehru and Dhareshwar (1993) to determine the initial physical capital stock supposes that the economy was at its steady state in the base year, that is:

$$K_0 = I_0 / (g_Y + \sigma) \quad (\text{A3.2.1})$$

where  $g_Y$  is the economic growth rate.

In practice, these two authors use the average rate between 1950 and 1973, while Harberger (1978) used a three-year average growth rate, and more recently, Caselli (2005) uses the average rate until 1970. However, obviously, China's economy was not at a steady state in 1952. As a consequence, we propose a method by iterations to settle this problem. The justification of such an iterative process rests in the idea that the economy will tend to a steady state when  $t \rightarrow +\infty$ . We can perform such a process because: *i)*  $\alpha_t = I_t/K_t$  is convergent when  $t \rightarrow +\infty$ ; and *ii)* the iterative system of  $\alpha_t$  is stable and gives this result.

Let us provide the respective proofs of these two conditions.

By the PIM definition, we know that:

$$K_t = \sum_{\tau=0}^{\infty} d_{\tau} I_{t-\tau} \quad (\text{A3.2.2})$$

Advancing a hypothesis of constancy of the capital stock depreciation rate, as we did it here, is equivalent to assuming the geometric declining of the relative age-efficiency of the capital goods:

$$d_{\tau} = (1 - \sigma)^{\tau} \quad (\text{A3.2.3})$$

with  $\sigma > 0$ , and:

$$I_t = (1 + g)^t I_0 \quad (\text{A3.2.4})$$

$g$  being the average growth rate of infinite past investments until  $t$ , supposed to be positive.

It comes:

$$\begin{aligned} \frac{I_t}{K_t} &= \frac{(1 + g)^t I_0}{\sum_{\tau=0}^{\infty} d_{\tau} I_{t-\tau}} \\ &= \frac{(1 + g)^t I_0}{\sum_{\tau=0}^{\infty} (1 - \sigma)^{\tau} (1 + g)^{t-\tau} I_0} \\ &= \frac{1}{\sum_{\tau=0}^{\infty} \left(\frac{1 - \sigma}{1 + g}\right)^{\tau}} \quad (\text{A3.2.5}) \end{aligned}$$

with  $0 < \sigma < 1$ ,

$$\begin{aligned} &g > 0 \\ &0 < \frac{1 - \sigma}{1 + g} < 1 \\ &\sum_{\tau=0}^{\infty} \left(\frac{1 - \sigma}{1 + g}\right)^{\tau} \rightarrow \frac{1}{1 - \frac{1 - \sigma}{1 + g}} \quad (\text{A3.2.6}) \end{aligned}$$

Therefore, we see that  $I_t/K_t$  is convergent, and that:

$$\frac{I_t}{K_t} = \frac{g + \sigma}{1 + g} \quad (\text{A3.2.7})$$

when  $t \rightarrow +\infty$ .

More strictly:

$$g \equiv g_t = \lim_{t_0 \rightarrow -\infty} \frac{1}{t - t_0 + 1} \sum_{\tau=t_0}^t \Delta \log I_{\tau} \quad (\text{A3.2.8})$$

we get:

$$K_0 = I_0 / \alpha_0 \quad (\text{A3.2.9})$$

$\alpha_0$  being an unknown variable.



Assuming that  $\alpha_t$  satisfies ergodicity for the mean, time average can be used instead of mathematical expectation:

$$E(\alpha_0) = \frac{1}{T} \sum_{t=1}^T \alpha_t = \frac{1}{T} \sum_{t=1}^T \frac{I_t}{K_t} \quad (\text{A3.2.10})$$

Then we have:

$$E(\alpha_0) = \frac{g + \sigma}{1 + g} \quad (\text{A3.2.11})$$

and:

$$E(K_0) = I_0 / E(\alpha_0) = I_0 / \left( \frac{g + \sigma}{1 + g} \right) = I_0 \frac{1 + g}{g + \sigma} \quad (\text{A3.2.12})$$

If  $g$  is ergodic for the mean, then we can use the average growth rate of infinite future instead of this average growth rate of infinite past as long as the sample size  $T$  is sufficient large. The iterative procedure can help us to reach the above convergent result, because of the stability of such an iteration system.

We use the stationarity conditions of the ARMA process. The following equation

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + w_t \quad (\text{A3.2.13})$$

is stable if two conditions are verified:

1) all the eigenvalues of the matrix  $F$  remain inside the unit circle:

$$F \equiv \begin{bmatrix} \phi_1 & \phi_2 & \dots & \phi_p \\ 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & 1 \end{bmatrix} \quad (\text{A3.2.14})$$

2)  $w_t$  is bounded.

From the PIM equation, whose both sides are divided by  $I_t$ , we get:

$$\frac{K_t}{I_t} = (1 - \sigma) \frac{K_{t-1}}{I_t} + 1/P_t \quad (\text{A3.2.15})$$

with  $I_t = (1 + g)I_{t-1}$ .

Then:

$$\begin{aligned} y_t &= 1/\alpha_t = \frac{K_t}{I_t} \\ &= \frac{(1 - \sigma)K_{t-1}}{(1 + g)I_{t-1}} + \frac{1}{P_t} \\ &= \frac{(1 - \sigma)}{(1 + g)} y_{t-1} + \frac{1}{P_t} \end{aligned} \quad (\text{A3.2.16})$$

That is to say,  $y_t$ , the inverse of  $\alpha_t$ , is a AR(1) process.

As  $0 < \sigma < 1$  and  $g > 0$ , thus  $0 < \frac{(1-\sigma)}{(1+g)} < 1$ , so the first condition of stability is verified. In the real world,  $P_t$  is generally increasing with time due to inflation. If the price index is initialized to be equal to 1, then  $0 < \frac{1}{P_t} < 1$  is bounded, and the second condition of stability is also verified. As the iterative system is stable, therefore we will obtain the convergent result for the initial capital.

So, we understand that to apply the method described above, three conditions are needed:

- 1) the average growth rate of investment  $g$  is positive;
- 2) the price index  $P_t$  is increasing;
- 3)  $\alpha_t$  is ergodic for the mean.

Whereas the first two conditions obviously hold in the case of China, the third one needs to be verified. But it is difficult to be directly verified. By definition (*cf.* theorem of Birkhoff [1931]), the ergodicity of mean corresponds to a stationary process  $X_t$  which satisfies:

$$P\{\langle X_t \rangle = E(X_t) = \mu_X\} = 1 \quad (\text{A3.2.17})$$

with

$$\langle X_t \rangle = \lim_{T \rightarrow +\infty} \frac{1}{2T} \int_{-T}^T X_t dt \quad (\text{A3.2.18})$$

Alternatively, we use here a sufficient condition for mean ergodicity in stationary processes (Hamilton [1994]):

$$\sum_{j=0}^{\infty} |\gamma_j| < \infty \quad (\text{A3.2.19})$$

where  $\gamma_j$  is the  $j$ -th auto-covariance of the second order stationary series.

Thus, if its autocorrelation function tends to zero sufficiently quickly when  $j$  becomes large, then the series is ergodic for mean.

As a consequence, what we need to do is just to test whether  $\alpha_t$  is stationary after the iterations and, if so, then to consider whether its autocorrelation function converges to zero quickly when  $j$  becomes large. If the two conditions are verified, we can use the ergodicity of  $\alpha_t$ .

The unit root tests show that  $\alpha_t$  is stationary.

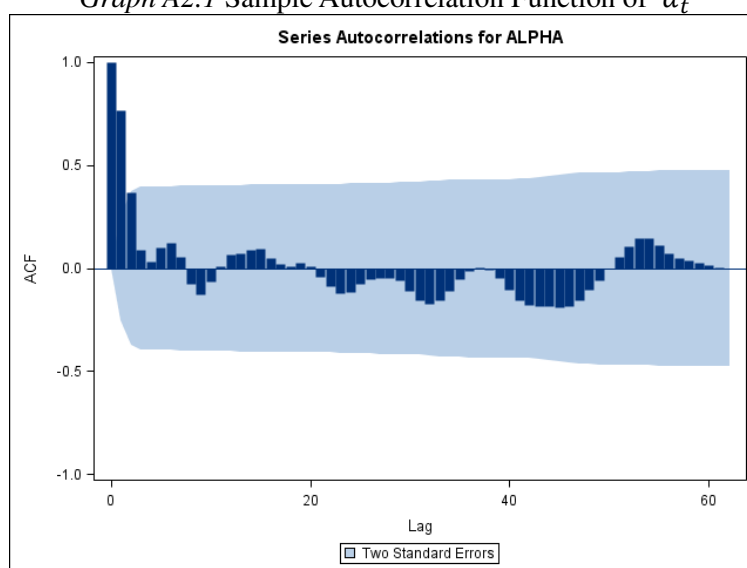
*Table A2.1. Verification of the stationarity of  $I_t/K_t$*

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC 10 SIC HQ 1	Trend	AIC:-3.235910 < -3.178578 (10%) SIC&HQ:-5.195254 < -3.48521 (5%)	Stationary
ERS	SIC 0 HQ 1	Trend	-2.961554 < -2.854000 (10%) -5.118662 < -3.177200 (5%)	Stationary
PP	SIC 0	Constant	-2.782109 < -2.592215 (10%) -4.685906 < -2.909206 (5%)	Stationary
KPSS	Bandwidth=4 (Bartlett Kernel)	Trend	0.137195 < 0.146000 (5%)	Stationary
ERS-PO NP	SIC & HQ 1 HQ 1	Trend Trend	2.010321 < 5.699200 (5%) {-45.0988, -4.74818, 0.10528, 2.02285} <{-17.3; -2.91; 0.168; 5.48} (5%)	Stationary Stationary

*Note:* With Spectral GLS detrended-AR as a method for estimating the PP tests.

Now let us consider the sample autocorrelation function (ACF) of  $\alpha_t$ .

*Graph A2.1 Sample Autocorrelation Function of  $\alpha_t$*



We see that the ACF become insignificant very quickly when the lag increases. When  $j > 2$ , it has already become nonsignificant, that is to say, it could be regarded as zero. In other words, the sufficient condition of ergodic mean is verified<sup>225</sup>. Consequently, we can apply the iterative procedure and equations above.

---

<sup>225</sup> The author proposes and idea to test the ergodicity but this work is uncompleted. The idea is as follow: According to the Wold theorem, any stationary series could be written as the sum of infinite moving average of white noise series:  $Y_t = \mu + \sum_{j=0}^{\infty} \varepsilon_t$ . A sufficient condition of ergodicity for second order is that the autocorrelation function of this stationary series is absolutely summable and the second order of innovation  $E(\varepsilon_t^2) < \infty$  exists:

$$\sum_{j=0}^{\infty} |\gamma_j| < \infty$$

We see that this condition holds if  $E(\varepsilon_t^r) < \infty$  for some  $r > 2$  then we can infer that the autocorrelation function is square summable:

$$\sum_{j=0}^{\infty} \gamma_j^2 < \infty$$

According to the Cauchy criterion,  $\forall \varepsilon > 0, \exists$  an integer  $N$ , such that when  $j > N$

$$|\gamma_j^2 - \gamma_N^2| < \varepsilon$$

That is to say the infinite sum of autocorrelation functions could be divided into two parts:

$$\sum_{j=0}^{\infty} \gamma_j^2 = \sum_{j=0}^{N-1} \gamma_j^2 + \sum_{j=N}^{\infty} \gamma_j^2 < \infty$$

The first term must be finite and the second term could be regarded as few as zero. Then the question has become that if we can find some truncation criterions to find an integer number  $N$ , such that the sum of square of the autocorrelations greater than  $N$  is nonsignificant to zero, then the ergodicity for the second order is verified.

The statistic is:

$$Z = \sum_{j=N}^{T-1} \widehat{\gamma}_j^2$$

$\widehat{\gamma}_j$  is the sample autocorrelation function. For a sample of  $T$  observations, we can calculate the sample autocorrelation until lag  $T-1$ .  $N$  is determinate by certain kind of truncation criterions. Several asymptotic distributions of  $\widehat{\gamma}_j$  could be used to determinate the distribution of the statistic  $Z$ . For example, Box and Jenkins (1976,p.55) suggested that if the series is generated by Gaussian MA( $q$ ), then:

$$\text{Var}(\widehat{\gamma}_j) = \frac{1}{T} (1 + 2 \sum_{i=1}^q \gamma_i^2)$$

Thus a simple idea is that under the hypothesis of  $Y_t$  is Gaussian white noise,  $\widehat{\gamma}_j \sim N(0, \frac{1}{T})$  approximately for  $j > N$ . So the statistics  $Z$  is a Gama distribution noted  $Z \sim \Gamma(T - N - 2, T)$  with  $E(Z) = \frac{T-N-2}{T}$  and  $\text{Var}(Z) = \frac{2(T-N-2)}{T^2}$ . As we are more familiar with the Chi2 test, this statistic could be also written in an equivalent expression:

$$L = \sum_{j=N}^{T-1} T \widehat{\gamma}_j^2 \sim \chi((T - N - 2))$$

Where  $N$  is the first lag of autocorrelation function in the 95% of interval of confidence (As in the *Graph A2.1*).

However the hypotheses of this test are relatively strong: 1) higher moment  $r > 2$  exists for the innovation series; 2) an ideal approximation of distribution of autocorrelation function. The author has not simulated the efficiency and power of this test yet. This is an uncompleted work and in progressing.

### Appendix 3.3 Results of our cointegration tests

Table A3.3.1 Results of the unit root tests for  $P_C$  and  $P_S$  according to the information criteria

	Criteria	Models	Delays	Statistics	Critical values	Stationarity
<b>ADF Test</b> $H_0 : P_c$ has a unit root	AIC	Trend	7	-3.333062	at 1% level: -4.467895	No
	SIC	Trend	7	-3.333062	at 5% level: -3.644963	No
	HQ	Trend	7	-3.333062	and at 10% level: -3.261452	No
	Modified AIC	Trend	2	-3.868219		No
	Modified SIC	Trend	2	-3.868219		No
	Modified HQ	Trend	2	-3.868219		No
<b>ERS Test</b> $H_0 : P_c$ has a unit root	AIC	Trend	5	-4.523001	at 1% level: -3.770000	Yes
	SIC	Trend	5	-4.523001	at 5% level: -3.190000	Yes
	HQ	Trend	5	-4.523001	and at 10% level: -2.890000	Yes
	Modified AIC	Trend	0	-1.996714		No
	Modified SIC	Trend	0	-1.996714		No
	Modified HQ	Trend	0	-1.996714		No
<b>KPSS Test</b> $H_0 : P_c$ has not a unit root	AIC	Trend	5	0.493707	at 1% level -3.770000	No
	SIC	Trend	5	0.493707	at 5% level: -3.190000	No
	HQ	Trend	5	0.493707	and at 10% level: -2.890000	No
	Modified AIC	Trend	0	0.819755		No
	Modified SIC	Trend	0	0.819755		No
	Modified HQ	Trend	0	0.819755		No
<b>PP Test</b> $H_0 : P_c$ has a unit root	AIC	Constant	5	-4.367265	at 1% level -3.752946	Yes
	SIC	Constant	0	-1.863733	at 5% level: -2.998064	No
	HQ	Constant	5	-4.367265	and at 10% level: -2.638752	Yes
	Modified AIC	Constant	8	-1.767226		No
	Modified SIC	Constant	8	-1.767226		No
	Modified HQ	Constant	8	-1.767226		No

Table A3.3.2 Unit root tests for  $P_C$  (with a truncation parameter of 2)

	Models	Test statistics	Critical value at 1%	Critical value at 5%	Critical value at 10%	Stationarity
ADF	Trend	-3.868219	-4.467895	-3.644963	-3.261452	No
ERS	Trend	-2.280488	-3.770000	-3.190000	-2.890000	No
PP	Intercept	-1.923615	-3.752946	-2.998064	-2.638752	No
KPSS	Trend	0.213466	0.216000	0.146000	0.119000	No
ERS (PO)	Trend	8.153188	4.220000	5.720000	6.770000	No

Table A3.3.3 Ng-Perron test critical values

	MZa	MZt	MSB	MPT	
Asymptotic critical values	1%	-23.8000	-3.42000	0.14300	4.03000
	5%	-17.3000	-2.91000	0.16800	5.48000
	10%	-14.2000	-2.62000	0.18500	6.67000

Table A3.3.4 Unit root tests for  $DP_C$  (with a truncation parameter of 2)

	Models	Comparison of the test statistics (and critical values)	Stationarity
<b>ADF</b>	None	-2.612867 > -3.6449635 (5%)	No
<b>ERS</b>	Trend	-2.258079 > -3.1900000 (5%)	No
<b>PP</b>	None	-1.868275 > -2.998064 (5%)	No
<b>KPSS</b>	Constant	1.209340 > 0.146000 (5%)	No
<b>ERS (PO)</b>	Trend	24.55721 > 5.720000 (5%)	No
<b>Ng-Perron</b>	Trend	{-3.38874; -1.29443; 0.38198; 26.7459} (*)	No

Note: (\*) Values superior to the corresponding critical values.

Table A3.3.5 Unit root tests for  $D2P_C$  (with a truncation parameter of 2)

	Models	Comparison of the test statistics (and critical values)	Stationarity
<b>ADF</b>	None	-3.434618 < -3.261452 (10%)	Yes
<b>ERS</b>	Constant	-2.741595 < -1.960171 (5%); -2.692358 (1%)	Yes
<b>PP</b>	Constant	-5.905146 < -3.012363 (5%); -3.788030 (1%)	Yes
<b>KPSS</b>	Constant	0.031569 < 0.463 (5%); 0.347 (10%); 0.739 (1%)	Yes
<b>ERS (PO)</b>	Constant	2.328865 < 2.97 (5%); 3.91 (10%)	Yes
<b>Ng-Perron</b>	Trend	{-14.7984; -2.72004; 0.18381; 6.15835} (**)	Yes

Note: (\*\*) = Respectively inferior to the critical values at 10% {-14.2000; -2.62000; 0.18500; 6.67000}.

Table A3.3.6 Unit root tests for  $P_S$  (with a truncation parameter of 2)

	Models	Comparison of the test statistics (and critical values)	Stationarity
<b>ADF</b>	Trend	-4.462184 > -3.6449635 (1%)	No
<b>ERS</b>	Trend	-2.321128 > -3.19(5%); -2.89 (10%)	No
<b>PP</b>	Constant	-2.102704 > -2.998064 (5%); -2.638752 (10%)	No
<b>KPSS</b>	Trend	0.232288 > 0.146 (5%); 0.216 (10%)	No
<b>ERS (PO)</b>	Trend	9.042192 > 5.72 (5%); 6.77 (1%)	No
<b>Ng-Perron</b>	Trend	{-10.9734; 2.33028; 0.21236; 8.36175} (***)	Yes

Note: (\*\*\*) = Values superior to the corresponding critical values.

Table A3.3.7 Unit root tests for  $DP_S$  (with a truncation parameter of 2)

	Models	Comparison of the test statistics (and critical values)	Stationarity
<b>ADF</b>	None	-3.095380 < -2.685718 (1%)	Yes
<b>ERS</b>	Trend	-2.411599 > -3.19 (5%); -2.89 (10%)	No
<b>PP</b>	None	-2.602289 > -2.674290 (1%)	No
<b>KPSS</b>	Constant	1.584383 > 0.463 (5%); 0.739 (1%)	No
<b>ERS (PO)</b>	Trend	34.62528 > 5.72 (5%); 6.77 (1%)	No
<b>Ng-Perron</b>	Trend	{-2.46895; -1.10924; 0.44928; 36.8327} (****)	Yes

Note: (\*\*\*\*) = Values superior to the corresponding critical values.

Table A3.3.8 Unit root tests for  $D2P_S$  (with a truncation parameter of 2)

	Models	Comparison of the test statistics (and critical values)	Stationarity
<b>ADF</b>	None	-3.083689 < -1.960171 (5%); -2.692358 (1%)	Yes
<b>ERS</b>	Constant	-2.396546 < -1.960171 (5%)	Yes
<b>PP</b>	None	-6.216319 < -1.958088 (5%); -2.679735 (1%)	Yes
<b>KPSS</b>	Constant	0.078957 < 0.463 (5%); 0.347 (10%)	Yes
<b>ERS (PO)</b>	Trend	6.213172 > 3.910000 (10%)	No
<b>Ng-Perron</b>	Trend	{-1.43700; -0.84727; 0.58961; 17.0401} (****)	No

Note: (\*\*\*\*) = Respectively inferior to the critical values at 10% {-5.70000; -1.62000; 0.27500; 4.45000}.

Table A3.3.9 Unit root tests for the four price indices (with a truncation parameter of 3)

Price indices		ADF		ERS		PP		KPSS		Stationarity
$P_{FBC S}$	Level	Trend	-1.73	Trend	-1.19	Trend	-1.95	Trend	8.51	No
	D	None	-2.04	Trend	-2.63	Trend	-5.82*	Trend	0.60	No
	D2	None	-6.01	Constant	-4.90	None	-11.03	Constant	0.01	Yes
$P_{FBC F}$	Level	Trend	-1.42	Trend	-0.91	Trend	-1.80	Trend	11.13	No
	D	None	-2.21	Constant	-1.90	Trend	-7.34	Trend	0.19	No
	D2	None	-7.57	Constant	-7.00	None	-18.21	Constant	0.03	Yes
$P_{FBC C}$	Level	None	1.74	Trend	-0.94	Trend	-1.936	Trend	4.29	No
	D	None	-1.69	Constant	-2.17	None	-2.12	Trend	0.11*	No
	D2	None	-4.10	Constant	-3.82	None	-23.44	Constant	0.01	Yes
$P_{FBC F}$	Level	None	1.68	Trend	-0.99	Trend	-2.08	Trend	3.74	No
	D	None	-1.49	Constant	-1.92	None	-1.78	Trend	0.15	No
	D2	None	-3.75	Constant	-3.59	None	-9.31	Constant	0.02	Yes

Notes: 1<sup>st</sup> column of each test = the valid model; 2<sup>nd</sup> column of each test = value of the corresponding statistical test.

### Appendix 3.4: New Databases for China, 1952-2014

Table A3.4.1 Price index series for gross capital formation and gross fixed capital formation: China, 1952-2014 (base 100 = 1952)

Years	Price index: gross capital formation $P_{FBC.C}$	Price index: gross fixed capital formation $P_{FBCF.C}$
1952	100	100
1953	99.321	98.807
1954	99.747	98.199
1955	95.947	94.003
1956	92.545	93.737
1957	92.007	89.745
1958	92.032	90.057
1959	97.656	97.596
1960	97.882	97.282
1961	97.203	95.507
1962	106.896	102.541
1963	111.074	107.490
1964	108.323	105.276
1965	102.019	101.790
1966	100.467	99.820
1967	98.635	100.154
1968	94.330	96.723
1969	93.228	94.494
1970	93.165	94.477
1971	93.780	95.490
1972	94.632	96.698
1973	94.507	96.793
1974	94.867	96.917
1975	96.020	98.105
1976	96.117	98.756
1977	97.349	100.230
1978	97.635	100.782
1979	101.053	102.964
1980	103.329	106.071
1981	106.170	109.486
1982	108.706	112.050
1983	111.653	114.781
1984	115.799	119.437
1985	123.984	128.004
1986	131.504	136.224
1987	139.774	143.344
1988	158.893	162.766
1989	173.721	176.639
1990	184.160	186.221
1991	198.332	202.014
1992	225.030	228.282
1993	281.244	285.493
1994	311.639	314.995
1995	336.082	333.901
1996	349.433	346.993
1997	348.453	352.793
1998	346.102	352.872
1999	348.854	351.392
2000	349.999	355.121
2001	351.063	356.561
2002	351.896	357.401
2003	359.872	365.433
2004	381.798	388.180
2005	389.988	397.362
2006	398.231	405.173
2007	402.515	410.037
2008	410.061	418.828
2009	419.379	427.169
2010	428.298	437.460
2011	435.108	449.175
2012	428.867	445.427
2013	430.842	448.345
2014	434.535	452.860

Table A3.4.2 **Intermediate Series: buildings and the value of their lands, and the inventories: China, 1952-2014**

Years	Built-up lands <i>B</i>	Inventories <i>V</i>
1952	322.250	73.000
1953	353.214	151.088
1954	377.158	224.986
1955	389.840	286.032
1956	418.595	311.004
1957	441.375	386.187
1958	449.756	460.022
1959	471.415	619.486
1960	498.363	679.328
1961	488.411	678.143
1962	468.200	628.692
1963	459.790	625.248
1964	466.064	631.114
1965	476.799	697.966
1966	491.180	810.960
1967	490.945	865.174
1968	486.488	955.188
1969	503.068	981.963
1970	518.136	1,138.103
1971	544.311	1,303.924
1972	571.601	1,409.456
1973	605.145	1,584.803
1974	640.650	1,693.797
1975	681.384	1,789.680
1976	717.989	1,824.227
1977	760.415	1,921.370
1978	828.9632	2,138.733
1979	950.167	2,339.449
1980	1,102.776	2,484.632
1981	1,279.438	2,630.856
1982	1,512.668	2,754.883
1983	1,774.138	2,895.667
1984	2,045.456	3,076.581
1985	2,410.078	3,572.303
1986	2,784.491	4,026.405
1987	3,206.855	4,299.687
1988	3,648.190	4,711.183
1989	4,080.843	5,539.853
1990	4,433.576	6,240.942
1991	4,839.047	6,786.249
1992	5,267.895	7,085.661
1993	5,870.771	7,539.143
1994	6,687.002	8,066.493
1995	7,658.903	8,851.335
1996	8,645.455	9,567.246
1997	9,590.272	10,168.610
1998	10,761.579	10,440.873
1999	12,051.510	10,501.540
2000	13,384.937	10,224.763
2001	14,829.579	10,281.540
2002	16,471.047	10,335.011
2003	18,324.076	10,557.814
2004	20,568.546	11,193.910
2005	23,076.978	11,728.632
2006	26,306.994	12,579.093
2007	30,647.916	13,950.313
2008	35,973.880	16,169.680
2009	42,098.656	17,626.765
2010	49,579.390	19,679.023
2011	59,140.953	22,827.037
2012	69,651.255	25,966.606
2013	81,697.894	29,288.481
2014	93,737.339	32,749.463

Notes: The monetary unit is the yì, or hundreds of millions ( $10^8$ ) of yuans (RMB).  
The stock of the inventories in 1951 is supposed to be zero.

Table A3.4.3 New Statistical series of physical capital stocks: China, 1952-2014

Years	Productive capital $K_{Pe}$	Productive capital $K_{Pl}$	Fixed capital $K_F$	Total capital $K_T$
1952	623.25	696.25	945.5	1,018.5
1953	645.8187	797.1779	999.0328	1,150.121
1954	698.6237	924.6013	1,075.782	1,300.768
1955	768.8622	1,056.587	1,158.702	1,444.735
1956	896.9786	1,208.856	1,315.573	1,626.577
1957	994.6854	1,382.935	1,436.06	1,822.248
1958	1,260.143	1,722.903	1,709.899	2,169.921
1959	1,570.695	2,192.767	2,042.11	2,661.596
1960	1,893.551	2,575.651	2,391.915	3,071.243
1961	1,982.03	2,663.167	2,470.442	3,148.584
1962	2,007.977	2,639.969	2,476.177	3,104.87
1963	2,051.276	2,680.341	2,511.066	3,136.314
1964	2,153.015	2,788.732	2,619.079	3,250.193
1965	2,311.269	3,013.624	2,788.068	3,486.034
1966	2,518.179	3,333.533	3,009.36	3,820.32
1967	2,640.593	3,509.366	3,131.538	3,996.712
1968	2,746.235	3,704.063	3,232.724	4,187.912
1969	2,944.325	3,928.085	3,447.393	4,429.356
1970	3,276.783	4,415.878	3,794.919	4,933.022
1971	3,628.585	4,932.326	4,172.896	5,476.82
1972	3,965.886	5,373.781	4,537.487	5,946.943
1973	4,315.753	5,897.365	4,920.898	6,505.701
1974	4,723.427	6,412.604	5,364.077	7,057.874
1975	5,221.677	7,005.232	5,903.06	7,692.741
1976	5,666.745	7,483.004	6,384.734	8,208.963
1977	6,106.824	8,018.08	6,867.239	8,788.608
1978	6,645.107	8,770.555	7,474.07	9,612.803
1979	7,144.542	9,468.255	8,094.709	10,434.16
1980	7,697.915	10,162.13	8,800.691	11,285.32
1981	8,156.634	10,760.62	9,436.071	12,066.93
1982	8,634.617	11,354.62	10,147.29	12,902.17
1983	9,196.687	12,049.64	10,970.83	13,866.49
1984	9,990.124	13,014.6	12,035.58	15,112.16
1985	10,908.96	14,416.39	13,319.04	16,891.34
1986	11,949.65	15,896.3	14,734.14	18,760.55
1987	13,193.1	17,402.82	16,399.96	20,699.64
1988	14,544.99	19,156.23	18,193.18	22,904.36
1989	15,398.98	20,834.21	19,479.82	25,019.67
1990	16,337.51	22,473.81	20,771.08	27,012.02
1991	17,549.41	24,224.99	22,388.46	29,174.71
1992	19,354.49	26,326	24,622.38	31,708.04
1993	21,768.67	29,186.87	27,639.45	35,178.59
1994	24,602.3	32,542.91	31,289.3	39,355.8
1995	27,795.13	36,538.2	35,454.03	44,305.37
1996	31,370.67	40,847.34	40,016.13	49,583.37
1997	35,112.62	45,177.75	44,702.89	54,871.5
1998	39,051.31	49,360.17	49,812.89	60,253.76
1999	43,121.41	53,485.14	55,172.92	65,674.46
2000	47,632.83	57,697.7	61,017.77	71,242.53
2001	52,700.7	62,796.39	67,530.28	77,811.82
2002	58,756.37	68,876.77	75,227.41	85,562.42
2003	66,515.79	76,827.69	84,839.86	95,397.68
2004	75,379.17	86,285.62	95,947.72	107,141.6
2005	85,142.84	96,529.81	108,219.8	119,948.5
2006	96,391.54	108,568.6	122,698.5	135,277.6
2007	109,205.4	122,666.6	139,853.3	153,803.6
2008	125,118.9	140,674.4	161,092.7	177,262.4
2009	144,911.7	161,807	187,010.4	204,637.2
2010	166,912.1	185,688.4	216,491.5	236,170.5
2011	190,906.3	212,474.7	250,047.2	272,874.3
2012	217,968.1	242,201.8	287,619.4	313,586.0
2013	246,723.8	273,716.7	328,421.7	357,710.2
2014	274,936.9	304,774.2	368,674.3	401,423.7

Notes: The monetary unit is the yì, or hundreds of millions ( $10^8$ ) of yuans (RMB).

$K_{Pe}$  = narrowly-defined productive capital stock (without the built-up lands, without the inventories);

$K_{Pl}$  = broadly-defined productive capital stock (without the built-up lands, with the inventories);

$K_F$  = fixed capital stock (with the built-up lands, without the inventories);

$K_T$  = total capital stock (with the built-up lands, with the inventories).



### Appendix 3.5 Error Analysis

From the PIM equation (A3.1.20) we have:

$$\frac{K_t - K_{t-1}}{K_{t-1}} = -\sigma + \frac{I_t/P_t}{K_{t-1}} \approx \Delta \log K_t = gK_t \quad (\text{A3.5.1})$$

Where  $gK_t$  is the growth rate of capital stock in year  $t$ .

If the last year is  $T$ , then:

$$-T\sigma + \sum_{t=0}^T \frac{I_t/P_t}{K_{t-1}} = \log K_T - \log K_0 = T\overline{gK} \quad (\text{A3.5.2})$$

$\overline{gK}$  presents the average growth rate of capital stock.

Equation (A3.5.2) is the basic equation for error analysis that could conduct many important conclusions.

1) The influence of the level of initial capital in the base year. From Equation (A3.5.2) we can get:

$$\frac{K_0}{K_T} = e^{-T\overline{gK}} \quad (\text{A3.5.3})$$

If the average growth rate of capital stock  $\overline{gK}$  is positive then  $K_0/K_T \rightarrow 0$  as  $T \rightarrow +\infty$ . That is to say, as time goes by, the influence of initial capital on level of capital stock of the last year dies out.

2) The influence of the value of depreciation rate. We note that conclusion 1 is based on the assumption of positive average growth rate of capital stock. In order to make sure  $\overline{gK} > 0$ , then it must satisfies:

$$\sigma < \frac{1}{T} \sum_{t=0}^T \frac{I_t/P_t}{K_{t-1}} \quad (\text{A3.5.4})$$

That is the depreciation rate cannot exceed the average investment rate<sup>226</sup>, which is calculated at 9.221% using our data. If the depreciation rate is too high, then the investments in initial years might be not able to compensate the depreciation of capital. As a consequence, the growth rate of capital stock  $gK_t$  in the initial years might be artificially underestimated with an excessive depreciation rate.

3) The influence of different values of depreciation rate. Assume that we use two different depreciation rates  $\sigma_1$  and  $\sigma_2$  satisfy:

$$\sigma_1 < \sigma_2 < \frac{1}{T} \sum_{t=0}^T \frac{I_t/P_t}{K_{t-1}} \quad (\text{A3.5.5})$$

Respectively the capital stock in year  $T$  are  $K_{1T}$  and  $K_{2T}$ . From Equation (A3.5.2) we can get:

$$\frac{K_{1T}}{K_{2T}} = e^{T(\sigma_2 - \sigma_1)} \quad (\text{A3.5.6})$$

$K_{1T}/K_{2T} \rightarrow +\infty$  as  $T \rightarrow +\infty$  because of  $\sigma_2 - \sigma_1 > 0$ . So, a slight difference in depreciation rates will make the levels of capital stocks diverge.

4) The influence in the regression analysis. We cite an example of univariate OLS regression to illustrate those influences. Suppose that we want to use the growth rate of capital stock  $gK_t$  (assuming stationary) to explain another stationary variable  $y_t$ , the mode is:

$$y_t = \alpha + \beta gK_t + \varepsilon_t \quad (\text{A3.5.7})$$

$\varepsilon_t$  is innovation term.

The OLS estimators are given by:

$$\begin{cases} \hat{\alpha} = \bar{y} - \hat{\beta} \overline{gK} \\ \hat{\beta} = \frac{Cov(y_t, gK_t)}{Var(gK_t)} \end{cases} \quad (\text{A3.5.8})$$

<sup>226</sup> This recalls  $\overline{\alpha_t}$  in Appendix 3.2, we see here that this conclusion is associated with the iteration procedure.

From (A3.5.2) we see that  $\overline{gK}$  is associated with  $\sigma$  or  $K_0$ . That is to say the depreciation rate and initial value of capital stock will affect the estimator of constant term.

While,  $Cov(y_t, gK_t)$  depends on the real relation between the two variables  $y_t$  and  $gK_t$ , and from (A3.5.1) we see that:

$$Var(gK_t) = Var\left(\frac{I_t/P_t}{K_{t-1}}\right) \quad (A3.5.9)$$

that does not depend on  $\sigma$  or  $K_0$ . So the depreciation rate and initial value of capital stock will not affect the estimator of  $gK_t$ .

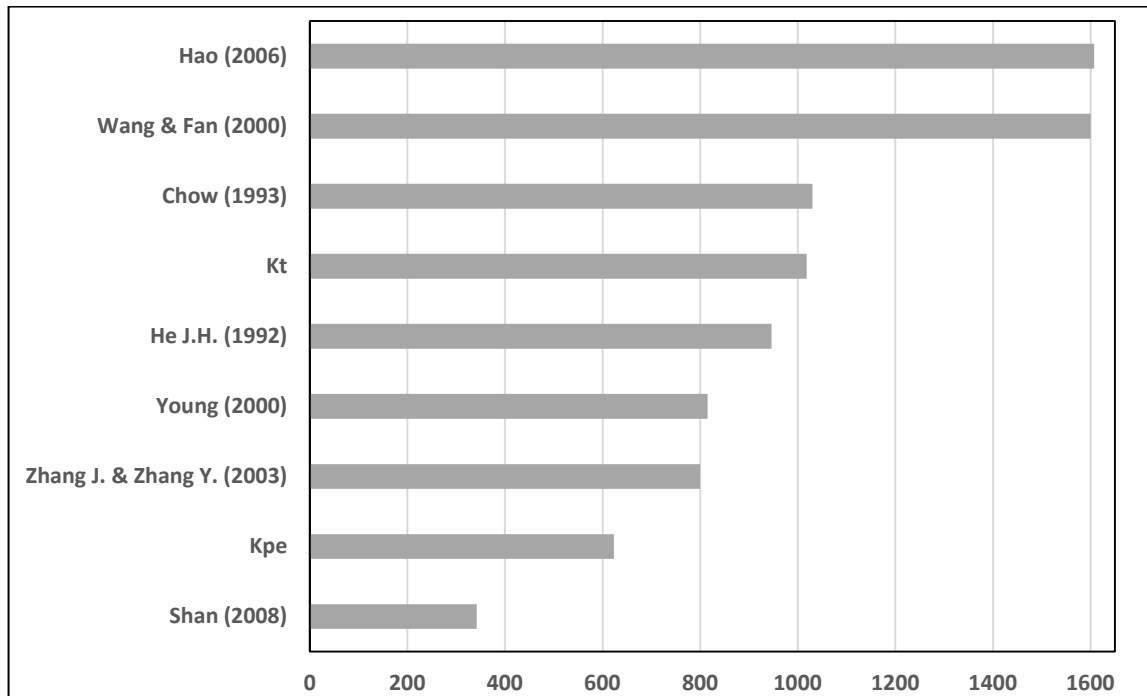
However, under the null hypothesis of  $\beta = 0$  the t-statistic is:

$$t_{\hat{\beta}} = \frac{\hat{\beta}}{\sqrt{Var(\hat{\beta})}} = \frac{\frac{Cov(y_t, gK_t)}{Var(gK_t)}}{\sqrt{\frac{\widehat{\sigma}_\varepsilon^2}{T * Var(gK_t)}}} = \frac{Cov(y_t, gK_t)}{\sqrt{\frac{Var(gK_t) * \widehat{\sigma}_\varepsilon^2}{T}}} \quad (A3.5.9)$$

Where  $\widehat{\sigma}_\varepsilon^2$  is the variance of regression residuals. We see that higher variance of  $gK_t$  (or investment rate  $\alpha_t$  in *Appendix 3.2*) smaller t-statistics, then we have more risk to reject null hypothesis of that the accumulation of capital has no contribution to the explicated variable  $y_t$ . For example,  $y_t$  might the economic growth rate, that is to say, if the investment rate fluctuates violently, then capital stock might be insignificant to explain economic growth.

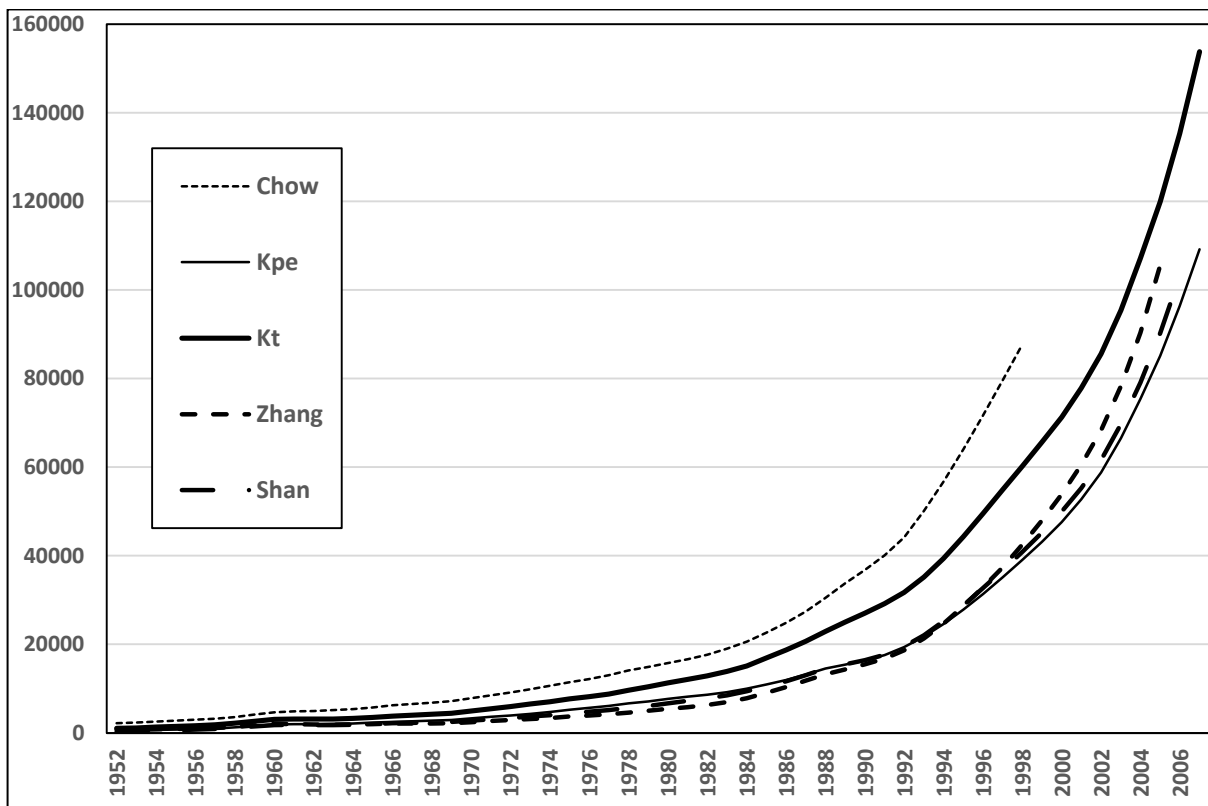
**Appendix 3.6: Comparisons of our new database with other series in the literature**

**Graph A3.6.1 Comparison with other initial physical capital stocks for China in 1952**



Notes: All estimates of the initial capital stocks are at 1952 prices – except He (1992), at 1990 prices.

**Graph A3.6.2 Comparison with other physical capital stock series for China since 1952**



Notes: All capital stock level trajectories are expressed in hundreds million yuan (RMB).

## Appendix 4.1 Other Possible Solutions for the Time Gap between Physical Capital and Human Capital Inputs

We propose four possible solutions and analyze their feasibility:

- 1) We convert the discrete time series of physical capital stock in the end of year  $K_t$  and human capital stock in the middle of year  $H_t$  into continuous time series. The quantitative analysis is hence in the continuous time series framework so that we can arbitrarily chose points in time.
- 2) We suppose that if the growth rate of human capital within a year is stationary, we could calculate the human capital stock in the end of year.
- 3) If the variables in the regression can pass the factionary cointegration test, we can try ARFIMA model.
- 4) Using equation:

$$H_t = (1 - \sigma_t)H_{t-1} + I_{t-1} \quad (A4.1)$$

The graduates in the year  $t-1$  must have fully entered into the labor market (employed or unemployed), so  $H_t$  estimated by equation (A4.1) is completely included in the input factor of production.

These four approaches both have their own advantages and disadvantages. Firstly, there is an implicit hypothesis that “the growth rates of variables are stationary within a year”. That is to say the seasonal factors have no effect on the variables (GDP, K, H, etc.). Such an assumption is probably not real. NBS had ever published the monthly GDP data before 2004 that GDP and total capital formation (the investment  $I$ ) presented seasonal fluctuations. It seems that the monthly mortality rate is also affected by seasonal factors (such as the data provided by *Population Yearbook 1992*). And the delivery of diploma is concentrated in the middle of the year. As a consequence, human capital’s formation is also affected by seasonal factors. The growth rate of  $H_t$  is not steady. Secondly, method 3 requires that the series could pass the factionary cointegration test that largely limits the application of ARFIMA model. Lastly, even though  $H_t$  estimated by equation (A4.1) is completely included in the input factor of production in year  $t$ , but it has also omitted a part of new increased human capital in that year. The econometric simulations show that, even there is not too much difference between two human capital series estimated by equation (4.2) and (A4.1). But the values of coefficients estimated and significances are very different. Thus we propose equation (4.5):

$$H_t = (1 - \sigma_t)H_{t-1} + (1 - \sigma_t/2)I_t \quad (4.5)$$

This is based on two facts:

- 1) The delivery of diploma in China is concentrated in the middle of a year, so that the new increased human capital are very few in the second half year. When we didn’t consider the depreciation of  $H_t$ , the new increased human capital in year  $t$  equals the new increased human capital in the mid-year.
- 2) The new increased human capital in the mid-year should also be depreciated when time goes to the end of year. When  $\sigma_t$  is small, the depreciation rate of half year is a half of the depreciation rate of a whole year. Because:

We note that  $\sigma_t^{demie}$  as the depreciation rate of half year,  $I_t^{end}$  is the new increased human capital in the end of year  $t$ :

$$I_t^{end} = I_t * (1 - \sigma_t)^{0.5} = I_t * (1 - \sigma_t^{demie}) \quad (A4.2)$$

Taking the logarithm for both sides:

$$0.5 * \log(1 - \sigma_t) = \log(1 - \sigma_t^{demie}) \quad (A4.3)$$

We know that when  $x$  is small, there is equivalent infinitesimal:

$$\log(1 + x) \approx x \quad (A4.3)$$

*i.e.*

$$\log(1 + (-x)) \approx -x \quad (A4.4)$$

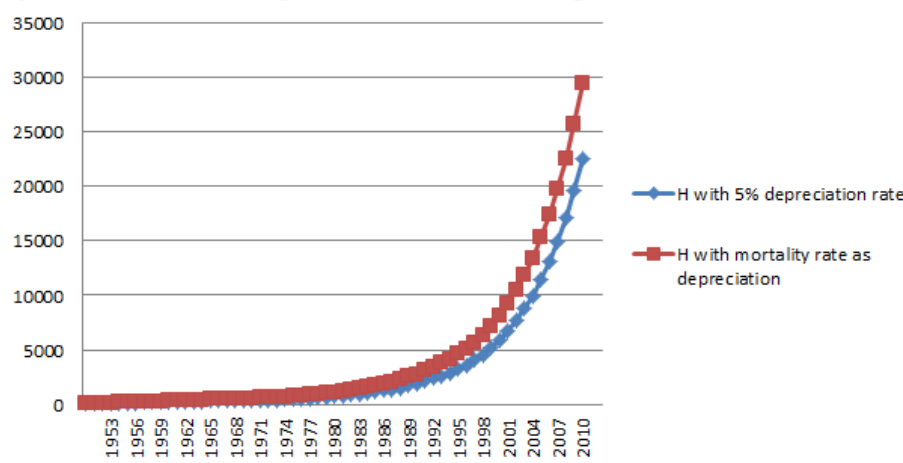
Substituting into the equation (A4.3), we have:

$$\sigma_t^{demie} = 0.5\sigma_t \quad (A4.5)$$

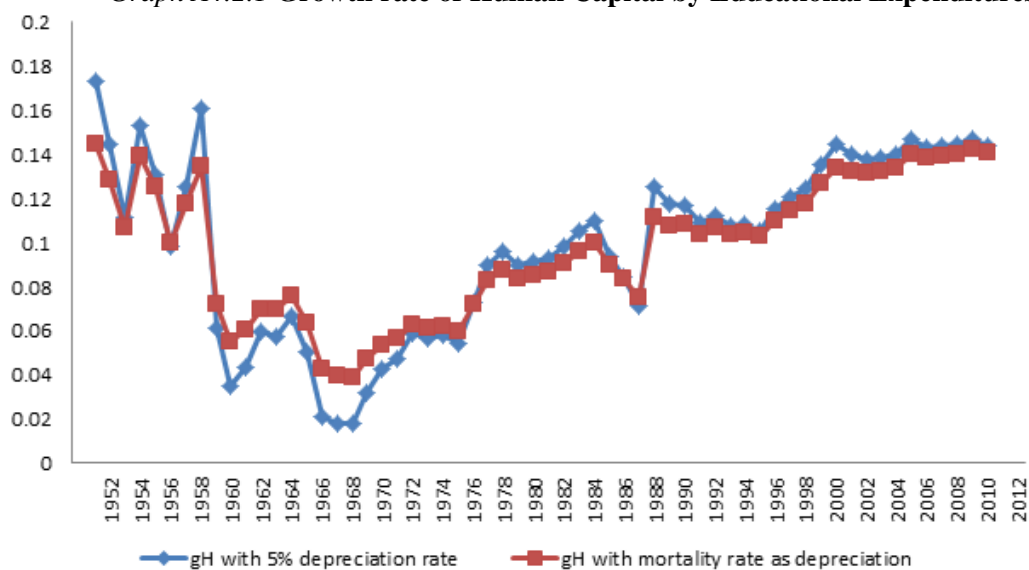
## Appendix 4.2 Human Capital with Method of Kendrick (1979)

According to the method of Kendrick (1979), the human capital is the accumulated (and depreciated) expenditures on labors' education in order to improve their quality of labor. The human capital in narrow sense is the accumulated expenditures on education, while the human capital in board sense also includes the accumulated expenditures on health. The expenditures on health are difficult to define in China and lacking of data. We define the total expenditures on education as the sum of Fiscal Education Expenditure of the State, Funds for Running Private Schools, Social Donation and Fund Raising, Business income of schools, and other educational funds. The data comes from NBS online database and *CHINA COMPENDIUM OF STATISTICS 1949-2008*<sup>227</sup> that provides the "investment series". The method applied is also PIM so that we need the initial human capital and depreciation rate. Zhang (2000) set the depreciation rate as 5%. We estimate two series with both constant depreciation rates 5% and a dynamic depreciation rate – the mortality rate of total population. The initial capital is obtained by the method of iteration suggested in chapter 3 for the physical capital stock. After 5 iterations we get a convergent result. We use CPI as price index. *Graph A4.2.1* and *A4.2* present the two human capital series with different depreciation rates and their annual growth rates. *Table A4.2* presents the database.

*Graph A4.2.1 Human Capital by Educational Expenditures (100 million Yuan)*



*Graph A4.2.1 Growth rate of Human Capital by Educational Expenditures*



<sup>227</sup> In Chinese: 《新中国六十年统计资料汇编》

**Table A4.2 Database of Human Capital with Method of Kendrick (1979)**

(Constant price of 1952, 100 million Yuan)

YEAR	Total Educational Expenditures	Human Capital with 5% Depreciation Rate	Growth Rate	Human Capital with Mortality rate as Depreciation Rate	Growth Rate
1952	11.03	82.15834		115.5727	
1953	18.31589	96.36631	0.172934	132.2706	0.144479
1954	18.73861	110.2866	0.144452	149.2659	0.128489
1955	17.7751	122.5474	0.111172	165.208	0.106803
1956	24.84449	141.2645	0.152734	188.1691	0.138983
1957	25.53837	159.7397	0.130784	211.6753	0.12492
1958	23.59826	175.3509	0.09773	232.7376	0.099503
1959	30.69548	197.2789	0.125052	260.0375	0.117299
1960	41.59877	229.0137	0.160863	295.0235	0.134542
1961	25.48469	243.0477	0.06128	316.2805	0.072052
1962	20.52185	251.4172	0.034435	333.6142	0.054805
1963	23.44716	262.2935	0.04326	353.6919	0.060182
1964	28.58963	277.7684	0.058999	378.1929	0.069272
1965	29.79383	293.6738	0.057261	404.3939	0.069279
1966	34.13042	313.1206	0.066219	434.9373	0.075529
1967	31.2781	328.7426	0.049892	462.5315	0.063444
1968	23.27434	335.5798	0.020798	481.9899	0.042069
1969	22.65844	341.4593	0.01752	500.7635	0.03895
1970	23.09418	347.4805	0.017634	520.0319	0.038478
1971	28.25913	358.3656	0.031326	544.474	0.047001
1972	32.96596	373.4133	0.04199	573.2747	0.052896
1973	36.33672	391.0793	0.04731	605.5527	0.056304
1974	42.37083	413.8962	0.058343	643.4545	0.062591
1975	43.9887	437.1901	0.05628	682.7074	0.061003
1976	47.17239	462.503	0.057899	724.9028	0.061806
1977	47.90763	487.2855	0.053583	767.8014	0.059178
1978	59.84703	522.7682	0.072817	822.8496	0.071696
1979	72.90331	569.5331	0.089456	890.6431	0.082389
1980	83.09697	624.1534	0.095904	968.0934	0.08696
1981	87.20641	680.1522	0.08972	1049.143	0.083721
1982	95.81538	741.9599	0.090873	1138.034	0.084727
1983	105.9714	810.8334	0.092826	1236.153	0.086218
1984	120.2279	890.5196	0.098277	1347.95	0.09044
1985	137.9415	983.9351	0.1049	1476.752	0.095554
1986	156.8683	1091.607	0.10943	1623.49	0.099365
1987	156.4188	1193.445	0.093292	1768.999	0.089627
1988	159.7655	1293.538	0.083869	1917.019	0.083674
1989	156.5506	1385.412	0.071025	2061.032	0.075124
1990	242.7861	1558.928	0.125245	2290.071	0.111128
1991	260.4855	1741.467	0.117093	2535.213	0.107046
1992	290.1814	1944.575	0.11663	2808.56	0.10782
1993	309.2735	2156.619	0.109044	3099.185	0.103478
1994	350.0431	2398.832	0.112311	3429.114	0.106457
1995	377.0664	2655.956	0.107188	3783.652	0.10339
1996	419.4335	2942.592	0.107922	4178.264	0.104294
1997	456.5938	3252.056	0.105167	4607.658	0.102768
1998	536.1472	3625.601	0.114864	5113.855	0.10986
1999	617.5102	4061.831	0.120319	5698.33	0.114292
2000	706.882	4565.621	0.12403	6368.457	0.117601
2001	845.7842	5183.124	0.135251	7173.292	0.126378
2002	1007.469	5931.437	0.144375	8134.78	0.134037
2003	1127.817	6762.682	0.140142	9210.534	0.132241
2004	1266.331	7690.878	0.137253	10417.73	0.131067
2005	1445.963	8752.297	0.13801	11795.88	0.132288
2006	1660.898	9975.58	0.139767	13376.44	0.133993
2007	1961.484	11438.28	0.146629	15245.23	0.139707
2008	2210.913	13077.28	0.143291	17348.51	0.137963
2009	2533.889	14957.31	0.143763	19759.57	0.138978
2010	2907.649	17117.09	0.144397	22526.73	0.140041
2011	3366.131	19627.37	0.146653	25732.02	0.142288
2012	3806.805	22452.8	0.143954	29354.84	0.14079

### Appendix 4.3 Intermediate series in the building of human capital stocks

Table A4.3.1 mortality rates, retirement rate and depreciation rate of human capital (%)

year	$M_t^{total}$	$M_t^{6+}$	$M_t^{10+}$	$M_t^{12+}$	$M_t^{14+}$	$M_t^{17+}$	$M_t^{18+}$	$M_t^{5-14}$	$M_t^{10-17}$	$M_t^{12-20}$	$r_t$	$\sigma_t$
1949	20	-	-	-	-	-	-	-	-	-	-	-
1950	18	14.26	16.54	17.37	18.31	19.58	20	1.61	3.26	4.22	-	-
1951	17	18.88	20.72	21.65	22.68	24.15	24.64	3.72	7.1	7.68	-	-
1952	17	21.9	23.71	24.63	25.63	27.02	27.49	6.43	9.22	10.29	20.53	19.46
1953	14	19.37	19.87	20.7	21.62	22.99	23.46	8.27	6.92	6.92	22	16.84
1954	13.18	16.75	15.18	15.71	16.29	17.51	17.99	17.37	4.96	3.5	20.97	15.82
1955	12.28	24.13	26.3	27.02	27.83	28.96	29.33	13.08	14.07	14.96	20.55	14.86
1956	11.4	13.46	15.15	15.95	16.83	18.13	18.57	0.53	2.76	3.11	20.47	14.06
1957	10.8	12.97	14.5	15.31	16.17	17.39	17.81	0.34	1.22	2.09	19.55	13.44
1958	11.98	14.57	15.07	15.85	16.71	17.94	18.35	5.01	2.95	3.04	12.01	14.37
1959	14.59	17.41	16.75	17.32	17.94	19.07	19.48	15.82	6.86	5.86	12.9	17.25
1960	25.43	14.91	17.93	18.7	19.58	20.73	21.09	2.42	5.56	6.34	12.43	28.37
1961	14.33	17.42	20.16	20.96	21.85	23.11	23.52	3.27	8.71	8.57	14.8	17.42
1962	10.08	21.57	24.06	24.95	25.92	27.17	27.56	7.86	11.14	11.92	15.08	12.72
1963	10.1	18.97	19.49	20.51	21.66	23.08	23.49	10.21	6.38	7.07	14.99	12.69
1964	11.56	14.55	12.72	13.59	14.6	16.03	16.48	16.28	1.45	1.18	16.36	14.41
1965	9.5	19.51	18.99	19.67	20.47	21.28	21.49	19.29	11.44	12.6	14.9	12.17
1966	8.87	8.63	8.4	9.24	10.2	11.26	11.53	3.38	0.49	1.28	14.14	11.41
1967	8.47	5.92	7.18	7.86	8.61	9.51	9.78	3.77	2.72	0.25	13	10.77
1968	8.25	4.91	6.57	7.03	7.54	8.37	8.66	1.18	0.95	0.28	12.6	10.47
1969	8.06	5.53	6.12	6.47	6.87	7.69	8.02	2.98	1.09	0.09	12.8	10.3
1970	7.64	9.45	10.14	10.62	11.18	11.89	12.12	6.35	4.21	4.98	12.67	9.96
1971	7.34	5.76	6.29	6.76	7.29	8.11	8.4	0.02	0.96	0.9	11.16	9.49
1972	7.65	7.88	8.76	9.19	9.64	10.35	10.62	1.45	2.78	3.11	10.88	9.83
1973	7.08	7.44	7.76	8.2	8.68	9.43	9.7	2.77	1.98	2.02	10.96	9.29
1974	7.38	6.2	5.89	6.26	6.67	7.39	7.65	6.43	0.8	0.47	11.05	9.65
1975	7.36	10.13	10.6	11.09	11.68	12.39	12.61	7.81	4.23	4.96	10.33	9.58
1976	7.29	5.84	6.29	6.83	7.43	8.21	8.45	0.28	0.55	0.52	10.51	9.64
1977	6.91	7	8.05	8.54	9.08	9.73	9.92	0.02	1.86	2.16	10.24	9.28
1978	6.25	6.72	7.31	7.8	8.34	9.04	9.25	1.18	1.5	1.45	10.82	8.81
1979	6.21	6.39	6.18	6.61	7.09	7.82	8.06	6.01	0.89	0.59	11.67	9.06
1980	6.34	7.76	7.78	8.31	8.95	9.71	9.94	6.45	1.24	1.93	11.83	9.28
1981	6.36	6.54	6.81	7.4	8.06	8.93	9.2	0.93	0.79	0.85	12.15	9.43
1982	6.6	8.84	10.14	10.64	11.2	11.93	12.17	0.57	3.91	4.21	12.35	9.72
1983	6.9	7.45	8.31	8.76	9.27	10.01	10.26	0.56	2.72	2.55	13.27	10.26
1984	6.82	5.59	5	5.4	5.85	6.6	6.87	5.67	2.41	2.56	14.18	10.42
1985	6.78	12.86	11.79	12.31	12.91	13.69	13.95	14.25	5.04	5.79	14.09	10.4
1986	6.86	6.82	6.15	6.76	7.45	8.35	8.64	0.64	0.68	0.87	14	10.49
1987	6.72	6.97	7.83	8.29	8.78	9.48	9.72	2.19	1.34	1.77	14.72	10.56
1988	6.64	5.82	7.13	7.43	7.75	8.36	8.6	1.4	2.08	1.55	14.15	10.36
1989	6.54	4.72	5.24	5.5	5.78	6.39	6.64	1.82	0.18	1.82	14.76	10.38
1990	6.67	12.95	12.75	13.11	13.52	14.14	14.36	10.28	6.28	6.74	12.7	10.01
1991	6.7	6.18	5.98	6.35	6.76	7.43	7.67	2.72	1.31	1.52	13.26	10.24
1992	6.64	6.56	7.07	7.38	7.69	8.19	8.38	0.72	0.75	0.92	13.35	10.24
1993	6.64	6.55	7.09	7.4	7.72	8.21	8.38	0.68	0.73	0.88	15.14	10.78
1994	6.49	6.43	7	7.29	7.59	8.09	8.26	0.61	0.63	0.81	15.05	10.65
1995	6.57	6.51	7.11	7.41	7.75	8.21	8.36	0.61	0.62	0.85	14.79	10.71
1996	6.56	6.59	7.22	7.51	7.83	8.32	8.47	0.56	0.59	0.75	16.52	11.33
1997	6.51	6.27	6.84	7.13	7.41	7.89	8.03	0.68	0.62	0.74	18.04	11.88
1998	6.5	6.24	6.76	7.08	7.38	7.83	7.96	0.56	0.62	0.87	18.58	12.18
1999	6.46	6.21	6.71	7.04	7.38	7.84	7.98	0.33	0.42	0.65	18.99	12.42
2000	6.45	5.99	6.39	6.68	7.01	7.45	7.62	0.48	0.46	0.58	18.71	12.46
2001	6.43	6	6.38	6.68	7	7.46	7.59	0.47	0.43	0.58	19.82	13
2002	6.41	6.39	6.78	7.04	7.39	7.92	8.06	0.44	0.49	0.5	21.8	13.89
2003	6.4	6.24	6.58	6.81	7.12	7.64	7.78	0.48	0.52	0.64	21.82	14.16
2004	6.42	6.11	6.45	6.65	6.92	7.42	7.58	0.44	0.54	0.56	23.31	14.99
2005	6.51	6.23	6.58	6.79	7.06	7.55	7.7	0.4	0.45	0.61	23.06	15.28
2006	6.81	5.55	5.83	6.01	6.22	6.61	6.76	0.38	0.38	0.53	23.44	16.07
2007	6.93	5.88	6.16	6.35	6.56	6.93	7.09	0.34	0.26	0.33	25.23	17.3
2008	7.06	5.95	6.24	6.41	6.61	6.97	7.08	0.37	0.45	0.52	23.61	17.09
2009	7.08	5.67	5.93	6.08	6.25	6.56	6.67	0.3	0.26	0.3	21.74	16.63
2010	7.11	5.91	6.17	6.32	6.49	6.85	6.97	0.48	0.33	0.38	19.07	15.8
2011	7.14	6.15	6.42	6.57	6.73	7.03	7.14	0.35	0.3	0.35	16.77	15.02
2012	7.15	6.25	6.54	6.69	6.86	7.18	7.29	0.17	0.18	0.31	23.93	18.72
2013	7.16	6.24	6.54	6.69	6.84	7.13	7.24	0.24	0.36	0.41	23.31	18.74
2014	7.16	6.43	6.88	4.23	4.31	4.43	4.49	0.17	0.27	0.22	26.49	20.64

**Table A4.3.2 Average Mortality Rates of Population by Age (%)**

Age	Average Mortality rate over 1953-1964 Total	Average Mortality rate over 1953-1964 Male	Average Mortality rate over 1953-1964 Female	Average Mortality rate over 1964-1982 Total	Average Mortality rate over 1964-1982 Male	Average Mortality rate over 1964-1982 Female
0	0.312839	0.175854	0.458561	0.693242	0.725633	0.6598
1	1.846876	1.754504	1.945359	0.552001	0.701344	0.39874
2	1.03285	0.932013	1.141479	0	0.234079	0
3	0.632413	0.54487	0.728382	0.421454	0.630034	0.206292
4	0.634293	0.553844	0.723045	0	0.085036	0
5	0.659787	0.608387	0.716872	0.228186	0.265253	0.188092
6	0.606568	0.724366	0.476422	0.260795	0.301815	0.215865
7	0.533578	0.868393	0.168766	0.241614	0.313545	0.163265
8	0.352637	0.642135	0.032997	0.225965	0.305765	0.13964
9	0.500487	0.751488	0.218452	0.232237	0.288314	0.171496
10	0.683408	0.992791	0.334337	0.178292	0.24257	0.109288
11	0.587317	0.914619	0.218768	0.263713	0.328755	0.194138
12	0.876758	1.195666	0.514484	0.154105	0.211977	0.092313
13	0.626498	0.933775	0.274974	0.278711	0.342316	0.210094
14	0.287871	0.528031	0.007906	0.111055	0.125283	0.095323
15	0	0.031701	0	0.133423	0.173154	0.089456
16	0	0	0	0.210373	0.246776	0.169944
17	0	0	0.163667	0.178643	0.139441	0.22161
18	1.143102	0.902284	1.405186	0.286018	0.161766	0.418685
19	0.308569	0.126215	0.510433	0.171785	0.05997	0.293185
20	0.388415	0.150879	0.647494	0.13518	0.039877	0.240667
21	0.126956	0	0.438519	0.168222	0.046724	0.302867
22	0.297851	0	0.653021	0.28493	0.171087	0.410383
23	0	0	0.278818	0.016922	0	0.164772
24	0.299598	0.020619	0.597312	0.180439	0.090399	0.28105
25	0.336803	0.08543	0.605124	0.315041	0.28451	0.349728
26	0.416976	0.224409	0.626868	0.330596	0.321463	0.341144
27	0.376048	0.217381	0.546953	0.285784	0.294474	0.275889
28	0.481303	0.311109	0.663372	0.331146	0.353549	0.305872
29	0.465605	0.363893	0.573724	0.349964	0.382557	0.313607
30	1.166919	1.055568	1.285195	0.368598	0.389767	0.344707
31	0.784714	0.7728	0.797522	0.202931	0.206554	0.198863
32	0.990435	0.967526	1.014845	0.265946	0.286542	0.242781
33	0.838969	0.83946	0.838449	0.54487	0.516111	0.577428
34	1.215742	1.245243	1.184753	0.290339	0.261061	0.322973
35	1.584254	1.640798	1.524657	0.557769	0.567894	0.546602
36	1.544005	1.65765	1.422838	0.53831	0.542333	0.533883
37	1.437611	1.640448	1.22604	0.585778	0.632546	0.53399
38	1.598563	1.768218	1.420758	0.712728	0.757833	0.663569
39	1.4009	1.677705	1.10679	0.792537	0.851086	0.729223
40	2.311486	2.587786	2.01902	0.801661	0.877534	0.721069
41	1.807848	2.183748	1.405808	0.807646	0.908206	0.701239
42	2.035003	2.409312	1.644523	0.680742	0.792775	0.562478
43	1.767357	2.220334	1.306526	1.013869	1.134247	0.887926
44	2.05211	2.599671	1.503466	1.068957	1.202702	0.930682
45	2.500864	3.073444	1.932603	1.331033	1.515239	1.144313
46	2.52106	3.166851	1.881951	1.395039	1.598382	1.1896
47	2.339757	3.036903	1.668626	1.451489	1.757857	1.146035
48	2.710599	3.376379	2.074011	1.739426	1.993178	1.492285
49	2.662324	3.483564	1.87153	1.990031	2.286241	1.701134
50	3.388482	4.205921	2.603481	2.034074	2.379212	1.700142
51	3.239235	4.223055	2.29596	2.197881	2.60246	1.811788
52	3.510874	4.472029	2.608182	2.438036	2.890518	2.010594
53	3.909991	4.948557	2.948012	2.548936	3.008931	2.124989
54	4.525125	5.684013	3.442184	3.021613	3.519346	2.58054
55	4.895037	6.199086	3.673532	3.261133	3.8168	2.785583
56	5.265259	6.592333	4.033456	3.545209	4.135207	3.049133
57	5.402902	6.73908	4.21267	3.957245	4.621834	3.411214
58	6.157953	7.413701	5.065491	4.404219	5.121649	3.837659
59	6.471179	7.898305	5.260001	4.935114	5.71649	4.326125
60	7.658524	9.052901	6.489825	5.367037	6.219018	4.717767
61	7.221302	8.856391	5.868906	5.833638	6.778797	5.125608
62	8.037622	9.667342	6.726692	6.120154	7.120825	5.391842
63	8.486214	10.21663	7.133457	6.972564	8.042065	6.215166
64	9.202676	10.96054	7.866706	7.600327	8.742394	6.817709
65	10.03261	11.89664	8.666814	8.424189	9.657305	7.59689
66	10.60265	12.56258	9.184316	9.166125	10.47208	8.313054



67	11.23557	13.27959	9.814855	9.915453	11.28838	9.038131
68	12.39898	14.46486	11.01769	10.94434	12.44027	10.0403
69	13.04636	15.22	11.60599	11.95212	13.52844	11.02392
70	14.78915	16.96114	13.42184	12.93048	14.54249	12.02553
71	15.2958	17.63351	13.87535	14.13643	15.8874	13.18365
72	16.61735	19.13205	15.18569	14.51389	16.09371	13.66649
73	17.47348	20.00323	16.06956	16.21975	18.04504	15.30017
74	18.94516	21.32354	17.64773	17.2916	19.10792	16.41038
75	20.49219	22.95891	19.20553	18.6244	20.45333	17.7666
76	21.63351	24.2216	20.35145	19.7941	21.38643	19.05821
77	22.7058	25.30305	21.46395	20.15569	21.21251	19.64036
78	24.58478	26.9782	23.47835	21.15675	21.79597	20.84022
79	25.3099	27.23105	24.42104	21.99895	22.71074	21.66428
80	28.34156	30.36481	27.47015	22.05687	22.08159	22.04419
81	28.48958	30.18309	27.75582	22.80576	22.73568	22.84043
82	29.65727	30.61658	29.23565	21.20835	21.52409	21.06893
83	29.24426	29.52309	29.11864			
84	28.27487	27.77476	28.50597			
85	28.44969	28.00617	28.64713			
86	28.3442	27.49365	28.7171			
87	26.75772	25.46596	27.32099			
88	25.67446	23.0323	26.9387			
89	14.82416	10.68555	16.91091			

Note: those mortality rates are biased for young population but what we need is just the mortality rates for ages 50, 55 and 60. So the biases have no effect on the final results.

**Table A4.3.3 Duration of Education and Educational Attainment of Graduates (years)**

year	Average Duration of Primary school	Average Duration of Junior High School	Average Duration of Senior High School	Average Educational Attainment of Primary School Graduates	Average Educational Attainment of Junior High School Graduates	Average Educational Attainment of Senior High School Graduates
1949	6	3	3	6	9	12
1950	6	3	3	6	9	12
1951	6	3	3	6	9	12
1952	5	3	3	5	9	12
1953	5	3	3	5	9	12
1954	6	3	3	6	9	12
1955	6	3	3	6	8	12
1956	6	3	3	6	8	12
1957	6	3	3	6	9	12
1958	5.85	2.8133	2.8133	5.85	8.8133	10.8133
1959	5.85	2.8133	2.8133	5.85	8.8133	10.8133
1960	5.85	2.8133	2.8133	5.85	8.8133	11.8133
1961	6	3	3	6	8.85	11.8133
1962	6	3	3	6	8.85	11.8133
1963	6	3	3	6	8.85	11.8133
1964	6	3	3	6	9	11.85
1965	6	3	3	6	9	11.85
1966	5	2	2	5	8	11
1967	5	2	2	5	8	11
1968	5	2	2	5	8	10
1969	5	2	2	5	7	10
1970	5	2	2	5	7	10
1971	5	2	2	5	7	9
1972	5	2	2	5	7	9
1973	5	2	2	5	7	9
1974	5	2.175507	2.003051	5	7.175507	9.003051
1975	5.010308	2.155037	2.002504	5.010308	7.155037	9.002504
1976	5.008986	2.148112	2.005603	5.008986	7.148112	9.18111
1977	5.007059	2.161249	2.003567	5.007059	7.161249	9.158604
1978	5.000944	2.335138	2.000989	5.000944	7.345446	9.149101
1979	5	2.768037	2.002201	5	7.777023	9.16345
1980	5	2.973097	2.01371	5	7.980157	9.359156
1981	5	2.980367	2.045144	5	7.981311	9.822167
1982	5.003325	2.987835	2.09578	5.003325	7.987835	10.07594
1983	5.030469	3	2	5.030469	8	9.981311
1984	5.142647	3	2.776979	5.142647	8	10.75829
1985	5.231587	3	2.978477	5.231587	8.003325	10.96631
1986	5.289594	3	2.961961	5.289594	8.030469	10.96196
1987	5.398149	3	2.980128	5.398149	8.142647	10.98013
1988	5.431531	3	2.989432	5.431531	8.231587	10.99276

1989	5.51005	3	2.994308	5.51005	8.289594	11.02478
1990	5.55744	3	2.996491	5.55744	8.398149	11.13914
1991	5.575723	3	3	5.575723	8.431531	11.23159
1992	5.597132	3	3	5.597132	8.51005	11.28959
1993	5.588577	3	3	5.588577	8.55744	11.39815
1994	5.598053	3	3	5.598053	8.575723	11.43153
1995	5.610173	3	3	5.610173	8.597132	11.51005
1996	5.618662	3	3	5.618662	8.588577	11.55744
1997	5.666473	3	3	5.666473	8.598053	11.57572
1998	5.685468	3	3	5.685468	8.610173	11.59713
1999	5.619131	3	3	5.619131	8.618662	11.58858
2000	5.6414	3	3	5.6414	8.666473	11.59805
2001	5.772847	3	3	5.772847	8.685468	11.61017
2002	5.883172	3	3	5.883172	8.619131	11.61866
2003	5.932544	3	3	5.932544	8.6414	11.66647
2004	6	3	3	6	8.772847	11.68547
2005	6	3	3	6	8.883172	11.61913
2006	6	3	3	6	8.932544	11.6414
2007	6	3	3	6	9	11.77285
2008	6	3	3	6	9	11.88317
2009	6	3	3	6	9	11.93254
2010	6	3	3	6	9	12
2011	6	3	3	6	9	12
2012	6	3	3	6	9	12
2013	6	3	3	6	9	12
2014	6	3	3	6	9	12

**Table A4.3.4 New Increased Human Capital Series (years\*10 000 persons)**

year	New Increased Human Capital TOTAL (in the middle of the year)	New Increased Human Capital TOTAL (in the end of the year, depreciated by $M_t^{6+}$ )	New Increased productive Human Capital (in the middle of the year)	New Increased productive Human Capital (in the end of the year, depreciated by $\sigma_t$ )
1949	1071.831	1061.113	684.2309	677.3886
1950	1134.95	1126.858	665.1502	659.1638
1951	1495.073	1480.959	795.4731	788.7116
1952	1464.462	1448.427	719.4622	714.0575
1953	2711.418	2685.152	1243.918	1234.856
1954	3418.48	3389.848	1423.48	1412.351
1955	3720.034	3675.147	1782.634	1769.474
1956	4532.371	4501.858	2101.771	2087.135
1957	5426.298	5391.122	2438.298	2422.017
1958	9624.458	9554.344	6077.603	6034.334
1959	8360.159	8287.366	5158.454	5115.879
1960	7509.381	7453.387	3215.481	3170.458
1961	6700.382	6642.033	3215.582	3187.78
1962	6140.471	6074.261	2786.471	2768.827
1963	5429.606	5378.098	2568.806	2552.675
1964	5859.248	5816.621	2454.848	2437.43
1965	6869.647	6802.62	2864.047	2846.877
1966	6537.448	6509.254	4971.548	4944.507
1967	6729.183	6709.248	5622.483	5593.912
1968	12565.76	12534.92	8804.856	8761.252
1969	10723.4	10693.76	4872.102	4849.315
1970	13469.2	13405.56	5914.032	5887.948
1971	13745.33	13705.75	5323.645	5298.818
1972	16426.6	16361.91	6838.101	6805.175
1973	18019.81	17952.75	9160.805	9119.112
1974	19265.02	19205.31	8656.855	8615.942
1975	22856.53	22740.76	9252.795	9209.363
1976	27737.35	27656.36	9839.546	9792.366
1977	31624.18	31513.52	12657.12	12599.33
1978	31843.4	31736.41	17359.64	17284.03
1979	31432.7	31332.28	18920.74	18836.18
1980	25583.06	25483.84	15582.29	15510.9
1981	26342.38	26256.3	17802.97	17720.64
1982	23963.15	23857.18	16111.95	16033.95
1983	21786.92	21705.8	14399.43	14323.13
1984	21969.64	21908.26	14812.85	14737.98
1985	23107.61	22959.02	15951.16	15870.62
1986	24228.68	24146.03	16816.95	16732.54
1987	25818.73	25728.75	17819.41	17725.28
1988	25909.2	25833.85	17838.31	17745.94

1989	25603.62	25543.14	17315.12	17216.44
1990	25884.24	25716.65	16991.25	16900.17
1991	26035.25	25954.82	16759.08	16672.43
1992	26425.52	26338.89	16654.6	16555.92
1993	26681.81	26594.43	16806.68	16702.82
1994	27138.32	27051.13	16662.58	16562.07
1995	28736.38	28642.84	17732.02	17624.14
1996	29439.09	29342.06	18572.04	18452.68
1997	31624.42	31525.22	20517.57	20382.13
1998	34290.2	34183.17	22251.79	22101.78
1999	35731.78	35620.88	22730.57	22575.34
2000	37403.05	37291.09	23755.49	23594.38
2001	38949.63	38832.77	25112.69	24936.04
2002	41050.26	40919	27213.51	27003.24
2003	43444.68	43309.2	29990.26	29758.29
2004	45938.6	45798.2	33127.4	32862.11
2005	48708.67	48556.94	36591.81	36290.28
2006	50194.12	50054.72	38623.12	38316.05
2007	51601.35	51449.68	40380.32	40030.36
2008	52893.25	52735.94	41703.54	41348.85
2009	52683.07	52533.62	41851.88	41514.22
2010	52635.78	52480.28	42197.96	41867.63
2011	52597.69	52436.02	42620.86	42298.59
2012	52302.5	52139.05	42452.9	42051.12
2013	51374.24	51219.54	41887.89	41495.44
2014	49360.56	49360.56	40500.79	40082.84

Note: the data after 2006 in this table are in fact redundant information because we calculate the human capital of reference years by Population Yearbooks not the PIM equation. However we can use that information to verify whether the PIM equations (4.5) and (4.7) are correct by comparing the data calculated from labor survey and data calculated by PIM equations. The results show that there is no significant difference between the two. That is to say the PIM equations are verified.

**Table A4.3.5 Educational Attainment of Different Cultural Levels for Total Population in Reference Years (years)**

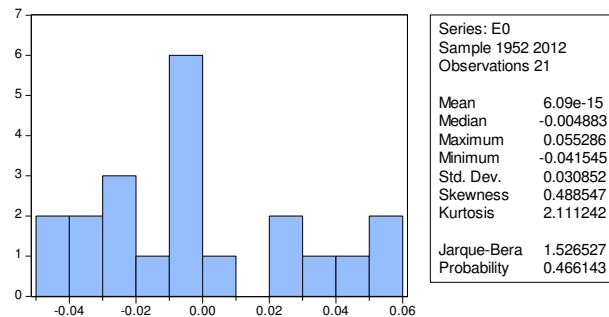
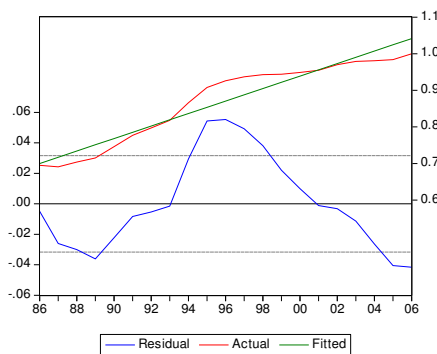
Base years	No schooling	Primary	Junior Secondary	Senior Secondary	College and higher
1964	0	3.589516	8.307569	10.37593	14.6086
1990	0	4.140418	8.135899	11.80585	13.74189
1993	0	4.500292	8.328257	11.17173	13.87258
1994	0	4.439792	8.335503	11.15428	14.24387
1995	0	4.401438	8.341133	11.2291	13.97613
1996	0	4.392676	8.332485	11.26622	14.09459
1997	0	4.425981	8.338915	11.28649	14.06121
1998	0	4.449159	8.348762	11.29458	14.12473
1999	0	4.429598	8.349053	11.27266	14.1229
2000	0	4.435325	8.308305	11.34742	14.02323
2001	0	4.611883	8.442118	11.31128	14.02399
2002	0	4.73949	8.377818	11.28758	13.98307
2003	0	4.839658	8.40213	11.32133	14.00238
2004	0	4.93055	8.546517	11.32459	14.06317
2005	0	4.867329	8.659831	11.18874	14.07618
2006	0	4.852054	8.721808	11.19543	14.11808
2007	0	4.903134	8.800483	11.31886	14.3089
2008	0	4.920046	8.805026	11.42644	14.50108
2009	0	4.969838	8.809866	11.46583	14.61053
2010	0	4.941948	8.759135	11.8784	14.56034
2011	0	4.9935	8.811849	11.60861	14.61481
2012	0	5.024027	8.812045	11.62161	14.68839
2013	0	5.043278	8.811091	11.63235	14.72702
2014	0	5.035941	8.80598	11.6397	14.80221

### Appendix 4.4 Fineness of Promotion Rate of Primary School Graduates

We assume that the gross promotion rate of primary graduates is a function of time over 1986-2006. From the graph, three functions are tested: linear function (the promotion rate increases steadily and slowly); exponential function (the growth rate of promotion rate is constant that means promotion rate accelerates), logical function (the growth rate of promotion rate is small in the beginning and then accelerated, and slowdown in the end; that is to say a “S” curve of promotion rate). The econometric fineness is given as follow:

Model 1: linear model:

Dependent Variable: PROMOTION		Method: Least Squares		
Sample: 1986 2006		Included observations: 21		
Newey-West HAC Standard Errors & Covariance (lag truncation=2)				
	Coefficient	Std. Error	t-Statistic	Prob.
C	-33.22719	3.114385	-10.66894	0.0000
T	0.017083	0.001561	10.94434	0.0000
R-squared	0.921899	Mean dependent var		0.870714
Adjusted R-squared	0.917789	S.D. dependent var		0.110397
S.E. of regression	0.031654	Akaike info criterion		-3.977542
Sum squared resid	0.019037	Schwarz criterion		-3.878063
Log likelihood	43.76419	Hannan-Quinn criter.		-3.955952
F-statistic	224.2750	Durbin-Watson stat		0.192833
Prob(F-statistic)	0.000000			



Source	SS	df	MS	Number of obs =	21
Model	.224711319	1	.224711319	F( 1, 19) =	224.27
Residual	.019036966	19	.001001946	Prob > F =	0.0000
Total	.243748286	20	.012187414	R-squared =	0.9219
				Adj R-squared =	0.9178
				Root MSE =	.03165

promotion	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
t	.0170831	.0011407	14.98	0.000	.0146956 .0194707
_cons	-33.22719	2.276875	-14.59	0.000	-37.99274 -28.46163

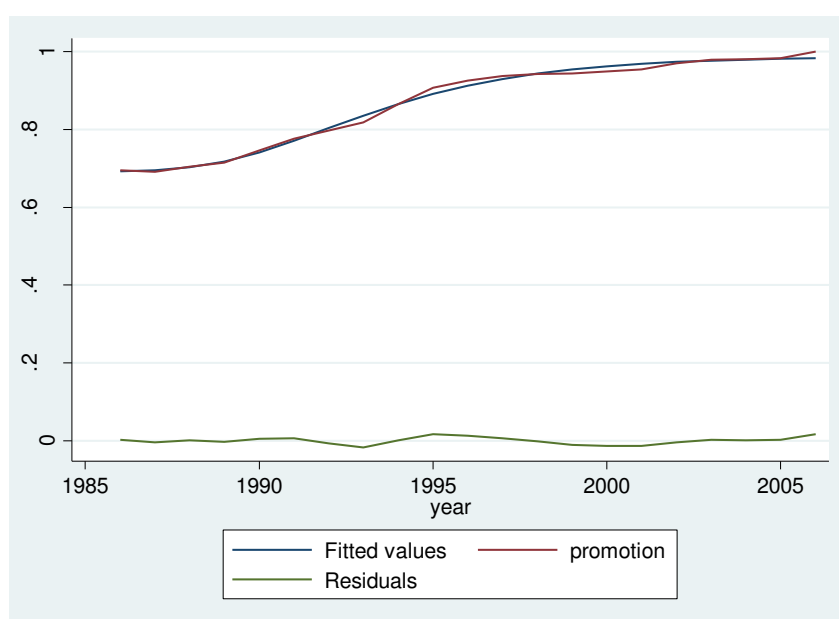
Model 2: exponential model:

Source	SS	df	MS	
Model	.241995268	3	.080665089	Number of obs = 21
Residual	.001753018	17	.000103119	R-squared = 0.9928
Total	.243748286	20	.012187414	Adj R-squared = 0.9915
				Root MSE = .0101547
				Res. dev. = -137.6143

4-parameter Gompertz function, promotion =  $b_0 + b_1 \cdot \exp(-\exp(-b_2 \cdot (t - b_3)))$

promotion	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
/b0	.6913134	.0075805	91.20	0.000	.6753199 .7073069
/b1	.2960262	.0108595	27.26	0.000	.2731147 .3189377
/b2	.3023839	.0254719	11.87	0.000	.2486429 .3561249
/b3	1991.904	.2299157	8663.63	0.000	1991.419 1992.389

Parameter b0 taken as constant term in model & ANOVA table



Skewness/Kurtosis tests for Normality

Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	joint	
				adj chi2(2)	Prob>chi2
e3	21	0.9754	0.9747	0.00	0.9990

Portmanteau test for white noise

Portmanteau (Q) statistic = 17.2775  
 Prob > chi2(8) = 0.0273

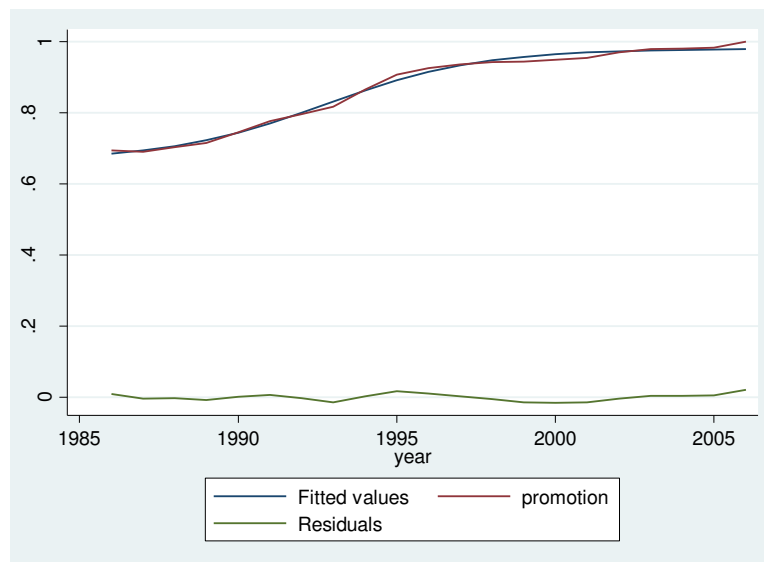
Model 3: logical model:

Source	SS	df	MS	
Model	.241701074	3	.080567025	Number of obs = 21
Residual	.002047211	17	.000120424	R-squared = 0.9916
Total	.243748286	20	.012187414	Adj R-squared = 0.9901
				Root MSE = .0109738
				Res. dev. = -134.3564

4-parameter logistic function, promotion =  $b_0 + b_1 / (1 + \exp(-b_2 * (t - b_3)))$

promotion	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
/b0	.6671245	.0137912	48.37	0.000	.6380276 .6962214
/b1	.3132097	.0168052	18.64	0.000	.2777538 .3486656
/b2	.4096175	.0438861	9.33	0.000	.317026 .5022091
/b3	1992.736	.3015383	6608.57	0.000	1992.1 1993.373

Parameter b0 taken as constant term in model & ANOVA table



Skewness/Kurtosis tests for Normality

Variable	Obs	Pr (Skewness)	Pr (Kurtosis)	joint	
				adj chi2 (2)	Prob>chi2
e2	21	0.7762	0.8839	0.10	0.9502

Portmanteau test for white noise

-----  
 Portmanteau (Q) statistic = 16.7680  
 Prob > chi2(8) = 0.0326

### Appendix 4.5 An Illustration for equations (4.23) – (4.25)

To better understand the equations (4.23) – (4.25), we cite an extremely simple case to illustrate the idea. We assume that:

- 1) The country has no education until the first year.
- 2) The enrollment of primary school for each year is 1 million.
- 3) There are 6 grades for the primary school.
- 4) Every year, 10 000 students die and 10 000 students give up their studies in each grade.

The following table summarized the evolutions of the variables in equations (4.23) – (4.25) and we have verified the equations (4.23) and (4.25). The table presents a special case with  $L_0^{D-P} = 0$ . The unit of population in this table is 10 000 persons (In Chinese: 万).

Year	Grade	Enrollments	Deaths	Dropouts	Graduates	In School	Accumulated enrollments	Accumulated deaths	Accumulated dropouts	Accumulated Graduates	Total in School	Verification of Equation: Accumulated Dropouts
1	1	100	1	1	0	98	100	1	1	0	98	1
	2		0	0		0						
	3		0	0		0						
	4		0	0		0						
	5		0	0		0						
	6		0	0		0						
2	1	100	1	1	0	98	200	3	3	0	194	3
	2		1	1		96						
	3		0	0		0						
	4		0	0		0						
	5		0	0		0						
	6		0	0		0						
3	1	100	1	1	0	98	300	6	6	0	288	6
	2		1	1		96						
	3		1	1		94						
	4		0	0		0						
	5		0	0		0						
	6		0	0		0						
4	1	100	1	1	0	98	400	10	10	0	380	10
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		0	0		0						
	6		0	0		0						
5	1	100	1	1	0	98	500	15	15	0	470	15
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		0	0		0						
6	1	100	1	1	0	98	600	21	21	0	558	21
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		1	1		88						
7	1	100	1	1	88	98	700	27	27	88	558	27
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		1	1		88						
8	1	100	1	1	88	98	800	33	33	176	558	33
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						

	5		1	1		90						
	6		1	1		88						
9	1	100	1	1	88	98	900	39	39	264	558	39
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		1	1		88						
10	1	100	1	1	88	98	1000	45	45	352	558	45
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		1	1		88						
11	1	100	1	1	88	98	1100	51	51	440	558	51
	2		1	1		96						
	3		1	1		94						
	4		1	1		92						
	5		1	1		90						
	6		1	1		88						



**Appendix 4.6 Database of Human Capital and Educational Attainment**

<b>Year</b>	<b>Index of Productive Human Capital: Educational Attainment (years)</b>	<b>Index of Total Human Capital: Educational Attainment (years)</b>	<b>Productive Human Capital (10 000 persons*years)</b>	<b>Total Human Capital (10 000 persons*years)</b>
1949	-	1.661363	52975.27	75499.12
1950	-	1.611056	52680.88	74739.34
1951	-	1.581098	52574.01	73932.17
1952	2.532596	1.553235	52498.18	73111.42
1953	2.479319	1.504484	52968.17	72358.36
1954	2.452926	1.505148	53552.27	73142.21
1955	2.442273	1.495671	54531.08	74169.13
1956	2.426741	1.50455	55858.72	75962.73
1957	2.420376	1.51289	57534.75	78974.94
1958	2.359017	1.539072	62749.85	82710.89
1959	2.553392	1.636246	66829.93	90232.82
1960	2.632492	1.767387	68128.89	96400.57
1961	2.740858	1.855566	70138.56	101468.7
1962	2.779589	1.881102	72019.15	105057.9
1963	2.765289	1.892675	73667.31	108027.6
1964	2.706208	1.88398	75059.37	110823.9
1965	2.685954	1.923337	77006.31	113882.9
1966	2.72146	1.942105	81113.12	117206.8
1967	2.787132	1.981926	85882.68	122216.7
1968	2.938847	2.101528	93793.3	133431.2
1969	2.942521	2.183032	97765.24	142736.1
1970	2.985328	2.284227	102790.8	154011.3
1971	3.007605	2.381435	107130.9	165383.3
1972	3.149004	2.516283	112904.4	179497.7
1973	3.301206	2.65358	120995.8	194711.2
1974	3.437825	2.808581	128468.1	211269.5
1975	3.575545	2.989263	136471.4	230573.6
1976	3.732683	3.224951	144955	254561.1
1977	3.967561	3.498719	156230.6	282816.9
1978	4.287547	3.75149	172153.6	310686.7
1979	4.618052	3.989364	189451	337959.2
1980	4.797477	4.154964	203225.9	358678.9
1981	5.010104	4.305844	219066.8	379827.1
1982	5.143608	4.471453	232979.7	397864.7
1983	5.272499	4.539877	244833.7	413115.3
1984	5.334295	4.670815	257097	429656.2
1985	5.421198	4.77887	270371.4	444719.3
1986	5.545608	4.899813	284389.9	460150.9
1987	5.666801	4.949181	299110.8	479555.5
1988	5.774639	5.194605	313759.2	499277.4
1989	5.917318	5.335863	327399.3	519571.7
1990	5.263244	5.339319	340789.8	519004
1991	5.40438	5.372887	353938.2	546943.7
1992	5.537248	5.470019	366300	567634
1993	5.665122	5.553464	378475.5	588406.2
1994	5.788621	5.447086	390471.4	585191.7
1995	5.925871	5.735072	403344.4	618961.5
1996	6.042241	5.808936	416612.5	650678.7
1997	6.180096	6.030021	431494.3	686066.8
1998	6.339149	6.127943	447778.4	707340.1
1999	6.502474	6.215343	464237.7	725378.8
2000	6.680101	6.628803	481535.1	781887.2
2001	6.864249	6.796719	499696.8	808887.9
2002	7.082126	6.875601	518978.2	827069.2
2003	7.333028	7.095361	540708.1	859990.8
2004	7.606782	7.282976	564910.1	889849.1
2005	7.929189	7.115449	591890.1	869729.7
2006	8.27969	7.330895	620794.6	903994.8
2007	8.40695	7.55475	633219.9	937152.6
2008	8.526371	7.674433	644286.7	956839.5
2009	8.648644	7.815117	655809.4	977470.1
2010	9.050352	8.24496	688777	1024474
2011	9.581349	8.290434	732206.7	1040989
2012	9.664047	8.402824	741271	1060084
2013	9.726813	8.513552	748740.9	1079031
2014	9.856383	8.507623	758714.8	1083728

### Appendix 5.1 Unit root tests applied to the different variables of the estimated models

The correlograms suggested that all the series in the regressions are stationary. So, unit root tests were performed on all the variables used in our estimates. As is known, their results depend on the size of the sample, but also and above all on the choice of the truncation setting of the parameter number of lags of the autocorrelation function. According to the three formulas of the selected criteria (Schwert [1989], Newey and West [1994], Lardic and Mignon [2002]), the value obtained here is 3. So we fix the number of lags at 3 in a first stage. As the use of the Schwert (1989) criteria also suggests a different number of lags (10), we set in a second step – in the event that the first one would not be successful –:

$$L_{maxi} = \max \left\{ T^{\frac{1}{4}}, \text{int} \left[ 4 \left( \frac{T}{100} \right)^{\frac{1}{4}} \right], l12 = \text{int} \left[ 12 \left( \frac{T}{100} \right)^{\frac{1}{4}} \right], l = \text{int} \left[ 4 \left( \frac{T}{100} \right)^{\frac{2}{9}} \right] \right\} \quad (A5.1)$$

We use the maximum lag  $L_{maxi} = 10$  in the unit root tests, then the information criteria (AIC SIC HQ and their modified forms) to determine the optimum lag  $L_{opti}$ . Critical values shown in the following tables come from: MacKinnon (1996) for the augmented Dickey-Fuller tests (ADF), Elliott-Rothenberg-Stock (ERS [DF-GLS]) and Phillips-Perron (PP); Table 1 in Kwiatkowski-Phillips-Schmidt-Shin (1992) for the KPSS tests; Table 1 in Elliott-Rothenberg-Stock (1996) for the ERS tests – optimal point and Table 1 in Ng-Perron (2001) for NP the tests.

Table A5.1.1 Verification of the stationarity of  $gY$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	Fixed at 3	Trend	-5.651646 < -3.492149 (5%)	Stationary
ERS	Fixed at 3	Trend	-3.802547 < -3.177200 (5%)	Stationary
PP	Fixed at 3	Constant	-4.906111 < -2.911730 (5%)	Stationary
KPSS	Fixed at 3	Trend	0.017122 < 0.146000 (5%)	Stationary
ERS-PO	Fixed at 3	Trend	1.949668 < 5.704000 (5%)	Stationary
NP	Fixed at 3	Trend	{-49.6494; -4.98154; 0.10033; 1.83986} < {-17.3; -2.91; 0.168; 5.48} (5%)	Stationary

Note: With Spectral GLS detrended-AR as a method for estimating the PP and KPSS tests.

Table A5.1.2 Verification of the stationarity of  $gK_{Pe}$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC SIC HQ 2	Constant	-4.247029 < -2.913549 (5%)	Stationary
ERS	Fixed at 3	Trend	-2.881809 < -2.872000 (10%)	Stationary
PP	Fixed at 3	Constant	-2.968648 < -2.911730 (5%)	Stationary
KPSS	AIC 2	Constant	0.145053 < 0.146000 (5%)	Stationary
ERS-PO	Fixed at 3	Trend	6.214140 < 6.774000 (10%)	Stationary
NP	Fixed at 3	Trend	{-6.00936; -1.62669; 0.27069; 4.41187} < {-5.7; -1.62; 0.275; 4.45} (10%)	Stationary

Table A5.1.3 Verification of the stationarity of  $gK_{Pl}$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	SIC 0	Constant	-2.772817 < -2.593551 (10%)	Stationary
ERS	Fixed at 3	Constant	-1.906751 < -1.613062 (10%)	Stationary
PP	SIC 0	Constant	-2.803811 < -2.593551 (10%)	Stationary
KPSS	Fixed at 3	Constant	0.180918 < 0.463000 (5%)	Stationary
ERS-PO	Fixed at 3	Constant	3.848106 < 3.962000 (10%)	Stationary
NP	Fixed at 3	Trend	{-7.14784; -1.88529; 0.26376; 3.44657} < {-5.7; -1.62; 0.275; 4.45} (10%)	Stationary

Table A5.1.4 Verification of the stationarity of  $gK_F$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC 6 SIC and HQ 1	Trend	For a lag of 6: -5.633805 < -3.496960 (5%) For a lag of 1: -4.016539 < -3.489228 (5%)	Stationary
ERS	Fixed at 3	Trend	-3.048851 < -2.872000 (10%)	Stationary
PP	AIC SIC HQ 2	Constant	For a lag of 2: 4.819035 < -2.911730 (5%)	Stationary

	modified HQ 4		For a lag of 4: 3.861121 < -2.911730 (5%)	
KPSS	AIC SIC HQ 2 modified AIC SIC HQ	Trend Constant	For a lag of 2: 0.083551 < 0.146000 (5%) For a lag of 4: 0.059806 < 0.146000 (5%)	Stationary
ERS-PO	Fixed at 3	Trend	5.574630 < 5.704000 (5%)	Stationary
NP	Fixed at 3	Trend	{-16.5149; -2.86897; 0.17372; 5.54577} < {-5.7; -1.62; 0.275; 4.45} (10%)	Stationary

Table A5.1.5 Verification of the stationarity of  $gK_T$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC SIC HQ 1	Trend	-4.976285 < -3.489228 (5%)	Stationary
ERS	Fixed at 3	Constant	-1.935007 < -1.613062 (10%)	Stationary
PP	SIC HQ 0	Constant	-2.683883 < -2.593551 (10%)	Stationary
KPSS	Fixed at 3	Trend	0.810268 > 0.216000 (1%)	Non-stationary
ERS-PO	Fixed at 3	Constant	2.622232 < 2.998000 (5%)	Stationary
NP	Fixed at 3	Constant	{-7.92287; -1.95897; 0.24726; 3.21084} < {-5.7; -1.62; 0.275; 4.45} (10%)	Stationary

Note: As the  $R^2$  of the KPSS test regression is zero, the result " $gK_T$  is non-stationary" is not accepted.

Table A5.1.6 Verification of the stationarity of  $gL$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	Fixed at 3	Constant	-3.161359 < -2.914517 (5%)	Stationary
ERS	Fixed at 3	Trend	-3.784782 < -3.170800 (5%)	Stationary
PP	Fixed at 3	Constant	-6.565217 < -2.911730 (5%)	Stationary
KPSS	Fixed at 3	Trend	0.083131 < 0.146000 (5%)	Stationary
ERS-PO	Fixed at 3	Constant	1.870849 < 5.704000 (5%)	Stationary
NP	Fixed at 3	Constant	{-46.1065; -4.79988; 0.10410; 1.98405} < {-5.7; -1.62; 0.275; 4.45} (5%)	Stationary

Table A5.1.7 Verification of the stationarity of  $gH_P$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC SIC HQ 0	Constant	-3.513657 < -2.911730 (5%)	Stationary
ERS	AIC SIC HQ 0	Constant	-2.397496 < -1.946447 (5%)	Stationary
PP	Fixed at 3	Constant	-2.955642 < -2.911730 (5%)	Stationary
KPSS	Fixed at 3	Constant	2.143550 > 0.739000 (1%)	Non-stationary
ERS-PO	AIC SIC HQ 0	Constant	3.446020 < 3.962000 (10%)	Stationary
NP	AIC 0	Constant	{-9.46486; -2.16371; 0.22860; 2.63460} < {-5.7; -1.62; 0.275; 4.45} (5%)	Stationary

Note: As the  $R^2$  of the KPSS test regression is zero, the result " $gH_P$  is non-stationary" is not accepted.

Table A5.1.8 Verification of the stationarity of  $gH_I$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	AIC HQ 1 SIC 0	Trend	For a lag of 1: -3.687920 < -3.485218 (5%) For a lag of 0: -6.127425 < -3.485218 (5%)	Stationary
ERS	SIC 1	Constant	-1.881110 < -1.613293 (10%)	Stationary
PP	AIC HQ 2 SIC 1	Trend	For a lag of 2: -6.326808 < -3.485218 (5%) For a lag of 1: -6.127425 < -3.485218 (5%)	Stationary
KPSS	AIC HQ 2	Trend	1.479043 > 0.216000 (1%)	Non-stationary
ERS-PO	SIC 0	Trend	6.012972 < 6.774800 (10%)	Stationary
NP	SIC 1	Constant	{-6.15920; -1.73726; 0.28206; 4.03593} < {-5.7; -1.62; 0.275; 4.45} (10%)	Stationary

Table A5.1.9 Verification of the stationarity of  $gH_T$

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	SIC 0	Trend	-4.229854 < -3.485218 (5%)	Stationary
ERS	Fixed at 3	Trend	-1.389270 > -3.164400 (5%)	Non-stationary
PP	AIC HQ 4	Trend	For a lag of 4: -4.096227 < -3.485218 (5%)	Stationary

	SIC 1		For a lag of 1: -3.980911 < -3.485218 (5%)	
KPSS	Bandwidth= 5	Trend	0.165485 < 0.216000 (1%)	Stationary
ERS-PO	SIC HQ 4	Trend	9.612190 > 5.704000 (5%)	Non-stationary
NP	SIC HQ 4	Trend	{-9.69338, -2.13180, 0.21992, 9.70404} > {-17.3; -2.91; 0.168; 5.48} (5%)	Non-stationary

Note: As the  $R^2$  of the KPSS test by AR Spectral GLS is zero, we changed the estimation method by using Bartlett Kernel test. The Newey-West criterion gives Bandwidth = 5 and that of Andrews gives Bandwidth = 6.58. This last criterion gives a statistics of  $0.151135 < 0.216000$  (at 1%), allowing us to conclude that the series is stationary.

**Table A5.1.10 Verification of the stationarity of  $gR\&D_1$**

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	Fixed at 3	None	-2.599472 < -1.946878 (5%)	Stationary
ERS	Fixed at 3	Constant	-3.480046 < -3.164400 (5%)	Non-stationary
PP	Fixed at 3	Constant	-6.867736 < -2.912631 (5%)	Stationary
KPSS	Fixed at 3	Constant	2.302908 > 0.739000 (1%)	Non-stationary
ERS-PO	SIC 9	Constant	1.331171 < 2.995200 (5%)	Stationary
NP	SIC 1	Constant	{-10.9047; 2.30726; 0.21158; 2.35629} < {-8.1; -1.98; 0.233; 3.17} (5%)	Stationary

Notes: - As the  $R^2$  of the KPSS test regression is zero, the result “ $gR\&D_1$  is non-stationary” is not accepted.  
- The numbers of lags vary according to the different criteria used for the ERS-OP and NP tests, but most of them favor stationarity, which led us to use the Default AR Spectral OLS.  
- The information criteria give high lags for the ERS tests, tending rather to conclude with non-stationarity. If the number of lags is fixed at 2 (the Lardic and Mignon criteria yield 2.77), then the ERS tests reveal stationarity (with  $-3.251121 < -3.170800$  [5%]).

**Table A5.1.11 Verification of the stationarity of  $gR\&D_2$**

Tests	Criteria and lags	Models	Test statistics and critical values	Stationarity
ADF	Fixed at 3	None	-2.610026 < -1.946878 (5%)	Stationary
ERS	SIC 0	Trend	-3.480046 < -3.164400 (5%)	Stationary
PP	Fixed at 3	Constant	-11.03722 < -2.912631 (5%)	Stationary
KPSS	Fixed at 3	Constant	3.401799 > 0.739000 (1%)	Non-stationary
ERS-PO	AIC 2	Trend	4.001652 < 5.705600 (5%)	Stationary
NP	SIC 0	Trend	{-15.1640; -2.72796; 0.17990; 6.16183} < {-14.2; -2.62; 0.185; 6.67} (10%)	Stationary

Notes: - As the  $R^2$  of the KPSS test regression is zero, the result “ $gR\&D_2$  is non-stationary” is not accepted.  
- Nevertheless, as some tests reject stationarity (in GLS-detrended AR), we also use the Bartlett-Kernel method whose results finally lean in the direction of stationarity for the KPSS tests.

## Appendix 5.2 Econometric tests of Total Factor Productivity

We have two alternatives to choose the technical progress indicator in models:

- 1) Use the growth rate of “total factor productivity (TFP)” as technical progress indicator.
- 2) Use some other indicators of technical progress such as R&D.

Here we firstly consider using the TFP. The measurement of TFP is based on the factor inputs. As we have already pointed out in *Table 5.3*, we have 16 linear regressions different from various labor and capital inputs, so we will get at least 16 kinds of TFPs according to different factor input combination.

If we use “Solow residuals” as TFP (we can also use alternative approaches such as Törnqvist quantity index), based on Hick-neutral assumption the basic equation is:

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \alpha_k \frac{\dot{K}}{K} - \beta_l \frac{\dot{L}}{L} \quad (\text{A5.2.1})$$

$K$  is capital input that could be productive capital in narrow sense  $K_{pe}$ , productive capital in board sense  $K_{pl}$ , fixe capital  $K_f$  or total capital  $K_t$  (even we argue that the fixe capital and total capital contain much “nonproductive investment” so that we don’t suggest them in a production function.).

$L$  is labor input. It could be “number of employed persons”  $l$ , productive human capital  $H_p$ , total human capital  $H_t$ , or intermediate human capital  $H_i$  (even we argue that total human capital contain population aged under 16 that is nonproductive so that we don’t suggest it in a productive function.).

The calculation of capital and labor elasticity  $\alpha_k$  and  $\beta_l$  are based on two basic hypotheses:

$$H_1: \quad \alpha_k + \beta_l = 1$$

That is the hypothesis of constant returns to scale of productive factors.

From the previous 16 regressions in *table 5.4*, Wald tests show that when we use productive human capital  $H_p$  and intermediate human capital  $H_i$  as labor input, this hypothesis is valid. However, when we use simple labor “number of employed persons”  $l$ , it is increasing return to scale and it is decreasing return to scale when the labor input is total human capital  $H_t$  (summarized in *table A5.2.1*).

**Table A5.2.1 Wald Tests for Return to Scale**

Return to Scale	Index Number of Regressions
$\alpha_k + \beta_l < 1$	11 15 19 23
$\alpha_k + \beta_l = 1$	10 12 14 16 18 20 22 24
$\alpha_k + \beta_l > 1$	9 13 17 21

We have already given explanations for such results: due to the birth control policy, population growth is limited so the labor supply growth rate is much lower than output growth. So if we use simple labor as labor input in the production function, the elasticity of labor  $\beta_l$  (or the share of GDP that is earned by labor under the perfect competition assumption), and or the coefficient of labor in the linear regression (in an econometric point of view) will be very high. As a consequence, there exists an increasing return to scale effect. At the meantime, using total human capital  $H_t$  as labor input, as it contains lots population aged over 6-15 and retired population; even some child labors and retired population might have externality on the output, most of them are still “nonproductive”. In this case, there is a decreasing return to scale effect.

The increasing return to scale of simple labor as labor input factor also suggests that Törnqvist quantity index may not be appropriate to calculate the TFP. Because in the Törnqvist quantity index,  $L$  is usually simple labor and contains an implicit hypothesis of constant returns to scale<sup>228</sup>.

<sup>228</sup> For example, Inklaar and Timmer (2013, page 4) used simple labor in PWT database.

The second basic hypothesis  $H_2$  is “perfect competition market” *i.e.*: the factors and commodity markets are both in perfect competition; in such context, the enterprises maximize their profit so the rentabilities of inputs are the values of their marginal output. As a consequence, the unobserved elasticities of  $\alpha_k$  and  $\beta_l$  have respectively become the observable shares of GDP  $s_k$  and  $s_l$  that are earned by the factors:

$$s_k = \frac{p_k K}{pY} \text{ and } s_l = \frac{p_l L}{pY} \quad (\text{A5.2.2})$$

Where  $p$  is the price level of output,  $p_k$  and  $p_l$  are respectively the prices of capital and labor in perfect competition market (in equilibrium):

$$p_k = p \frac{\partial Y}{\partial K} \text{ and } p_l = p \frac{\partial Y}{\partial L} \quad (\text{A5.2.3})$$

That could be regarded as salary  $w_l$  and interest rate  $r_k$ . The distribution shares of input factors could also be written as:

$$s_k = \frac{\partial Y}{\partial K} \frac{K}{Y} \text{ and } s_l = \frac{\partial Y}{\partial L} \frac{L}{Y} \quad (\text{A5.2.4})$$

Or

$$s_k = \frac{r_k K}{pY} \text{ and } s_l = \frac{w_l L}{pY} \quad (\text{A5.2.5})$$

Based on different choices of two basic hypotheses, the equations used to calculate the elasticities  $\alpha_k$  and  $\beta_l$  are also different.

**Case 1:** if we consider that  $H_1$  and  $H_2$  are both valid, so the formula to calculate the elasticities should be:

$$\alpha_k = \frac{r_k K}{r_k K + w_l L} \text{ and } \beta_l = \frac{w_l L}{r_k K + w_l L} \quad (\text{A5.2.6})$$

**Case 2:** if we argue that China is not a pure market economy, so the perfect competition is probably not hold. So we don't adopt  $H_2$  but only adopt  $H_1$ . In this case, the formula to calculate the capital elasticity  $\alpha_k$  has become:

$$\alpha_k = \frac{\partial y}{\partial k} \frac{k}{y} \quad (\text{A5.2.7})$$

Where  $y$  and  $k$  are respectively output per labor and capital per labor:

$$y = \frac{Y}{L} \text{ and } k = \frac{K}{L} \quad (\text{A5.2.8})$$

**Case 3:** we also notice that in some situations,  $H_1$  is not hold neither (for example when we use simple labor and total human capital as labor factor input). So we have to calculate the elasticity according the original definition. As the specific form of production function is unknown (here we don't assume that it is a Cobb-Douglas function but a production function that satisfies the Inada conditions), the terms of partial differential are unknown; we use the differences to approximate:

$$\alpha_k = \frac{\partial Y}{\partial K} \frac{K}{Y} \approx \frac{\Delta Y}{\Delta K} \frac{K}{Y} \text{ and } \beta_l = \frac{\partial Y}{\partial L} \frac{L}{Y} \approx \frac{\Delta Y}{\Delta L} \frac{L}{Y} \quad (\text{A5.2.9})$$

Now we firstly consider the 3<sup>rd</sup> case that is Solow residuals without any constraint. We respectively calculate out  $w_{kpe}$   $w_{kpl}$   $w_{kf}$  and  $w_{kt}$  also  $w_l$   $w_{hp}$   $w_{ht}$  and  $w_{hi}$  (Table A5.2.2), then we get the TFPs corresponding to 16 regressions (Table A5.2.3).

**Table A5.2.2 Average Elasticity of Input Factors without any Restrictions**

	Mean		Mean
$w_{kpe}$	0.686549	$w_l$	7.838600
$w_{kpl}$	0.994089	$w_{hp}$	2.212890
$w_{kf}$	0.064151	$w_{hi}$	2.076013
$w_{kt}$	0.921681	$w_{ht}$	1.187591

**Table A5.2.3 Average Growth Rates of TFPs according the 16 Solow Regressions**

	Elasticity	Average growth rates			Average growth rates
TFP9	$w_{kpe} w_l$	-0.070682	TFP17	$w_{kf} w_l$	-0.070623
TFP10	$w_{kpe} w_{hp}$	-0.071291	TFP18	$w_{kf} w_{hp}$	-0.071231
TFP11	$w_{kpe} w_{ht}$	-0.071237	TFP19	$w_{kf} w_{ht}$	-0.071178
TFP12	$w_{kpe} w_{hi}$	-0.071596	TFP20	$w_{kf} w_{hi}$	-0.071537
TFP13	$w_{kpl} w_l$	-0.070692	TFP21	$w_{kt} w_l$	-0.070641
TFP14	$w_{kpl} w_{hp}$	-0.071301	TFP22	$w_{kt} w_{hp}$	-0.071249
TFP15	$w_{kpl} w_{ht}$	-0.071247	TFP23	$w_{kt} w_{ht}$	-0.071195
TFP16	$w_{kpl} w_{hi}$	-0.071606	TFP24	$w_{kt} w_{hi}$	-0.071554

We see that the growth rates of TFPs without any constraint are negative and around -7%. It should be pointed out that we didn't consider the effects of institutional changes in this calculation. However the analysis in section 5.2 indicates that it is fundamental. The institutional changes, especially the negative institutional changes, their influences on output are also included in the TFPs with the definition of Solow residuals. We could see that, for the three years of difficult period in the early 1960s, the Cultural Revolution began 1966 and the political turmoil in 1989, their negative influences on output are so important. But the usual TFPs only excluded contribution of capital and labor that still includes those influences of negative institutional changes, as a consequence the growth rate of non-constrained TFPs are negative in average.

We propose a method of amelioration to calculate the TFPs. We define a new concepts of TFPs that is the TFPs excluded the effects of institutional changes, that is the “real” technique progress or “augmented” technique progress:

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \alpha_k \frac{\dot{K}}{K} - \beta_l \frac{\dot{L}}{L} - \widehat{\alpha}_d D \quad (A5.2.10)$$

Where D is the dummy variable of institutional changes that values 1 if there is an important positive institutional change and values -1 if the important institutional change is negative;0 for no important institutional changes. D is defined by the method proposed in Chapter 5.  $\widehat{\alpha}_d$  is the elasticity of institutional changes variable to output that is approximated by the OLS estimator.

With new definition, we get the “real” technique progress that excluded the institutional changes:

**Table A5.2.4 Average Growth Rates of Augmented TFPs according the 16 Solow Regressions**

	Elasticity	Mean		Elasticity	Mean
TFP9	$w_{kpe} w_l$ 0.118987	-0.068699	TFP17	$w_{kf} w_l$ 0.117048	-0.068673
TFP10	$w_{kpe} w_{hp}$ 0.117659	-0.069330	TFP18	$w_{kf} w_{hp}$ 0.114836	-0.069317
TFP11	$w_{kpe} w_{ht}$ 0.115308	-0.069315	TFP19	$w_{kf} w_{ht}$ 0.112852	-0.069297
TFP12	$w_{kpe} w_{hi}$ 0.120679	-0.069584	TFP20	$w_{kf} w_{hi}$ 0.118473	-0.069562
TFP13	$w_{kpl} w_l$ 0.118850	-0.068712	TFP21	$w_{kt} w_l$ 0.117250	-0.068687
TFP14	$w_{kpl} w_{hp}$ 0.118036	-0.069333	TFP22	$w_{kt} w_{hp}$ 0.115546	-0.069323
TFP15	$w_{kpl} w_{ht}$ 0.115739	-0.069318	TFP23	$w_{kt} w_{ht}$ 0.113437	-0.069304
TFP16	$w_{kpl} w_{hi}$ 0.120640	-0.069595	TFP24	$w_{kt} w_{hi}$ 0.118628	-0.069577

Now we consider the second situation. We assume that the constant return to scale is valid. According to the Wald tests, in the case without TFPs, the constant returns to scale assumption is valid both for models consisted by productive human capital and intermediate human capital. But for the models who uses simple labor and total human capital as labor factor input, we must construct a post-estimation test after we get the TFPs to verify if  $H_1$  is valid after introduction of such a TFPs (in fact we don't recommend to use simple labor and total human capital as input factor in the models).

Under  $H_1$  we have two methods to calculate the elasticity of capital and TFPs. Firstly we can introduce  $H_1$  in the last step of the calculation of TFP that is we directly use the capital elasticity in

table A5.2.2 and then use 1 minus the capital elasticity to get the labor elasticity. Or we can introduce  $H_1$  in the beginning that is we transfer production function into per labor form (in order to make use of the homogeneity of production function (Inada condition)):

$$\frac{\dot{A}}{A} = \frac{\dot{y}}{y} - \alpha_k \frac{\dot{k}}{k} \quad (\text{A5.2.11})$$

The results of those two methods are different and the first method has not really introduced  $H_1$  except when the production function is exactly constant returns to scale, the two methods are equivalent. However we have already pointed out that when we use simple labor as factor input, the production function is increasing return to scale; so the capital coefficient calculated by method two will be seriously underestimated (even negative). For the same reason, as the production function is decreasing return to scale for total human capital, the capital coefficient calculated by methods two will be overestimated. Table A5.2.5 summarized the results by method two.

**Table A5.2.5 Average Growth Rates of TFPs under Assumption of Constant Returns to Scale**

Capital Elasticity	Mean	TFP	Average growth rate of TFP	Augmented TFP	Elasticity	Average growth rate of TFP
Simple labor as labor input						
$w_{kpe}$	-2.630462	TFP9	0.023631	TFP9	$w_{kpe} w_l$ 0.118987	0.025614
$w_{kpl}$	-3.146507	TFP13	0.023668	TFP13	$w_{kpl} w_l$ 0.118850	0.025649
$w_{kf}$	2.296574	TFP17	0.023646	TFP17	$w_{kf} w_l$ 0.117048	0.025597
$w_{kt}$	-0.094220	TFP21	0.023673	TFP21	$w_{kt} w_l$ 0.117250	0.025627
Productive human capital as labor input						
$w_{kpe}$	1.669600	TFP10	0.046483	TFP10	$w_{kpe} w_l$ 0.115308	0.048444
$w_{kpl}$	-1.744363	TFP14	0.046444	TFP14	$w_{kpl} w_l$ 0.118036	0.048411
$w_{kf}$	-1.292383	TFP18	0.046484	TFP18	$w_{kf} w_l$ 0.114836	0.048398
$w_{kt}$	2.367989	TFP22	0.046458	TFP22	$w_{kt} w_l$ 0.115546	0.048384
Total human capital as labor input						
$w_{kpe}$	4.371352	TFP11	0.049860	TFP11	$w_{kpe} w_l$ 0.117659	0.051821
$w_{kpl}$	1.124522	TFP15	0.049829	TFP15	$w_{kpl} w_l$ 0.115739	0.051758
$w_{kf}$	1.245862	TFP19	0.049802	TFP19	$w_{kf} w_l$ 0.112852	0.051683
$w_{kt}$	23.01203	TFP23	0.049790	TFP23	$w_{kt} w_l$ 0.118628	0.051767
Intermediate human capital as labor input						
$w_{kpe}$	1.266492	TFP12	0.055098	TFP12	$w_{kpe} w_l$ 0.120679	0.057109
$w_{kpl}$	51.15039	TFP16	0.055098	TFP16	$w_{kpl} w_l$ 0.120640	0.057109
$w_{kf}$	-4.792879	TFP20	0.055029	TFP20	$w_{kf} w_l$ 0.118473	0.057004
$w_{kt}$	1.550984	TFP24	0.055045	TFP24	$w_{kt} w_l$ 0.118628	0.057022

Note: we still use fist difference to approximate the 1<sup>st</sup> order partial differential

We see that after the introduce of  $H_1$ , the TFPs calculated by method 2 seem to be logical and consistent with the literature. For example, with simple labor as labor input, the average growth rate of TFPs is about 2.3% that is consistent with Chow and Li (2003). With productive human capital as labor input, an average growth rate of TFPs around 4.6% plus a low population growth rate 1-2% and about 5% depreciation rate equals 10% economic growth rate in long-run. It recalls us the “golden rule<sup>229</sup>” in neoclassic model. However, we bring them back to corresponding models (and under  $H_1$ ), that is to say the so called “augmented Solow models”, the TFPs are nonsignificant<sup>230</sup>. Summarized in table A5.2.6:

**A5.2.6 Regressions of Augmented Solow Models under assumption of Constant Returns to Scale**

	D	Capital	Growth	R <sup>2</sup>	Autocorrelation	Heteroscedasticity	Correction
--	---	---------	--------	----------------	-----------------	--------------------	------------

<sup>229</sup> Phelps (1966)

<sup>230</sup> It should be pointed out that if we use the augmented TFPs, we have no need to use dummy variable anymore because this new TFP has already considered the institutional changes; from an econometric perspective, this is because the augmented TFP is a linear combination of TFP and dummy that contains the information of dummy.



		per Labor	rate of TFP				
9	0.118672 (5.832274)	0.652764 (10.74081)	0.261065 (1.337967)	0.640409	No	Yes	N-W
10	0.115339 (4.812125)	0.710297 (9.389488)	-0.157289 (0.4106)	0.597327	No	Yes	N-W
11	0.111991 (4.687062)	0.818137 (11.21741)	-0.314247 (-1.756634)	0.600026	No	Yes	N-W
12	0.118432 (5.322993)	0.656521 (6.949718)	-0.117120 (-1.046855)	0.610633	No	Yes	N-W
13	0.118372 (8.642681)	0.661703 (8.977617)	0.215698 (1.268630)	0.633697	No	Yes	N-W
14	0.116057 (5.533018)	0.694971 (7.082562)	-0.124053 (-0.662292)	0.602733	No	Yes	N-W
15	0.112803 (5.464187)	0.807309 (8.240703)	-0.293522 (-1.731589)	0.601953	No	Yes	N-W
16	0.118527 (5.991694)	0.662433 (6.187561)	-0.117904 (-1.157664)	0.612621	No	Yes	N-W
17	0.116775 (5.973366)	0.691955 (15.02440)	0.296642 (1.726290)	0.668538	No	Yes	N-W
18	0.112464 (4.898881)	0.790352 (9.106673)	-0.174248 (-0.958735)	0.622469	No	Yes	N-W
19	0.110028 (4.821258)	0.859449 (10.68721)	-0.267409 (-1.651088)	0.626598	No	Yes	N-W
20	0.116573 (5.406839)	0.699247 (8.995286)	-0.082646 (-0.797159)	0.637145	No	Yes	N-W
21	0.116818 (6.491370)	0.697989 (12.18572)	0.248863 (1.561743)	0.662242	No	Yes	N-W
22	0.113420 (5.492795)	0.775814 (8.172679)	-0.155141 (-0.862760)	0.626439	No	Yes	N-W
23	0.112803 (5.464187)	0.807309 (8.240703)	-0.293522 (-1.731589)	0.601953	No	Yes	N-W
24	0.118527 (5.991694)	0.662433 (6.187561)	-0.117904 (-1.157664)	0.612621	No	Yes	N-W

Note: *t* statistics in parentheses.

We see that, except particular models (the regressions with total physical capital as input factor) have weak significance, all other TFPs are nonsignificant. It suggests that TFP is not the source of economic growth. This conclusion is consistent with Su and Xu (1999). We need another definition of technical progress; TFP has no contribution to explain China's economic growth.

If one wants to stay in the neoclassic framework, he might argue that an implicit hypothesis of Hicks-neutral is used in the calculation. This implicit hypothesis may not be hold in reality. We examined the stylized facts to verify the nature of technical progress of China. We founded that the behaviors of China's Kaldor's facts are complicated: increasing K/Y coefficient, increasing GDP per capita; increasing capital per capita and decreasing interest rate. It suggests that the technical progress of China is rather mixed than any simple neutrality (Hicks, Solow and Harrod).

If we recognize that the technical progress in China might be mixed type, a single Solow residuals equation is insufficient to filter out the three variables. We need more assumptions. In additional the productive human capital defined by educational attainment is some kind of Harrod type technical progress. As a consequence, a better alternative solution is that we turn to other technical progress indicator such as R&D. That is to say we turn to endogenous economic growth models. *Appendix 5.3* discussed several technical progress indicators and provided the details of construction of R&D series.

### Appendix 5.3 Construction of R&D 1953-2014

Our evidences from time series have demonstrated that the contributions of TFPs to economic growth are nonsignificant. This suggests that we need to look for new technical progress indicators, so we turn from neoclassical economic growth models to endogenous economic growth models.

Generally speaking, the science and technology (S&T hereafter) activities could be divided into 4 categories: 1) Research and Experimental Development (R&D); 2) application of R&D; 3) S&T Service; 4) S&T education and formation. Where R&D is the systematic and creative work in order to improve knowledge and create new use with that knowledge. It is the most creative part of S&T activities. So we generally use indicators associated to R&D as technical progress indicators.

The *Frascati Manuel* of OECD (1963) formed regulatory documents of R&D statistics in the first time. *Frascati Manuel* has been revised several times and gradually been adopted as a worldwide statistical standard. China has introduced R&D statistical standard in a very late time – in the middle of 1980s: the first R&D sampling in national wide was in 1988. The first R&D census was in 2003 and the second census was in 2009. So the precise data concerned R&D indicators before 1987 are impossible to get. But under the statistical system at that time, there were some similar and closed indicators: such as “number of persons in S&T activities” and “S&T expenditures” etc.

We might use the following 3 categories of technical progress indicators: 1) number of persons of R&D (or converted into “Full-time Equivalent”); 2) Number of Patents Granted (or Number of Patents Accepted); and 3) the most used R&D expenditures. For the case of China, we summarized the sources and the lengths of those 3 categories of indicators as follow:

Table A5.3.1 Data Source and Length of Available Technical Progress Indicators

Indicator	Length	Source	Notes
Number of persons of R&D or converted into Full-time Equivalent	1991-present and some isolated years.	NBS online database (since 1995) and <i>China Statistical Yearbook on Science and Technology</i> <sup>231</sup> diverse years ( since 1991)	In the early years, it was the “number of persons of S&T” that contains a subentry “number of persons of scientists and engineers” and repealed since 2009. Data of 1952, 1960, population census years and since 1978 are available in “ <i>Statistics on Science and Technology of China 1949-1989</i> ” <sup>232</sup> .
Number of Patents (Granted or accepted)	1986-present	NBS online database and State Intellectual Property Office	“Patent law” was applied since 1 <sup>st</sup> April 1985, before that time there is no patent in China <sup>233</sup> .
R&D expenditures	1987-present	NBS online database and Ministry of Science and Technology(MOST)	NBS has only provided data since 1995, China Science and Technology Statistics Network of MOST provided data since 1987.

We see that the first category of technical progress indicators is number of persons that participated R&D activities or the series converted as Full-time Equivalent (the unit is person-years). Those indicators have longer available length than other categories (if we considered some similar indicators such as number of persons of S&T or/and number of persons of scientists and engineers as substitute). But the data are still missing for many years. Secondly this kind of indicators is some kind of tautology with the human capital in a same regression. So we don’t recommend using those indicators.

The second category is number of patents (granted or accepted, and there are more detailed data about the sub-categories of Invention, Utility Models and Designs). But China has no “Patent law”<sup>234</sup> until

<sup>231</sup> In Chinese: 《中国科技统计年鉴》

<sup>232</sup> In Chinese: 《中国科学技术四十年》

<sup>233</sup> Though over 1950-1963, Government Administration Council of the Central People's Government has authorized 10 patents. See Han (2015)

1985. Before that time, due to the spirit of socialist public ownership, there was no patent. The scientific and technological achievements are basically national sharing. Any individuals and organizations cannot get profits from a patent<sup>235</sup>. Our econometric analysis requires complete time series data since 1952 so the second category doesn't match our needs.

The third category is R&D expenditures. The official data started in 1987 but Gu and Lundvall (2006) provided R&D expenditures data since 1953. To figure out their data source we have founded the original text of the yearbook mentioned in their references. We founded that their data of R&D expenditures over 1953-1986 are in fact comes from the page 202 of "*Statistics on Science and Technology of China 1949-1989*"<sup>236</sup>. They are not real R&D expenditures in strict sense but a part of national government expenditure granted to science and technology, it should be better called as "S&T expenditures". As we have mentioned above, S&T activities contain 4 categories, R&D activities are just one part of them. So Gu and Lundvall (2006) have overestimated the R&D expenditures for early years.

Since China has introduced R&D statistical system in the middle of 1980s, the statistical caliber is not the same in the S&T statistical system. So it is difficult to estimate accurately R&D indicators according to *Frascati Manuel* for the early years. Based on available historical data, we start from the definition of R&D and try to construct the R&D data as accurate as possible.

Before 1986, the R&D activities are mainly undertaken by state-owned units, all the expenditures are granted by government. In 1985 China has implemented the reform of "governmental appropriations replaced by loans" that is to say; the main financing method of state-owned enterprises has been gradually changed from national financial allocations to bank loans. Before 1986 the R&D expenditures of enterprises and research institutions are both part of S&T expenditures. So we construct R&D expenditures base on S&T expenditures (Gu and Lundvall (2006) directly use S&T expenditures to replace R&D expenditures) before 1986.

In the S&T system<sup>237</sup>: S&T expenditures<sup>238</sup> = three items of S&T funds<sup>239</sup> + Operating Expenses for Sciences<sup>240</sup> + Expenses for Capital Construction of S&T Institutes<sup>241</sup> + Other S&T Operating Expenses<sup>242</sup>

Note that the translation of the titles of each items is difficult and even the official English translation didn't express the meaning of each expenditures well. We will explain in detail for each term.

The three items of S&T funds (officially Expense on S&T Promotion) is referred to the 1) New product trial fee, 2) Intermediate Experiment fee and 3) Allowance for important scientific research projects set up by state in order to promote S&T development. According to the definition of R&D, those three items basically belong to R&D framework. Now we explain why.

---

<sup>234</sup> Though in the period of Republic of China, the "Patent law" was applied in 1<sup>st</sup> January 1949 but it didn't play any role in history.

<sup>235</sup> For example the Nobel Prize in Physiology or Medicine of 2015 is granted to Mz. TU Youyou to honor her contribution of finding Artemisinin in 1972. This scientific achievement during Cultural Revolution has no patent or intellectual property right but it is free to use in worldwide that saves million people's lives.

<sup>236</sup> In Chinese: 《中国科学技术四十年》 Gu and Lundvall translated as "Statistics on Science and Technology of China 1949-1989".

<sup>237</sup> This system has been repealed since 2007. The *Public Income and Expenditure to Budgetary Accounting* is performed, expenditure subject listed in that formula was adjusted accordingly. But what we need is the data before 1986 so the changes don't affect our calculation.

<sup>238</sup> In Chinese: 科学研究支出 official English translation is EXPENDITURE ON SCIENTIFIC RESEARCH.

<sup>239</sup> In Chinese: 科技三项费用 official English translation is Expense on S&T Promotion.

<sup>240</sup> In Chinese: 科学支出 or 科学事业费

<sup>241</sup> In Chinese: 科研基建费

<sup>242</sup> In Chinese: 其他科研事业费

Firstly, most new product trials belong to R&D. But among those activities, the process of fabricating new product by importing (or purchasing) existed technology (such as patents, technical tricks, drawings and prototype machines *etc.*) are not R&D activities. Because they are duplication or application of R&D. so we have only need to deduct the import amount of S&T. Before the opening reform, under the guide of self-reliance development strategy, the import of technology was not too much. We convert the amount of technology import contracts of the early years<sup>243</sup> from U.S. dollar to national currency, and we founded that the technology importation is not included in the S&T expenditures. So we consider that the new product trial fee belongs to R&D expenditures.

Secondly, whether the intermediate experiment belongs to R&D should depend on the purposes of those experiments. If the purpose of experiment is to further ameliorate the technology of product, or to get experience and data with such purpose; then the experiment should belong to R&D. But if the purpose of experiment is just to collect production parameters for final design, then such an experiment is no longer a R&D activity but application of R&D. However the boundary of the two are very ambiguous because when we experiment in order to get production parameters, we usually found that there is something need to be further improved; some products are even corrected alongside the production process. In practical statistical work, there is no distinction between the two. We can hardly distinguish the purposes of intermediate experiments. For simplicity, we argue that all intermediate experiments are R&D activities. Finally the important scientific research projects are basic research that is undoubtedly belonged to R&D. In a word, we consider that the three items of S&T funds (or Expense on S&T Promotion) belong to R&D expenditures.

The funds for potentiality exploration and technical innovation of enterprises<sup>244</sup> (officially Innovation Funds) should also belong to R&D expenditures. This term has several names in different yearbooks. It is a governmental allocation granted to enterprises in order to promote technological innovation (including some fixed asset renewal). Since the reform of 1983, this funds gradually was replaced by subsidized loans or/and semi-subsidized loans, the governmental allocation canceled. This part data is a little difficult to get because it was generally included in other expenses. In the “60 years statistics compilation of new China<sup>245</sup>”, it was published with Expense on S&T Promotion as a whole. And in the “China Statistical Yearbook 1988” it was published with new product trial fee as a whole. This indicator has been totally repealed in 2007. We compared several yearbooks, and we founded that there are errors of the data of “Expense on S&T Promotion and Innovation Funds” in “60 years statistics compilation of new China”. The data in this yearbook before 1970 only contains new product trial fee. So we use the data of “China Statistical Yearbook 1988<sup>246</sup>” minus “new product trial fee” to get the “innovation funds”.

The Operating Expenses for Sciences administrative and operational fees of research institutions. It is not creative so shouldn't belong to R&D expenditures. The Expenses for Capital Construction of S&T Institutes is infrastructure expenses of research institutions such as office buildings. So it is no creative either should not belong to R&D expenditures. The Other S&T Operating Expenses is also the other administrative fees not R&D.

So combining with S&T system, we depart from the core definition of R&D – “creative” and get the approximated R&D expenditures over 1953-1986:

**Approximated R&D expenditures = New product trial fee + Intermediate Experiment fee + allowance for important scientific research projects + Innovation Funds of enterprise.**

This approximated R&D expenditures has some insufficiencies. Firstly, it didn't consider the R&D in private sector. However we have pointed out that what we estimate here is the R&D expenditures

---

<sup>243</sup> Page 327 of China Statistical Yearbook on Science and Technology 1991

<sup>244</sup> In Chinese: 企业挖潜改造资金 or 挖潜革新改造拨款 or 国家更改措施拨款 in different yearbooks.

<sup>245</sup> In Chinese: 《新中国六十年统计资料汇编》 official English translation is CHINA COMPENDIUM OF STATISTICS

<sup>246</sup> Page 757

before 1986 that most R&D activities are undertaken by state. After 1986, the great institutional changes especially the reform of “governmental appropriations replaced by loans<sup>247</sup>” and “Patent law” in 1986 largely incited the R&D activities in private sectors. Such an approximation before 1986 is acceptable.

Secondly, we have emphasized above, whether intermediate experiments belong to R&D should depend on the purposes of experiments. But such a purpose is not distinguished in S&T statistical system. This bias is impossible to avoid.

Treating all the intermediate experiments as R&D will overestimate the R&D expenditures while ignoring the private R&D expenditures before 1986 will underestimate the R&D expenditures. Those two biases are opposite before 1986, it could cancel each other out in a certain degree and the final error is very small as a consequence.

The R&D expenditure data after 1995 could be directly got from the database of NBS. As the online database of MOST is sometimes unavailable<sup>248</sup>, we propose alternative data sources by yearbooks, Summarized in *table A5.3.2*. And the database is presented in *table A5.3.3*.

**Table A5.3.2 Data Source and Components of R&D Expenditure**

Period	Component	Data source	Notes
1953	Expense on S&T Promotion	<i>55 years statistics compilation of new China</i>	No data for Innovation Funds
1954-1970	Expense on S&T Promotion	<i>55 years statistics compilation of new China and China Statistical Yearbook 1988</i>	Calculated according to <i>China Statistical Yearbook 1988</i> Innovation Funds is integrated in New product trial fee.
1971-1985	Expense on S&T Promotion + Innovation Funds of enterprises	<i>55 years statistics compilation of new China and China Statistical Yearbook 1988</i>	Innovation Funds is calculated by <i>China Statistical Yearbook 1988</i>
1986-1988	Government R&D + higher education R&D	<i>40 years statistics of China's Science and Technology 1949-1989</i>	Transitory period
1989-1994	R&D	<i>China Statistical Yearbook on Science and Technology</i> diverse year	After introduce of R&D system
1995-2013	R&D	NBS	Normal period

**Table A5.3.3 Database for R&D Expenditures (100 millions)**

year	R&D1	R&D2	R&D1 constant price	R&D2 constant price
1952	-	-	-	-
1953	0.56	0.27	0.532826	0.256898
1954	1.22	1.1	1.144772	1.032172
1955	2.13	1.92	1.992682	1.79622
1956	5.23	3.53	4.897727	3.305732
1957	5.23	2.98	4.773613	2.719956
1958	11.24	7.25	10.37327	6.690942
1959	19.15	12.33	17.62045	11.34518
1960	33.81	22.68	30.35076	20.35952
1961	19.49	15.54	15.06968	12.01554
1962	13.73	10.62	10.2274	7.910782
1963	18.61	13.85	14.73166	10.96365
1964	24.27	17.62	19.95027	14.48388
1965	27.17	20.27	22.60537	16.86459
1966	25.06	19.26	21.10309	16.2189
1967	15.35	13.56	13.0043	11.48784
1968	14.8	11.29	12.52582	9.555173
1969	24.15	10.74	20.23673	8.99969
1970	29.96	14.78	25.10528	12.38505

<sup>247</sup> In Chinese: 拨改贷

<sup>248</sup> <http://www.sts.org.cn/index.asp> It was unavailable since mid-2015 but recovered in the end of 2016.

1971	37.68	26.4	31.60594	22.14429
1972	36.1	25.46	30.22019	21.31319
1973	34.59	25.49	28.92721	21.31699
1974	34.65	27.2	28.77595	22.58892
1975	40.31	31.47	33.34307	26.03092
1976	39.25	34.34	32.36917	28.31993
1977	41.48	39.45	33.30889	31.67878
1978	52.89	63.24	42.17601	50.4294
1979	62.29	71.79	48.74567	56.18
1980	64.59	80.45	47.01913	58.56462
1981	61.58	65.3	43.73459	46.37657
1982	65.29	69.02	45.46026	48.05739
1983	79.1	78.71	53.996	53.72977
1984	94.72	111.77	62.95878	74.29163
1985	102.59	103.42	62.38778	62.89252
1986	111.3879	111.3879	63.6038	63.6038
1987	118.6126	118.6126	63.12129	63.12129
1988	142.3867	142.3867	63.782	63.782
1989	149.0863	149.0863	56.59583	56.59583
1990	169.3919	169.3919	62.37069	62.37069
1991	206.9894	206.9894	73.70815	73.70815
1992	254.1688	254.1688	85.06446	85.06446
1993	325.5125	325.5125	94.97954	94.97954
1994	369.1092	369.1092	86.78518	86.78518
1995	348.69	348.69	70.01212	70.01212
1996	404.48	404.48	74.98983	74.98983
1997	509.16	509.16	91.82617	91.82617
1998	551.12	551.12	100.1951	100.1951
1999	678.91	678.91	125.1802	125.1802
2000	895.66	895.66	164.4876	164.4876
2001	1042.49	1042.49	190.122	190.122
2002	1287.64	1287.64	236.7245	236.7245
2003	1539.63	1539.63	279.6949	279.6949
2004	1966.33	1966.33	343.8026	343.8026
2005	2449.97	2449.97	420.7903	420.7903
2006	3003.1	3003.1	508.1696	508.1696
2007	3710.24	3710.24	599.0728	599.0728
2008	4616.02	4616.02	703.8001	703.8001
2009	5802.11	5802.11	890.8782	890.8782
2010	7062.58	7062.58	1049.773	1049.773
2011	8687	8687	1225.071	1225.071
2012	10298.41	10298.41	1415.514	1415.514
2013	11846.6	11846.6	1587.049	1587.049
2014	13015.63	13015.63	1709.471	1709.471

*Note: R&D1 is the S&T expenditures before 1986.*

## Appendix 5.4 Causality tests between dependent and explicative variables

Table A5.4.1 Results of the Pairwise Granger Causality Tests

Lag = 2	$gK_{Pe}$	$gK_{Pl}$	$gK_F$	$gK_T$	$gL$	$gH_P$	$gH_T$	$gH_I$	$gR\&D_1$	$gR\&D_2$
$gY$	0.1955	0.6603	0.0112	0.2145	0.0944	0.5306	0.9109	0.3036	0.0039	0.0032
Inverse	0.0036	0.0036	0.0023	0.0481	0.7473	0.2693	0.0443	0.0779	0.0022	0.0021
Lag = 3	$gK_{Pe}$	$gK_{Pl}$	$gK_F$	$gK_T$	$gL$	$gH_P$	$gH_T$	$gH_I$	$gR\&D_1$	$gR\&D_2$
$gY$	0.1418	0.8497	0.0099	0.4328	0.0616	0.7103	0.6899	0.4420	0.0403	0.0279
Inverse	0.0276	0.0241	0.0176	0.1019	0.0483	0.2170	0.0372	0.0328	0.0023	0.0012
Lag = 4	$gK_{Pe}$	$gK_{Pl}$	$gK_F$	$gK_T$	$gL$	$gH_P$	$gH_T$	$gH_I$	$gR\&D_1$	$gR\&D_2$
$gY$	0.5230	0.3577	0.0779	0.1628	0.0651	0.3442	0.7893	0.3279	0.0389	0.0093
Inverse	0.0021	0.0005	0.0033	0.0055	0.0953	0.0692	0.0810	0.0846	0.0058	0.0006

Note: For each lag, the first line gives the Pairwise Granger Causality Test  $p$ -values with a null hypothesis that  $g_Y$  doesn't Granger cause the explicative variable. The second line corresponds to the inverse: the explicative variable doesn't Granger cause  $g_Y$ . The value of the first line is expected to be high to indicate that the explicative variable is not endogenous, while that of the second line to be small because it might be a significant explicative variable. It can be observed that there is small significant feedback effect between economic growth and technical progress.

The results of our causality tests are sensitive to the choice of the lag, and become better as lag increases. We also test the causality within VAR models, using the following strategy to fit these models: *i*) we guess an initial lag at 3 with the truncation criterions, according to the size of the sample, and fit a VAR model with dummy as exogenous variable; *ii*) we use the information criterions to choose an optimal maximum lag (with the maximum set at 5, corresponding to a five-year plan); *iii*) we apply the VAR Lag Exclusion Wald Tests with a maximum lag (given by the information criterions) in order to determine the final significant lags, and we keep the model with significant joint lags.

Table A5.4.2. VAR Granger Causality / Block Exogeneity Wald Tests

Endogenous variables	Exogenous variables	Truncation criterions	LR	FPE	AIC	SIC	HQ	Lag Exclusion Wald Tests	X doesn't Granger cause Y	Y doesn't Granger cause X
$gY, gK_{Pe}$	$D$	3	5	5	5	5	5	1	0.0001	0.2970
$gY, gK_{Pl}$	$D$	3	4	4	4	1	4	2	0.0002	0.9181
$gY, gK_F$	$D$	3	5	5	5	2	5	1	0.0000	0.2043
$gY, gK_T$	$D$	3	4	4	4	1	1	2	0.0000	0.5542
$gY, gL$	$D$	3	4	5	5	1	1	1	0.0056	0.5009
$gY, gH_P$	$D$	3	4	4	4	1	1	1	0.0000	0.6284
$gY, gH_T$	$D$	3	1	4	4	1	1	1	0.0002	0.0787
$gY, gH_I$	$D$	3	2	2	4	2	2	2	0.0002	0.3404
$gY, gR\&D_1$	$D$	3	5	5	5	1	5	1	0.1002	0.5421
$gY, gR\&D_2$	$D$	3	4	4	4	1	4	1	0.1346	0.0750

Notes:

- LR: sequential modified likelihood ratio test statistics (at 5% level); FPE: final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion;
- $D$  = dummy variables;  $C$  = constant;  $X$  = explicative variables;  $Y$  = dependent variable ( $gY$ ).
- The last two columns are the  $p$ -values of VAR Granger Causality / Block Exogeneity Wald Tests. The structures of VAR are consistent with the regression models. Consequently, the technical progress is no longer endogenous. The results are exactly as expected: all the explicative variables are not endogenous.

Finally, we built a VAR for each regression equation, respectively, all variables being included. The results of VARs 1 to 8 are the same as above.

Table A5.4.3. VAR Granger Causality / Block Exogeneity Wald Tests for Each Regressions

	Endogenous variables	LR	FPE	AIC	SIC	HQ	Lag Exclusion Wald Tests	Final lag	Explicative variables don't Granger cause Y	Excluded variables don't Granger cause dependent variable
[9]	$gY, gK_{Pe}, gL$	5	5	5	1	5	1	1	0.0000	0.1566 ( $gK_{Pe}$ ) 0.1732 ( $gL$ )
[10]	$gY, gK_{Pe}, gH_P$	5	5	5	1	5	1	1	0.0000	0.2721 ( $gK_{Pe}$ ) 0.4317 ( $gH_P$ )
[11]	$gY, gK_{Pe}, gH_T$	5	5	5	1	4	1	1	0.0001	0.4778 ( $gK_{Pe}$ ) 0.0295 ( $gH_T$ )
[12]	$gY, gK_{Pe}, gH_I$	5	5	5	1	2	1	1	0.0001	0.4819 ( $gK_{Pl}$ ) 0.0518 ( $gH_I$ )
[13]	$gY, gK_{Pl}, gL$	4	4	4	1	1	2	2	0.0004	0.3645 ( $gK_{Pl}$ ) 0.4502 ( $gL$ )
[14]	$gY, gK_{Pl}, gH_P$	4	5	5	1	1	2	2	0.0001	0.7439 ( $gK_{Pl}$ ) 0.2006 ( $gH_P$ )
[15]	$gY, gK_{Pl}, gH_T$	4	4	4	1	1	1	1	0.0000	0.2243 ( $gK_{Pl}$ ) 0.0289 ( $gH_T$ )
[16]	$gY, gK_{Pl}, gH_I$	4	4	4	1	2	2	2	0.0001	0.7778 ( $gK_{Pl}$ ) 0.4938 ( $gH_I$ )
[17]	$gY, gK_F, gL$	5	5	5	1	2	1	1	0.0000	0.1014 ( $gK_F$ ) 0.0714 ( $gL$ )
[18]	$gY, gK_F, gH_P$	5	5	5	1	5	1	1	0.0000	0.0957 ( $gK_F$ ) 0.3599 ( $gH_P$ )
[19]	$gY, gK_F, gH_T$	4	4	4	1	2	1	1	0.0000	0.3036 ( $gK_F$ ) 0.0581 ( $gH_T$ )
[20]	$gY, gK_F, gH_I$	5	5	5	1	2	1	1	0.0000	0.2917 ( $gK_F$ ) 0.0271 ( $gH_I$ )
[21]	$gY, gK_T, gL$	4	1	1	1	1	2	2	0.0001	0.2618 ( $gK_T$ ) 0.3782 ( $gL$ )
[22]	$gY, gK_T, gH_P$	3	4	5	1	1	2	2	0.0000	0.3923 ( $gK_T$ ) 0.0843 ( $gH_P$ )
[23]	$gY, gK_T, gH_T$	4	4	4	1	1	1	1	0.0000	0.1052 ( $gK_T$ ) 0.0500 ( $gH_T$ )
[24]	$gY, gK_T, gH_I$	3	4	4	1	1	2	2	0.0001	0.6087 ( $gK_T$ ) 0.5032 ( $gH_I$ )
[25]	$gY, gK_{Pe}, gH_P, gR&D_1$	5	5	5	1	1	1	1	0.0000	0.4399 ( $gK_{Pe}$ ) 0.3038 ( $gH_P$ ) 0.0251 ( $gR&D_1$ )
[26]	$gY, gK_{Pl}, gH_P, gR&D_1$	5	5	5	1	5	5	1	0.0000	0.1426 ( $gK_{Pl}$ ) 0.2479 ( $gH_P$ ) 0.0028 ( $gR&D_1$ )
[27]	$gY, gK_F, gH_P, gR&D_1$	5	5	5	1	1	1	1	0.0000	0.1615 ( $gK_F$ ) 0.3274 ( $gH_P$ ) 0.0300 ( $gR&D_1$ )
[28]	$gY, gK_T, gH_P, gR&D_1$	5	5	5	1	5	5	1	0.0000	0.0492 ( $gK_T$ ) 0.3055 ( $gH_P$ ) 0.0082 ( $gR&D_1$ )
[29]	$gY, gK_{Pe}, gH_P, gR&D_2$	5	5	5	1	1	1	1	0.0000	0.3010 ( $gK_{Pe}$ ) 0.5002 ( $gH_P$ ) 0.0438 ( $gR&D_2$ )
[30]	$gY, gK_{Pl}, gH_P, gR&D_2$	5	5	5	1	1	2	2	0.0000	0.0045 ( $gK_{Pl}$ ) 0.2990 ( $gH_P$ ) 0.0000 ( $gR&D_2$ )
[31]	$gY, gK_F, gH_P, gR&D_2$	3	5	5	1	1	1	1	0.0000	0.0915 ( $gK_F$ ) 0.4778 ( $gH_P$ ) 0.0635 ( $gR&D_2$ )
[32]	$gY, gK_T, gH_P, gR&D_2$	5	3	5	1	1	2	2	0.0000	0.0061 ( $gK_T$ ) 0.1660 ( $gH_P$ ) 0.0000 ( $gR&D_2$ )

Notes: Dependent variables are indicated between parentheses. If the Lag Exclusion Wald Tests tend to reserve lags as max as possible; the optimal lag might exceed the possible maximum lag for a small sample. But too many lags will introduce too many coefficients in the VAR models; as a consequence the number of observations might be not enough to estimate so many parameters. From previous tests we see that the Lag Exclusion Wald



Tests generally give consistent results with SIC, so if the Lag Exclusion Wald Tests reserve all lags, then we adopt SIC.

As we can see in the joint tests for models 26, 28, 30 and 32, technical progress seems to be weakly endogenous, whereas all the other explicative variables are found to be exogenous.

**Table A5.4.4. Some details of VAR Granger Causality/Block Exogeneity Wald Tests**

	<b>Dependent variable</b>	<b>Excluded variable</b>	<b>The excluded variable doesn't Granger cause the dependent one</b>
[26]	$gR\&D_1$	$gY$	0.0500
		$gK_{Pl}$	0.0272
		$gH_p$	0.5900
[28]	$gR\&D_1$	$gY$	0.0591
		$gK_T$	0.0890
		$gH_p$	0.3760
[30]	$gR\&D_2$	$gY$	0.0000
		$gK_{Pl}$	0.0000
		$gH_p$	0.2270
[32]	$gK_T$	$gY$	0.0585
		$gH_p$	0.4253
		$gR\&D_2$	0.0010
	$gR\&D_2$	$gY$	0.0000
		$gK_T$	0.0000
		$gH_p$	0.7704

**APPENDIX 6.1 – DATABASE: CHINA, 1952-2012**

**Stock of general capital stock à la Piketty, rate of return of capital,  
income growth rate, coefficient of capital, ratio savings rate – income growth rate**

<b>Years</b>	<b>Stock of General Capital 'à la Piketty'</b>	<b>Rate of Return of General Capital</b>	<b>Growth Rate of National Income</b>	<b>Coefficient of General Capital</b>	<b>Savings Rate / Income Growth Rate</b>
1952	1,024.9	0.3043	-	1.5094	-
1953	1,156.7	0.3113	0.1547	1.4754	1.4093
1954	1,307.2	0.2832	0.0281	1.6218	8.4940
1955	1,452.9	0.2694	0.0574	1.7048	3.6109
1956	1,633.3	0.2710	0.1307	1.6950	1.9071
1957	1,828.9	0.2450	0.0125	1.8745	18.8336
1958	2,175.5	0.2549	0.2372	1.8022	1.4679
1959	2,667.2	0.2282	0.0976	2.0130	4.3997
1960	3,075.4	0.1954	-0.0129	2.3513	-27.9599
1961	3,153.0	0.1375	-0.2782	3.3397	-0.6651
1962	3,108.3	0.1267	-0.0918	3.6254	-1.5637
1963	3,140.7	0.1431	0.1412	3.2100	1.2705
1964	3,255.7	0.1689	0.2233	2.7202	1.1610
1965	3,491.8	0.1879	0.1936	2.4443	1.6800
1966	3,828.3	0.1892	0.1041	2.4272	3.1884
1967	4,004.8	0.1730	-0.0439	2.6557	-6.4512
1968	4,198.8	0.1602	-0.0291	2.8677	-9.1675
1969	4,445.3	0.1685	0.1137	2.7260	2.6508
1970	4,940.0	0.1762	0.1619	2.6074	2.1894
1971	5,485.1	0.1710	0.0780	2.6855	4.6159
1972	5,961.3	0.1632	0.0369	2.8147	9.4768
1973	6,518.9	0.1610	0.0792	2.8522	4.5378
1974	7,090.0	0.1509	0.0188	3.0447	18.8167
1975	7,727.2	0.1481	0.0703	3.1005	5.3175
1976	8,243.8	0.1360	-0.0202	3.3760	-16.5786
1977	8,831.0	0.1345	0.0592	3.4143	6.0992
1978	9,648.3	0.1386	0.1254	3.3147	3.0835
1979	10,491.8	0.1394	0.0936	3.2960	3.8904
1980	11,357.0	0.1340	0.0409	3.4276	8.4739
1981	12,170.2	0.1312	0.0494	3.5000	6.6679
1982	13,056.9	0.1308	0.0693	3.5115	4.7517
1983	14,058.9	0.1338	0.1012	3.4334	3.1777
1984	15,310.0	0.1448	0.1788	3.1718	1.8981
1985	17,010.4	0.1489	0.1420	3.0858	2.4341
1986	18,893.3	0.1431	0.0678	3.2099	5.1086
1987	20,869.6	0.1417	0.0935	3.2426	3.9327
1988	23,052.9	0.1347	0.0506	3.4093	7.4101
1989	25,168.0	0.1185	-0.0401	3.8773	-8.8439
1990	27,293.0	0.1167	0.0678	3.9376	5.3359
1991	29,673.3	0.1209	0.1272	3.7980	2.9789
1992	32,147.3	0.1295	0.1601	3.5468	2.4990
1993	35,611.7	0.1334	0.1412	3.4428	2.9206
1994	40,500.5	0.1290	0.0995	3.5612	4.1699
1995	45,621.0	0.1216	0.0619	3.7776	6.4273
1996	51,278.1	0.1171	0.0829	3.9210	4.6895
1997	57,025.7	0.1141	0.0828	4.0271	4.7624
1998	62,491.7	0.1116	0.0721	4.1163	5.3136
1999	68,089.3	0.1107	0.0808	4.1497	4.4930
2000	73,813.6	0.1126	0.1032	4.0779	3.4260

<b>2001</b>	81,080.2	0.1123	0.0950	4.0906	3.8796
<b>2002</b>	90,011.5	0.1124	0.1109	4.0881	3.4343
<b>2003</b>	101,566.5	0.1115	0.1200	4.1195	3.4498
<b>2004</b>	116,082.5	0.1109	0.1367	4.1420	3.2430
<b>2005</b>	131,590.2	0.1107	0.1312	4.1509	3.4275
<b>2006</b>	149,819.1	0.1127	0.1596	4.0754	2.9518
<b>2007</b>	172,731.8	0.1153	0.1799	3.9823	2.7355
<b>2008</b>	198,047.3	0.1127	0.1204	4.0753	4.1945
<b>2009</b>	230,146.5	0.1057	0.0902	4.3440	5.5265
<b>2010</b>	265,238.3	0.1048	0.1423	4.3829	3.5849
<b>2011</b>	302,334.6	0.1028	0.1176	4.4703	4.2210
<b>2012</b>	342,809.8	0.0981	0.0830	4.6804	5.9065

*Notes: The rate of return is calculated on the basis of an elasticity of output with respect to general capital of 0.45. The general capital stock, at constant 1952 prices, is expressed in hundreds of millions of yuans ( $10^8$ , or yì).*

## APPENDIX 6.2 Brief Discussions about China's Inequality

For now we have no data at all to analyze the third law of Piketty in China and we also argue that the parents' heritage is not the major cause of current inequality in China, the major causes are the corruption and unfair income distribution system.

Firstly we have no data to calculate the inheritance flow  $b_y$  because there is no inheritance tax in China until now so that there is no notarization data as abundant as France. China has no real house property tax (except the experiments in Shanghai and Chongqing since 2011). So we don't have any method to get information of average wealth at time of death (to calculate the ratio of average wealth at time of death to average wealth of living individuals  $\mu$ ). As a consequence, the third law of capitalism is hardly impossible to test in China at present.

Secondly, the history of "capitalist" period of modern China is short, that is less than 30 years. The so-called generation of "getting rich firstly (said by Deng Xiaoping)" was generally started from scratch. Most entrepreneurs of this generation are still alive and in the "gold age" for their business. Consequently there wouldn't be too much "inheritance".

Thirdly, Piketty argued in the preface of his book of Chinese version that the inheritance will aggravate the inequality of China in the future. For example, if the couple has only one child, this child will inherit assets in both sides<sup>249</sup>. However China has recognized the increasing negative consequences of such a radical "One Child Policy" that the birth control policy has been relaxed since 2015<sup>250</sup>. That is to say, the generation birthed in 1980s is in fact the only generation of "one child" in 5000 years Chinese history. The rise of fertility rate could probably ease the inequality brought by inheritance (at least partly).

Lastly, in China, the main wealth of a family is real estate. However the proprietorship is limited by the "70-years using right"<sup>251</sup>. The laws related the proprietorship of land is uncertain in the future. That is to say, for now the government has no clear explanation that how to renew the use right when the use right expires after 70 years<sup>252</sup>. If the cost is expensive to renew the use right then the inheritance of house could be a burden not a wealth for the next generation.

It is no doubt that the inequality caused by inheritance will be a serious problem in the future. But for now, it is not the most important cause of inequality. As mentioned above, during the short "capitalist" period after the reform, inequality at present stage is mainly caused by corruption and unfair distribution system. So the current anti-corruption movement in China (since 2012) is extremely necessary, it is more directly and quickly to improve the inequality problem than imposing an inheritance tax in short-run. We need to examine the evolution of inequality in the past three decades. We launch this analysis with the GINI coefficient.

Limited by data, Piketty and Qian (2009) have only studied the top 1% income in China with the data of "urban household survey (1986-2003)" of NBS. They assume that over 2004-2015 both income levels and income tax schedules have constant trends to the period 2003-2008 and they have estimated the data of rest years. Piketty and Qian didn't use the "rural household survey". They argue that exclusion of rural households should not be too problematic because they find that in 2000 97% rural income are exempt from income tax.

However the situations change very fast in last decade. Firstly, the growth rate of income slows down. Over 2003-2008 (their base period) the average growth rate of income was 14.1% (constant price) but

---

<sup>249</sup> "Si chaque couple n'a qu'un seul enfant, alors on hérite des deux côtés, tout du moins quand les parents ont du bien. tout laisse à penser que l'héritage va prendre une importance considérable dans les années et décennies à venir en Chine."

<sup>250</sup> The 5<sup>th</sup> Plenary Session of the 18<sup>th</sup> Central Committee of C.P.C. in 29 October 2015.

<sup>251</sup> The proprietorship of land belongs to the country, owner of house has only the using right of land.

<sup>252</sup> The housing reform began in 1988.

over 2004-2014 (their forecast period) the average growth rate of income was 11.7%. This is because the forecast period contains the recent years that the economic growth slowdowns. Secondly Piketty and Qian assume income brackets have remained the same (they said “as they did in the past”). But the modification of *Individual Income Tax Law* in 30th June 2011 has important modifications on income brackets. At last, the restrictions of Hukou imposed to rural householders largely reduced. The mobility between rural and urban increased; the rural residents could work in cities so that their income largely increased. It could no longer be excluded. Their conclusion of exclusion is made based on data of 2000 but the development of last decade has far beyond their expectations.

NBS has published the “*CHINA YEARBOOK OF HOUSEHOLD SURVEY*” since 2011. This year book contains the “urban household survey” data used by Piketty and Qian (2006, 2009) and provides more complete information. The data of their forecast period could be completed by this yearbook. But we are not tending to just to fill the top 1% income data or simply reproduce the work of them. This is because, for the top income, a considerable part is obtained by corruption. This part cannot be reflected in the tax statistics or “household survey”. Wang (2010) has estimated that this part of “gray income” is about 17% of the GNI in 2008. Even Wang’s estimation might overestimate the severity of corruption. But it is no doubt that the income distribution tables will seriously underestimate the income level of high-income earners. Even if we don’t consider the corruption, under the current tax law and Chinese cultural background, the tax statistics and “household survey” could not fully reflect the real income level of riches. Even the individual tax law will tax on the income from transfer of property but the money earned through selling stocks is exempted from income tax<sup>253</sup>. As richer people have higher proportion of income from capital gain, so the real income of rich people is underestimated by the tax data. Secondly even the size of sample of NBS’ household survey is enough big (140 000 families in 2012 and 500 000 families in 2001 and 2002.) but Chinese rich people has the tradition to “hidden” their wealth, so that it has more errors than other hierarchical group.

In a word, the income distribution table will seriously under-estimated the top income level. But the top income has less influence on the GINI coefficient compared to the top 1% incomes table. For GINI coefficient it is the middle class has most important influences. The household survey of NBS began in 1954. So theoretically, NBS has sufficient data to calculate the GINI coefficients since 1954 if they will to do this. But NBS has only published the urban and rural GINI since 1978 and the total GINI over 1995-2000 in the year 2001<sup>254</sup> (see *table A6.2.2*). As the GINI coefficient exceeded 0.4 since 2000, NBS didn’t publish GINI anymore due to political reasons. Only until 18 January, 2013 NBS has published total GINI over 2003-2012<sup>255</sup>. The “*CHINA YEARBOOK OF HOUSEHOLD SURVEY*” mentioned above published again the rural GINI over 2000-2012<sup>256</sup>.

For the missing total GINI over 1978-1999, just as pointed out by NBS (2001) the urban and rural household surveys are different in statistical scopes, statistical methods and sampling methods so that the data are not comparable. Those data could not be directly used to calculate the GINI coefficients. However Chen (2007), Wu (2012) and Chotikapanich et al. (2007) still calculated the total GINI based on the data of NBS. Generally they firstly assume that the distribution of income obey a certain type of law and then filter out the parameters with OLS or MLE or GMM methods based on the data of NBS. For example, Chen (2007) assumed that the income distribution is the generalized logistic distribution and used OLS to estimate the parameters. Chotikapanich (2007) assumed that rural income is Weibull distribution while urban income is Beta II distribution and used MLE to estimate the parameters. Wu (2012) has compared the fineness of Weibull, lognormal and Beta II, he concluded that Beta II is relatively better for China and used MLE and MoM to estimate the parameters.

Their works are excellent however the “income data by group of NBS” used are only classified in “five-quintiles” that is: lowest income households (10% of population), low income households (10%),

---

<sup>253</sup> CSZ (1998) document No. 061. China started tax on the income from gains from restricted shares since 2010.

<sup>254</sup> <http://www.stats.gov.cn/tjzs/tjsj/tjcb/zggqgl/200210/P020130912449774536261.htm>

<sup>255</sup> <http://www.stats.gov.cn/tjzs/tjsj/tjcb/zggqgl/200210/P020130912449774383370.htm>

<sup>256</sup> Page4 of *CHINA YEARBOOK OF HOUSEHOLD SURVEY 2013*

relative low income households (20%), middle-income households (20%), relative high income households (20%), high income households (10%) and highest income households (10%). Such a classification of income seems to be too rough to filter out the parameters of distribution laws.

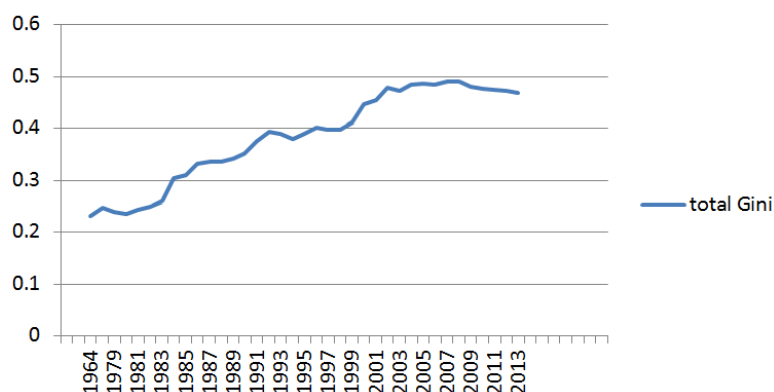
We argue that in the background that we have no more detailed data and the urban and rural household data are not comparable before 2011, it might be better to use the suggestion of LI Yining (2007)<sup>257</sup> to calculate the total GINI coefficient: we apply a weight to the rural and urban GINI to get the total GINI.

$$GINI_t^{total} = w_1 * GINI_t^{rural} + w_2 * GINI_t^{urban} \quad (A6.1)$$

As Bourguignon (1979) and Shorrocks (1980) have demonstrated that the GINI didn't satisfy the additive decomposability so  $w_1 + w_2$  does not necessarily equal to 1. We could not simple use the proportions of rural population and urban population as weights just as we did in the human capital. We suggest to use the average weights over 1995-1999 as the average weights over 1978-1994. This is because under the strict Hukou system, the mobility between rural and urban regions is very low. The rural residents have little chance to work in the cities<sup>258</sup>. So the evolution of rural and urban GINI are respectively are almost independent.

In additional according to the household survey data provided by “China labor and wage statistics 1949-1985”<sup>259</sup> we could get an approximated urban and rural GINI for 1957 and 1964. However the nature of society and inequality in 1957 and 1964 are totally different from the period after reform, so our hypothesis of weights is not agreeable for the years before 1978. So we don't discuss the GINI before the reform here<sup>260</sup>. The average rural weight  $\bar{w}_1 = 0.541864496$  and average urban weight  $\bar{w}_2 = 0.728404552$  then we can draw the Kunzets curve in national level:

Table A6.2.1 Evolution of GINI Coefficient or Kunzets Curve in China 1978-2014



Wang and Fan (2005) used panel data of rural and urban GINI in Provincial level over 1996-2002 to examine whether the Kunzets curve could be hold in China. They found that the trend of rural and urban GINI in provincial level indeed has some mathematical characteristics of Kunzets curve but the difference between urban-rural incomes has only an increasing trend. Their conclusion thus is quite prudent but argued that the income gap of China will not necessarily decrease when economic develops.

From our estimation, the GINI has a very slight tendency of amelioration until 2010. This slight amelioration could not be the argument of prevision for the far future as well. The most probable case

<sup>257</sup> As Li has many students who are the policymakers of China such as the Prime Minister Li Keqiang and Vice-president Li Yuanchao, his suggestions have a very powerful influence on the decision makers. NBS calculate GINI by segmentation (urban and rural) that also probably followed his suggestion. So adopting his suggestion might be helpful to make use of NBS data

<sup>258</sup> For example, Piketty has mentioned in his research in 2000, 97% rural income are exempted to income tax that indicates rural residents have almost no chance to work in the urban region.

<sup>259</sup> Page 244 and page 247, In Chinese: 《中国劳动工资统计资料 1949-1985》

<sup>260</sup> Chen (2007) has estimated that the urban GINI in 1964 was 0.2923. But the available data of 1964 are only the salary data of state-owned units.

is that: China is still a developing country; we are still in the first phrase of Kunznets curve that is the phrase that inequality continues to rise. Or optimist, we are in the turning point of Kunznets curve, the inequality of income distribution is facing the amelioration. After all we have reasons to believe that the current anti-corruption movement in China will help reducing the inequality and the subsequent “good institutional construction” brought by the “Deepening Reform” will keep this amelioration as a tendency so the Kunznets curve will be verified in China.

**Table A6.2.1 Database of GINI 1978-2014**

	Rural GINI	Urban GINI	total GINI
1978	0.2124	0.16	0.231637
1979			0.246972
1980	0.2407	0.16	0.239633
1981	0.2406	0.15	0.234811
1982	0.2317	0.15	0.242614
1983	0.2461	0.15	0.248705
1984	0.2439	0.16	0.261238
1985	0.2267	0.19	0.303232
1986	0.3042	0.19	0.310679
1987	0.3045	0.2	0.331501
1988	0.3026	0.23	0.335457
1989	0.3099	0.23	0.335457
1990	0.3099	0.23	0.341278
1991	0.3072	0.24	0.351921
1992	0.3134	0.25	0.375051
1993	0.3292	0.27	0.39246
1994	0.321	0.3	0.389
1995	0.3415	0.28	0.378921
1996	0.3229	0.28	0.38924
1997	0.3285	0.29	0.401076
1998	0.3369	0.3	0.397
1999	0.3361	0.295	0.397
2000			0.412
2001			0.447
2002			0.454
2003			0.479
2004			0.473
2005			0.485
2006			0.487
2007			0.484
2008			0.491
2009			0.49
2010			0.481
2011			0.477
2012			0.474
2013			0.473
2014			0.469

*Note: NBS didn't publish the total GINI of 2001 and 2002. The data of GINI in 2001 comes from World Bank (2004) and data of 2002 comes from the Income Distribution Team of Chinese Academy of Social Sciences (2003).*

**Appendix 7 Database for Calculating the Profit Rate Associated to the Productive Capital with Inventories**

<b>Year</b>	<b>Remuneration</b>	<b>Total Tax Excluding the Personal Income Tax</b>	<b>Expenditure of Welfare</b>	<b>Profit rate</b>	<b>CYCLE</b>	<b>TREND</b>
1952	102.9162	97.69	2.049	0.594528	-0.016063361	0.610591215
1953	121.2055	113.863	2.568982	0.593275	0.01908461	0.57419013
1954	120.0189	124.0295	2.781234	0.533895	-0.001323573	0.535218907
1955	135.0088	119.2335	3.053575	0.498032	0.00387091	0.494160947
1956	190.445	131.9296	4.455714	0.453636	0.002348601	0.451287876
1957	214.4236	141.3738	5.224505	0.383564	-0.023926327	0.407490669
1958	235.8903	172.9124	5.836347	0.403384	0.0393475	0.364036075
1959	280.8515	188.3594	7.262572	0.34202	0.023657461	0.318362632
1960	299.9871	182.8138	7.990303	0.283371	0.009166725	0.274204477
1961	264.0165	122.7533	6.511123	0.187749	-0.05133234	0.239080941
1962	236.3294	120.7251	5.682802	0.171631	-0.050347336	0.221978032
1963	237.1996	130.0676	5.934618	0.207019	-0.016649716	0.223668582
1964	259.9232	149.6065	6.502949	0.255574	0.018704162	0.23686985
1965	297.8789	169.9771	7.046187	0.287366	0.035730655	0.251635141
1966	328.2517	186.9131	7.485451	0.287416	0.026405885	0.261010425
1967	312.3085	166.5822	7.835622	0.266683	0.002924207	0.263758577
1968	338.6607	162.1248	7.921738	0.235878	-0.026988928	0.262867414
1969	344.5401	197.2893	8.109776	0.252464	-0.00932878	0.261792625
1970	368.8727	235.6343	8.4039	0.267406	0.007733934	0.259671673
1971	372.2134	262.1749	9.159682	0.263268	0.009118586	0.254149413
1972	413.4438	265.3852	10.28659	0.246452	0.002344056	0.244108131
1973	490.706	291.8228	10.76554	0.233211	0.003322275	0.229889087
1974	583.3337	299.3031	11.00961	0.204797	-0.007411122	0.21220859
1975	624.1982	333.1577	11.50175	0.199373	0.007058299	0.192314512
1976	643.5258	336.4414	12.10318	0.178143	0.007874369	0.170268947
1977	822.1836	376.0259	12.4017	0.155421	0.008157296	0.147263315
1978	1378.152	414.0888	62.27919	0.103052	-0.022696462	0.125748935
1979	1569.304	420.8765	83.96871	0.099364	-0.010118255	0.109482297
1980	1617.559	416.1764	99.29415	0.098998	0.000409861	0.098588453
1981	1750.619	447.3173	110.0112	0.092392	0.000818673	0.091573535
1982	1904.354	487.3418	125.6789	0.088849	0.0018398	0.087009254
1983	2092.1	529.3246	145.0588	0.091261	0.007662947	0.083598307
1984	2578.364	629.4615	171.2888	0.089569	0.009231166	0.080337762
1985	2903.069	1240.257	199.1009	0.065099	-0.012351338	0.077450755
1986	3104.987	1190.833	205.6127	0.071111	-0.005526285	0.076637411
1987	3346.441	1135.206	208.3991	0.082409	0.004787441	0.07762164
1988	3495.02	1066.84	188.4899	0.087044	0.007800692	0.079243145
1989	3338.545	1028.875	165.42	0.078796	-0.002311992	0.081107622
1990	3692.812	1031.25	197.9323	0.074022	-0.010046884	0.084068878
1991	4066.921	1055.875	227.1076	0.084379	-0.004231752	0.088610798
1992	4538.102	1092.938	289.1944	0.099201	0.005591335	0.093609768
1993	5150.834	1227.97	337.7202	0.103629	0.006363489	0.097265095
1994	5782.606	1188.393	377.3952	0.102936	0.004265329	0.098670697
1995	6364.393	1185.992	415.0044	0.097908	-3.05246E-05	0.097938651
1996	6867.957	1245.275	463.4883	0.095878	1.45482E-05	0.095863487
1997	7395.978	1438.186	521.9827	0.092032	-0.001202853	0.093234852
1998	7953.854	1622.446	600.3113	0.089235	-0.001610148	0.090844719
1999	8436.92	1893.426	754.9968	0.086949	-0.002343832	0.089292605
2000	9082.746	2189.446	869.5524	0.089859	0.000938768	0.088920405
2001	9879.468	2609.049	988.349	0.088527	-0.001167945	0.089694998
2002	10857.85	3019.572	1236.033	0.086562	-0.00517176	0.091733468
2003	11716.78	3378.815	1424.983	0.090625	-0.004340866	0.094966027
2004	12078.88	3921.527	1553.528	0.104085	0.005589437	0.098495406
2005	13907.6	4583	1808.859	0.102134	0.001404014	0.100729797
2006	15901.38	5474.214	1935.397	0.105159	0.004187186	0.100971702
2007	18547.65	6851.979	2284.27	0.106169	0.007420632	0.098748265
2008	22442.86	7699.911	2706.968	0.090653	-0.003603665	0.09425658
2009	24740.82	8532.775	3238.238	0.083419	-0.005462457	0.088881042
2010	27353.51	10162.95	3737.108	0.085003	0.001573162	0.08342946
2011	30683.26	11801.45	4484.523	0.079624	0.001787913	0.07783565
2012	33471.73	13029.42	5336.295	0.069547	-0.002738525	0.072285133
2013	36130.24	13932.42	6048.363	0.063614	-0.003635803	0.067249498
2014	38855.27	14683.63	6815.827	0.066189	0.003426905	0.062762167



Appendix 8.1 Micro and macroeconomic series of industrial capital stocks: China, 1952-2014

Years	Original value of fixed assets $K_{AO}$	Total value of fixed assets $K_{AT}$	Capital <i>stricto sensu</i> $K_{Pe(I)}$	Capital <i>lato sensu</i> $K_{Pl(I)}$
1952	107.300	71.100	113.646	126.957
1953	128.473	86.588	132.819	163.948
1954	166.722	115.893	155.091	205.257
1955	199.277	139.140	167.243	229.829
1956	245.718	176.454	207.357	279.455
1957	297.808	217.376	263.757	366.708
1958	405.727	308.804	421.914	576.852
1959	532.586	417.078	621.013	866.964
1960	673.157	533.703	781.348	1062.807
1961	759.748	591.132	601.486	808.190
1962	735.295	567.375	585.795	770.169
1963	747.970	567.640	629.520	822.574
1964	829.741	622.952	708.301	917.440
1965	950.605	710.748	760.725	991.897
1966	1,041.141	771.101	903.819	1,196.464
1967	1,114.103	809.750	838.496	1,114.367
1968	1,211.812	872.895	803.341	1,083.528
1969	1,296.931	921.721	983.221	1,311.736
1970	1,467.608	1,037.619	1,251.270	1,686.244
1971	1,674.776	1,203.672	1,442.901	1,961.331
1972	1,846.308	1,327.245	1,619.701	2,194.697
1973	2,034.664	1,461.268	1,766.389	2,413.724
1974	2,210.578	1,574.316	1,908.747	2,591.347
1975	2,410.124	1,703.917	2,263.630	3,036.812
1976	2,624.818	1,843.896	2,428.288	3,206.583
1977	2,828.387	1,973.109	2,734.244	3,589.982
1978	3,561.860	2,165.714	3,028.473	3,997.135
1979	3,764.166	2,221.410	3,209.372	4,253.197
1980	4,000.826	2,290.265	3,513.955	4,638.821
1981	4,244.834	2,391.830	3,547.691	4,680.282
1982	4,532.105	2,529.856	3,637.901	4,783.880
1983	4,835.878	2,682.051	3,814.808	4,998.221
1984	5,108.879	2,705.114	4,016.987	5,233.116
1985	5,553.841	3,759.587	4,346.779	5,744.347
1986	6,023.689	4,119.151	4,826.923	6,421.127
1987	6,552.186	4,540.750	5,269.982	6,951.553
1988	6,697.069	4,670.000	5,857.292	7,714.247
1989	7,180.445	5,037.744	6,103.626	8,257.965
1990	7,813.844	5,505.479	6,230.638	8,570.844
1991	8,650.287	6,060.395	6,771.309	9,347.031
1992	8,871.327	6,273.975	7,729.648	10,513.879
1993	9,180.052	7,635.822	9,250.405	12,402.703
1994	10,730.842	7,771.550	10,493.428	13,880.276
1995	13,386.258	9,211.488	12,034.331	15,819.778
1996	14,888.875	10,627.496	13,695.783	17,833.101
1997	17,095.481	12,041.169	15,391.362	19,803.337
1998	18,732.052	13,206.835	16,562.156	20,934.276
1999	20,595.198	14,717.765	18,118.860	22,473.519
2000	22,470.454	16,990.777	20,152.811	24,411.121
2001	24,580.541	18,077.679	21,926.956	26,127.428
2002	26,680.607	19,290.523	24,237.911	28,412.732
2003	29,331.870	20,996.596	28,204.736	32,577.299
2004	32,939.410	24,158.612	32,207.952	36,868.050
2005	36,704.600	27,167.962	37,308.417	42,298.027
2006	42,400.036	31,436.532	42,706.353	48,101.417
2007	49,374.386	36,446.299	47,566.145	53,429.380
2008	59,833.301	43,698.837	54,445.784	61,214.836
2009	66,417.490	49,443.465	60,829.439	67,921.557
2010	78,179.153	55,591.677	70,861.167	78,832.498
2011	88,733.538	58,192.033	80,857.266	89,992.452
2012	101,307.418	66,209.522	89,441.292	99,385.376
2013	115,913.556	73,398.420	97,733.525	108,426.101
2014	129,761.692	81,877.888	105,896.939	117,389.290

Notes: Monetary unit in hundreds of millions of yuans (RMB), in constant prices of 1952.

$K_{AO}$  = original value of fixed assets of the industrial enterprises at the microeconomic level;

$K_{AT}$  = total value of fixed assets of the industrial enterprises at the microeconomic level;

$K_{Pe(I)}$  = narrowly-defined productive capital stock of the industrial sector at the macroeconomic level (without inventories).

$K_{Pl(I)}$  = broadly-defined productive capital stock of the industrial sector at the macroeconomic level (with inventories).

**Appendix 8.2 Industrial profit rates in micro and macroeconomic level: China, 1952-2014**

Year	r1	r2	r3	r4	r5	r6	r7	r8
1952	0.282386	0.205965	0.42616	0.31083	0.895472	0.596209	0.801584	0.533698
1953	0.306426	0.217868	0.454651	0.323256	0.996185	0.616725	0.807041	0.499628
1954	0.301263	0.217679	0.433391	0.313149	0.942355	0.586359	0.712038	0.44305
1955	0.294456	0.218096	0.421723	0.31236	0.893272	0.557137	0.65002	0.40542
1956	0.278804	0.199648	0.388242	0.278016	0.810684	0.49595	0.601533	0.367998
1957	0.288686	0.207299	0.3955	0.284	0.730054	0.448991	0.525096	0.32294
1958	0.552491	0.401446	0.725897	0.527445	0.74226	0.50355	0.542894	0.3683
1959	0.587772	0.419727	0.750552	0.535969	0.650511	0.464474	0.465965	0.332706
1960	0.53908	0.394749	0.679939	0.497894	0.524278	0.377461	0.385435	0.277499
1961	0.19323	0.110359	0.248347	0.141838	0.341216	0.221666	0.253946	0.164973
1962	0.152036	0.082316	0.197032	0.106678	0.301822	0.186781	0.229568	0.142066
1963	0.196317	0.12494	0.258684	0.164631	0.344072	0.225241	0.263319	0.172378
1964	0.246217	0.164553	0.327949	0.219176	0.418335	0.289944	0.322972	0.223849
1965	0.290163	0.200351	0.388084	0.267963	0.480344	0.337573	0.368395	0.258899
1966	0.342734	0.238623	0.46276	0.322189	0.490539	0.35313	0.370558	0.266757
1967	0.221312	0.1365	0.304495	0.187805	0.431902	0.303141	0.324981	0.228096
1968	0.179337	0.101391	0.248968	0.140758	0.396781	0.271412	0.294178	0.201228
1969	0.265735	0.167315	0.373909	0.235424	0.427491	0.291113	0.320429	0.218206
1970	0.327214	0.215973	0.462812	0.305472	0.46047	0.327436	0.341689	0.242973
1971	0.318095	0.2061	0.442594	0.286765	0.44789	0.313557	0.329501	0.230676
1972	0.29098	0.187672	0.404777	0.261067	0.419805	0.294777	0.309819	0.217547
1973	0.276457	0.179469	0.384938	0.249891	0.418768	0.299129	0.306459	0.218905
1974	0.227219	0.138811	0.319049	0.194911	0.387804	0.276482	0.28565	0.203652
1975	0.236972	0.146184	0.335187	0.206772	0.377824	0.27075	0.281629	0.201816
1976	0.199968	0.117484	0.284658	0.16724	0.334107	0.233441	0.253013	0.176781
1977	0.215297	0.128859	0.308621	0.184715	0.335041	0.235658	0.255178	0.179484
1978	0.172344	0.151338	0.343438	0.217735	0.35448	0.254479	0.268575	0.192809
1979	0.17201	0.1557	0.356112	0.228528	0.357009	0.260545	0.269392	0.196602
1980	0.167392	0.156495	0.362688	0.23296	0.338601	0.251522	0.256494	0.190531
1981	0.141835	0.136672	0.334567	0.205245	0.334918	0.245816	0.253871	0.186331
1982	0.127529	0.125093	0.316461	0.188829	0.33729	0.242788	0.256492	0.184628
1983	0.139491	0.126877	0.313531	0.190777	0.350905	0.254399	0.267822	0.194166
1984	0.141618	0.129747	0.327374	0.196201	0.381939	0.28035	0.29318	0.215199
1985	0.134914	0.089128	0.199302	0.131664	0.405385	0.241586	0.306757	0.182809
1986	0.110786	0.076178	0.162009	0.1114	0.391816	0.249569	0.294538	0.187608
1987	0.109733	0.079597	0.158342	0.114857	0.389561	0.268869	0.295327	0.20383
1988	0.111822	0.089377	0.160359	0.128172	0.373609	0.27638	0.283675	0.209851
1989	0.080194	0.063633	0.114303	0.090698	0.341591	0.25551	0.252476	0.188852
1990	0.038916	0.027283	0.055233	0.038722	0.340015	0.256128	0.247177	0.186194
1991	0.037466	0.027853	0.053477	0.039756	0.361316	0.283948	0.26175	0.205701
1992	0.048707	0.041986	0.068872	0.059368	0.383229	0.314893	0.281744	0.231505
1993	0.062067	0.058008	0.074619	0.06974	0.389627	0.334105	0.290598	0.249188
1994	0.053728	0.035495	0.074187	0.049011	0.380324	0.332715	0.287523	0.251531
1995	0.036342	0.019463	0.052813	0.028284	0.364498	0.322916	0.277279	0.245647
1996	0.028639	0.012833	0.040123	0.017979	0.351261	0.31158	0.269768	0.239293
1997	0.028588	0.015252	0.040588	0.021654	0.343639	0.30273	0.26708	0.235285
1998	0.022491	0.011016	0.0319	0.015624	0.335967	0.294477	0.2658	0.232975
1999	0.031845	0.022952	0.044563	0.032117	0.328808	0.286731	0.265095	0.231171
2000	0.055864	0.046164	0.07388	0.061053	0.329178	0.283166	0.271756	0.23377
2001	0.054848	0.044584	0.074578	0.060622	0.327059	0.262733	0.274478	0.220494
2002	0.06161	0.049886	0.085213	0.068998	0.324263	0.256629	0.276617	0.218922
2003	0.078983	0.065396	0.110338	0.091357	0.320874	0.252427	0.277806	0.218546
2004	0.094856	0.078138	0.129333	0.106538	0.321641	0.248478	0.280986	0.217071
2005	0.10341	0.085342	0.13971	0.115299	0.323195	0.259539	0.28507	0.228923
2006	0.115513	0.096626	0.155799	0.130324	0.328575	0.253071	0.291722	0.224687
2007	0.136637	0.115629	0.185105	0.156645	0.341149	0.262274	0.303712	0.233493
2008	0.124565	0.105696	0.170557	0.144721	0.331572	0.267502	0.294907	0.237922
2009	0.124011	0.106556	0.166584	0.143137	0.310913	0.23661	0.278448	0.211904
2010	0.158433	0.13755	0.222806	0.193438	0.308995	0.246117	0.27775	0.22123
2011	0.159022	0.13714	0.242483	0.209116	0.299305	0.236286	0.268922	0.2123
2012	0.142494	0.122532	0.218031	0.187487	0.27857	0.205753	0.250698	0.185167
2013	0.136921	0.117946	0.216231	0.186264	0.25516	0.189004	0.229998	0.170365
2014	0.120872	0.103333	0.19156	0.163764	0.241128	0.178391	0.217522	0.160926

## Appendix 9.1 Database of Chapter 9: Profit rates and their Technical Components

Year	rKpe	rKpec	rt	rtc	C1	C2	C3T	C4T	C5	C3PE	C4PE
1952	0.654126	0.764292	0.423996	0.467692	0.701539	6.468809	9.703213	0.666667	4.53812	5.937681	1.08945
1953	0.709957	0.846023	0.428903	0.475061	0.696897	6.334224	9.292065	0.681681	4.414301	5.217705	1.213987
1954	0.680772	0.800435	0.392818	0.429902	0.693772	6.563775	10.59257	0.619659	4.553764	5.689113	1.153743
1955	0.656034	0.773836	0.3759	0.411822	0.698105	6.173073	10.46436	0.589914	4.309453	5.568948	1.108481
1956	0.58321	0.709934	0.349604	0.391494	0.660833	4.944187	8.345671	0.592425	3.26728	4.602234	1.074301
1957	0.506198	0.617978	0.301041	0.337327	0.629993	4.442177	8.296214	0.535446	2.798539	4.528541	0.980929
1958	0.527675	0.628896	0.328613	0.36522	0.656511	4.993815	8.976756	0.556305	3.278493	5.21309	0.957938
1959	0.456481	0.540214	0.287659	0.318798	0.640393	4.598819	9.237994	0.497816	2.945053	5.451642	0.843566
1960	0.371168	0.431537	0.241812	0.266061	0.624757	4.246832	9.972297	0.425863	2.653237	6.148343	0.690728
1961	0.244521	0.277895	0.161094	0.174935	0.583423	3.489765	11.63868	0.299842	2.03601	7.326535	0.476319
1962	0.219839	0.246336	0.14779	0.15931	0.57692	3.542688	12.82939	0.276138	2.043849	8.297009	0.426984
1963	0.263778	0.295043	0.179087	0.19297	0.618565	4.024183	12.89952	0.311964	2.48922	8.436807	0.476979
1964	0.322727	0.362663	0.222037	0.240238	0.652394	4.492245	12.19923	0.36824	2.930714	8.081094	0.555896
1965	0.364513	0.412604	0.251556	0.273559	0.667561	4.684888	11.43243	0.409789	3.127449	7.579792	0.618076
1966	0.36953	0.418798	0.253752	0.276052	0.668634	4.697897	11.3789	0.41286	3.141173	7.50045	0.626349
1967	0.344936	0.386756	0.236576	0.255526	0.677235	4.710349	12.4841	0.377308	3.190014	8.248138	0.57108
1968	0.308929	0.347916	0.210709	0.228147	0.652562	4.224586	12.08345	0.349618	2.756804	7.923757	0.533154
1969	0.327795	0.367056	0.225999	0.243993	0.662753	4.624048	12.56021	0.368151	3.0646	8.349145	0.553835
1970	0.350765	0.391151	0.241364	0.259824	0.676501	5.021853	13.07535	0.38407	3.397286	8.685361	0.578197
1971	0.348863	0.38553	0.238798	0.255427	0.684918	5.355582	14.36079	0.372931	3.668132	9.514529	0.562885
1972	0.325498	0.360275	0.224279	0.240259	0.674627	4.998284	14.03473	0.356137	3.371977	9.359456	0.534036
1973	0.30978	0.345775	0.212965	0.229381	0.652913	4.557737	12.97322	0.351319	2.975804	8.606177	0.529589
1974	0.269851	0.303806	0.187528	0.20332	0.616239	3.918024	11.87508	0.329937	2.414438	7.947304	0.493
1975	0.260081	0.291744	0.182915	0.19803	0.611252	3.920485	12.10121	0.323974	2.396404	8.214059	0.47729
1976	0.229319	0.255851	0.163554	0.176617	0.593732	3.724536	12.52074	0.297469	2.211377	8.64322	0.43092
1977	0.198214	0.225303	0.142976	0.156553	0.53195	3.099141	10.53051	0.294301	1.648587	7.317196	0.423542
1978	0.130142	0.158352	0.0952	0.109465	0.362004	2.017998	6.673558	0.302387	0.730522	4.613276	0.437433
1979	0.125608	0.154675	0.091424	0.10591	0.347594	1.922991	6.311215	0.304694	0.66842	4.321455	0.444987
1980	0.12491	0.152768	0.090446	0.104206	0.355391	1.92738	6.573261	0.293215	0.684974	4.483735	0.42986
1981	0.11641	0.142964	0.083726	0.096636	0.335661	1.867137	6.485399	0.287899	0.626726	4.383802	0.425917
1982	0.11151	0.137726	0.079641	0.092172	0.320838	1.825876	6.355645	0.287284	0.58581	4.253437	0.429271
1983	0.114033	0.141772	0.080965	0.094028	0.320327	1.819413	6.19826	0.293536	0.582807	4.110878	0.442585
1984	0.110833	0.141338	0.079051	0.093434	0.29471	1.742439	5.496024	0.317036	0.513515	3.63323	0.479584
1985	0.081396	0.104542	0.057041	0.067517	0.208002	1.767432	5.445009	0.324597	0.367629	3.516559	0.502603
1986	0.089502	0.114298	0.061883	0.072803	0.232788	1.772264	5.666812	0.312744	0.412561	3.609512	0.490998
1987	0.103123	0.130909	0.071208	0.083436	0.269139	1.805186	5.822946	0.310012	0.485845	3.711307	0.486402
1988	0.109063	0.136683	0.074773	0.086798	0.295034	1.829345	6.218081	0.294198	0.539719	3.948677	0.46328
1989	0.101452	0.124537	0.067233	0.076649	0.297297	1.840938	7.140388	0.25782	0.547306	4.394728	0.418897
1990	0.096477	0.119453	0.063152	0.072248	0.283923	1.766642	6.942637	0.254463	0.50159	4.19907	0.420722
1991	0.110166	0.137122	0.0719	0.082483	0.310252	1.806302	6.794251	0.265857	0.560408	4.086934	0.44197
1992	0.1278	0.159676	0.084588	0.097466	0.342976	1.866609	6.568489	0.284176	0.640201	4.009384	0.46556
1993	0.131832	0.16507	0.08836	0.102146	0.348536	1.878434	6.409445	0.293073	0.654702	3.966194	0.473611
1994	0.129507	0.161933	0.087528	0.101228	0.351554	1.839662	6.388927	0.287945	0.646741	3.99388	0.46062
1995	0.122667	0.152586	0.083022	0.095725	0.347449	1.800534	6.535296	0.275509	0.625593	4.099942	0.439161
1996	0.119355	0.147249	0.081161	0.093162	0.350052	1.799919	6.76311	0.266138	0.630065	4.278921	0.420648
1997	0.113559	0.139167	0.077824	0.089054	0.34309	1.798778	6.930005	0.259564	0.617142	4.434554	0.405628
1998	0.108558	0.132338	0.075107	0.08577	0.336794	1.793813	7.043792	0.254666	0.604146	4.56518	0.392934
1999	0.104174	0.12638	0.072792	0.08298	0.329585	1.798867	7.144806	0.251773	0.592879	4.691232	0.383453
2000	0.105565	0.127621	0.074869	0.085328	0.33363	1.830805	7.158399	0.255756	0.610811	4.786113	0.382524
2001	0.102587	0.123742	0.073537	0.083808	0.326094	1.840125	7.159839	0.257006	0.600054	4.849244	0.379466
2002	0.098926	0.119288	0.071772	0.081916	0.316826	1.829224	7.074853	0.258553	0.579546	4.858356	0.376511
2003	0.102357	0.12258	0.07512	0.085469	0.330448	1.877531	7.259121	0.258644	0.620426	5.061404	0.370951
2004	0.116838	0.137969	0.086111	0.097067	0.37204	2.050547	7.859332	0.260906	0.762884	5.52941	0.370844
2005	0.113665	0.134646	0.084503	0.095576	0.360921	2.02104	7.632029	0.26481	0.729435	5.417432	0.373062
2006	0.116369	0.137903	0.086815	0.098262	0.363151	2.052144	7.584197	0.270582	0.745238	5.40409	0.379739
2007	0.117159	0.139508	0.087239	0.099055	0.354973	2.06025	7.383072	0.279051	0.731333	5.242212	0.393012
2008	0.100037	0.120145	0.074267	0.084803	0.313947	1.903877	7.048255	0.27012	0.597716	4.974938	0.382694
2009	0.09157	0.109251	0.068059	0.077365	0.302457	1.870811	7.31394	0.255787	0.565841	5.179293	0.36121
2010	0.093063	0.110398	0.068947	0.078023	0.308758	1.919562	7.596199	0.2527	0.59268	5.368569	0.357556
2011	0.08722	0.103287	0.064011	0.072261	0.295681	1.896264	7.75921	0.244389	0.560689	5.428441	0.34932
2012	0.07611	0.089661	0.055459	0.062322	0.273789	1.839329	8.080441	0.227627	0.503589	5.616573	0.327482
2013	0.069557	0.081448	0.050252	0.056178	0.263696	1.806752	8.480844	0.213039	0.476433	5.849501	0.308873
2014	0.072349	0.084367	0.051881	0.057783	0.277625	1.829393	8.789448	0.208135	0.507885	6.019933	0.303889

## Appendix 9.2 Brief Introduction of Technical Details of Bayesian VAR

Here we introduce briefly if we regard the information provided by pre-sample as prior, how we estimate the BVAR. The Bayesian approaches regard the coefficients to be estimated as random variables. However, as we don't have too much prior information about the distribution of coefficients here (especially how the coefficients are correlated) so in this chapter we treat each equation in BVAR as a single equation in isolation. That is to say, we assume the matrix of variance-covariance  $M$  is diagonal. For example, consider the linear regression:

$$\underset{(T*1)}{\mathbf{y}} = \underset{(T*k)}{\mathbf{X}} \underset{(k*1)}{\boldsymbol{\beta}} + \boldsymbol{\varepsilon} \quad (A9.1)$$

Where  $\varepsilon_t \sim N(0, \sigma^2)$ ,  $\boldsymbol{\beta}$  is a  $(k*1)$  vector of coefficients regarded as random here.

Suppose that prior information about  $\boldsymbol{\beta}$  is that  $\boldsymbol{\beta} \sim N(\mathbf{m}, \sigma^2 \mathbf{M})$ . If we argue that our best guess about  $\mathbf{m}$  and  $\mathbf{M}$  should be provided by making full use of the pre-sample data over 1952-1992. Then  $\mathbf{m}$  is the estimator of  $\boldsymbol{\beta}$  with the pre-sample model and  $\sigma^2 \mathbf{M}$  is also the matrix of variance given by the pre-sample model.

The Bayesian estimator is then:

$$\hat{\boldsymbol{\beta}} = (\mathbf{M}^{-1} + \mathbf{X}'\mathbf{X})^{-1}(\mathbf{M}^{-1}\mathbf{m} + \mathbf{X}'\mathbf{y}) \quad (A9.2)$$

The estimator of matrix of variance-covariance is given by:

$$\hat{\boldsymbol{\Omega}} = \sigma^2(\mathbf{M}^{-1} + \mathbf{X}'\mathbf{X})^{-1} \quad (A9.3)$$

The pre-sample model has given the estimation of  $\boldsymbol{\beta}$ s is:

GRT(-1)	0.358913	0.195695	0.024362	0.030224
GRT(-2)	-0.31266	-0.00317	-0.01974	-0.07328
GRT(-3)	0.096589	0.006244	-0.00235	-0.03156
GIT(-1)	-0.4341	-1.18583	-0.07906	-0.2988
GIT(-2)	-0.08987	-0.15312	0.063769	0.043833
GIT(-3)	-0.1544	-0.3506	-0.04372	-0.09366
GKT(-1)	2.976872	8.362236	1.611018	2.479188
GKT(-2)	-4.60761	-8.2131	-1.44519	-3.60411
GKT(-3)	0.79267	-0.81138	0.535996	0.286056
GY(-1)	-0.42779	0.767681	0.040516	0.080906
GY(-2)	0.92907	-0.0576	0.014875	0.10258
GY(-3)	-0.27504	0.320287	0.049189	-0.05194
C	0.081237	0.227763	0.023429	0.153906

Note the matrix in the above table as  $\boldsymbol{\Pi}$ , then the initial guess for  $\mathbf{m}$  (all  $\boldsymbol{\beta}$ s) is:

$$\mathbf{m} = \text{vec}(\boldsymbol{\Pi}) \quad (A9.4)$$

Similarly, the standard errors matrix of those estimators of pre-sample model is:

0.2218	0.28442	0.04449	0.12979
0.23636	0.30309	0.04741	0.1383
0.23405	0.30013	0.04695	0.13695
0.47551	0.60976	0.09539	0.27824
0.46466	0.59585	0.09321	0.27189
0.2952	0.37854	0.05922	0.17273
2.82609	3.62397	0.56691	1.65367
3.43398	4.40349	0.68886	2.00937
2.92691	3.75327	0.58714	1.71266
0.72173	0.92549	0.14478	0.42231
0.78795	1.01041	0.15806	0.46106
0.70365	0.90231	0.14115	0.41174
0.10791	0.13837	0.02165	0.06314

Note this matrix as  $\boldsymbol{\Lambda}$ , then the initial guess for  $\sigma^2 \mathbf{M}$  is:

$$\sigma^2 \mathbf{M} = \text{diag}((\text{vec}(\boldsymbol{\Lambda}))^2) \quad (A9.5)$$

### Appendix 9.3 Database of Trend and Cycle Components of Technical Components

Year	c1_cycle	c1_trend	c2_cycle	c2_trend	c3pe_cycle	c3pe_trend	c3t_cycle	c3t_trend	c4pe_cycle	c4pe_trend	c4t_cycle	c4t_trend	c5_cycle	c5_trend
1952	-0.0054	0.707	-0.2036	6.6724	0.195	5.7426	-0.1238	9.827	-0.0769	1.1663	-0.0144	0.6811	-0.1614	4.6996
1953	-0.002	0.6989	-0.0781	6.4123	-0.2943	5.512	-0.4458	9.7379	0.054	1.16	0.0236	0.6581	-0.0629	4.4772
1954	0.0038	0.69	0.4442	6.1196	0.3766	5.3125	0.9635	9.6291	0.0124	1.1414	-0.0131	0.6328	0.3248	4.229
1955	0.0191	0.679	0.4239	5.7492	0.4406	5.1284	1.0551	9.4093	0.0017	1.1068	-0.0167	0.6066	0.3904	3.9191
1956	-0.0045	0.6653	-0.383	5.3272	-0.4017	5.004	-0.7959	9.1416	0.0198	1.0545	0.0135	0.579	-0.2962	3.5635
1957	-0.0216	0.6516	-0.5051	4.9473	-0.5256	5.0541	-0.7616	9.0578	-0.0023	0.9832	-0.0111	0.5466	-0.4423	3.2408
1958	0.0171	0.6394	0.3518	4.6421	-0.1164	5.3295	-0.2857	9.2624	0.0633	0.8946	0.0481	0.5082	0.2963	2.9822
1959	0.0132	0.6272	0.2355	4.3633	-0.3449	5.7966	-0.5001	9.7381	0.0535	0.7901	0.0367	0.4611	0.1972	2.7478
1960	0.0088	0.6159	0.1279	4.1189	-0.2548	6.4032	-0.4496	10.4219	0.0096	0.6811	0.016	0.4099	0.1076	2.5456
1961	-0.0254	0.6089	-0.4649	3.9546	0.2844	7.0421	0.4681	11.1706	-0.1115	0.5878	-0.0654	0.3653	-0.3789	2.4149
1962	-0.0336	0.6105	-0.394	3.9367	0.7319	7.5652	1.0602	11.7692	-0.1048	0.5317	-0.0643	0.3404	-0.3684	2.4122
1963	-0.0028	0.6214	-0.0325	4.0567	0.567	7.8698	0.8219	12.0777	-0.0398	0.5168	-0.0261	0.3381	-0.0442	2.5334
1964	0.0158	0.6366	0.2486	4.2436	0.1105	7.9706	0.0738	12.1255	0.0261	0.5298	0.0176	0.3507	0.2152	2.7156
1965	0.0166	0.6509	0.2641	4.4208	-0.393	7.9728	-0.6412	12.0737	0.0664	0.5516	0.0434	0.3664	0.2389	2.8885
1966	0.0071	0.6615	0.1462	4.4557	-0.4988	7.9993	-0.7161	12.095	0.0594	0.567	0.0364	0.3765	0.1245	3.0167
1967	0.0091	0.6682	0.0685	4.6419	0.1381	8.11	0.2243	12.2598	-0.0002	0.5713	-0.0015	0.3788	0.0875	3.1025
1968	-0.0194	0.672	-0.4957	4.7202	-0.3615	8.2853	-0.4402	12.5236	-0.0365	0.5696	-0.0276	0.3772	-0.4117	3.1686
1969	-0.0126	0.6754	-0.2027	4.8268	-0.1783	8.5275	-0.3179	12.8781	-0.0129	0.5668	-0.0072	0.3753	-0.1867	3.2513
1970	-0.0012	0.6777	0.0998	4.922	-0.0956	8.7809	-0.1688	13.2442	0.0164	0.5618	0.0117	0.3724	0.0759	3.3214
1971	0.0086	0.6763	0.4214	4.9342	0.5528	8.9617	0.8685	13.4923	0.011	0.5518	0.0066	0.3663	0.3487	3.3195
1972	0.0063	0.6683	0.1908	4.8075	0.3891	8.9704	0.5692	13.4655	-0.0024	0.5364	-0.001	0.3571	0.1735	3.1985
1973	0.0007	0.6522	0.0043	4.5534	-0.1899	8.7961	-0.1729	13.1461	0.0126	0.517	0.0056	0.3457	0.0087	2.9671
1974	-0.0113	0.6275	-0.2961	4.2141	-0.5429	8.4902	-0.7323	12.6074	-0.0015	0.4945	-0.003	0.3329	-0.2473	2.6617
1975	0.0174	0.5938	0.0881	3.8324	0.1404	8.0737	0.2062	11.895	0.0052	0.472	0.0035	0.3205	0.0762	2.3202
1976	0.0448	0.549	0.3208	3.4037	1.1625	7.4807	1.5835	10.9373	-0.0214	0.4524	-0.0122	0.3097	0.2705	1.9409
1977	0.0384	0.4935	0.1616	2.9375	0.6494	6.6678	0.8348	9.6957	-0.0156	0.4391	-0.0079	0.3022	0.1146	1.534
1978	-0.0733	0.4353	-0.4767	2.4947	-1.1642	5.7775	-1.7115	8.3851	0.0049	0.4325	0.0045	0.2979	-0.4229	1.1534
1979	-0.0405	0.3881	-0.239	2.162	-0.735	5.0564	-1.0425	7.3537	0.0148	0.4302	0.0093	0.2954	-0.2028	0.8712
1980	0.0012	0.3542	-0.0225	1.9499	-0.0809	4.5646	-0.1029	6.6762	-0.0008	0.4307	-0.0007	0.2939	-0.0067	0.6917
1981	0.0064	0.3293	0.0367	1.8304	0.1389	4.2449	0.2253	6.2601	-0.009	0.4349	-0.0064	0.2943	0.0399	0.5868
1982	0.0117	0.3091	0.0536	1.7723	0.2267	4.0267	0.3588	5.9969	-0.0142	0.4435	-0.01	0.2972	0.0584	0.5275
1983	0.0296	0.2907	0.0694	1.75	0.2488	3.8621	0.3846	5.8136	-0.0132	0.4558	-0.0087	0.3023	0.0919	0.4909
1984	0.0219	0.2728	-0.0041	1.7466	-0.106	3.7392	-0.1992	5.6952	0.0108	0.4688	0.0095	0.3075	0.0498	0.4637
1985	-0.0509	0.2589	0.0113	1.7561	-0.1695	3.6861	-0.2427	5.6877	0.0252	0.4774	0.015	0.3096	-0.0795	0.4471
1986	-0.0232	0.256	0.0001	1.7722	-0.1041	3.7136	-0.1388	5.8056	0.0127	0.4783	0.0062	0.3066	-0.038	0.4506
1987	0.0062	0.263	0.0152	1.79	-0.0944	3.8057	-0.2015	6.0245	0.0144	0.472	0.0108	0.2992	0.0154	0.4705
1988	0.0201	0.2749	0.0244	1.8049	0.0189	3.9297	-0.0794	6.2975	0.0021	0.4612	0.0053	0.2889	0.0424	0.4974
1989	0.0093	0.288	0.0262	1.8147	0.357	4.0378	0.5945	6.5459	-0.0321	0.451	-0.0212	0.279	0.0232	0.5241
1990	-0.0176	0.3015	-0.0543	1.821	0.1141	4.0849	0.2647	6.6779	-0.026	0.4467	-0.0193	0.2737	-0.0489	0.5505
1991	-0.006	0.3163	-0.0233	1.8296	0.0034	4.0836	0.0971	6.6972	-0.0065	0.4484	-0.0078	0.2737	-0.0195	0.58
1992	0.0126	0.3304	0.0289	1.8377	-0.0548	4.0642	-0.0809	6.6494	0.0133	0.4523	0.0075	0.2766	0.0322	0.608
1993	0.0077	0.3409	0.0398	1.8387	-0.0917	4.0579	-0.1865	6.596	0.0205	0.4531	0.0142	0.2789	0.0276	0.6271
1994	0.0048	0.3468	0.009	1.8307	-0.0931	4.087	-0.1965	6.5854	0.0124	0.4482	0.0098	0.2782	0.0119	0.6348
1995	-0.0009	0.3484	-0.0175	1.8181	-0.0592	4.1591	-0.101	6.6363	0.0013	0.4379	0.0013	0.2742	-0.0077	0.6333
1996	0.0033	0.3467	-0.0068	1.8068	0.0119	4.267	0.0274	6.7357	-0.0039	0.4245	-0.0025	0.2686	0.0036	0.6264
1997	0.0003	0.3428	-0.001	1.7998	0.0406	4.3939	0.0754	6.8546	-0.0051	0.4107	-0.0034	0.2629	0.0003	0.6169
1998	-0.0012	0.338	-0.0053	1.7991	0.0401	4.525	0.0753	6.9685	-0.0054	0.3984	-0.0037	0.2584	-0.0038	0.6079
1999	-0.0043	0.3339	-0.0076	1.8065	0.0392	4.652	0.0801	7.0647	-0.0053	0.3887	-0.004	0.2558	-0.01	0.6029
2000	0.002	0.3316	0.0079	1.8229	0.0132	4.7729	0.0156	7.1428	0.0005	0.382	0.0006	0.2552	0.0063	0.6046
2001	-0.0057	0.3318	-0.008	1.8482	-0.0428	4.8921	-0.0552	7.215	0.0018	0.3777	0.001	0.256	-0.0139	0.614
2002	-0.0187	0.3355	-0.054	1.8832	-0.1577	5.0161	-0.2213	7.2962	0.0013	0.3752	0.0006	0.258	-0.0538	0.6333
2003	-0.0121	0.3426	-0.0502	1.9278	-0.083	5.1444	-0.1331	7.3923	-0.0035	0.3744	-0.002	0.2606	-0.042	0.6624
2004	0.0219	0.3502	0.0776	1.9729	0.2778	5.2516	0.3855	7.4739	-0.0046	0.3754	-0.0029	0.2638	0.0703	0.6926
2005	0.0076	0.3533	0.0193	2.0017	0.1188	5.2986	0.1418	7.4902	-0.0045	0.3775	-0.0023	0.2671	0.021	0.7084
2006	0.0126	0.3506	0.0425	2.0096	0.113	5.2911	0.1319	7.4523	0.0002	0.3796	0.0011	0.2695	0.0396	0.7057
2007	0.0132	0.3418	0.0651	1.9952	-0.0114	5.2536	-0.0106	7.3937	0.0135	0.3795	0.0095	0.2696	0.0478	0.6835
2008	-0.0148	0.3288	-0.0598	1.9637	-0.2539	5.2289	-0.3209	7.3692	0.0073	0.3754	0.0038	0.2663	-0.0498	0.6475
2009	-0.0129	0.3154	-0.0602	1.931	-0.0783	5.2576	-0.1178	7.4318	-0.0062	0.3674	-0.0042	0.26	-0.0449	0.6108
2010	0.0055	0.3033	0.0163	1.9033	0.0286	5.34	0.013	7.5832	0.0005	0.357	0.0011	0.2516	0.0142	0.5784
2011	0.0038	0.2918	0.0192	1.877	-0.0353	5.4638	-0.0471	7.8063	0.0048	0.3445	0.003	0.2414	0.0121	0.5486
2012	-0.0077	0.2815	-0.0121	1.8514	-0.0046	5.6212	-0.0055	8.086	-0.0029	0.3304	-0.0023	0.23	-0.0178	0.5214
2013	-0.0094	0.2731	-0.022	1.8288	0.0508	5.7987	0.0812	8.3997	-0.007	0.3159	-0.0051	0.2182	-0.0227	0.4991
2014	0.0111	0.2666	0.0201	1.8093	0.0377	5.9823	0.0656	8.7238	0.0022	0.3017	0.0015	0.2066	0.0267	0.4812

# Growth, Institutions and "Socialist Transition with Chinese Characteristics"

Zhiming LONG

**Key words;** China, Economic growth, Economic growth models, Time series analysis, Marxism, Spurious regression, Simulation, Physical capital stock, Human capital stock, R&D, Piketty's law, Inequality, Profit rate, Industrial profit rate, Organic composition of capital, Socialist Transition with Chinese Characteristics, Ergodicity, Spectral analysis, Filter analysis, VAR, SVAR, Bayesian approaches, Identification, Economic cycles, Economic crisis, Financial crisis, Forecast.

## Abstract in English:

The rise of emerging economies and their increasing contributions to the world's economy has led to the development of the science of economics. China is a typical representative of emerging market economies. This economic phenomenon pushes the development of economic growth theory, and the problems in empirical analyses also promote econometric techniques. Though China is still a developing country, China has successfully dragged itself out of absolute poverty. Is the technique of China's economic development an alternative method for the struggle against the poverty of other poor countries?

With the lack of modern international standard data, the empirical analyses of modern economic growth theories in the literature are generally focused on the period after the opening-up reform in 1978 or the period after the fiscal reform in 1993. In this thesis, the author attempts to extend the vision, by further analyzing China's economy using modern economic approaches since the foundation of the People's Republic of China in 1949.

Alongside the wave of privatization, marketization, and liberalization in the countries of the former Soviet Union, socialist countries, and developing countries, China has also begun its economic reform since 1978 in which it has achieved great economic success. Chinese policymakers themselves contribute the rapid economic growth to the success of the institutional choice. For instance, Hu Jintao's report at the 17th Party Congress (2007) has the following assertion: "To sum up, the fundamental reason behind all our achievements and progress since the reform and opening up policy was introduced is that we have blazed a path of socialism with Chinese characteristics and established a system of theories of socialism with Chinese characteristics." However, what does the so-called "socialism with Chinese characteristics" really mean? How does it work on the path of economic growth? All those interesting questions incite this thesis to explore the answers.

Chapter 1 has underlined the background and difficulties in analyzing China's economy: the first difficulty is the particularity of China that is also classified as "socialism with Chinese characteristics," which includes the unique cultural background and language, nature of the economy, lack of data, and frequent institutional changes. The second difficulty is the insufficiency of modern economic growth models suffered by all researchers. In addition, researchers also suffer from the general econometric problems for macroeconomic modeling, for example, the small sample problem, weak identification, and sensible estimation for the stationarity of series and truncate parameters.

Consequently, we need to find and work in an appropriate framework. This thesis will gradually show the insufficiency of mainstream economic growth models to explain China's economic growth and the necessity to step out from neoclassical framework. The analysis gradually turns to Marxist approaches and concentrates on profit rate analysis.

Following Nelson and Kang (1981, 1984), Chapter 2 provides a mathematical proof to show that OLS estimators of detrending method with a linear trend in difference-stationary processes are spurious. To perform this proof, the author uses Chebyshev's inequality. However, the author also pointed out that if disturbance term is a martingale difference sequence, then conclusions are still held using the law of large numbers for  $L^1$ -Mixingale sequence proposed by Andrews (1988). That is, spurious regression exists in a broader sense in reality. The author then designs a statistical series through Monte Carlo simulation to verify it, with a sample size of a million points as an approximation of infinity. The seed values used correspond to the true random numbers generated by a hardware random number generator to avoid the pseudo-randomness of random numbers given by software. The author repeats such experiment 100 times and obtains results consistent with the mathematical proof provided. The author then provides a justification to use the first difference of log in the economic growth models in Chapter 5.

The lack of data hinders econometric studies of growth in this country. A series of such stocks are proposed in the literature, but most available empirical work on this topic suffers from multiple deficiencies. Chapter 3 has built the most reliable and longest possible statistical series of capital stocks for China. The initial capital stocks are calculated by an iteration procedure. The investment flows are consistent with the perimeters of the initial stocks. The investment price indices are strictly tailored to the content of these stocks, and the unit root tests show that all the indices are non-stationary and integrated to the order of 2, which means that they cannot be substitutes, as supposed in many other studies. The depreciation rates are estimated by type of capital, under assumptions consistent with age efficiency and retirement. Investment shares are used to approximate an overall capital structure and to calculate the total depreciation rate. Built from 1952 to 2014, the original series are available to econometricians seeking to conduct new long-term empirical studies on China.

As regards human capital, Chapter 4 has distinguished the difference between total human capital and productive human capital in employed persons. The author has considered the influences of education reforms and Cultural Revolution on the human capital level. By comparing the new statistical database with those in the existing literature, the author feels confident in suggesting that the original estimates of human capital stocks, which the author offers, are substantially more reliable than the series provided by PTW. The stocks are improving in terms of quality, frequency, and/or length, compared with those of Cai and Du (2003) or Barro and Lee (2012), although remaining relatively close to the latter. The author also has proposed a new human capital indicator with the method of Kendrick (1976) as an effort to avoid the limitation of "educational attainment" of Barro–Lee framework.

Supported by new statistical series of physical capital stocks and of human capital, Chapter 5 attempts to improve the explanation of China's long-term economic growth and offers econometric estimates performed within the framework of a broad range of theoretical models, going from standard specifications to more sophisticated endogenous models with *R&D* indicators. The author also proposed a method for designing a compressed dummy variable and tests to quantitatively analyze institutional changes. Finally, this chapter finds that

productive physical capital and human capital stocks, *R&D*, and institutional changes positively and significantly contribute to the Chinese GDP growth. However, the Total Factor of Productivity is nonsignificant to economic growth.

However the persistence of a heteroscedasticity problem at the end of this work, in several tests, suggests the need to further analyze the issue of the possible cycles in the growth trajectory of the Chinese economy, thus opening up new research perspectives.

Before doing this, Chapter 6 builds a capital stock à la Piketty for China over 1952–2012 and estimates elasticities associated with it through specifications also integrating human capital, *R&D*, and institutional change. This chapter calculates an implicit rate of return of this capital to test the validity of what Piketty states as a “fundamental inequality,” comparing the rate of return on capital and the income growth rate in the long run. Piketty’s “law” then connects the coefficient of capital with the ratio between savings rate and income growth rate. These results are compared with estimates in 1978–2012, i.e., the sub-period of “capitalism with Chinese characteristics.” But the broad definition of “capital” proposed by Piketty, a definition questionable in itself and hardly compatible with his own theoretical framework, refers to a production function, but with “capital” input that was not constructed as a strictly “productive” factor.

The author finally chooses to move the methodological reflection toward clearer heterodox perspectives, by introducing a profit rate indicator, to enrich the study of China’s economic growth. Chapter 7 has calculated a profit rate associated with productive capital stock with inventories. By observing the changes in this variable over the past six decades, the author realizes that China’s economic growth trajectory—exceptional for its force and its scale—did not operate smoothly or without difficulties.

Those fluctuations imply the potential economic cycles and crises. To filter those cycles, the author also suggests the need for an “exit” from the usual framework of the time domain and turning to the spectral analysis and filter analysis in an econometric perspective.

Chapter 8 concentrated in the profit rate of industrial sectors, that is, a traditional Marxist analytical view. Based on various originally constructed statistical series of stocks of productive physical capital and of enterprises’ fixed assets, and on a rigorous definition of the scope of the industrial sector, the author calculates several indicators of profit rates at the micro- and macroeconomic levels for China from 1952 to 2014. The results obtained by these two methods (micro and macro) are similar. However, the industrial profit rates calculated in Chapter 8 are insufficient to analyze the economic cycles of all economic sectors in China. Chapter 9 then deepens the analysis of Chapter 8 from a reviewed Marxist perspective.

Chapter 9 first calculated four different total profit rates of all economic sectors over 1952–2014. The author then uses the SVARs to analyze China’s economic structure. The author examined the influences of profit rates on several key economic variables through impulse response functions. Based on *a priori* restrictions hypotheses, through two different approaches of short-run and long-run restrictions, the author has tested those economic structures.

Our empirical tests show that the short-run *a priori* restriction assumptions are difficult to validate, and the long-run restrictions are valid only in the subsample over 1993–2014. Bayesian approaches fail to improve the estimation. The key identifiable condition is



ambiguous, which implies that if Chinese leaders observed economic crisis, then they might subjectively increase the investment as an anti-crisis policy: powerful governmental intervention for anti-crisis.

The author has predicted the values of some economic variables of 2015. The author predicts that the profit rate will continue to fall even if it is already low (5% in 2014). If the profit rate continues to fall, then the Marxists might argue that a crisis will occur in the future. However, this argument is consistent with the facts that a financial crisis in the stock market will happen in 2015 and 2016. The forecast for economic growth is also highly successful. In addition, the author has also extended the economic decomposition of profit rates of Chapter 8. The author proposed three different decompositions and then applied filter to those components. The economic cycles and crises have been confirmed with such a reviewed Marxist perspective. Chapter 10 concludes and has prospected the promising future research directions.

# Croissance, Institutions et "Transition Socialiste aux Caractéristiques Chinoises"

Zhiming LONG

**Mots clés:** Chine, Croissance économique, Modèles de croissance économique, Analyse des séries temporelles, Marxisme, Régressions fallacieux, Simulation, Stock de capital physique, Stock de capital humain, R&D, Lois de Piketty, Inégalité, Taux de profit, Taux de profit industriel, Composition organique du capital, Transition socialiste aux caractéristiques chinoises, Ergodicité, Analyse spectrale, Analyse des filtres, VAR, SVAR, Approches bayésiennes, Identification, Cycles économiques, Crise économique, Crise financière, Prévisions.

## Résumé en français:

Cette thèse commence par souligner les contextes et les difficultés d'analyse de l'économie chinoise: la première difficulté est la particularité de la Chine qui est également référencé comme «socialisme avec des caractéristiques chinoises», qui comprend le contexte culturel unique et la langue, la nature de l'économie, le manque de données, et les changements institutionnels fréquents. La deuxième difficulté est l'insuffisance des modèles de croissance économique modernes. En outre, les chercheurs souffrent également des problèmes économétriques généraux de la modélisation macroéconomique, par exemple le problème de petit échantillon, la faible identification et l'estimation sensible pour la stationnarité des séries et paramètres tronqués.

Par conséquent, nous devons trouver et travailler dans un cadre approprié. Cette thèse montrera l'insuffisance des modèles de croissance économique dominante pour expliquer la croissance économique de la Chine et la nécessité de sortir du cadre néoclassique. L'analyse se tourne progressivement vers les approches marxistes et se concentre sur l'analyse des taux de profit.

À la suite de Nelson et Kang (1981, 1984), Le chapitre 2 fournit une preuve mathématique pour montrer que les estimateurs MCO avec méthode detrending inapproprié sont fallacieux. L'estimateur MCO de la tendance converge vers zéro en probabilité, et les autres MCO estimateurs sont divergents lorsque la taille de l'échantillon tend vers l'infini. Pour réaliser cette preuve, l'auteur utilise l'inégalité de Chebyshev. Cependant, l'auteur a également souligné que si le terme perturbation est une séquence martingale différentielle, les conclusions sont toujours maintenues en utilisant la loi des grands nombres pour la séquence  $L^1$ -Mixingale proposée par Andrews (1988). Autrement dit, la régression fallacieuse existe dans un sens plus large dans la réalité. L'auteur conçoit ensuite une série statistique par simulation Monte Carlo pour la vérifier, avec une taille d'échantillon d'un million comme une approximation de l'infini. L'auteur répète telle expérience 100 fois et obtient des résultats cohérents avec la preuve mathématique fournie. L'auteur fournit alors une justification pour utiliser la première différence de log dans les modèles de croissance économique dans le chapitre 5.

Il n'existe pas, à ce jour, de données statistiques officielles de la Chine relatives aux stocks de capital. Ce manque handicape les études économétriques portant sur la croissance de ce pays.

Des séries de ces stocks sont proposées dans la littérature, mais la plupart des travaux empiriques disponibles sur ce sujet présentent des insuffisances. Un des objets de cette thèse est de construire des séries statistiques de stocks de capital physique de la Chine, les plus fiables et les plus longues possibles. Nos stocks de capital initiaux sont calculés sur la base d'un coefficient capital-*output* moins approximatif (et moins élevé) que ceux généralement avancés dans la littérature. Nos flux d'investissement sont cohérents avec les périmètres statistiques des stocks initiaux. Nos indices de prix des investissements sont strictement adaptés aux contenus de ces stocks, et les tests de racine unitaire montrent que ces indices sont non stationnaires et cointégrés d'ordre 2 – ce qui signifie qu'ils ne peuvent être utilisés les uns à la place des autres, comme le font nombre d'auteurs. Nos taux de dépréciation sont estimés par type de capitaux, avec une compatibilité des hypothèses d'âge-efficience et de mise hors service, et les parts respectives des investissements sont employées afin d'approximer une structure globale de capital et calculer un taux de dépréciation total. Nos séries sont ainsi mises à la disposition des économètres pour réaliser de nouvelles études empiriques sur la Chine en longue période (1952-2014).

Ensuite, nous examinons, en premier lieu, les méthodes utilisées dans la littérature pour estimer le capital humain de la Chine, et les limites de ces approches. Puis, nous exposons notre propre méthodologie, appuyée sur la méthode de l'inventaire permanent, pour la période 1949-2014. Aussi explicitons-nous successivement les manières dont sont déterminés les taux de dépréciation de ce stock, lesquels mettent en jeu des taux de mortalité, de départ à la retraite et de chômage ; ensuite, les accroissements du stock de capital humain, qui exigent de calculer les nombres de nouveaux diplômés pour chaque type d'éducation et les durées des cycles d'enseignement ; et enfin, des valeurs de stocks de capital humain correspondant à des années de référence, ce qui passe par l'identification des nombres moyens d'années d'études des personnes par type d'éducation et de leur poids dans la population. Nous fournissons finalement deux séries originales de stocks de capital humain pour la Chine de 1949 à 2014, ainsi que les indicateurs intermédiaires grâce auxquels ces stocks ont été élaborés.

Appuyé sur des séries de stocks de capital physique et capital humain entièrement reconstruites, cette thèse entend contribuer à améliorer les explications de la croissance du PIB chinois sur le long terme. Il commence par présenter les bases de données originales que nous utilisons par la suite, en insistant sur les méthodes de construction de plusieurs stocks de capital physique et humain pour la Chine sur la période 1952-2014. Puis il propose des estimations économétriques dans le cadre d'une large gamme de modèles théoriques allant de spécifications solowiennes standard ou augmentées jusqu'à des formalisations linéarisées plus ou moins sophistiquées de croissance endogène avec indicateurs de recherche-et-développement. Les stocks productifs de capital physique et de capital humain, ainsi que la R&D contribuent positivement et significativement à la croissance de l'économie chinoise.

La persistance d'un très léger problème d'hétéroscédasticité à l'issue de ce travail, dans quelques tests, suggère la nécessité d'analyser de façon plus approfondie la question de l'existence d'éventuels cycles dans la trajectoire de croissance de l'économie chinoise, ce qui ouvre de nouvelles perspectives de recherche. Pour filtrer ces cycles, l'auteur suggère également la nécessité d'une «sortie» du cadre habituel du domaine temporel et se tourne vers l'analyse spectrale et l'analyse de filtre dans une perspective économétrique.

Avant de le faire, nous proposons également une méthode de construction d'un stock de capital global à la Piketty pour la Chine sur une période allant de 1952 à 2012 (1<sup>ère</sup> partie). Les élasticités associées à ce capital sont estimées économétriquement grâce à des

spécifications qui intègrent à ses côtés le capital humain, la recherche-et-développement et une variable de changement institutionnel, dans le cadre de modèles macrodynamiques néoclassiques modernes – cadre d’analyse dont cet auteur se réclame, quoique non exclusivement. Sur cette base, nous calculons un taux de rentabilité implicite de ce capital afin de tester la validité de ce que Piketty énonce comme étant une « inégalité fondamentale », comparant le taux de rendement du capital et le taux de la croissance du revenu à long terme. La « loi économique » de Piketty, reliant le coefficient de capital au rapport des taux d’épargne et de croissance, est ensuite examinée. Les résultats obtenus sont confrontés à de nouvelles estimations sur la sous-période 1978-2012, correspondant à ce que maints auteurs appellent un « capitalisme à la chinoise ». Est enfin brièvement abordée la question des inégalités en Chine.

Cette thèse propose quelques éléments de réflexion méthodologique sur le thème de la croissance de l’économie chinoise dans la longue période. À partir de données statistiques officielles chinoises retravaillées, nous reconstruisons des séries temporelles de stocks de capital physique les plus longues possibles, soit de 1952 à 2014, de façon à remonter au plus près de la date de formation de la République populaire et étendre cette base de données jusqu’au présent, pour tenir compte des derniers annuaires statistiques publiés en 2016. Nous testons ces nouvelles données afin d’estimer les contributions des facteurs de production à la croissance dans un cadre théorique néoclassique, en soulignant les limites de tels modèles – problématiques, car selon nous indépassables. C’est ensuite un cadre théorique plus original qui est mobilisé, dans l’esprit des récents travaux de Thomas Piketty, combinant références orthodoxes et composantes empruntant à des formalisations keynésiennes et institutionnalistes, déjà anciennes. Plusieurs problèmes associés à ces recherches sont alors identifiés. Enfin, nous déplaçons la réflexion vers une approche plus hétérodoxe, et fructueuse, faisant appel à des indicateurs de taux de profit pour une analyse de la croissance de l’économie chinoise.

Sur la base d’une définition aussi rigoureuse que possible du périmètre du secteur industriel, et de la construction de stocks d’actifs fixes d’entreprises et de capital physique productif, nous calculons des indicateurs de taux de profit aux niveaux micro et macroéconomiques pour la Chine de 1952 à 2014. Les résultats obtenus selon ces deux approches, micro et macro, sont assez similaires.

Enfin, nous avons calculé quatre taux de profit total de tous les secteurs économiques sur la période 1952-2014. L’auteur utilise ensuite les SVARs pour analyser la structure économique de la Chine. L’auteur a examiné les influences des taux de profit sur plusieurs variables économiques clés par les fonctions de réponse impulsionnelle. Basé sur des hypothèses de restriction à priori, par deux approches différentes de restrictions à court et à long terme, l’auteur a testé ces structures économiques. Nos tests empiriques montrent que les restrictions à court terme sont difficiles à valider, et les restrictions à long terme ne sont valables que dans le sous-échantillon de 1993 à 2014. Les approches bayésienne ne parviennent pas à améliorer l’estimation. La condition d’identification clé est ambiguë, ce qui implique que si les dirigeants chinois ont observé la crise économique, alors ils pourraient objectivement augmenter l’investissement comme une politique anti-crise: puissante intervention gouvernementale pour l’anti-crise.

L’auteur a prédit les valeurs de certaines variables économiques de 2015. L’auteur prédit que le taux de profit continuera à baisser même s’il est déjà faible dans 2014. Si le taux de profit continue à baisser, les marxistes pourraient soutenir qu’une crise se produira à l’avenir. Toutefois, l’argument est cohérent avec les faits qu’une crise financière sur le marché boursier

se produira en 2015 et 2016. La prévision pour la croissance économique est également très réussie. En outre, l'auteur a également étendu la décomposition économique des taux de profit. L'auteur a proposé trois décompositions différentes puis appliqué un filtre à ces composants. Les cycles économiques et les crises ont été confirmés avec une perspective marxiste révisé.

## Résumé en français étendu:

Il n'existe toujours pas, au jour d'aujourd'hui, de données statistiques officielles établies par la République populaire de Chine pour ce qui regarde le stock de capital physique – variable pourtant fondamentale pour appréhender les dynamiques d'accumulation et de croissance de cette économie. Bien que la Chine collabore avec l'OCDE (Organisation de Coopération et de Développement économiques), notamment dans le cadre d'une « résolution d'engagement renforcé », il n'est pas prévu dans un proche avenir que le *National Bureau of Statistics of China* (NBS) publie de telles séries, selon les normes harmonisées élaborées par l'OCDE. Ce manque de données de référence entrave considérablement les possibilités d'effectuer des estimations économétriques en séries temporelles ou en panel de modèles de croissance pour ce pays. De très nombreuses analyses empiriques relatives à l'expansion extraordinaire de la Chine existent cependant dans la littérature, mais la grande majorité d'entre elles n'utilise pas de stocks de capital. Quelques tentatives de construction de séries de stocks de capital chinois ont bien sûr été réalisées, à commencer par celles des *Penn World Tables* (PWT). Toutefois, force est de constater que la plupart d'entre elles se heurtent à des difficultés et révèlent des insuffisances multiples. L'objet du présent article est précisément d'identifier ces problèmes méthodologiques et de suggérer des propositions de solutions afin de construire pour la Chine des séries de stocks de capital physique originales, les plus fiables et longues possibles.

Dans le domaine qui nous occupe, les problèmes proviennent en premier lieu de la rareté des données historiques antérieures à 1949 (date d'indépendance du pays), mais également, sur la période récente, de l'existence de ruptures statistiques, dont la plus importante est survenue en 1993 lors du passage de la comptabilité nationale selon le système de balances en produits matériels (*Material Product System*, MPS) à celle des Comptes nationaux (*System of National Accounts*, SNA). Cette transformation a rendu hasardeuses les comparaisons impliquant des données statistiques chinoises, qu'elles soient présentées en séries horizontales (transversales) ou même verticales (chronologiques). Ajouté à ceci, c'est un euphémisme de dire que la tâche est ardue pour qui ne lit pas le chinois de retrouver l'information nécessaire à l'élaboration de statistiques nouvelles au milieu des annuaires, fort abondants mais éparpillés, que publient les autorités chinoises. Des économistes, étrangers ou chinois – parfois mondialement connus, comme Gregory C. Chow, concepteur du test du même nom – ont utilisé des stocks de capital qu'ils avaient eux-mêmes bâtis, aux niveaux national, provincial ou sectoriel, avec des succès assez variables. Les séries que l'on peut considérer comme les plus crédibles et sérieusement conçues sont dues à Chow (1993) et à ses coauteurs, mais le changement de régime statistique de 1993 a provoqué une interruption de la publication des documents ayant servi de base à l'élaboration de ces séries, désormais indisponibles. Les PWT incluent certes la Chine, mais, sur plusieurs points délicats, les notes explicatives fournies par leurs statisticiens demeurent étrangement floues, en ne distinguant pas la méthodologie employée pour le pays que nous étudions de celles des nombreux autres couverts par ce célèbre programme interuniversitaire. Quelques autres bases de données sont accessibles dans la littérature, mais leur mode de calcul, qui s'inspire presque toujours de la méthode de l'inventaire perpétuel (MIP), est fréquemment entâché de biais d'estimation, dus à une maîtrise trop approximative de cette approche. Nos critiques se concentreront principalement sur les paramétrisations contestables du stock de capital de l'année initiale et du taux de dépréciation, mais aussi sur les contenus indéterminés des séries d'investissement et, surtout, sur le choix inapproprié d'indices de prix.

L'un des problèmes majeurs rencontrés dans la littérature est l'imprécision des contours des capitaux agrégés, dont il n'est pas toujours clair s'ils contiennent ou non les terres ( $T$ ) et/ou

les stocks (*inventories*, notés  $V$ ). Pour éviter les confusions et fournir au lecteur plusieurs séries lui permettant d’orienter ses recherches selon la conception qu’il se donne du capital, nous distinguerons quatre catégories de stock de capital physique  $K$  : (1) un stock de capital productif étroit,  $K_{Pe}$ , excluant terres et stocks ; (2) un stock de capital productif large,  $K_{Pl}$ , incluant les stocks, mais pas les terres ; (3) un stock de capital fixe,  $K_F$ , incluant les terres, mais pas les stocks ; et (4) un stock de capital total,  $K_T$ , incluant et les terres et les stocks. Pour construire ces séries d’après la MIP, nous utiliserons la formule d’accrétion standard. Examinons tour à tour les quatre composantes nécessaires à la construction de nos séries de stocks de capital : le niveau de capital initial ; le flux d’investissement ; l’indice des prix ; et le taux de dépréciation. Comme il est de tradition en comptabilité chinoise, l’unité de mesure de grande écriture monétaire que nous retiendrons par la suite est le  $yì$  (亿, soit  $10^8$ ), ou centaine de millions de yuans.

Pour estimer les niveaux initiaux de stocks de capital physique, nous reculons jusqu’à l’année de base la plus ancienne possible, à savoir 1952. C’est à cette date (et non en 1949) qu’est achevée l’unification complète du territoire continental chinois et qu’est fondé le NBS, dont le système statistique moderne aida à la préparation des calculs du premier Plan quinquennal (1953-1957). Le manque de données antérieures à 1952 empêche de recourir directement à un capital dérivé de séries à la fiabilité assurée. Les études utilisant des stocks de capital initiaux pour 1952 font apparaître des écarts notables, tenant aux différences de méthodologies que mobilisent les auteurs. Mais même lorsque leurs hypothèses sont identiques, des divergences sont constatées. Une détermination du niveau initial de capital total par itérations confirme le bien-fondé de l’hypothèse de ratio capital-*output* à 1,50 en 1952. En posant une valeur quelconque (positive non nulle) du capital de base  $K_0^{(0)}$  et en estimant la série de stock  $\{K_0^{(0)}, \dots, K_T^{(0)}\}$  selon la MIP, on obtient la part moyenne  $I_t/K_t$  telle que  $\alpha_0 = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(0)}$  ; part utilisée pour recalculer la nouvelle série  $\{K_0^{(1)}, \dots, K_T^{(1)}\}$ , jusqu’à trouver un  $K_0^{(N)}$  inchangé, soit :  $\alpha_N = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(N)} = \alpha_{N-1} = \frac{1}{T} \sum_{t=0}^T I_t/K_t^{(N-1)}$ . Une telle procédure, qui converge vers une valeur de  $K_0$  de 1018,5 en 1952, équivalant à un coefficient de capital de 1,50, évite le recours à l’hypothèse – délicate, car hautement improbable, mais coutumière – de *steady state* atteint dès l’année de base.

On l’a dit, le contenu du capital initial est rarement explicité dans la littérature avec la rigueur exigée par cette question – dont dépend aussi celle du caractère productif ou non des diverses composantes de ce stock. De manière connexe, les séries d’investissement sélectionnées pour procéder adéquatement à l’accrétion des différents stocks de capital doivent être strictement compatibles avec les périmètres de ces derniers. L’erreur consistant à incrémenter un stock de capital par une série d’investissement qui ne lui correspond pas, pour ce qui regarde les terres et les stocks en particulier, est cependant très fréquemment commise. Pour éviter de telles incohérences, il convient de faire coïncider de façon aussi exacte que possible les flux d’investissement avec nos quatre stocks de capital initiaux.

Parmi ces diverses séries disponibles, celle d’« investissement d’accumulation productive » (*productive accumulation investment*) – déjà amortie, et de fait préférée par nombre d’auteurs, y compris Chow (1993) –, ne paraît plus depuis le passage du MPS au SNA. D’autres séries, complètes, existent néanmoins depuis 1952 pour les formations brutes de capital et de capital fixe. La première de ces notions (*gross capital formation*), qui provient d’une décomposition du PIB par l’approche des dépenses, adaptée aux définitions de l’investissement données par la MIP et le SNA, englobe la seconde (*gross fixed capital formation*), ainsi que les variations de stocks. L’écart entre ces séries correspond donc aux stocks, à considérer comme productifs

ou non selon le capital productif choisi (*stricto* ou *lato sensu*). Une partie des deux formations brutes concerne d'ailleurs des dépenses relatives à l'acquisition de terrains et à la construction d'habitations – éléments non directement productifs, contrairement à ceux liés à l'édification d'usines et à l'achat d'équipements. Les séries d'actifs fixes, fournies par le NBS, font appel à un investissement tel que le MPS l'interprétait, excédant celui du SNA.

En conséquence, et logiquement, nous mobiliserons, sur la période allant de 1952 à nos jours, la série de formation brute de capital ( $F_{BC}$  ou  $I_T$ ) pour construire celle de stock de capital total ( $K_T$ ), puisque toutes les deux intègrent les terres et les stocks ; et la série de formation brute de capital fixe ( $F_{BCF}$  ou  $I_F$ ), qui contient les terres mais pas les stocks, pour le stock de capital fixe ( $K_F$ ). Pour obtenir les profils d'investissements productifs nécessaires à l'élaboration de nos deux autres stocks de capital productif ( $K_{Pe}$  et  $K_{Pl}$ ), il nous faut encore déduire tous les investissements en terres et non directement productifs de la formation brute de capital fixe. On trouve, dans les *Finance Yearbooks of China*, une série d'investissement en constructions d'habitations résidentielles incluant les investissements improductifs et en terres. Ces données n'étant disponibles que depuis 1982, nous utiliserons pour les années antérieures une série très similaire, l'investissement en constructions non productives, qui intègre celui en habitations résidentielles.

La MIP faisant appel à des prix constants, il nous faut disposer d'indices de prix pour nos flux d'investissement, exprimés jusqu'à présent en prix courants. Rares sont cependant les auteurs qui, force est de le constater, accordent à cette question l'attention qu'elle mérite. Car c'est là la composante de la MIP à l'impact le plus décisif sur la construction des différentes séries de stocks. Et une majorité d'entre ceux qui s'y intéressent commettent l'imprudence de prolonger leur série de prix partiellement incomplète en utilisant des tronçons d'indice de prix distinct, voire de substituer purement et simplement un indice de prix manquant par un autre indice, tout à fait différent, mais disponible. Le risque est dès lors grand de les voir déboucher sur des régressions fallacieuses au sens de Granger et Newbold (1974). Face à ces problèmes, nous devons au préalable clarifier la nature de la relation existant entre les indices de prix de l'investissement en capital fixe shanghaien ( $P_S$ ) et chinois ( $P_C$ ). Nos tests de racine unitaire indiquent tous, avec consistance, que la différence première de  $P_C$  (que l'on notera  $DP_C$ ) est non stationnaire, mais que sa différence seconde ( $D^2P_C$ ) est stationnaire.  $P_C$  est donc intégrée d'ordre 2 :  $P_C \sim I(2)$ . Au vu de la cohérence d'une majorité des tests, nous concluons que  $P_S$  est également intégrée à l'ordre 2 :  $P_S \sim I(2)$ . Aussi ne peut-il exister ni relation linéaire ( $P_C \equiv P_S$ ) ni relation de cointégration d'ordre 1 entre  $P_C$  et  $P_S$  ; et ce, contrairement à ce que présupposent, souvent sans même l'expliquer, les auteurs qui, à la façon de Zhang et Zhang (2003), parmi d'autres, utilisent  $P_S$  à la place de  $P_C$ .

La relation non linéaire confirme que les indices  $P_S$  et  $P_C$  ne sont pas substituables, mais elle caractérise la liaison entre leurs évolutions après 1990 et ne saurait donc être utilisée pour estimer la trajectoire antérieure de  $P_{Ct}$  – d'autant que les fluctuations de prix observées sur les dernières décennies sont beaucoup plus fortes qu'au cours de la période d'économie planifiée. Nous complétons donc la série  $P_{St}$  grâce à celle de l'indice de prix de la formation de capital ( $Index_t$ , avec  $Index_{1952} = 100$ ), tel qu'elle apparaît en *Table 20.17* du *Yearbook of Shanghai*. Deux  $Index_t$  étant à notre disposition, pour les formations brutes de capital et de capital fixe, nous calculerons par conséquent deux indices de prix distincts, avec ou sans stocks, afin de construire les flux d'investissement correspondants. On notera respectivement  $P_{FBCS}$  et  $P_{FBC}$  les indices des prix de la formation brute de capital (comprenant les stocks) pour Shanghai et la Chine,  $P_{FBCFS}$  et  $P_{FBCF}$  ceux de la formation brute de capital fixe aux niveaux shanghaien et national. Ces indices sont calculés grâce à la méthode présentée sur



données historiques des *Yearbooks of Shanghai* et *Gross Domestic Products of China*. La taille de notre échantillon passe de 24 à 53 et 61 observations, et atteint le seuil minimum requis par MacKinnon (1991), accroissant la pertinence des tests. Les résultats économétriques obtenus sur la période 1952-2004 servent ainsi à prédire les valeurs prises par les indices entre 2005 et 2014 (10 points). Les quatre indices étant trouvés cointégrés d'ordre 2, ce sont donc deux relations de cointégration distinctes qu'il s'agit d'estimer, entre  $P_{FBC\ St}$  et  $P_{FBC\ Ct}$ , et entre  $P_{FBCF\ St}$  et  $P_{FBCF\ Ct}$  respectivement. Ces relations cointégration de nous permettant de calculer les variables  $P_{FBC\ C}$  et  $P_{FBCF\ C}$  entre 2005 et 2014.

Il aurait été envisageable, comme certains l'avancent, de calculer un (ou des) taux de dépréciation des stocks de capital de manière dynamique, influençant l'amortissement des biens capitaux dans une structure elle-même variable dans le temps. Néanmoins, pour rester en cohérence avec la MIP, qui ne recourt pas à des taux dynamiques, nous choisirons un taux de dépréciation total constant. La simplification permise par cette hypothèse, courante dans la littérature, n'empêche pas nombre d'auteurs d'en méconnaître certaines des implications. Car, mathématiquement, supposer une hypothèse de constance du taux de dépréciation du stock de capital équivaut à se placer dans une axiomatique où quatre autres hypothèses à la fois sont vérifiées : (1) l'âge-efficience des biens constitutifs du capital décline géométriquement, et (2) est proportionnel à l'indice de prix (constants) ; mais encore (3) le taux de remplacement du capital est égal au taux de dépréciation retenu, et (4) le profil de mortalité des diverses catégories d'actifs est tel que les mises hors service des capitaux qui arrivent en fin de durée de vie se font simultanément. Si l'on suppose, avec d'autres, et raisonnablement, que l'âge-efficience des biens capitaux va déclinant géométriquement, alors le taux de dépréciation peut s'écrire ainsi :  $\sigma_i = 1 - d_i^{1/\tau}$ , avec  $\sigma_i$  le taux de dépréciation pour la catégorie de biens capitaux indicé  $i$ ,  $\tau$  la durée de vie de ces biens et  $d_i$  l'âge-efficience lors de la mise au rebut des biens résiduels du même type. Nous utilisons donc le taux de dépréciation total pour le calcul des trajectoires respectives de nos quatre stocks de capital différents, en y intégrant cette fois l'indice de prix (avec stocks).

Les biens capitaux sont classés par le NBS en trois catégories : constructions et installations, équipements et matériels, autres. On dispose de leurs durées de vie respectives et des valeurs résiduelles. En Chine, les durées de vie de ces biens capitaux sont réglementées : 70 ans pour les habitations, 40 pour les immeubles à usage commercial – ceux-ci étant minoritaires par rapport à celles-là. Nous retenons les valeurs suivantes : 55 ans pour les constructions et installations, 16 pour les équipements et matériels, 25 pour le reste. Et, contrairement aux 5 % habituellement retenus en Chine, nous supposons des valeurs de biens résiduels de 10 % – du fait de l'existence d'une concurrence entre gouvernements locaux pour leur « bon classement » selon le taux de croissance de la production, entraînant de fréquentes démolitions et la mise au rebut de biens ayant des valeurs d'usage encore souvent élevées. Nos calculs de somme pondérée des différents taux d'amortissement par type de biens nous amènent à un taux de dépréciation total de  $\sigma = 6,6789\%$ . Le bien fondé d'un tel paramétrage est validé par une analyse d'erreurs, dont on tire plusieurs leçons. Ainsi, d'une hypothèse de taux de croissance moyen du capital positif le taux de dépréciation ne doit donc pas dépasser le taux d'investissement moyen, calculé à 9,221 %, en utilisant nos données. Notre estimation se situe bien sous ce seuil, mais celles des auteurs retenant un taux supérieur introduisent un biais : chez eux, le taux de croissance du stock de capital est excessivement bas (voire négatif) lors des premières années d'accrétion. Une analyse d'erreurs de paramétrage montre que nos séries de stocks de capital physique sont solidement construites et qu'elles pourraient ainsi bénéficier à la communauté des chercheurs désireux d'effectuer, dans l'élément de l'empirie, des estimations économétriques sur la Chine en longue période.

Le très rapide taux de croissance du produit intérieur brut (PIB) de la Chine depuis plusieurs décennies maintenant suscite bien des interrogations à propos des contributions des divers facteurs de production à ce phénomène, au premier rang desquels le stock de capital physique. Ce rythme économique soutenu contraste avec la modération de l'évolution démographique, en particulier de la population active, due dans une large mesure à la politique de contrôle des naissances mise en œuvre. Dans les modèles macrodynamiques d'estimation empirique, qui mobilisent les plus communément un cadre théorique solowien ou proche de lui, l'utilisation du nombre de personnes employées pour approcher le travail simple conduit très souvent à un coefficient de l'élasticité associé à cet intrant (trop) élevé – traduisant une sous-estimation de la productivité totale des facteurs. Il ne fait guère de doute qu'une différenciation statistique entre travail simple et complexe (ou non qualifié et qualifié) est nécessaire pour vérifier que la main-d'œuvre disposant d'un meilleur niveau d'éducation est plus productive. Nous devrions plutôt utiliser économétriquement un indicateur de capital humain chinois en tant que facteur travail. Mais, pour cela, il nous faudra le construire, car, comme nous allons le voir, les séries disponibles pour ce pays sont loin d'être satisfaisantes. C'est le cas de celles élaborées par les méthodes de Kendrick *et al.* (1976) ou de Jorgenson et Fraumeli (1989), ou de celles établies en référence à un niveau moyen d'éducation atteint, comme les *Penn World Tables* (PWT).

Nous examinerons, en premier lieu, la littérature estimant le capital humain de la Chine, et ses limites. Puis, à partir de deux concepts distincts de stock de capital humain, nous exposerons notre méthodologie, appuyée sur la méthode de l'inventaire permanent (MIP) et étendue de la fondation de la République populaire en 1949 jusqu'à la date la plus récente de collecte des informations du *National Bureau of Statistics of China* (NBS), soit 2014. Aussi, après une présentation du cadre méthodologique général, expliciterons-nous successivement les manières dont sont déterminés les taux de dépréciation de ce stock, qui mettent en action des taux de mortalité, de départ à la retraite et de chômage ; puis, les accroissements de capital humain, exigeant de calculer le nombre de nouveaux diplômés et la durée des études pour chaque type d'enseignement afin d'obtenir les investissements venant incrémenter ces stocks ; enfin des valeurs de capital humain correspondant à plusieurs années de base choisies au long des 66 années étudiées, ce qui passe par l'identification des durées moyennes d'études par type d'éducation des personnes et du nombre de ces dernières dans la population. Nous serons ainsi en mesure de fournir au lecteur deux séries originales de stocks de capital humain chinois de 1949 à 2014, ainsi que celles des niveaux d'éducation moyens atteints par la population.

À partir de la décennie 2000, allait se renforcer en Chine l'influence de travaux menés sur le capital humain par des économistes occidentaux, surtout Kendrick *et al.* (1976), approximant le capital humain par la somme des budgets cumulés (et dépréciés) consacrés à la formation des travailleurs, en y intégrant la méthode de l'inventaire permanent. Notre propre tentative préalable d'élaboration d'un indicateur de capital humain à la Kendrick pour la Chine sur la période 1952-2014 nous a apporté la démonstration des limites de cette approche. Nous avons choisi de définir le coût total de la formation comme l'ensemble des dépenses d'éducation prises en charge par les budgets de l'État et des gouvernements locaux, mais aussi par les organismes privés. Ces données sont tirées des bases en ligne du NBS et, pour les séries d'investissements, des *China Compendium of Statistics 1949-2008* – l'indice de prix employé étant celui des prix à la consommation. Plusieurs configurations de taux de dépréciation sont considérées, allant du taux constant de 5 % souvent utilisé dans la littérature à des dépréciations dynamiques variant avec le taux de mortalité). Le capital humain initial est déterminé d'après une procédure de convergence par itérations. Le résultat est décevant :

notre indicateur de capital humain à la Kendrick se révèle au final avoir un taux de croissance non stationnaire, ce qui compromet son utilisation dans des régressions économétriques.

La littérature mobilise aussi d'autres méthodologies, comme celle proposée par Jorgenson et Fraumeni (1989) utilisant la valeur actualisée des revenus futurs des travailleurs, ou Mulligan et Sala-i-Martin (1995) qui recourt à des indicateurs dérivés des revenus. Dans les deux cas, on suppose que sont vérifiées les hypothèses de concurrence sur les marchés et d'équivalence entre la rémunération perçue par le travailleur, son revenu marginal, sa contribution marginale et son niveau de capital humain. La mesure de stock de capital humain désormais dominante requiert de déterminer un niveau moyen d'éducation atteint ou nombre d'années d'études par habitant.

Les PWT (2013) ont estimé cet indicateur en se fondant sur des nombres d'années d'études de Barro et Lee (2012) et des rendements éducatifs à la Psacharopoulos (1994). Ce dernier auteur a en effet utilisé le niveau d'éducation pour évaluer des rendements du capital humain, tandis que Barro et Lee (2012) ont soutenu l'idée que les niveaux d'éducation des travailleurs reflétaient leurs niveaux de capital humain. Dans les travaux ayant cherché à appliquer la méthode Barro-Lee, ce sont d'abord des taux de scolarisation des enfants et/ou d'alphabétisation des adultes qui ont été employés en tant que mesures du capital humain – ce qui contribua à leur succès en Chine, du fait de la disponibilité de ces données et du manque corrélatif d'informations sur les nombres d'années d'études longtemps constaté dans ce pays. Aujourd'hui, l'indicateur le plus utilisé sur le sujet, y compris en Chine, est le nombre moyen d'années d'études. C'est dans cette optique que Cai et Du (2003) ont estimé le capital humain chinois, mais repris les hypothèses contestables de Cai (1999) qui supposait l'analphabétisme équivalant à zéro année d'études, l'éducation primaire à six ans, le 1<sup>er</sup> cycle du secondaire à neuf ans, le 2<sup>e</sup> cycle secondaire à 12, l'école secondaire technique à 13, le lycée à 14 et l'université à 16. Or, la définition relative au niveau d'éducation primaire de la population totale que donne le NBS est précise : elle fait référence à toutes les personnes dont le niveau de scolarisation le plus haut est l'école primaire, qu'elles soient en cours de scolarité, déjà diplômées, ou qu'elles aient abandonné leurs études. Ainsi, par exemple, d'après la *Table B0301a* du recensement de population de 2010 indiquant l'état d'achèvement des études, on peut calculer que le niveau éducatif primaire représente 4,942 années d'études, et non pas six. Cai (1999) a probablement surestimé le niveau de capital humain chinois.

Il va donc falloir l'estimer par nous-mêmes afin d'être en mesure de construire des séries de stocks de capital humain chinois. Pour ce faire, on dispose de données officielles nombreuses, mais disjointes, et incomplètes. Dans son *China Population Statistics Yearbook*, le NBS a publié en 1987, puis à partir de 1993, un tableau intitulé « population âgée de six ans et plus selon l'âge, le sexe et le niveau d'éducation », qui se fonde sur les résultats d'enquêtes par sondage. Cet annuaire a changé de nom à partir de 2007 pour s'appeler désormais *China Population and Employment Statistics Yearbook*, lequel comprend également, et depuis 2006, un tableau sur le « niveau d'éducation des personnes employées » (*Table 3-1*), établi grâce aux enquêtes par sondage portant sur la main-d'œuvre. L'information de l'année  $t$  est donnée dans l'annuaire  $t+1$ . De surcroît, pour les années au cours desquelles un recensement de population a été effectué (à savoir : 1964, 1983, 1990, 2000, 2010), il existe des données plus détaillées, complètes, sur les populations selon différents niveaux éducatifs. Par la combinaison des durées de chaque type d'éducation, nous pouvons obtenir le niveau moyen d'éducation pour les années en question, et ce à partir de sources officielles et homogènes. Autrement dit, pour les années 1964, 1982, 1987, 1990, puis pour la période 1993-2014, il est possible d'avoir le niveau moyen d'éducation atteint par la population âgée de six ans et plus,

et de multiplier ensuite ce niveau par le nombre de personnes composant la population de six ans et plus, de façon à calculer le stock de capital humain total, soit celui correspondant à la population ayant au moins six ans. De 2006 à 2013, on peut aussi obtenir le niveau moyen d'éducation des employés, ainsi que le capital humain productif, toujours à partir de statistiques officielles chinoises. La base de Barro et Lee (2012) est relativement proche de ces dernières, mais ne propose que des points espacés de cinq ans ; celle des PWT (2013) est en revanche très en-dessous. Notre effort va donc consister à estimer pour les années manquantes, passablement nombreuses comme on peut le constater, les valeurs prises par deux stocks distincts : le capital humain total de la population âgée de six ans ou plus et le capital humain productif porté par les personnes employées.

Dans ce qui suit, on entendra par capital humain le produit d'un niveau moyen d'éducation atteint, ou nombre d'années d'études diplômantes *per capita*, et d'une population considérée. Ce stock est supposé s'accumuler de la façon suivante : pour une année  $t$ , le capital humain  $H_t$  sera égal à celui de la période précédente  $H_{t-1}$  (déduction faite d'un taux de dépréciation  $\sigma_{Et}$ ), plus l'investissement en capital humain  $I_{Et}$  réalisé au cours de l'année  $t$ . En  $t$ , l'accroissement de capital humain  $I_{Et}$  est la somme des produits du nombre de nouveaux diplômés par type d'éducation  $i$ , noté  $l_{it}$ , et du nombre d'années d'études cumulées,  $\eta_t$ . Dans ce cadre, ce sont deux catégories distinctes de capital humain que nous allons construire, en recourant à des niveaux moyens d'éducation correspondant à des populations différentes : un stock total, calculé pour la population âgée de plus de six ans ; et un stock productif, pour la population active, soit l'ensemble des personnes employées âgées d'au moins de 16 ans. Nous prenons en compte toutes les catégories d'éducation dans nos calculs de capital humain, à quelques exceptions près. Ces dernières, non intégrées aux stocks, correspondent à des types d'enseignement ne débouchant pas sur un diplôme ; même si elles jouent à l'évidence, pour la plupart, un rôle positif dans l'acquisition de connaissances de base, de compétences plus approfondies, voire de qualifications de haut niveau.

Nous avons besoin de déterminer les valeurs des variables entrant dans la composition de ces stocks. La première correspond aux taux de dépréciation, qui impliquent de mobiliser des taux de mortalité, de départ à la retraite et de chômage. En deuxième lieu, nous devons disposer d'informations sur les nouveaux accroissements de capital humain, ce qui exige de connaître les durées des cycles éducatifs et pour chacun d'eux les nombres de diplômés. Pour le stock total, on utilise le taux de mortalité des personnes de six ans ou plus comme dépréciation, et toutes les nouvelles augmentations de capital humain comme investissements. Mais pour le stock productif, on retient en dépréciation la somme du taux de mortalité de la population de 16 ans ou plus, pondéré entre zones urbaine et rurale, et du taux de départ à la retraite, et en tant qu'incrémentation, les accroissements nouveaux de niveaux éducatifs correspondant aux mêmes tranches d'âge que celles des employés. Finalement, pour déterminer les stocks des années de base, on doit disposer de niveaux moyens d'éducation et des nombres de personnes ayant atteint un certain niveau éducatif. Grâce aux annuaires démographiques, il est possible de calculer les stocks du capital humain total en 1964, 1982, 1987, 1990 et de 1993 à 2013, comme aussi ceux du capital humain productif de 2006 à 2013. Nous pourrons de la sorte utiliser ces valeurs comme autant de points de passage en bases multiples afin de compléter nos séries pour leurs moments respectifs par rétropolation à partir de ces années, de 1992 à 1952 pour la première, de 2005 à 1952 pour la seconde. Les données étant collectées selon des procédures distinctes, les équations servant à leurs calculs seront elles-mêmes différentes.

Le principe de construction que nous avons ici adopté a consisté à mobiliser au maximum les données historiques officielles du NBS et à chercher à limiter les risques d'erreurs, associés

notamment à la détermination des flux d'accroissements nouveaux de capital humain et des taux de dépréciation des stocks, par le recours à une méthode de rétropolation prenant appui sur plusieurs points de passage de nos séries, calculés grâce aux recensements de population disponibles. Sur cette base, nous nous sommes trouvés en mesure de fournir au lecteur deux séries originales de stocks de capital humain pour la Chine sur la période 1949-2014 (66 ans). Par comparaison avec ce qui existe dans la littérature, nos estimations constituent un apport. Elles sont plus fiables que les séries des PTW (2013), qui sous-estiment gravement le stock de capital humain chinois. Selon nous, cela est principalement dû à l'hypothèse utilisée par les PWT, suivant Psacharopoulos (1994), de rendements de l'éducation ; hypothèse inappropriée à la réalité chinoise et amenant des valeurs du capital humain biaisées. Mais nos nouvelles séries améliorent aussi, en qualité, fréquence et/ou longueur, celles de Cai et Du (2003) et même celles de Barro et Lee (2012), tout en demeurant relativement proches d'elles. Pour ne prendre qu'un exemple, nous avons pu calculer selon notre méthodologie recourant aux données du NBS et de recensement qu'en 2010, le niveau moyen d'éducation atteint par la population totale chinoise était de 8,24 ans, alors que la base de Barro et Lee (2012) donne 7,51 ans, et les PWT seulement 2,58.

Pour parvenir à ces résultats, nous avons dû, comme on a pu le constater, prendre en compte les particularités du système éducatif chinois, ainsi que les évolutions politiques et historiques du pays depuis la fondation de la République populaire en 1949. Nos efforts ont en particulier porté sur un strict respect des définitions du NBS distinguant entre élèves scolarisés, diplômés ou ayant abandonné l'école ; l'effet des réformes du système éducatif sur les durées d'études ; l'éducation des adultes et l'alphabétisation ; l'examen de la question des départs à la retraite ; ou les temps de référence des recensements démographiques... Le traitement de cette masse d'informations fut une tâche ingrate, mais nécessaire pour estimer avec le plus de précision possible le capital humain chinois et offrir de la sorte aux économistes (et aux démographes) une matière renouvelée pour leurs recherches.

La théorie de la croissance est en effet l'un des domaines des sciences économiques qui a expérimenté les avancées les plus décisives au cours des dernières années, sous l'influence surtout de la nouvelle théorie de la croissance, ou croissance à progrès technique endogène. Le cadre traditionnel de la macro-dynamique, dû à Solow, et d'autres, dans la décennie 1950, s'est vu amélioré grâce aux explications de la productivité globale des facteurs et à l'analyse des contributions spécifiques du capital humain et de la R&D, notamment. Ces travaux ont remobilisé certains thèmes déjà étudiés depuis longtemps par la microéconomie, comme ceux des non-convexités. Néanmoins, il ne serait pas tout à fait juste de considérer, comme Solow (1988) l'a d'ailleurs lui-même fait remarquer, que les formalisations en croissance endogène sont très différentes des anciennes représentations de la croissance. Tel est le cas du modèle AK (qui revisite à sa façon les premières dynamisations keynésiennes), mais aussi de modèles plus sophistiqués, non linéaires et recourant fréquemment aux rendements croissants associés à des externalités de la R&D ou de l'éducation. Pourtant, dès lors que l'on souhaite les tester empiriquement, les spécifications dérivées de ces modèles s'avèrent en réalité très proches de formes solowiennes augmentées, log-linéarisées. Ce sont très précisément ces trois catégories (liées, mais distinctes) de modèles – Solow, AK et croissance endogène – que nous utilisons dans nos applications économétriques des séries statistiques de stocks de capital physique.

Sur la base de séries chronologiques entièrement reconstruites pour l'occasion de stocks de capital physique et de capital humain pour la Chine de 1952 à nos jours, nous avons ici estimé économétriquement plusieurs spécifications dérivées d'une gamme assez large de modèles macro-dynamiques, allant de versions simplifiées de type AK jusqu'à des représentations plus

complexes de croissance endogène avec indicateurs de R&D, en passant par les formalisations solowiennes standard ou augmentées. Les meilleurs résultats empiriques sont obtenus lorsque nous retenons les concepts de stocks de capital physique et de capital humain les plus proches de leurs « cœurs » productifs respectifs. Car dans nos ultimes régressions, les plus complètes, nous observons en effet clairement des contributions positives et statistiquement significatives du capital physique productif *stricto sensu* ( $K_{pe}$ ), du capital humain productif ( $H_p$ ), mais aussi de la R&D, à la croissance du produit chinois sur la longue période ; et ce, dans des cadres théoriques où les rendements d'échelle constants sont souvent acceptés.

Nos régressions sont effectuées en moindres carrés sur les différences premières des formes logarithmiques en niveaux. Celles de Chow et Li (2002) étaient réalisées en moindres carrés sur des formes logarithmiques en niveaux, avec ajout d'une tendance linéaire faisant office de méthode de *detrending*, comme fréquemment dans la littérature macrodynamique. Toutefois, Nelson et Kang (1981), à la suite de Chan, Hayya et Ord (1977), ont montré qu'assimiler en MCO, à la façon de Chow et Li (2002), un *difference-stationary process* (DS) – processus le plus probable pour le PIB, avec celui de racine unitaire – à un *trend-stationary process* (TS) peut conduire à faire dépendre la covariance des résidus de la taille de l'échantillon ; ce qui implique le risque d'introduire artificiellement une autocorrélation des résidus pour les retards, ainsi qu'un mouvement cyclique dans les séries. Nos tests révèlent que le log du PIB chinois a une racine unitaire. Si l'on utilise cette méthode inappropriée de *detrending*, l'estimateur en MCO de la tendance convergera vers zéro en probabilité, et les autres estimateurs divergeront quand la taille de l'échantillon tendra vers l'infini. Aussi recommandons-nous d'estimer les modèles macrodynamiques choisis en différences premières de log-niveaux pour des variables ayant des racines unitaires, afin d'éviter les régressions fallacieuses.

Nos séries chronologiques couvrent la période 1953-2014, soit 63 ans d'histoire économique de la Chine. Les tests de racines unitaires préalables indiquent que les taux de croissance des variables sont tous stationnaires. Dès lors qu'au moins un des tests révèle un risque d'hétéroscédasticité (à 5 %), il est procédé à une correction par les méthodes de White ou de Newey-West afin d'obtenir des régressions robustes. A ici été écarté le recours à un système d'équations simultanées, destiné à endogénéiser par effet *feedback* les facteurs de production expliquant la croissance économique, en raison de résultats de tests de causalité de Granger par paires (en modèles bivariable et VAR) indiquant que nos variables explicatives ne sont pas endogènes – à l'exception du progrès technique, mais très faiblement.

Une variable qualitative,  $D$ , est introduite pour tenir compte des changements institutionnels et de leur impact sur la croissance économique, en distinguant chocs positifs et négatifs. La *dummy*  $D$  prend la valeur +1 en 1963-1965 (récupération), 1984 (réforme fiscale), 1992 (tournée de Deng Xiaoping) et 2007 (surchauffe), mais -1 en 1960-1962 (récession), 1967 (début de la révolution culturelle), 1976 (mort de Mao) et 1989-1990 (agitation politique). Ses valeurs ne sont pas déterminées arbitrairement, mais résultent d'une méthodologie consistant à régresser (sans *dummy*) le modèle sélectionné avec constante afin de vérifier si les résidus obtenus sont des bruits blancs. S'ils ne le sont pas, et si les tests du Lagrange Multiplier et de Ljung-Box révèlent un problème d'autocorrélation, des *dummies* sont générées – le système étant testé pour la singularité de la matrice de régresseurs et la multi-collinéarité. Puis nous regardons si les nouveaux résidus de la régression avec *dummy* comprimée sont transformés en bruits blancs. Si les tests ne sont pas satisfaits (du fait d'éventuelles influences symétriques de chocs positifs et négatifs), une estimation par balayage permet de déterminer les valeurs de la *dummy* comprimée en certains points du temps en s'assurant qu'elles sont statistiquement significatives. À notre avis, les chocs exogènes constatés sont probablement causés par des

changements politico-institutionnels – qui ne sont pas des ruptures, mais additifs, c'est-à-dire que l'influence de tels chocs est à considérer comme temporaire, et non permanente.

Il convient de noter que la Chine n'a commencé à s'insérer dans le système international de comptabilisation des activités de R&D qu'à partir de 1986 – sans qu'il ne soit possible de disposer avant cette date d'une série homogène, telle qu'établie par le *Manuel de Frascati*. Face à cette contrainte, nous distinguons deux indicateurs de dépenses de R&D (Tableau 5) : d'une part,  $R\&D_1$ , construit d'après les budgets de *Science and Technology* (1952-1985), de R&D des entités publiques et de l'enseignement supérieur (1986-1988), et de R&D agrégée des *Statistical Yearbooks of Science and Technology* (1989-1994), puis du NBS (1995-2012) ; d'autre part,  $R\&D_2$ , correspondant aux financements des diverses composantes fondamentales ou appliquées des sciences et technologies (1952-1970), auxquels sont également ajoutés ceux de l'innovation technique des entreprises (1971-1985), avant que les profils des deux séries se rejoignent à compter de l'année 1986.

Le calcul des taux de croissance moyens de dépenses de R&D (de l'ordre de 14,5 % sur notre période 1952-2012) donne des valeurs largement plus élevées que celles que nous obtenons par ailleurs pour les expressions de la productivité totale des facteurs (PTF), quelle que soit la manière dont nous la définissons en tant que résidu de Solow, avec progrès technique neutre au sens de Hicks. Mais, en général, la contribution de cette PTF ne sort pas statistiquement significative ; ce qui vient appuyer un résultat déjà mis en évidence par Su et Xu (1999). C'est aussi bien davantage que le taux de croissance du terme de PTF (+2,5 %) avancé par Chow et Li (2002), dans un cadre demeurant solowien, expliquant en logarithmes un PIB exprimé *per capita* et intégrant une tendance linéaire. Leur échantillon est cependant plus limité que le nôtre, et qui plus est découpé en sous-périodes. Mais c'est surtout parce que nous doutons non seulement de l'ampleur de ce *trend*, selon nous sous-estimée, mais encore de la pertinence de son introduction dans des estimations en MCO – en raison, notamment, du constat de la présence de ruptures dans les séries de Chow et Li (2002), même épurées des années jugées « problématiques » 1958-1969 –, que nous avons opté *in fine* pour des régressions écrites en différences premières des formes logarithmiques en niveaux sur des spécifications débordant le strict cadre solowien pour mobiliser des modélisations à progrès technique endogène.

Tout en captant les informations économiques relatives aux changements institutionnels ayant caractérisé l'histoire contemporaine de la Chine, l'introduction de notre variable qualitative  $D$  réduit nettement l'autocorrélation des résidus, laquelle dérive vraisemblablement des ruptures provoquées par la présence de fortes fluctuations des variables étudiées en certaines périodes de cette histoire (spécialement au cours des décennies 1960 et 1990), et améliore fortement le pouvoir explicatif de nos estimations économétriques. La persistance d'un très léger problème d'hétéroscédasticité à l'issue de ce travail, dans quelques tests, suggère la nécessité d'analyser de façon plus approfondie la question de l'existence d'éventuels cycles dans la trajectoire de croissance de l'économie chinoise, ce qui ouvre de nouvelles perspectives de recherche.

Le succès du *Capital au XXI<sup>e</sup> siècle* de Thomas Piketty a été fulgurant, y compris en Chine, où il fut publié en 2015, peu après ses éditions en versions française (2013) et anglaise (2014). Dans cet ouvrage, l'auteur y définit un « capital » en un sens extrêmement large et révèle ce qui constitue à ses yeux des « lois fondamentales » du fonctionnement dynamique du système capitaliste (ou, disons plutôt, des régularités sur le long terme). L'objet de cet article est de reconstruire, dans la longue période (1952-2012), une série statistique de stock de capital aussi proche que possible de la définition donnée par T. Piketty, afin de tester la validité de ces « lois » pour le cas de l'économie de la République populaire de Chine.

Une question préliminaire est de savoir si le système économique chinois peut être assimilé ou non au capitalisme. Une très grande majorité d’auteurs, à la fois à l’étranger et en Chine, soutiennent que depuis son ouverture au système mondial en 1978, l’économie chinoise s’est considérablement rapprochée du capitalisme ; suffisamment en tout cas pour nous autoriser, d’un point de vue méthodologique, à tenter d’appliquer à ce pays le cadre proposé par Piketty. Nous poserons donc ici l’hypothèse, généralement admise, selon laquelle ce système constitue aujourd’hui l’une des formes du capitalisme – l’expression de « capitalisme d’État » pouvant sans doute paraître la plus appropriée. Le concept de capital utilisé par Piketty s’appliquerait d’ailleurs selon lui à n’importe quel système patrimonial, tout comme le mode de régulation suggéré vaudrait pour tout système de propriété, même publique (Piketty [2013], p. 83). Aussi nous semble-t-il pertinent de s’interroger sur la portée et les limites de la réflexion que Piketty a consacrée aux pays capitalistes développés dans le cas, fort singulier, de la Chine.

Le présent article propose au lecteur une méthode statistique de construction d’un capital à la manière de Piketty pour la Chine sur une période relativement longue (1952-2012), en dilatant progressivement un stock de capital physique productif étroit – traditionnellement conçu – pour y adjoindre les stocks nécessaires à la production (*inventories*), mais encore les valeurs de composantes non directement productives, telles que les terres et constructions – y compris les logements –, ainsi que des éléments monétaires représentatifs de la position patrimoniale nette du pays vis-à-vis de l’extérieur. Nous appellerons ce capital à la Piketty « stock de capital global », en raisonnant, comme il le fait, en économie ouverte (1<sup>ère</sup> partie). Par la suite, les élasticités associées à ce capital sont estimées économétriquement grâce à des spécifications qui intègrent, aux côtés de ce stock global, le capital humain, la recherche-et-développement (R&D) et une variable de changements institutionnels, dans le cadre de modèles néoclassiques macrodynamiques modernes – cadre d’analyse dont cet auteur se réclame, non exclusivement, mais explicitement. Sur cette base, nous calculons alors un taux de rentabilité implicite de ce capital afin de vérifier (ou d’infirmer) ce que Piketty décrit comme étant une « inégalité fondamentale », comparant taux de rendement du capital et taux de la croissance du revenu à long terme. La « loi économique » qu’il énonce, reliant le coefficient de capital au rapport des taux d’épargne et de croissance, est ensuite examinée, en proposant plusieurs indicateurs d’épargne (2<sup>e</sup> partie). Les résultats ainsi obtenus sont confrontés à de nouvelles estimations effectuées cette fois sur la sous-période 1978-2012, nettement plus courte, mais correspondant plus clairement à ce que maints auteurs affirment être celle d’un « capitalisme à la chinoise » (3<sup>e</sup> partie). Est enfin abordée, en conclusion, la question des inégalités dans la Chine actuelle ; question fondamentale, mais complexe et qui, en tant que sujet en soi, ne peut faire l’objet de plus longs développements dans l’espace imparti à cet article.

Le « capital », tel que l’entend Piketty dans son *best seller*, comme dans d’autres publications signées ou co-signées par lui dans le passé, est une notion particulièrement large, élargie bien au-delà de celle, habituelle, de capital physique. La conception de l’auteur se rapproche plutôt de celle de « patrimoine » – synonyme, « pour simplifier l’exposition » (Piketty [2013], p. 54) ou de « richesse » (Piketty et Zucman [2014]). Elle correspond en fait à (presque) tout ce qui peut rapporter de l’argent à son propriétaire – à l’exception du « capital humain » –, soit toute composante permettant à ce propriétaire d’en obtenir un rendement quelconque. Il s’agit ainsi de tous les actifs auxquels il s’avère possible de conférer un prix, qu’ils soient matériel ou non (immatériel), de nature réelle ou non (financière), de fonction directement productive ou non, de propriété privée ou non (publique ou collective)... Sont ici concernés tous les « actifs non humains (...) possédés et échangés sur un marché » (p. 82) par des « individus ou groupes d’individus », y compris l’État ; soit « l’ensemble du capital mobilier (...) utilisé pour le logement, et du capital financier et professionnel (bâtiments, équipement, machines, brevets,



etc.) utilisés par les entreprises et les administrations ». Ce capital est vu comme un facteur de production, et donc rémunéré à sa productivité marginale, qui dépend de la substituabilité entre capital et travail, « supérieure à un » d'après Piketty. Par là même, cet auteur s'inscrit distinctement, aux plans conceptuel, méthodologique et analytique, dans le cadre néoclassique – parmi d'autres (keynésien et institutionnaliste), également mobilisés.

Dès lors, et dans l'optique qui est la nôtre, le défi à relever sera de reconstruire pour la Chine une série de stock de capital conçue au sens de Piketty. Ce pays est incorporé dans les bases de données mises à disposition du public sur son site (*cf.* [piketty.pse.ens.fr](http://piketty.pse.ens.fr)), sans toutefois que le visiteur curieux ne puisse y trouver de stocks de capital. La tâche est certes difficile, du fait notamment des spécificités de cette économie qui conserve encore aujourd'hui certains traits du système socialiste. C'est le cas, à titre d'exemples, du statut des terres agricoles dans un régime foncier original les considérant toujours comme « publiques » ; ou bien de la propriété intellectuelle, qui n'est comptabilisée et réglementée en Chine que depuis la seconde moitié de la décennie 1980. Plus généralement, les valeurs des divers biens capitaux à calculer sont influencées par des variations de prix établis par des marchés sur lesquels les interventions étatiques sont très énergiques, multiformes, et pour ainsi dire omniprésentes.

Pour parvenir à construire, de façon statistiquement rigoureuse, un capital global à la Piketty,  $K_G$ , notre méthode consistera à élargir, étape par étape, un stock de capital physique productif, entendu *stricto sensu* ( $K_{pe}$ ), puis *lato sensu* ( $K_{pl}$ ), afin d'obtenir un capital fixe ( $K_F$ ) incluant les terres ( $T$ ), ensuite un capital physique total ( $K_T$ ) comprenant aussi les stocks ou *inventories* ( $V$ ), et enfin le stock global recherché, appelé  $K_G$ . Au final, le stock de capital global  $K_G$ , défini au sens de Piketty en économie ouverte, est donc obtenu en ajoutant au capital total précédent ( $K_T$ ), la richesse nette que le pays détient vis-à-vis de l'extérieur et telle qu'elle est représentée par les stocks de réserves en or et en devises étrangères accumulées par les autorités monétaires ; stocks convertis en monnaie nationale au taux de change officiel annuel moyen et exprimés à prix constants base 1952. Captées par la Banque centrale chinoise dans le cadre de son « système de règlement du taux de change obligatoire » (*Compulsory Foreign Exchange Settlement System*) – dispositif resté en vigueur jusqu'en 2012 –, ces réserves aurifères et monétaires nous permettent d'approximer les soldes cumulés des exportations et des importations de la Chine avec l'étranger (L'incomplétude des données d'investissements directs étrangers chinois (disponibles depuis 1983) contraint à ne recourir qu'aux réserves des autorités monétaires pour approcher la position patrimoniale nette du pays.).

Dans *Le Capital au XXI<sup>e</sup> siècle*, ouvrage où se mêlent recherches économiques et positions engagées, Piketty (2013) énonce un certain nombre de « lois », ou régularités de long terme. Il soutient ainsi que le rendement du capital, noté  $r_{KG}$ , tel que nous venons de le définir, doit être supérieur au taux de croissance du revenu,  $g_R$ , soit  $r_{KG} > g_R$ , afin d'actionner les mécanismes dynamiques de l'économie – capitaliste. Sinon, cela « tuerait le moteur de l'accumulation » (p. 943), car les capitalistes verraient leurs profits se réduire jusqu'à ce qu'ils n'investissent plus suffisamment. La première « loi » – ou relation comptable, en réalité – qu'il formule avance que la part des profits dans le revenu national est égale au produit du taux de profit et du ratio capital-revenu. Nous calculerons donc ce dernier à partir de notre série de stock de capital global  $K_G$  et des données de revenu national brut  $R$  fournies par les *China Statistical Yearbooks* du NBS (années variées).

Dans *Le Capital au XXI<sup>e</sup> siècle*, ouvrage où se mêlent recherches économiques et positions engagées, Piketty (2013) énonce un certain nombre de « lois », ou régularités de long terme. Il soutient ainsi que le rendement du capital, noté  $r_{KG}$ , tel que nous venons de le définir, doit

être supérieur au taux de croissance du revenu,  $g_R$ , soit  $r_{KG} > g_R$ , afin d'actionner les mécanismes dynamiques de l'économie – capitaliste. Sinon, cela « tuerait le moteur de l'accumulation » (p. 943), car les capitalistes verraient leurs profits se réduire jusqu'à ce qu'ils n'investissent plus suffisamment. La première « loi » – ou relation comptable, en réalité – qu'il formule avance que la part des profits dans le revenu national est égale au produit du taux de profit et du ratio capital-revenu. Nous calculerons donc ce dernier à partir de notre série de stock de capital global  $K_G$  et des données de revenu national brut  $R$  fournies par les *China Statistical Yearbooks* du NBS (années variées).

Pour calculer le taux de rendement du capital global à la Piketty,  $r_{KG}$ , on utilise la formule :

$$r_{KG} = \alpha_{KG} \cdot \frac{R}{K_G}$$

où  $\alpha_{KG} = \partial R / \partial K_G \cdot K_G / R$  est l'élasticité du revenu au stock de capital.

Pour estimer cette élasticité, il nous faut tester économétriquement une fonction de production dans laquelle ce capital global est considéré comme le ou l'un des facteur(s) de production. Pour ce faire, nous choisissons de recourir à différentes spécifications dérivées de plusieurs cadres théoriques néoclassiques, en l'espèce de formes fonctionnelles linéarisées de modèles : (1) simple, à la AK, où le seul *input* est le capital global à la Piketty ; (2) standard, à la Solow, où les deux facteurs considérés sont le capital global et le travail simple ; et (3) plus complexe, augmenté de façon à intégrer, aux côtés du capital global, un intrant de capital humain, mais aussi les dépenses de R&D, à la manière des formalisations en croissance endogène.

La théorie de la croissance est en effet l'un des domaines des sciences économiques qui a expérimenté les avancées les plus décisives au cours des dernières années, sous l'influence surtout de la nouvelle théorie de la croissance, ou croissance à progrès technique endogène. Le cadre traditionnel de la macro-dynamique, dû à Solow, et d'autres, dans la décennie 1950, s'est vu amélioré grâce aux explications de la productivité globale des facteurs et à l'analyse des contributions spécifiques du capital humain et de la R&D, notamment. Ces travaux ont remobilisé certains thèmes déjà étudiés depuis longtemps par la microéconomie, comme ceux des non-convexités. Néanmoins, il ne serait pas tout à fait juste de considérer, comme Solow (1988) l'a d'ailleurs lui-même fait remarquer, que les formalisations en croissance endogène sont très différentes des anciennes représentations de la croissance. Tel est le cas du modèle AK (qui revisite à sa façon les premières dynamisations keynésiennes), mais aussi de modèles plus sophistiqués, non linéaires et recourant fréquemment aux rendements croissants associés à des externalités de la R&D ou de l'éducation. Pourtant, dès lors que l'on souhaite les tester empiriquement, les spécifications dérivées de ces modèles s'avèrent en réalité très proches de formes solowiennes augmentées, log-linéarisées. Ce sont très précisément ces trois catégories (liées, mais distinctes) de modèles – Solow, AK et croissance endogène – que nous utilisons dans nos applications économétriques des séries statistiques de stocks de capital physique.

L'« inégalité fondamentale » entre les taux de rendement du capital et de croissance du revenu ( $r_{KG} > g_R$ ), telle que l'énonce Piketty, semble apparemment vérifiée sur notre base de données pour la Chine des 60 années considérées. Ce résultat doit toutefois être à nuancer, pour trois raisons au moins. D'abord, plus le modèle permettant de fonder en théorie la spécification que l'on teste empiriquement est complet, plus le coefficient du capital à la Piketty tend à devenir faible (0,46), et moins nettement se trouve validée ladite « inégalité ». Ensuite, pour des valeurs plus basses encore du même coefficient (inférieures à 0,40, de l'ordre de celles proposées par des auteurs comme Zhang *et al.* [2003], Jefferson *et al.* [2008] ou Perkins et

Rawski [2008]), la « loi » de Piketty n'est plus vérifiée. Dans un travail économétrique antérieur, nous avons d'ailleurs nous-mêmes mis en évidence des élasticités associées à divers stocks de capital comprises entre 0,35 et 0,40, en nous concentrant sur des « cœurs productifs » de capital physique plus compatibles avec l'usage de fonctions de production – ce qui revient *de facto* à contester la pertinence de la définition pikettyenne du capital comme patrimoine. Enfin, on observe que cette « inégalité » commence à se voir remise en question, tendanciellement, au cours de la dernière décennie, et ce même pour des valeurs d'élasticités élevées (0,57).

Selon Piketty, outre l'« inégalité »  $r_{KG} > g_R$  et la relation donnant la part des profits examinées précédemment, une « seconde loi » dynamique de l'économie capitaliste – « fondamentale » en ce sens qu'elle occupe une place très importante dans l'explication que propose l'auteur des inégalités sociales – voudrait que le rapport du stock du capital global ou patrimoine au revenu national (ratio noté  $\beta = K_G/R$ ) tendrait asymptotiquement vers la valeur du quotient du taux d'épargne ( $s$ ) et du taux de croissance du revenu ( $g_R$ , proche de celui de la production) ; ce qui s'écrit :  $\beta = K_G/R = s / g_R$ . Dans ce paragraphe, nous tenterons donc, empiriquement, de confirmer ou d'infirmer cette « loi ».

Pour ce faire, il nous faut disposer, pour la Chine sur la période concernée, du taux d'épargne entendu en une conception large, englobant l'ensemble des différents agents économiques. Or aucune série correspondant à cette variable n'existe pour ce pays de 1952 à 2012. Plusieurs options s'offrent alors à nous pour la reconstruire. La meilleure d'entre elles consiste à tenir l'épargne pour la différence entre revenu national et consommation finale totale, telle qu'elle se présente comme somme des consommations publiques et privées dans le calcul du produit intérieur brut selon l'approche des dépenses par le Système de Comptes nationaux (*System of National Accounts*, ou SNA) :  $s_{(1)} = (1 - C)_G/R$ . Cette méthode a l'avantage de la cohérence, du fait que la construction du stock de capital global  $K_G$  recourait elle aussi aux séries de flux fournies par le SNA (celles d'investissement, ou *gross capital formation*).

Tout bien considéré, c'est donc le taux d'épargne  $s_{(1)}$  que nous choisissons de retenir pour le calcul du ratio  $s / g_R$ , utilisant au dénominateur le taux de croissance du revenu national brut (*gross national income*, GNI). Si nous comparons ce rapport au coefficient de capital global, nous observons une certaine tendance de  $s / g_R$  à converger vers  $\beta$ . Piketty décrit cette « loi » comme une relation de long terme, qui exigerait au moins 30 années pour être évaluée. Aussi utilisons-nous, à sa façon, une moyenne mobile rétroactive sur 10 ans pour représenter le taux d'épargne dans la longue période, lissant ses fortes fluctuations de court terme. Il semble bien, « à l'œil nu » et en omettant la volatilité de  $s_{(1)} / g_R$ , qu'il y ait convergence. Et plus longue est la durée de la moyenne mobile, plus cette convergence paraît « évidente ».

Il nous faut pourtant aller au-delà des apparences ou de l'intuition. Comme nous avons affaire à une liaison de long terme, l'« égalité » peut ne pas être validée par un simple test de Wald. Cela nous amène donc à examiner si une relation de cointégration existe entre les séries de  $\beta = K_G/R$  et  $s / g_R$  en moyenne mobile.

Nous commençons par tester une approche univariante à la Engle et Granger (1987). La méthode consiste – premier temps – à effectuer des tests de racine unitaire sur les variables considérées, lesquels révèlent que les séries de coefficient de capital et de ratio taux d'épargne / taux de croissance, quelle que soit la durée de moyenne mobile retenue, sont non stationnaires et que leurs différences premières, stationnaires, sont intégrées d'ordre 1 :  $\beta \sim I(1)$  et  $s_{(1)MM} / g_R \sim I(1)$ . Puis on teste – deuxième temps – l'équation :  $s_{(1)MM} / g_R =$

$c(0) + c(1)\beta$ , avec contrainte de constante nulle – le test de Wald vérifiant, lui, si  $c(1)$  est unitaire. La stationnarité de la série de résidus obtenue est estimée par un test ADF, en utilisant les valeurs critiques de Engle-Granger (1987) – celles de Mackinnon (1991), plus précises mais exigeant au moins 50 observations, ne pouvant être mobilisées sans biais du fait de la taille insuffisante de l'échantillon quand la moyenne mobile excède 15 ans. Ambiguïté confirmée par ceux trouvés en appliquant l'approche multivariée à la Johansen (1988), présentant l'avantage d'autoriser l'introduction dans un modèle vectoriel à correction d'erreurs, adapté à l'étude des liaisons de long terme, de composantes déterministes et de variables qualitatives du type de la *dummy* que nous utilisons pour rendre compte des changements institutionnels. Une fois construit un *VAR(p)* faisant des résidus des bruits blancs, et incorporée la *dummy* – le cas échéant –, nous utilisons les critères d'information pour choisir le nombre optimal de retards  $p$  et estimons la cointégration grâce à un *VECM(p-1)*, avec composantes déterministes spécifiques. En accord avec les tests de racine unitaire effectués sur  $\beta$  et  $s_{(1)MM} / g_R$ , on pose une tendance linéaire dans l'équation de cointégration (long terme), mais pas dans le *VAR* (court terme).

Au final, nos conclusions seront prudentes : nos résultats, partagés, penchent plutôt en faveur de l'existence de relations de cointégration d'ordre 1 entre  $\beta$  et  $s_{(1)MM} / g_R$ , vérifiées au moins jusqu'à 10 ans – sans que le rejet de la cointégration ne puisse être tenu pour assuré pour des durées de moyenne mobile de plus de 15 ans compte tenu de la taille réduite des échantillons. En d'autres termes, il est probable que la « loi fondamentale » de Piketty soit *quasi* valide, c'est-à-dire à interpréter comme un processus de convergence asymptotique de long terme.

D'évidence, la considération de l'ensemble de l'histoire économique de la Chine depuis 1952 pour nos estimations est problématique, dans la mesure où ce qui a été expérimenté par les dirigeants politiques de ce pays à compter de 1949, durant plusieurs décennies et avec plus ou moins de succès, fut précisément une tentative de rupture (socialiste) avec les lois du système capitaliste. On le sait, une orientation déterminante vers une plus grande ouverture fut décidée et mise en pratique à partir de l'année 1978, que maints auteurs, en économie et dans d'autres sciences sociales, ont analysé comme étant une inflexion dans le sens d'un « capitalisme à la chinoise ». Si l'on accepte une telle hypothèse, il convient alors d'examiner ce que deviennent les résultats de nos tests sur la seule période postérieure à cette date décisive : 1978-2012.

Comme on le constate, les coefficients obtenus sur la sous-période 1978-2012 sont tous statistiquement significatifs, et ceux du stock de capital global plus élevés – comme le seront aussi logiquement les taux de rendement correspondants – que sur la période entière (1952-2012). En outre, la structure de la fonction de production demeure cohérente, révélant des rendements à l'échelle à peu près constants, que soit considéré le travail simple ou le capital humain. La sous-période étudiée étant marquée par de moindres bouleversements politiques, il n'est pas étonnant de noter une baisse de l'impact des changements institutionnels sur la trajectoire de croissance post-1978. Presque parfaitement gaussiens, les résidus de nos régressions ne présentent plus de problème d'hétéroscédasticité – du fait de la nette atténuation des fluctuations économiques –, ce qui renforce la robustesse de nos résultats, malgré la relative petitesse des nouveaux échantillons : ainsi, entre 1978 et 2012, l'« inégalité fondamentale » de Piketty est tendanciellement vérifiée

Pour ce qui est de la « loi fondamentale », faisant converger asymptotiquement le quotient des taux d'épargne et de croissance du revenu vers le rapport du stock de capital global au revenu national, sa validation ne peut être que supposée, laissée à l'interprétation « visuelle » (donc à

l'appréciation de chacun) des tendances de long terme de ces deux variables. L'ambiguïté des résultats des tests de cointégration entre les séries de  $s/g_R$  et  $\beta$  déjà soulignée est aggravée sur la sous-période 1978-2012 par la réduction substantielle (de 27 années) de la taille de nos échantillons, enlevant tout fondement statistique aux tentatives d'estimations des relations de cointégration entre les deux séries. Compte tenu de nos commentaires précédents, mais aussi du fait que la volatilité du ratio du taux d'épargne au taux de croissance du revenu a considérablement diminué, en liaison avec la forte réduction des fluctuations de l'économie et des institutions, il ne nous paraît pas déraisonnable de suggérer, avec les nuances précisées et la précaution exigée, la *quasi*-validité de la « loi fondamentale » de Piketty de 1978 à 2012

Ceci dit, le lecteur pourrait manifester – à juste titre – sa frustration de ne pas nous avoir vus aborder dans nos argumentations sur la Chine la question, ô combien cruciale pour Piketty, des inégalités. Il ne nous semble pourtant pas pertinent, à notre avis, de poser dans les termes qui sont les siens – donnant la plus grande importance à la transmission des patrimoines, par l'intermédiaire des successions et des donations – le problème des inégalités qui caractérisent le développement actuel de la Chine. Les origines de ces dernières, ainsi que les mécanismes par lesquels elles opèrent, sont autres, et exigent des explications dont les détails techniques ne sauraient occuper les quelques lignes qui nous restent. Il en ira de même de la critique, que nous jugeons nécessaire, des travaux que Thomas Piketty, en cosignature avec Nancy Qian, a consacrés à ce sujet et appliqués au cas de la Chine – ainsi que de celle devant aussi viser les données statistiques utilisées, et plus précisément les *China Yearbooks of Household Survey* du NBS, lesquels sous-estiment substantiellement les revenus des déciles et centiles supérieurs dans les tables de distribution. Mais ceci relève d'une toute autre recherche...

Ensuite on proposera au lecteur quelques éléments de réflexion méthodologique sur le thème de la croissance de l'économie chinoise sur la longue période. À partir de données statistiques officielles chinoises retravaillées, nous reconstruirons, dans un tout premier temps, une série temporelle de stock de capital physique productif, la plus étendue possible (de 1952 à 2014), afin de remonter au plus près de la date de formation de la République populaire et d'amener cette série jusqu'au présent, pour pouvoir tenir compte de la publication du dernier annuaire du *National Bureau of Statistics of China* (NBS) au début de l'année 2016. Dans un second temps, nous testerons ces nouvelles données pour estimer les contributions de divers facteurs de production à la croissance économique chinoise dans un cadre théorique néoclassique, puis pour mettre en évidence les limites méthodologiques de ces modèles – problématiques, car selon nous indépassables. Dans un troisième temps, c'est un cadre théorique plus original qui sera mobilisé, dans l'esprit des recherches récemment menées par Thomas Piketty et exposées dans *Le Capital au XXI<sup>e</sup> siècle*, où se trouvent combinées des références orthodoxes avec des composantes qui empruntent à des formalisations keynésiennes et néo-institutionnalistes plus anciennes. Certains problèmes attachés aux travaux pikettyens sont à cette occasion identifiés. Nous choisirons finalement de déplacer la réflexion méthodologique pour l'inscrire dans une perspective plus clairement hétérodoxe, par l'introduction d'un indicateur de taux de profit, et pouvoir ainsi enrichir sensiblement l'analyse de la croissance de l'économie chinoise.

L'intégration d'une variable qualitative  $D$ , captant les informations économiques relatives aux changements institutionnels survenus entre 1952 et 2014, réduit l'autocorrélation des résidus – provenant sans doute des ruptures causées par les fluctuations de variables enregistrées sur certaines périodes (décennies 1960 et 1990) – et améliore le pouvoir explicatif des estimations en renforçant leur cohérence d'ensemble. Mais, sur fond de résultats assez peu satisfaisants, la persistance du problème d'hétéroscédasticité rend selon nous nécessaire d'aborder la question de l'existence éventuelle de cycles dans la trajectoire de croissance de la Chine.

Pour cela, le choix est finalement fait d'une sortie du *mainstream*. L'objet du présent article n'est pas de revenir sur la critique théorique du *corpus* macrodynamique néoclassique, jusqu'à ses formalisations sophistiquées visant à endogénéiser le progrès technique. Nous considérons que cette critique a été menée de façon suffisamment approfondie pour justifier l'invitation ici faite aux lecteurs à nous suivre en direction de réflexions « hétérodoxes » sur la croissance et les cycles – ce qui écarte du même coup le recours aux modèles avec *real business cycles*, dont les fondements (paradigme de Frisch-Slutsky) sont à notre avis tout aussi fragiles que ceux des représentations orthodoxes du long terme.

Outrement, À ces réserves s'ajoutent celles attachées à la définition du capital comme patrimoine défendue par Piketty, contestable et difficilement compatible avec le cadre théorique de cet auteur faisant appel à une fonction de production à intrant « capital » n'étant pas conçu comme facteur strictement « productif ». De surcroît, des critiques peuvent également être formulées quant aux fondements théoriques des liaisons étudiées par Piketty ou, dans un autre ordre d'idées, aux indicateurs statistiques qu'il retient pour rendre compte de la montée des inégalités sociales dans la Chine actuelle.

Il est tout à fait clair que l'analyse de l'accumulation du capital en Chine ne peut être menée, sans risque de confusion, dans les mêmes termes que celle d'un pays capitaliste développé. Mais nous pensons que les fondements théoriques d'une telle réflexion ne sauraient reposer, comme chez Piketty, sur le concept de productivité marginale du capital. Nous proposerons donc de déplacer la discussion vers l'examen des évolutions de la variable du taux de profit, selon nous plus importante pour interroger la question qui nous intéresse. Car, contrairement à la lecture trop rapide que Piketty fait de Marx, le capital ne s'accumule pas « sans limite » ; il pourrait même voir son taux de profit diminuer à mesure de l'accumulation, pour freiner cette dernière, y compris dans le cas fort singulier (du capitalisme d'État ?) de l'économie chinoise. C'est ce que paraît d'ailleurs indiquer la tendance du taux de rendement du capital. Mais, pour tenter de vérifier une telle hypothèse de baisse tendancielle du taux de profit, il convient au préalable d'abandonner la notion de capital-patrimoine, beaucoup trop large et ambiguë, afin de revenir à la conception du capital, proche d'un « cœur » productif, par laquelle nous avons débuté notre argumentation.

Nous calculons ainsi, dans cette troisième et dernière étape, un taux de profit ( $r$ ) du stock de capital physique tel que défini initialement ( $K_p$ ) selon une formule interprétant, en des termes assez libres, le rapport marxiste d'un « surplus » ( $P$ ) à la somme du capital constant et du capital variable, pour la Chine de 1952 à 2014 :

$$r = \Pi / K$$

où le surplus, ou « profit » ( $\Pi$ ), s'écrit :

$$\Pi = Y - (Z + B + T)$$

c'est-à-dire comme le produit ( $Y$ ) diminué des revenus directs et indirects des employés ( $Z$ ), des autres allocations sociales de bien-être dont ceux-ci bénéficient ( $B$ ) et des taxations ( $T$ ). Le capital avancé total  $K$  est déterminé par :

$$K = K_p + Z + B$$

Pour calculer  $r$ , nous utilisons des données provenant de sources différentes, mais homogènes. Nous recourons d'abord, comme précédemment, à la série de PIB, défini selon l'approche de la production, telle que publiée dans les *China Statistical Yearbooks* (NBS [années variées]). Les revenus directs et indirects des employés proviennent des mêmes annuaires du NBS, mais de la décomposition du PIB par l'approche des revenus. Ils comprenant les rémunérations totales perçues par les employés, y compris sous forme de primes et de versements en nature.

Sont retenues les séries de « *total wage bills of employed persons in urban units* » avant 1978, « *total earnings of employed persons in urban units* » de 1995 à 2008 et « *compensations of employees* » après 2008. Deux corrections sont introduites : l'une pour minimiser le biais dû à l'écart existant entre les différentes séries de PIB (de l'ordre de 5 % en moyenne entre agrégat national et somme des PIB provinciaux) ; l'autre afin de tenir compte des modifications de la carte administrative des régions (notamment, de la création du Hainan en 1998 – appartenant antérieurement au Guangdong – ou la division du Sichuan – séparé du Chongqing – en 1997). Les allocations sociales de bien-être, que l'on considère comme faisant aussi partie des coûts de production des entreprises, correspondent aux couvertures de sécurité sociale, de retraites et d'indemnités chômage, ou encore aux subventions de transports, aides au logement, etc. Cette série a été reconstruite par nos soins à partir des données du NBS, complétées par celles d'autres sources, comme les *China Labor and Wage Statistics* et les *China Labor Yearbooks*. Enfin, la variable  $T$  comprend l'ensemble des taxations, y compris celles sur les importations. Toutes ces données sont exprimées à prix constants en base 1952, en utilisant l'indice des prix à la consommation pour leur conversion.

Le *Graphique* présente l'évolution de 1952 à 2014 du taux de profit chinois ainsi calculé,  $r$ . Comme on peut le voir, cet indicateur est orienté à la baisse, avec, semble-t-il, trois périodes assez distinctes : une forte chute au long de la décennie 1950 jusqu'au début des années 1960, correspondant aux temps de la formation de la République populaire de Chine et de la rupture avec l'Union soviétique ; puis une diminution du taux de profit assez nette, mais sensiblement moins marquée dans les décennies 1960 et 1970 ; enfin, une relative stabilisation du taux de profit à un niveau plus bas, à partir de l'instauration des réformes en 1978, des années 1980 jusqu'à nos jours. Le taux de profit moyen entre 1952 et 2014 est de 17,8 %, avec trois paliers situés autour de 40, 20 et (un peu moins de) 10 % pour les sous-périodes identifiées 1952-1962, 1963-1978 et 1979-2014.

Cette tendance à la baisse du taux de profit observée sur le long terme doit être distinguée des fluctuations de court terme de cet indicateur. Pour ce faire, nous utilisons la méthode de filtre proposée par Hodrick et Prescott. Cette décomposition statistique du taux de profit fait ainsi apparaître des oscillations présentant une certaine régularité, et ressemblant fort à des cycles économiques. L'amplitude de ces derniers tend à se réduire dans le temps, mais la fréquence de leur récurrence paraît quant à elle s'accroître. Les années pour lesquelles la composante du profit attribuable aux cycles, exprimée en différences premières, enregistre une valeur négative sont 1954, 1957, 1961-1963, 1968-1969, 1974, 1978-1979, 1985-1986, 1989-1991, 1995, 1997-1999, 2001-2003, 2008-2009, 2012-2013 – ce qui correspond environ à la moitié du nombre d'années de la période totale (27 sur 60). Treize moments historiques successifs de ce type sont ainsi repérables. Parmi eux, les plus fortes variations négatives du taux de profit sont intervenues au cours des années 1957, 1961-1963, 1968-1969, 1974, 1978-1979, 1985-1986, 1990-1991, 1999, 2002 et 2009. L'utilisation du terme de « récession » est appropriée pour caractériser ces moments quand le taux de croissance du PIB devient négatif – mais probablement pas lorsque ce taux demeure élevé, comme c'est le cas depuis 1978.

En observant attentivement les évolutions de ce dernier au cours des six décennies passées, on se rend compte que la trajectoire de croissance de l'économie chinoise – tout à fait exceptionnelle par sa vigueur comme par son ampleur – n'a pas opéré sans heurts, ni difficultés. Le présent travail n'en est encore qu'à une étape préliminaire, et exploratrice, mais il apporte déjà un certain nombre de résultats intéressants.

Beaucoup reste toutefois à faire, et dans des directions différentes. Les raisons des évolutions constatées pour la tendance de long terme du taux de profit restent à examiner, en termes de

productivité du travail, de part des profits dans la valeur ajoutée, de compositions du capital... Il en va de même des interprétations des fluctuations ou cycles de court terme, de leurs points de retournement, de leur amplitude, périodicité... Les moments de variations négatives de la composante cyclique mis en évidence correspondent-ils toujours à des « récessions » ? Ou ne s'agirait-il, surtout depuis 1978, que de simples « ralentissements » ? Y aurait-il des cas, bien particuliers, pour lesquels il serait possible de parler de... « crises » ? Pour esquisser des réponses à ces questions, extrêmement complexes – s'ajoutant à celles, qui le sont tout autant, relatives aux outils mathématiques et statistiques utilisés pour décomposer le taux de profit –, ce sont ici assurément les institutions, ainsi que les politiques menées sur 60 ans d'histoire de ce pays, qu'il conviendrait d'examiner de façon approfondie ; et sans doute aussi sous l'angle de l'économie non quantitative, que peuvent éclairer et aider les autres sciences sociales.

Exceptionnelle par sa vigueur comme par sa relative stabilité au cours des dernières années, la trajectoire de croissance de l'économie chinoise suscite, en même temps que de nombreuses études académiques, bien des interrogations. Ces dernières concernent tant les causes d'un tel dynamisme que ses mécanismes et moteurs, mais aussi sa soutenabilité et les conséquences à attendre de l'ascension de la Chine dans la hiérarchie des pays du système mondial capitaliste. La plupart de ces questions renvoient à la nature *sui generis*, singulièrement complexe, de cette économie, qui a su adopter maintes caractéristiques du capitalisme depuis son ouverture en 1978, en conservant certains traits du socialisme, notamment en matière de régime foncier, de propriété intellectuelle ou de participations massives et d'interventions volontaristes de l'État – lui-même placé sous l'autorité d'un puissant Parti communiste. L'interprétation qui est la nôtre nous incite plutôt à parler, dans le cas de la Chine, d'un « capitalisme d'État », mais dans des conditions qui demeurent celles d'une transition au socialisme.

Le présent article n'a pas la prétention de définir la nature du système économique chinois actuel ; moins encore celle d'aborder toutes les facettes qu'une telle démarche exige. Il visera plus modestement à proposer des éléments de réflexion sur le rôle tenu par les taux de profit dans la dynamique d'accumulation du capital de l'économie chinoise sur la longue période. Notre postulat de départ est en effet que le fonctionnement de ce système économique partage aujourd'hui suffisamment (et de plus en plus) de points communs avec le capitalisme pour nous autoriser à recourir méthodologiquement au concept de « taux de profit » afin d'en mener l'examen. Celui-ci sera conduit dans un cadre marxiste, original au sein de ce courant, car sous les angles à la fois micro et macroéconomiques. Nous entendons ces derniers de façon simple : analyse micro veut dire pour nous menée à partir de données statistiques tirées de comptabilités d'entreprises et analyse macro à partir de séries de l'économie nationale ; l'une et l'autre se rencontrant au niveau du secteur industriel, ainsi abordé sous deux angles bien distincts. Cette approche s'est imposée à nous à l'issue d'une série de travaux consacrés à la croissance économique en Chine par lesquels nous avons souligné les limites – selon nous indépassables – des outils fournis par le *mainstream* néoclassique, ou ses dépendances.

Il convient d'emblée d'insister sur le fait que les différents indicateurs de taux de profit que nous concevons, mettant en rapport un surplus ou « profit » et un stock de capital ou d'actifs, ne sauraient s'interpréter dans les mêmes termes que dans les cas de pays capitalistes avancés. Mais l'attention portée à ces indicateurs est fondamentale si l'on veut expliquer la dynamique de reproduction de l'économie chinoise dans le long terme, y compris à l'époque où elle était largement planifiée. Aussi, une fois déterminé le cœur de notre objet d'étude – en l'espèce, l'industrie –, nos efforts se concentreront-ils sur les calculs de taux de profit des entreprises industrielles au niveau microéconomique et de taux de profit du secteur industriel au niveau macroéconomique, ainsi que sur l'étude de leurs évolutions et de leurs décompositions, jetant



la lumière sur une succession de cycles rythmant le processus d'accumulation de cette économie au cours des six dernières décennies.

Les contours du « secteur industriel » doivent être délimités avec soin, car ce concept a été appréhendé de différentes façons dans les systèmes comptables qui se sont succédé en Chine (*Tableau 1*). Proche du modèle de planification soviétique, le dispositif de balances en produits matériels (*Material Product System*, MPS) resta en vigueur de 1952 à 1992. Il reconnaissait les contributions productives de l'agriculture et de l'industrie, mais pas des services – dont les valeurs ajoutées n'étaient pas intégrées au calcul du revenu national. Ainsi, toutes les activités autres qu'agricoles recensées dans la classification de l'époque pouvaient être considérées comme « industrielles ». À la suite des réformes de la fin des années 1970, le système des MPS fut peu à peu remplacé par celui des comptes nationaux (*System of National Accounts*, SNA), introduisant une distinction trisectorielle : primaire pour l'agriculture, secondaire pour les industries et la construction, tertiaire pour tout le reste (poste et télécommunications, transports, commerce, services sociaux ...).

Le passage complet des MPS au SNA s'acheva en 1993 et, dès l'année suivante, le *National Bureau of Statistics of China* (NBS) publiait une Classification des Industries de l'Économie nationale, dite « GB/T4754-1994 » (国民经济行业分类). Le secteur secondaire y avait été divisé en quatre sections, sous les intitulés « B » pour les industries minières et extractives, « C » pour les industries manufacturières, « D » pour la production et distribution d'électricité, de gaz et d'eau, et « E » pour la construction. L'agrégation des sections B, C et D correspondait donc le mieux à la conception traditionnelle de l'« industrie ». En 2004 fut instaurée la classification « GB/T4754-2002 », appuyée sur la typologie des « 2003 Three-Sector Classification Rules » (三次产业划分规定). Les modifications effectuées (redécoupage de sous-sections, ou divisions, à l'intérieur du secteur secondaire, ou entre ce dernier et le secteur tertiaire) ne remettaient pas en cause la définition précédente de l'industrie. Il en va de même des changements introduits par la nouvelle « GB/T4754-2011 », en application depuis 2012, lesquels concernent pour la plupart les activités de l'agriculture (section « A ») et des services (précisément identifiés au secteur tertiaire, et accueillant des divisions supplémentaires transférées du secondaire).

La cohérence statistique des Classifications « GB/T4754 » et la relative stabilité du périmètre de l'industrie lors de leurs différentes périodes d'élaboration nous conduisent à définir les « entreprises industrielles » comme celles appartenant à l'ensemble des sections B + C + D, telles que les conçoit le NBS. En clair, nous retenons les entités productives dont les activités relèvent à titre principal des sections des « mines » (B), des « industries manufacturières » (C) et des « production et distribution d'électricité, de gaz et d'eau » (D), c'est-à-dire de toutes les composantes secondaires, sauf la construction. Il s'agit d'une interprétation similaire à celle de l'*International Standard Industrial Classification 2008* (ISIC). Au total, les ajustements successifs des systèmes de comptabilité chinois n'ont eu qu'un impact limité sur les contours du concept fondamental d'industrie.

Nous chercherons d'abord à calculer des taux de profit microéconomiques à partir de données collectées au niveau des entreprises de l'industrie, telle que nous l'avons définie. Ce calcul nécessite de disposer de deux types de variables : les profits de ces entreprises et leurs stocks de capital. Pour ce qui concerne ces derniers, nous reprenons la méthode proposée par Chow (1993) qui recourait à des données cumulées afin de déterminer les stocks d'actifs fixes des entreprises industrielles. L'objectif de l'auteur était d'évaluer des stocks à l'échelle nationale. Or, les séries qu'il utilisa ne sont plus mises à la disposition du public par le NBS depuis le passage au SNA, de sorte qu'il n'est pas possible de les étendre au-delà de 1993. Toutefois,

grâce à l'existence de balances comptables standardisées d'entreprises (*Enterprise Accounting Standards*), des données continues concernant les dépréciations cumulées nous permettent de reconstruire les stocks d'actifs fixes des entreprises industrielles, à la manière de Chow. Les *Enterprise Accounting Standards* auxquels nous avons recours sont ceux établis pour l'année 2006 (会计准则). Toutes les entités productives sont en effet censées s'y conformer, mais une partie non négligeable d'entre elles est encore enregistrée en se référant aux normes de 1992 dans les documents du NBS, comme dans ceux du Ministère des Finances.

Les stocks de capital ici considérés sont ceux des actifs matériels ayant une durée de mise en service de plus d'une année budgétaire. Il s'agit, entre autres, des bâtiments, équipements, machines, outils, moyens de transport, détenus par les entreprises pour leurs productions de biens et de services, la location ou des activités administratives. Les *Enterprise Accounting Standards 2006* adoptent pour la valeur totale des actifs fixes des entreprises industrielles, notée  $K_{AT}$  et enregistrée en valeur de fin d'exercice dans les *Assets and Liability Tables of Enterprises*, la définition suivante :

$$K_{AT} = K_{AO} - A_C - L_A$$

avec  $K_{AO}$  la valeur d'origine des actifs fixes, correspondant à leur coût initial, c'est-à-dire aux dépenses effectuées par les entreprises pour l'achat, la construction, l'installation, l'extension, la transformation ou la modernisation technique de ces actifs. Cette valeur est diminuée des amortissements cumulés sur les années de fonctionnement et des pertes de valeur des actifs comptablement enregistrés sur la période. Lorsque le NBS ne fournissait pas de données sur ces pertes de valeur, celles-ci ont été recalculées pour les années manquantes. Les profits totaux réalisés au cours de l'exercice comptable,  $P_T$ , sont quant à eux donnés par la formule suivante :

$$P_T = B_E + R_E - D_E$$

où  $R_E$  et  $D_E$  représentent respectivement les recettes et les dépenses d'exploitation, tandis que  $B_E$  correspond aux bénéfices d'exploitation, qui s'interprètent eux-mêmes comme les revenus des entreprises (y compris ceux tirés des investissements) diminués de la somme des charges, des taxes diverses, des autres dépenses de l'exercice et des pertes de valeur des actifs.

Nous sommes dès lors en mesure de calculer, au plan microéconomique, quatre taux de profit distincts pour les entreprises industrielles. Deux critères sont ici retenus : selon que les amortissements cumulés sont intégrés au capital d'actifs fixes (taux de profit nominal) ou pas (taux réel) ; et selon que les taxes sont déduites des profits (taux après taxations) ou non (avant taxations).

Les documents comptables disponibles pour construire nos séries de stocks de capital micro n'intègrent pas les entreprises ayant une taille inférieure à un certain seuil d'actifs. Le poids de ces petites unités productives étant limité, nos calculs sont à regarder comme des approximations acceptables de taux de profit de l'ensemble des entreprises industrielles. Mais cette omission est probablement suffisante pour induire un biais. Nous y reviendrons.

Dans une deuxième étape, nous calculerons des taux de profit macroéconomiques, toujours pour le secteur de l'industrie, afin de les comparer aux résultats microéconomiques obtenus précédemment. Ces taux mettent en rapport un numérateur représentant l'excédent agrégé du secteur industriel ou « profit » et un dénominateur correspondant au stock de capital du même secteur. Pour ce qui regarde ce stock, nous nous appuyons sur des séries statistiques originales de capital physique reconstruites par nos soins pour la Chine en longue période : 1952-2014. Élaborées à partir de données officielles (spécialement celles du NBS), nos séries recourent à

des méthodes d'élaboration complexes – mettant notamment en jeu des techniques modernes de cointégration pour la détermination des indices de prix – ; méthodes qu'il ne nous sera pas possible d'exposer de façon développée dans ces lignes, mais dont le détail est à la disposition du lecteur dans un article que nous avons récemment publié dans la *China Economic Review* (Long et Herrera [2016]). Cette nouvelle base de données comprend des séries longues de stocks de capital physique dit « productif » – c'est-à-dire hors bâtiments résidentiels et valeur de leurs terrains –, conçus selon des acceptions plus ou moins larges. Nous disposons ainsi, en particulier, d'un capital productif *lato sensu*  $K_{Pl}$ , incluant les stocks (ou *inventories*) et d'un capital productif *stricto sensu*  $K_{Pe}$ , qui ne les incorpore pas.

Quatre taux de profit industriels sont donc calculés au niveau macroéconomique. De la même manière que nous avons défini au niveau microéconomique le secteur industriel comme l'ensemble des entreprises des sections « B + C + D », hors construction (« E »), c'est logiquement un stock de capital productif excluant les habitations résidentielles et leurs terres que nous utilisons en abordant le niveau macroéconomique. On suppose que la part du stock de capital industriel  $K_{(I)}$  dans le stock de capital productif est égal à celle de la production industrielle  $Y_{(I)}$  (somme des valeurs ajoutées industrielles) dans le produit intérieur brut (PIB) total, mais diminué de la valeur ajoutée du secteur de la construction, noté  $Y^*$ , soit :

$$K_{(I)t} = \frac{Y_{(I)t}}{Y_t^*} \cdot K_t = \alpha_t \cdot K_t$$

où  $K_t$  est le stock total de capital productif *stricto sensu*  $K_{Pe}$ , ou respectivement *lato sensu*  $K_{Pl}$ . Est de ce fait attachée à la trajectoire de  $\alpha_t$  une hypothèse de rendements d'échelle constants dans la production. Le calcul de cette variable est permis grâce aux séries en ligne du NBS (*NBS online database*) après 1978 et, avant cette date, aux « *Comprehensive Statistical Data and Materials on 50 Years of New China* » (新中国 50 年五十年统计资料汇编).

Les évolutions des taux de profit industriels calculés aux plans micro et macroéconomiques sont présentées aux *Figures 3* et *4*. Les résultats obtenus au niveau macro sont plus élevés que ceux mis en évidence microéconomiquement. Ainsi, en moyennes, les taux de profit micro sont respectivement de 17,9 % pour  $r_1$  (taux nominal avant taxes des entreprises industrielles), 13,0 % pour  $r_2$  (nominal après taxes), 26,2 % pour  $r_3$  (taux réel avant taxes) et 18,2 % pour  $r_4$  (réel après taxes) sur la période complète de 1952 à 2014. Les moyennes des taux de profit macro sont trouvées à 42,2 % pour  $r_5$  (taux de profit du capital productif industriel étroit avant taxes), 30,4 % pour  $r_6$  (capital industriel *stricto sensu* après taxes), 32,9 % pour  $r_7$  (taux du capital industriel *lato sensu* avant taxes) et 23,7 % pour  $r_8$  (capital large après taxes) au cours de la même période 1952-2014. Comme nous le voyons, les moyennes des deux taux de profit que l'on peut considérer comme les plus représentatifs de l'activité effective de l'industrie, c'est-à-dire  $r_4$  au plan micro (calculé en retranchant les taxes et excluant les amortissements cumulés des actifs fixes des entreprises industrielles) et  $r_8$  au niveau macro (obtenu à partir du stock de capital productif du secteur industriel incluant les *inventories*, mais pas la valeur des logements résidentiels ni de leurs terrains), sont du même ordre de grandeur : 18,2 % pour le premier, 23,7 % pour le second. Elles restent encore relativement proches sur la sous-période postérieure aux réformes, soit 1978-2014 : 12,0 % et 21,2 %, respectivement.

De façon générale, les profils d'ensemble des taux de profit micro et macroéconomiques sont assez similaires, fondamentalement caractérisés par une tendance à la baisse sur le long terme. Des fluctuations très marquées sont observables pour les deux niveaux d'analyse durant une première étape, allant de la fondation de la République populaire à la rupture avec l'Union soviétique (1952-1961). Suivant une tendance baissière, les oscillations des taux de profit

continuent, quoique de manière nettement moins heurtées, jusqu'en 1978, et même, toujours en s'atténuant, jusqu'à la décennie 1990. C'est à partir de là que les choses semblent quelque peu changer. La trajectoire du taux de profit macro paraît s'orienter légèrement à la hausse, à compter du début des années 1990, tandis que celle du taux de profit micro poursuit quant à elle sa descente, avant de remonter plus vigoureusement à la fin de la même décennie. Les deux courbes, micro et macro, se rejoignent de nouveau dans les premières années de la décennie 2010, pour repartir l'une et l'autre plus clairement à la baisse. Ces séquences sont bien visibles dans le cas des indicateurs  $r_4$  et  $r_8$ . Mais au-delà du résultat sécurisant – pour un économiste marxiste – apporté par la mise en lumière sur la longue période d'une baisse du taux de profit en tendance (mesurée en termes logarithmiques pour les taux  $r_4$  et  $r_8$ ), l'observation, d'une part, d'une remontée très nette de la trajectoire de  $r_4$  à partir de 1999 jusqu'en 2007 (ou plutôt 2011) et, d'autre part, pour celle de  $r_8$ , d'une relative stabilité prolongée sur une cinquantaine d'années (approximativement de 1962 à 2011), exige d'introduire quelque complexité dans ces interprétations trop intuitives.

Aussi, pour approfondir l'analyse, proposons-nous une décomposition technique des taux de profit afin d'en distinguer les tendances de long terme et les composantes cycliques captant les fluctuations de court terme. Cette décomposition technique, dont nous ne présentons l'application qu'aux cas des taux de profit macro  $r_6$  et  $r_8$ , est effectuée par le recours à la méthode du filtre de Hodrick-Prescott en complétant ses paramètres propres par ceux suggérés par Ravn-Uhlig. D'autres décompositions de la tendance et des cycles en séries temporelles ont également été utilisées, donnant des résultats similaires et confirmant leur solidité. La *Figure 8* montre que les cycles de court terme des taux de profit considérés voient l'amplitude de leurs fluctuations s'estomper avec le temps, depuis le début des années 1950 jusqu'à la fin de la décennie 2000 – mais elles semblent à partir de là s'accroître de nouveau. Ces fluctuations font ainsi alterner assez régulièrement les périodes ascendantes et descendantes. Pour les taux macro  $r_6$  et  $r_8$ , avec deux paramétrages des filtres (Hodrick-Prescott et Ravn-Uhlig), les années de récession commune, marquées par des différences premières des composantes cycliques enregistrant un signe négatif, se repèrent 24 fois ; précisément en 1957, 1961-63, 1968, 1976-77, 1981-82, 1985-86, 1989-91, 1998-99, 2001-04, 2009 et 2012-14. Cela correspond à plus d'un tiers des 63 années composant la période étudiée – ce, quand bien même le taux de croissance du PIB peut parfois atteindre, simultanément, un rythme assez élevé.

À travers ces 11 séquences de récession, nous reconnaissons aisément les ralentissements qui ont caractérisé l'histoire économique du pays depuis la fondation de la République populaire. Après les difficultés des premiers temps (1949-1952), dus surtout aux convulsions traversées durant les décennies précédant la révolution, nous trouvons trace de la période récessive qui commença en 1954 et dont le point bas se situe en 1957. La crise du début des années 1960, la plus grave qu'ait connue la Chine, résulte des effets conjugués – clairement visibles en 1961-62 – de l'interruption de l'aide de l'URSS après la rupture sino-soviétique, de l'échec relatif du « Grand Bond en Avant » et des catastrophes intervenues sur le Fleuve jaune. Autre point bas, 1968 coïncide avec le durcissement de la Révolution culturelle, lancée deux ans plus tôt. Les problèmes rencontrés en 1976-77 révèlent ceux de la transition qui suivit la mort de Mao. 1981-82 sont des années de mise en œuvre des réformes structurelles (« ouverture ») adoptées lors du XI<sup>e</sup> Congrès du Parti communiste, et 1985-86 celles de l'application de la réforme fiscale de 1984 – l'un des points tournants vers l'économie de marché. Sur fond de chute de l'URSS, la brève expérience « néolibérale » s'est traduite par un très brutal ralentissement de l'économie (1989-91), accompagné d'affaires de corruption. Dans un contexte (paradoxal) de fort dynamisme du PIB chinois, les reculs enregistrés à partir de 1998

sont attribuables, en grande partie, à des chocs exogènes liés à la généralisation des crises : asiatique (1998-99), de la « nouvelle économie » et « post-11 septembre » (2001-04), et « financière » de 2008 (dont les effets se font sentir en Chine en deux temps : 2009, puis de 2012 à nos jours).

Nous procédons enfin à une décomposition économique du taux de profit macroéconomique (ici  $r_8$ ) pour distinguer les évolutions respectives de la composition organique du capital (soit l'inverse de  $R_{PI(I)}^*/K_{PI(I)}$ ), de la productivité de l'unité de coût de travail ( $Y_{(I)}/R_{(I)}^*$ ) et de la part des profits ( $\pi_{(I)}/Y_{(I)}$ ), selon la formule simple suivante, proche de celle de Weisskopf (1979) :

$$r = \Pi_{(I)}/Y_{(I)} \cdot Y_{(I)}/R_{(I)}^* \cdot R_{(I)}^*/K_{PI(I)}$$

où  $\Pi_{(I)}$  est le profit, avec  $\Pi_{(I)} = Y_{(I)} - R_{(I)} - T_{(I)}$  ; et  $R_{(I)}^*$  le coût du travail du secteur industriel (hors taxes), approché par le produit du nombre d'employés et de la rémunération moyenne.

Comme l'indique la *Figure 10*, c'est l'augmentation de la composition organique du capital qui contribue à expliquer, dans de larges proportions, la tendance à la baisse du taux de profit à long terme. Si la part des profits demeure assez stable, le *trend* ascendant de la productivité (de l'unité de coût) du travail est plus prononcé – mais déclinante sur la dernière décennie.

Toutefois, un certain nombre de difficultés d'interprétation persistent à l'issue de cet exercice. En premier lieu, c'est l'analyse de cette baisse du taux de profit elle-même qui pose problème, dans la mesure où cette tendance de long terme trouve ici une partie de son explication dans l'extrême rareté du capital physique qui caractérisait la Chine au tout début de la révolution. Ajouté à ceci, sur des périodes de temps assez prolongées, sont très distinctement observables au niveau macroéconomique des intervalles de relative stabilité des taux de profit industriels, voire des phases de remontée de ces taux, comme dans la première moitié des années 1990. L'analyse microéconomique met également en lumière un net redressement des taux de profit, mais à partir de la fin de la décennie 1990 – jusqu'aux effets subis de la crise financière de 2008. Notre conclusion d'une tendance à la baisse du taux de profit doit donc tolérer quelques nuances. Ensuite, et abstraction faite des perturbations des premiers moments de la révolution, l'écart le plus notable entre les trajectoires de taux de profit micro et macroéconomiques est constaté à compter de l'adoption des réformes de structure (1978) – et de la fiscalité (1984). Les causes d'une telle divergence, qui perdure jusqu'à la fin des années 2000 (l'éclatement de l'étape la plus récente de la crise systémique en 2008), sont à rechercher dans les différences d'angles d'observation – et donc de sources statistiques –, de contours du secteur industriel (à titre d'exemple, le périmètre microéconomique des entreprises industrielles est changeant et, de surcroît, n'intègre pas les unités productives de petite taille, dont la rentabilité est souvent plus élevée que celle des très grandes entreprises), mais encore d'indicateurs représentatifs des taxations prises en considération. Et si l'écart précédemment souligné entre niveaux micro et macro paraît se résorber lorsque les effets de la crise systémique touchent la Chine à la fin de la décennie 2000, en orientant de nouveau conjointement à la baisse les taux de profit micro et macro, la question reste entière de savoir comment qualifier de tels phénomènes récessifs affectant négativement les taux de profit dans des contextes économiques où sont enregistrés des taux de croissance du PIB très élevés, comme c'est encore le cas de la Chine à l'époque actuelle – y compris en 2015. Les réponses à ces interrogations, ainsi qu'à celles portant entre autres sur les formes fonctionnelles à même de rendre compte de la manière la plus pertinente possible des tendances de long terme et des fluctuations de court terme des taux de profit, appellent par conséquent de nouvelles recherches, plus approfondies.

Le Chapitre 7 engageait une discussion préliminaire suggérant la nécessité d'une "sortie" du cadre habituel du courant dominant néoclassique, mais aussi celle d'un déplacement de la méthodologie du cadre habituel du domaine temporel en direction de l'analyse spectrale et de celle des filtres en économétrie. Le taux de profit qui y était calculé était associé au capital productif entendu au sens large. Toutefois, d'un point de vue marxiste classique, l'analyse du taux de profit devrait se concentrer sur l'industrie. Dans ces conditions, le chapitre 8 calcule les taux de profit industriels aux niveaux macro- et microéconomique. Cependant, les taux de profit industriels calculés au Chapitre 8 présentent des insuffisances pour analyser les cycles économiques de tous les secteurs en Chine. Comme nous l'avons souligné, nous devrions calculer le taux de profit total de tous les secteurs économiques pour identifier les cycles économiques et les crises potentielles car les cycles et les crises affecteront tous les secteurs, et non pas seulement les industries. En outre, la manière dont les taux de profit influencent les variables économiques clés reste encore indéterminée dans l'analyse du Chapitre 8. Autrement dit, la structure économique sous-jacente à notre interprétation de la dynamique de croissance de la Chine demeure à définir.

Au Chapitre 9, nous avons d'abord calculé 4 différents taux de profit total de tous les secteurs économiques sur la période allant de 1952 à 2014 ; ce, d'un point de vue marxiste revisité. Les taux de profit présentent une tendance à la baisse à long terme et des fluctuations cycliques. Nous utilisons ensuite les modèles vectoriels autorégressifs de structure (SVAR) pour analyser la structure économique de la Chine. Nous examinons les influences des taux de profit sur plusieurs variables économiques clés telles que la croissance de l'investissement, l'accumulation de capital et la croissance du PIB par des fonctions de réponses impulsionnelles. Sur la base d'hypothèses de restrictions *a priori*, en recourant à deux approches différentes des restrictions de court terme et de long terme, nous avons prudemment testé ces structures économiques *a priori* dans le contexte de l'économie de marché. Nous trouvons que l'économie chinoise ne satisfait pas nécessairement ces hypothèses sur toutes les périodes.

Contrairement à la dichotomie suggérée par l'analyse spectrale du Chapitre 8, les tests montrent que la trajectoire économique de la Chine doit être distinguée en moins trois périodes différentes : 1) 1952-1977, c'est la période d'économie planifiée de type soviétique. Les caractéristiques spécifiques sont que l'économie chinoise connaît de fortes fluctuations à la hausse comme à la baisse. Le taux de croissance du taux de profit est caractérisé par un co-mouvement simultanément à d'autres variables macro-économiques. Les fluctuations et les crises économiques sont motivées davantage par des causes de nature politique, tandis que le taux de profit ne constitue pas le principal facteur qui détermine la croissance de l'investissement, l'accumulation de capital et la croissance économique. 2) 1978-1992 : c'était la période d'économie planifiée avec des caractéristiques chinoises. Même si la Chine a commencé sa réforme d'ouverture depuis 1978, la nature de cette période devrait encore être considérée comme relevant de l'économie planifiée plutôt que de l'économie de marché. Les caractéristiques de cette période sont les suivantes : les fluctuations économiques commencèrent à se relâcher, tandis que les variations de la croissance économique précèdent celles du taux de profit. La structure économique de cette période transitoire est relativement complexe et ne peut pas être simplement classifiée. Deng Xiaoping (1979, 1984, 1992) l'a qualifiée lui-même, il s'agissait de l'« économie planifiée avec le marché en supplément » : « le socialisme peut aussi prendre la forme de l'économie de marché » : 3) 1993-présent : c'est la période dite d'économie de marché avec des caractéristiques chinoises. Après la réforme fiscale (une réforme du système de distribution des impôts) par l'ancien Premier ministre Zhu Rongji, la Chine est également passée du système comptable de MPS à celui de

SNA. La volatilité politique joue toujours un rôle important pour expliquer les fluctuations économiques, mais elle est passée au second plan. Dans le même temps, comme la Chine s'est de plus en plus profondément intégrée dans l'économie mondiale, elle a pu bénéficier d'une réduction additionnelle de la volatilité économique grâce au marché externe qui agit comme un amortisseur. C'est aussi en raison de l'arrière-plan de cette intégration de la Chine au sein de l'économie mondiale et de son exposition grandissante que les fluctuations économiques de la Chine présentent de plus en plus les caractéristiques de crises importées.

les tests économétriques que nous avons effectués montrent que les restrictions *a priori* imposées pour analyser la structure économique de la Chine sont difficiles à valider pendant la première et la deuxième périodes, alors qu'elles sont quasi valables dans la troisième période. Nous constatons que la deuxième période paraît être plus proche des caractéristiques de celle de l'économie planifiée. Nous fournissons ainsi une preuve analytique afin de montrer que la condition clé identifiable pour le modèle d'échantillon complet est de savoir si  $C24$  est égal à zéro. Mais cette condition est ambiguë. Cela implique que si les dirigeants chinois observaient une crise économique, ils pourraient augmenter subjectivement l'investissement en tant que politique anti-crise plutôt que de laisser le taux de profit déterminer le niveau plus ou moins élevé de l'investissement. C'est aussi l'une des caractéristiques les plus importantes de l'économie chinoise : une très puissante intervention de l'Etat pour agir contre la crise.

Cependant, la taille de l'échantillon de la troisième période est faible, ce qui entraîne une incertitude statistique dans l'analyse quantitative. Nous tentons d'améliorer la précision des estimations économétriques sur cette période par des approches bayésiennes. Mais la pratique montre que de telles approches n'ont pas permis d'améliorer l'estimation sur cette période, les fonctions de réponses impulsionnelles calculées ne se différenciant pas beaucoup par rapport aux méthodes statistiques traditionnelles. Cela est dû, tout d'abord, et comme nous l'avons souligné, les deux périodes avant et après 1993 sont de nature économique totalement différente. Il convient de se demander s'il est approprié d'utiliser les informations sur la période d'économie planifiée s'étendant de 1952 à 1992 comme information *a priori* de pré-échantillon pour la période correspondant à l'économie de marché (soit 1993-2014). Deuxièmement, les hypothèses de distribution *a priori* dans l'estimation des BVAR ne sont pas nécessairement valables pour la Chine. Par exemple, les *a priori* de Litterman exigent que l'on suppose que les changements de variables sont impossibles à prévoir, c'est-à-dire que la différence première d'une variable est un bruit blanc (plus une constante). Cela équivaut à supposer que le marché du capital est en concurrence parfaite : taux de croissance du taux de profit de la Chine, taux de croissance de l'investissement, taux de croissance de l'accumulation de capital et taux de croissance du PIB suivent des marches aléatoires. Évidemment, il est difficile de croire que de telles hypothèses soient satisfaites pour la Chine, même après 1993. Ainsi, nous ne sommes pas surpris ici que l'analyse bayésienne ne soit pas nécessairement meilleure que les méthodes statistiques traditionnelles.

Cependant, les fonctions de réponses impulsionnelles données par l'analyse bayésienne sont très semblables à celles fournies par les SVAR traditionnels. Cela suggère que même si nous disposons d'un petit échantillon, la structure économique donnée par les méthodes économétriques traditionnelles devrait être stable et fiable, dans une certaine mesure. Et finalement, comme le NBS a récemment publié une partie des données macroéconomiques de 2015, nous avons prédit les données économiques pour 2015 en utilisant les SVAR précédemment décrits avec des données sur la période 1952-2014. Nous avons utilisé les modèles d'échantillons et de sous-échantillons complets pour prédire les valeurs de certaines

variables économiques de 2015. Nous avons ainsi prédit que le taux de profit continuerait à baisser même s'il était déjà assez faible (à 5 % en 2014). Si le taux de profit continue à baisser, les marxistes pourraient faire valoir qu'il y aura une crise à l'avenir, mais ce résultat est cohérent avec les faits qu'il y a effectivement eu une crise financière qui éclata sur le marché boursier en 2015/2016. Par ailleurs, les prévisions de croissance économique sont également très fructueuses. Les données initiales publiées par le NBS sont que le taux de croissance du PIB de 2015 serait de 6,9 % à prix constants, tandis le modèle complet de l'échantillon prévoit que le taux de croissance du PIB en 2015 serait de 6,6 % à prix constants. Les résultats de prévision de l'échantillon complet suggèrent également que la crise financière de 2015 pourrait être endogène et causée par des facteurs accumulés sur le long terme.

Ce résultat de prévision d'un point au-delà de l'échantillon correspond bien aux données publiées par le NBS. Dans l'intervalle, il semble que nous puissions prédire avec succès la turbulence boursière chinoise de 2015 qui pourrait être considérée comme une crise financière locale. Mais il n'était pas clair qu'une crise se produirait dans le secteur financier lorsque nous aurons effectué la prévision grâce aux données sur la période 1952-2014. Cela implique que, bien que nous soyons très conscients que la structure économique réelle puisse être beaucoup plus complexe que notre modèle simplifié à quatre variables, nos modèles ont en effet une assez bonne capacité de prédiction hors de l'échantillon. Il a une valeur d'application, ce qui est très rare dans l'expérience de la modélisation. En outre, les résultats de prédiction de modèles d'échantillons complets sont meilleurs que ceux de modèles de sous-échantillon. Cela implique que, bien que les arguments de validation des restrictions *a priori* soient faibles sur la période 1952-1992, d'utiles informations supplémentaires sont tout de même fournies. On comprend notamment que la crise financière locale qui frappe la Chine en 2015 pourrait être la conséquence de facteurs accumulés dans le long terme – ce qui mériterait ici quelques approfondissements.

De plus, nous avons également étendu la décomposition économique des taux de profit du Chapitre 8. Nous avons proposé trois décompositions différentes, puis appliqué un filtre à ces composantes. Les cycles économiques et les crises mis en lumière au Chapitre 8 sont confirmés par les indicateurs économiques de tous les secteurs selon un point de vue marxiste revisité.