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Four essays on fiscal policy after the global financial crisis

Francesco Molteni

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Titre:
**FOUR ESSAYS ON FISCAL POLICY AFTER THE GLOBAL
FINANCIAL CRISIS**

présentée et soutenue publiquement
par

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le

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Introduction

Fiscal policy received renewed attention after the global financial crisis and returned to the center of debates in the academia and the press. In the last two decades, fiscal policy was thought as playing a secondary role and monetary policy was considered the primary instrument to stabilize economic fluctuations. The abandonment of fiscal policy as a cyclical tool may have been the result of the belief that, on the one hand, financial market developments increased the effectiveness of monetary policy and, on the other hand, fiscal policy was ineffective, on the basis of the Ricardian equivalence principle. In several neoclassical models Government spending was treated as a “pure waste” and according to the expansionary fiscal contraction hypothesis, fiscal adjustments could even foster the economic growth by reducing the country risk premium.

Other arguments were in favor of a reduction in fiscal policy interventions. Lags in the design and the implementation of fiscal policy, together with the short length of recessions, implied that fiscal measures were likely to be ill-timed and come too late when the economy was already recovering. Moreover, the literature of political economy highlights that fiscal policy is likely to be distorted by political constraints and that discretionary fiscal interventions would follow closely electoral cycles. For these reasons, the focus was primarily on debt sustainability and on fiscal rules designed to constraint the procyclicality of fiscal policies and automatic stabilizers played a key role in the conduct of fiscal policy.

The global financial crisis has returned discretionary fiscal policy to center stage as a macroeconomic tool. To the extent that monetary policy, including credit and quantitative easing, had largely reached its limits, policymakers had little choice but to rely on fiscal policy. Direct interventions to recapitalize the financial institutions and fiscal stimuli to sustain the weak internal demand inflated public deficits in all the advanced countries.

In the periphery of the Eurozone growing public debts and increasing yields of government bonds undermined the capacity of country to serve the debt. Greece, Ireland, Portugal and Cyprus received financial support from the IMF, European Commission and ECB. European countries implemented austerity measures in an effort to reduce the public debt and to alleviate tensions in the sovereign-debt markets. Analogously, the “fiscal cliff” imposed fiscal adjustments in US.

The long-standing debate about the size of fiscal multiplier tilted towards a Keynesian fiscal multiplier bigger than one, suggesting a more effective role of fiscal policy in stabilizing output fluctuations, in particular during recessions, with zero lower bound, financial frictions, weak demand and hysteresis in unemployment. Other topics such as the optimal composition of fiscal packages, the use of spending increase versus tax decreases and the factors that underlie sustainability

of public debts had been a more active areas of research after the crises.

The extraordinary measures implemented during the crisis and the occurrence of sovereign-debt crises in the periphery of the Eurozone, which were thought to be a phenomenon of emerging economies, raised new and unexplored issues related to fiscal policy. The impact of unconventional monetary policies which crossed the line between fiscal and monetary policy as Central Banks by purchasing government securities, or promising to buy them, reduced the pressure on the bonds and the interest payments giving more scope for fiscal policy. The effect of cuts in interest rates combined with expansionary or contractionary fiscal policy. The strong interaction between fiscal and banking weakness in countries of the periphery of the Eurozone, deriving from the fact that a reduction in the value of government bonds affects negatively the activities of banks, which hold a considerable share of domestic debt, and in turn increases the probability of sovereigns to rescue their banks, creating a “diabolic loop”. The increasingly use of government bonds as collateral in interbank loans and the consequences of a reduction in their pledgeability.

This dissertation aims to tackle some of these questions. The remainder of this introduction is organized as follows. Section 1 introduces the research questions analyzed in the dissertation and summarizes the main conclusions. Section 2 describes the principal contributions of this thesis with respect to the existing literature. Section 3 presents the outline of the dissertation.

1 Organization and general conclusions of the thesis

1.1 Organization of the thesis

This dissertation addresses four main questions in chapters 1, 2, 3 and 4:

1. Chapter 1 proposes an alternative approach to identify a discretionary government spending shock. The identification strategy is based on a two-step procedure. First, on the basis of the volatility, persistence and comovements with the GDP, the total primary spending is separated into two aggregates: discretionary public expenditure and automatic public expenditure. Second, the discretionary government spending shock is identified via sign restrictions in a structural VAR including only the discretionary component of public spending.
2. Chapter 2 jointly analyzes the effects of a combination of fiscal and monetary policy shocks on macroeconomic and financial variables using a Time-Varying Parameters Factor Augmented VAR model. The impulse response

function of a monetary policy shock is estimated during periods characterized by different fiscal stances identified via the narrative approach.

3. Chapter 3 investigates the role of government bonds as collateral in collateralized interbank loans, in particular repurchase agreements (repos), and examines how a reduction in the pledgeability of government bonds, i.e. a rise in repo haircuts, may represent a channel in the transmission mechanism of banking and sovereign-debt crises in the periphery of the Eurozone.
4. Chapter 4 studies the impact of a liquidity shock on government bonds, such as a rise in the haircuts of repos collateralized by government bonds, in a DSGE model with financial frictions and analyzes the consequences of unconventional policies to restore the liquidity in the markets.

1.2 Conclusions

The general conclusions of this dissertation can be summarized in four points:

1. Chapter 1 shows that a discretionary government spending shock has a positive effect on economic activity but only in the short run. Moreover, the government spending shock is not anticipated by private agents, contrary to a government spending shock identified with a structural VAR including the total primary spending, reducing the problem of fiscal foresight and making the estimation more robust.
2. Chapter 2 shows that the impact of a monetary policy shock is sensitive to the fiscal stance especially on economic activity, for which the contractionary effect of a negative monetary policy shock is offset by the expansionary effect of a positive government spending shock or a positive tax shock.
3. Chapter 3 shows that European banks rely increasingly on repurchase agreements collateralized by government bonds as a source of liquidity, especially after the onset of the global financial crisis, and that increases in haircuts may trigger a margin spiral that reduces the value of government bonds and intensifies tensions in the sovereign-debt markets.
4. Chapter 4 shows that a liquidity shock has a negative impact on output, consumption and investment and that the unconventional policy may reduce the contractionary effects on the economy by issuing a short-term bond that provides liquidity to the economy.

2 General contributions

In this section, I develop the main contributions of this dissertation to the existing literature along the four directions of research explored

Chapter 1 assesses the effect of a government spending shock which is a thorny question in the literature because the results of empirical studies are sensitive to the identification scheme of the government spending shock. Three main identification strategies have been employed in the literature: the recursive approach, which assumes that government spending does not react contemporaneously to other shocks (e.g. *Fatas and Mihov (2001)*), the approach of *Blanchard and Perotti (2002)*, which consists in using external information on the elasticity of fiscal variables to GDP in order to impose short run restrictions and the sign restrictions (e.g. *Pappa (2009)*). An alternative methodology to identify government spending shock is the narrative approach which consists in isolating episodes of large variations of fiscal variables which are not related to the state of the economy and not anticipated, such as the military builds-up considered by *Ramey and Shapiro (1998)*. On the one hand, by selecting the public expenditures that are not correlated with the business cycle, the two-step approach proposed in this dissertation limits the problem of endogeneity of fiscal variables. On the other hand, contrary to the narrative approach, it does not rely on subjective judgments and avoids problems of delays between the decision and the implementation of fiscal policy interventions.

The existing empirical literature on the basis of structural VAR models separately analyzes the impact of either a fiscal policy shock or monetary policy shock, without examining the effects of their interaction. *Rossi and Zubairy (2011)* compare the impact of a monetary and fiscal policy shocks via a structural VAR model. *Davig and Leeper (2011)* analyze the interactions of monetary and fiscal policy in a DSGE model in which the policy rules evolve over time following a Markov chain and they compute the government spending multipliers when monetary and fiscal policy regimes vary. However, few empirical works study the consequences of a policy shock taking into account the implementation of other policies. An example is *Ilzetski et al. (2011)*, who assess the impact of a fiscal policy shock under different. **Chapter 2** investigates how macroeconomic and financial variables react to a combination of fiscal and monetary policy, allowing to study the complementary of macroeconomic measures.

Chapter 3 explores the European market of repurchase agreements. Although a growing strand of the literature analyzes the role of the US repo market in the liquidity crisis of 2007-2009 (e.g. *Gorton and Metrick (2012)*, *Copeland et al. (2010)*, *Krishnamurthy et al. (2013)*), the only study that investigates the developments

of the repo market in the Euro area is Hordal and King (2008), who compare the evolution of US, UK and Euro repo markets in the first stage of the global financial crisis. **Chapter 3** tries to fill this gap using novel data and measuring quantities, maturities, underlying collateral and haircuts. It shows that variations in the repo haircuts may trigger a margin spiral on government bonds which represents a channel through which sovereign and banking weakness reinforce each other. Not only the credit risk in government bonds may explain the combination of banking and sovereign-debt crises in Europe, as argued by Acharya et al. (2011) and Brunnermeier et al. (2011), but also the liquidity of these securities played a key role.

Kiyotaki and Moore (2012) propose a model characterized by differences in liquidity across assets to investigate how aggregate activity and asset prices fluctuate with shocks to liquidity. Del Negro, Eggerston, Ferrero and Kiyotaki (2012) introduce this framework in a DSGE model to study the impact of a shock to the liquidity of private paper and effect of the FED's intervention with credit facilities that exchanged liquid government papers for private papers in the midst of the liquidity crisis in 2007-2009. **Chapter 4** presents a model to analyze the impact of a shock to the liquidity of government bonds that can be thought as a rise in haircuts on bonds. It also shows the consequence of unconventional policy based on the issuing of a liquid short-term bond.

3 Outline of the thesis

This dissertation investigates the fiscal policy in several directions and contexts that can be divided in two main fields of research. **Chapter 1 and 2** analyze the impact of fiscal policy shocks on the economy and **chapter 3 and 4** investigate the role of liquidity of government bonds during the European financial crises.

Chapter 1 studies the impact of a discretionary government spending shock on economic activity and other macroeconomic variables by using an alternative two-step procedure for the identification of the government spending shock. Following Coricelli and Fiorito (2013), I separate the public outlays into two components on the basis of their statistical properties: discretionary public expenditure and automatic public expenditure. After having removed the trend from the series with a HP filter, discretionary expenditure turns out to be more volatile and less persistent than automatic expenditure for a panel of OECD countries. Moreover, automatic expenditure is negatively correlated with the GDP while discretionary expenditure is not correlated. This component of government spending is a-cyclical also during recessions, suggesting that most government spending

is driven by automatic stabilizers. Discretionary public expenditure is then employed for the identification of a government spending shock. The elimination of automatic component from the government expenditure, allows to avoid the problem of endogeneity of fiscal variables. Hence, discretionary spending is included in a VAR model and structural shocks are identified via sign restrictions. Residuals of discretionary public expenditure are not Granger-caused by professional forecasts, suggesting that this expenditure is less predicted than total primary expenditure and reducing the problem of fiscal foresight. The impulse response function shows that government spending shock has a positive impact on economic activity but only in the short run.

Chapter 2 studies the effects of a combination of fiscal and monetary policy shocks on macroeconomic and financial variables which played a key role in the amplification of the liquidity crisis in 2007-2009. The objective of this chapter is twofold. First, it aims to investigate the impulse response function of a monetary policy under different fiscal regimes (expansionary and contractionary). Second, it tries to assess the reaction of fiscal variables to different policy mix in order to provide new insights on the transmission mechanism of monetary and fiscal policy. To address these questions a Time Varying Parameters Factor Augmented VAR (FAVAR) is employed. The purpose of the time varying structure of the model is not to investigate the evolution of monetary policy over past years, but to estimate the impulse response function of a monetary policy when the US economy was hit by a fiscal policy shock identified using external information and the narrative approach proposed by Romer and Romer (2010) for tax shocks and Ramey and Shapiro (1998) for government spending shocks. Including unobserved factors, this methodology increases the information set and permits the impulse response analysis for a large number of variables. Results shows that the transmission mechanism of monetary policy is sensitive to the fiscal stance, in particular for the response of economic activity. The contractionary effect of a negative monetary policy shock is offset by the expansionary effect of a positive tax shock and, in particular, of a positive government spending shock. This implies that the current policy mix adopted by European countries based on loose monetary policy and fiscal adjustments fails to stimulate the economic activity.

Chapter 3 explores the research area of sovereign debt, fiscal weakness and banking crises, which recently is growing considerably, because these linkages are characterizing the economies of the periphery of the Eurozone. This chapter analyzes the funding liquidity of government bonds, in the sense of their pledgeability in collateralized interbank loans and in particular in the market of repurchase agreements (repos). Although the extensive literature on the US

repo market and its role during the propagation of the liquidity crisis in 2007-2009, little attention has been paid to the European repo market because of the paucity of data. I reconstruct information on quantities, maturities, underlying collateral and haircuts and analyze the structural characteristics and the developments during the global financial crisis of this market. A significant difference between the European and the US market concerns the collateral in repos. Only half of repo transactions in US are collateralized by government securities, while in Europe they represent more than 4/5 of the pool of collateral, suggesting that European banks hold government bonds not only for their maturity value, but also for their exchange value. **Chapter 3** shows that haircuts on bonds issued by governments in the periphery of the Eurozone increased during the crisis, triggering the “margin spiral”, the negative feedback between asset price and haircuts described by Brunnermeier and Pedersen (2009). A rise in haircuts represents a negative liquidity shock that reduces the value of collateral. I assess this mechanism by estimating the impulse response function of a haircut shock via a Bayesian VAR. Results show that this negative liquidity increases the yields of government bonds. This implies that variations in the funding liquidity of government bonds may represent a channel through which banking and sovereign-debt crises reinforce each others.

The empirical findings of **Chapter 3** highlight that a liquidity shock on government bonds has pervasive effects on financial markets. In order to study the impact of a liquidity shock on the real economy, **Chapter 4** proposes a Dynamic Stochastic General Equilibrium (DSGE) model with financial friction, built on Del Negro, Eggerston, Ferrero and Kiyotaki (2012). Following their model and the seminal paper of Kiyotaki and Moore (2012), I introduce two liquidity frictions in the model, which constraint the investments in the economy. A borrowing constraint, which limits the amount that entrepreneurs can borrow, and a resaleability constraint, which limits the sell of assets in their portfolio to finance investment projects. The main departure from Kiyotaki and Moore (2012) and Del Negro, Eggerston, Ferrero and Kiyotaki (2012) is that in their model equity is subject to the resaleability constraint that reduces its liquidity and government bonds are perfectly liquid, while in my model equity is completely illiquid and government bonds are subject to the resaleability constraint. As a consequence, in their model a liquidity shock derives from a tightening in the resaleability constraint of equity. In my model the liquidity shock is modeled as a tightening in the resaleability constraint of government bonds, which is equivalent to a rise in haircuts of government securities. The model includes the same nominal and real rigidities as in Del Negro, Eggerston, Ferrero and Kiyotaki (2012) and it analyze

the consequences of a negative liquidity shock in the economy: output, investment and consumption all fall. The model also shows the effect of unconventional policy which consists in issuing a short-term bond which is completely liquid. By providing an alternative liquid means of saving, public authorities reduce the contractionary effect of a negative liquidity shock on the economy.

CHAPTER 1

Discretionary versus Automatic Public expenditures: An alternative approach for the identification of a Government spending shock

1 Introduction

Following the recent financial crisis and the Great Recession an intense debate has been raging about the impact of public spending on economic activity and the size of fiscal multiplier. The disagreement among economists and policy makers concerned, first, the effectiveness of fiscal stimuli implemented in advanced economies in the aftermath of the global financial crisis to recover the economic activity and then the consequences of fiscal consolidation carried out in most of the European countries from 2010 to reduce public deficits.

Economic theories offer different explanations of how an increase in public expenditure affects the economic activity. On the one hand, neoclassical models, which consider consumption and leisure as normal goods and separable preferences, predict that an expansion in government spending financed with non-distortionary taxes increases the output but less than the initial stimulus. This is due to the negative wealth effect of higher taxes: agents anticipating future higher taxes reduce consumption and leisure and increase labor supply, so the fiscal multiplier is smaller than one. With non-separable preferences consumption is completely crowded out as labor supply does not increase and in this case the fiscal multiplier is zero.¹

On the other hand, New Keynesian models suggest a stronger response of output to a fiscal stimulus. With price stickiness, monopolistically competitive firms meet the extra demand caused by additional Government spending by supplying more output. As a consequence, labor demand and real wages increase inducing agents to substitute from leisure into consumption. Therefore, the fiscal multiplier is higher than one. Recent studies argue that a fiscal stimulus is more effective in a context of liquidity trap (Christiano *et al.* (2009), Woodford (2011)) and financial constraints (Carillo and Poilly (2010) and Fernandez-Villaverde *et al.* (2011)). In the case of zero lower bound, a fiscal stimulus leads inflation expectations to increase and, when the nominal interest rate does not rise, real interest rate falls with a positive effect on investments. With financial frictions, if agents cannot perfectly smooth their consumption, the Ricardian equivalence principle does not hold and the current consumption tracks more closely the current income.

By contrast, the expansionary fiscal contraction hypothesis, developed by the seminal paper of Giavazzi and Pagano (1990), suggests that a fiscal adjustment based on spending cuts may have a positive impact on economic activity, by reducing the risk premium in the short run and the tax burden in the long run.

¹See Ramey 2011 for a description of effects of temporary and permanent increase in Government spending in neoclassical model.

According to this theory, the fiscal multiplier could even be negative.

The empirical literature does not agree regarding which alternative economic theory is valid and a growing strand of the literature point out that the effectiveness of fiscal stimulus depend on the regime of the economy.² One of the main difficulties to assess the effect of Government spending on economic activity is the endogeneity of fiscal variables to the business cycles. For instance, tax receipts weaken and social transfers increase during recessions and show reversed movements during expansions. As a consequence, it is arduous to distinguish movements in Government spending caused by fiscal policy shocks from those which are simply the automatic movements of fiscal variables in response to business cycle fluctuations.

The literature proposes different methods to identify a discretionary fiscal impulse. The cyclically-adjusted primary balance (CAPB) shows the underlying fiscal positions when cyclical or automatic movements are removed. Alesina and Ardagna (2010) define a discretionary fiscal adjustment when the CAPB improve by at least 1.5 percent of GDP. However, this indicator is subject to several criticisms. In particular, the cyclical adjustments correct government receipts and transfers for the cycles in economic activity, but do not adjust revenues for cycles in asset prices, resulting in changes in the CAPB that are not necessarily linked to policy action. As a result, the CAPB could be overestimated during phases of boom and underestimated during phases of bust.

Devries *et al.* (2011) follow an alternative approach to identify episodes of exogenous fiscal consolidation. Examining policy documents, such as presidential speeches and government reports, they select discretionary changes in taxes and government spending motivated by the desire to reduce the budget deficit and not by a response to prospective economic conditions. This “narrative approach” has been employed by Romer and Romer (2010) to distinguish exogenous and endogenous tax changes.

Fatás and Mihov (2003) consider residuals of a panel regression of public spending on GDP and economic controls to determine a measure of discretionary fiscal policy independent from the business cycle. Nevertheless, this unobservable measure is subject to measurement errors and is sensitive to the econometric specification. Moreover, if the econometric model is well specified the residuals should be white noise and have zero persistence, which is an implausible

²Ramey (2011 a) conducts a survey on the literature of fiscal multiplier based on SVAR models and deduces that the U.S. aggregate multiplier for a temporary, deficit-financed increase in government purchases should lie between 0.8 and 1.5. Auerbach and Gorodnichenko (2010), using a non linear smooth transition VAR, find that the range is larger, distinguishing between expansions (from -0.3 to 0.8) and contractions (from 1 to 3.6).

assumption for fiscal variables.

Barro (1981) and Barro and Redlick (2011) suggest consideration of the military spending in order to measure the discretionary public expenditure, because they argue that this spending aggregate is less correlated to the business cycle. In the same vein, Ramey and Shapiro (1998) stress the importance of taking into account the different effects of Government spending across sectors and identify Government spending shocks as changes in military builds-up that occurred for reasons unrelated to the state of the economy. In particular they consider the World War II, the Korean War and the Vietnam War. Eichenbaum and Fisher (2005) and Ramey (2011) add the Bush build-up after the 9/11. Following the same idea, Fisher and Peters (2009) use stock returns of large military contractors to identify unanticipated government spending shocks.

In the present study, we revisit the question of the effects of government spending using an alternative strategy for the identification of a discretionary government spending shock. Instead of decomposing the public expenditure into military and non-military outlays, we consider an alternative classification of public expenditures. Following Coricelli and Fiorito (2009), we differentiate the government spending into two aggregates according to their cyclical properties: discretionary expenditure and automatic expenditure. Empirical evidence shows that discretionary expenditure is more volatile and less persistent than automatic expenditure and that discretionary expenditure is acyclical, while automatic expenditure is countercyclical. This decomposition of public outlays is used for the identification of a discretionary and exogenous spending shock. A VAR including the discretionary expenditure and other macroeconomic variables is estimated and sign restrictions are imposed on the reduced-form residuals to achieve the identification of shocks. The exclusion of automatic expenditures with high elasticity to output from total spending reduces the problem of endogeneity. The impulse response analysis suggests that a fiscal stimulus has an expansionary effect on economic activity in the short run.

The remainder of the chapter is organized as follows. Section 2 shows the stylized facts for public spending components. Section 3 analyzes the evolution of discretionary spending during recessions. Section 4 presents the methodology and the identification scheme used for the SVAR model. Section 5 shows the impulse response function and assess the predictability of Government spending shock. Section 7 concludes.

2 Stylized facts for public expenditures

Following Coricelli and Fiorito (2013), public outlays are aggregated into two components: discretionary expenditure (GD) and automatic expenditure (GN) on the basis of the statistical properties of their cyclical fluctuations. GD includes public intermediate consumption, public investments, capital transfer (unrequired payments from the government or the debt cancellation without any counterpart being received in return), and subsidies paid to firms. GN comprises public wages and salaries, retirement benefits and transfers (payments to individual health, subsistence, children care, invalidity and unemployment compensation). Interest payments are not considered as largely determined by past fiscal policies and financial conditions. The data appendix describes the variables used in the analysis.

Figure 1.1 and table 1.1 show that for most of OECD countries included in the analysis, GN is larger than GD, which accounts for around one third of total primary spending (except for Iceland 43.7%, Japan 51.7% and Netherland 48.3%) and that during the Great Recession the composition of public expenditure does not vary significantly (except for Iceland where the discretionary expenditure surged up to 51% of total public spending due to banking rescue plans). For discretionary expenditure the main item is intermediate consumption, which represents between 20% and 25% of total primary public expenditure (in Japan and Netherlands is respectively 30% and 35%, while in USA 17.5%). Public investments are only between 5% and 10% of total spending and in 2009 their share reduced in most of countries. Capital transfers paid and other capital payment and subsidies are both less than 5% in all countries (except for UK where capital transfers are 5.7% and for Austria where subsidies are 8%). Capital transfers is the item that grew most during the crisis as it includes government interventions to support financial sector (especially in Finland, Belgium, Iceland, Ireland, Netherlands and USA).³ Japan is the only country to experience a considerable expansion in subsidies to firms. Social security benefits are the main spending of automatic expenditure especially in Italy, Austria and USA where they account for more than 40% of the primary spending, while public salaries and wages are between 20% and 30% (except for Nordic countries where it is between 30 and 40% and Japan where it is 17%).

Stylized facts show some regularity for the two spending aggregates in OECD countries, confirming the distinction between discretionary and automatic expenditure. In order to analyze cyclical fluctuations of the series a Hodrick-Prescott

³The OECD Economic Outlook No. 84 reports how financial rescue plans are reflected in fiscal position.

Figure 1.1: Discretionary and automatic public expenditure over GDP

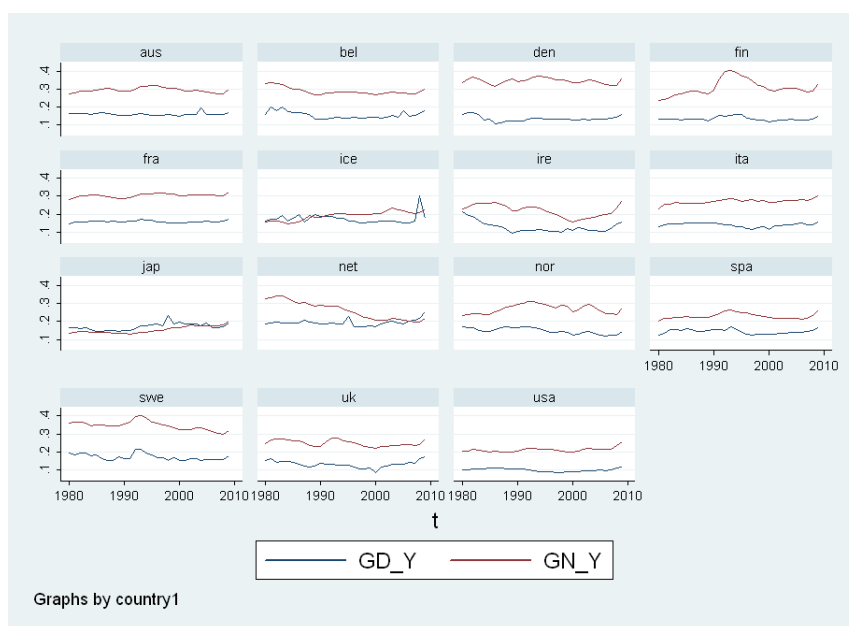


Table 1.1: Primary Government Spending

	% of total primary spending		% of GDP	
	Mean	St. Dev.	Mean	St. Dev.
Government final non-wage consumption	21.3	4.8	8.8	2.1
Government fixed capital formation	7.6	3.2	3.1	0.9
Capital Transfers paid and other capital payments	3.2	1.3	4.3	2.2
Subsidies	4.3	2.2	1.8	1.0
Government final wage consumption	29.3	4.9	12.2	2.9
Social security benefits paid by general government	34.1	6.2	14.4	3.8
Discretionary expenditure	36.6	7.0	15.1	2.8
Automatic expenditure	63.4	7.0	26.7	5.8
Total Primary expenditure	100		41.8	6.4

filter is applied to the logarithm of real variables to remove the trend.⁴ Table 1.2 reports the volatility, the persistence and the comovements of the cycles. Since the data are yearly, a smoothing parameter of 6.25 is used adjusting with the fourth power of frequency ratios, as suggested by Ravn and Uhlig (1997). As robustness test, a smoothing parameter of 100 is also applied, as proposed by Backus and Kehoe (1992) and largely used in the literature. It does not emerge significant differences in the properties of the series. Volatility is calculated as standard deviation and relative standard deviation with respect to the output. Persistence is computed with the Q statistics of the Ljung-Box test for autocorrelation.

Table 1.2 shows two evidences. First, discretionary expenditure is at the same

⁴A similar exercise is carried out by Fiorito (1997) for disaggregated public disbursement and receipts for OECD countries.

time more volatile and less persistent than automatic expenditure (except for France). Second, discretionary expenditure is not contemporaneously correlated with GDP (except for Sweden where it is negatively correlated). The correlation between GDP and discretionary spending is weak at one lead, excluding a delayed response of discretionary expenditure to the GDP. On the other hand, automatic expenditure is negative correlated with GDP (except for Austria, Norway, Spain and Sweden where is not correlated and Iceland and Ireland where is positively correlated, probably due to the spending cuts during the recent recession).

These results suggest that the automatic spending is more inertial, while discretionary spending, being more volatile, is more subject to policy interventions. Moreover, thinking about the error term in an autoregressive process of order one, the higher volatility and lower persistence of discretionary spending imply a strong variability of the error and we can interpret this parameter as a measure of the discretionality of spending.

Table 1.2: Stylized facts

VARIABLES	Stand.Dev.		Corr(G(t-j),Y(t))			Corr(GD,GN)	Persistence
	%	relative	-1	0	+1		
AUSTRIA (1960:2010)							
GD	3.12	2.89	-0.20	-0.03	0.08	-0.236	12.19
GN	1.22	1.13	-0.06	-0.06	-0.18	(0.175)	19.90
Y	1.08	1					23.67
BELGIUM (1980:2010)							
GD	3.76	3.93	0.07	-0.16	0.11	0.123	18.07
GN	1.17	1.22	-0.32	-0.64	-0.13	(0.148)	21.50
Y	0.96	1					14.98
DENMARK (1970:2010)							
GD	2.53	1.76	-0.23	0.06	-0.03	0.047	7.59
GN	1.43	0.99	-0.03	-0.55	-0.46	(0.154)	46.80
Y	1.45	1					22.01
FINLAND (1970:2010)							
GD	2.30	1.06	-0.13	-0.01	0.02	0.093	13.87
GN	2.04	0.95	-0.39	-0.55	-0.16	(0.150)	29.25
Y	2.16	1					34.89
FRANCE (1978:2010)							
GD	0.98	1.07	0.07	-0.08	0.22	-0.038	12.40
GN	0.82	0.89	-0.06	-0.45	-0.29	(0.161)	10.01
Y	0.92	1					26.15
ICELAND (1980:2010)							
GD	10.49	4.46	-0.22	0.13	0.23	-0.17	3.68
GN	4.48	1.91	0.08	0.48	0.41	(0.171)	36.40
Y	2.35	1					28.90
IRELAND (1990:2010)							
GD	15.37	7.44	-0.25	-0.27	-0.40	0.23	9.33
GN	4.48	1.91	0.08	0.48	0.41	(0.171)	36.40
Y	2.06	1					17.17
ITALY (1963:2010)							
GD	2.66	2.13	0.09	-0.13	0.14	-0.42	15.74
GN	1.86	1.49	0.01	-0.34	0.00	(0.168)	20.41
Y	1.24	1					26.60

Note: The standard errors for the correlation of GD and GN are in parenthesis. Persistence is calculated by the Ljung-Box statistics with 10 lags. All series are deflated, in logarithms and detrended with the HP filter applied with a smoothing parameter of 6.25

VARIABLES	Stand.Dev.		Corr(G(t-j),Y(t))			Corr(GD,GN)	Persistence
	%	relative	-1	0	+1		
JAPAN (1966:2010)							
GD	3.95	2.70	0.15	-0.06	-0.04	-0.081	14.05
GN	1.19	0.82	-0.05	-0.29	-0.28	(0.164)	8.86
Y	1.46	1					13.17
NETHERLANDS (1969:2010)							
GD	4.26	3.88	-0.20	-0.04	0.15	0.015	11.53
GN	1.35	1.23	-0.32	-0.41	0.06	(0.156)	16.03
Y	1.09	1					27.42
NORWAY (1962:2010)							
GD	1.71	1.67	-0.38	-0.23	0.00	0.211	20.04
GN	1.14	1.11	-0.37	-0.07	-0.09	(0.141)	29.47
Y	1.45	1					22.01
SPAIN (1965:2010)							
GD	3.42	3.01	-0.05	-0.11	0.17	-0.041	16.92
GN	1.90	1.68	-0.29	-0.151	0.26	(0.161)	20.31
Y	1.13	1					19.85
SWEDEN (1963:2010)							
GD	3.20	2.24	-0.21	-0.38	-0.20	0.297	17.88
GN	1.40	0.98	-0.02	0.03	0.08	(0.132)	29.41
Y	1.42	1					25.08
UK (1970:2010)							
GD	3.47	2.45	-0.41	-0.02	0.26	-0.02	12.58
GN	1.88	1.33	-0.10	-0.64	-0.45	(0.159)	21.12
Y	1.41	1					27.17
USA (1960:2010)							
GD	2.22	1.56	-0.23	-0.26	0.21	0.417	30.72
GN	1.33	0.94	-0.01	-0.54	-0.40	(0.131)	27.01
Y	1.42	1					33.89

Note: The standard errors for the correlation of GD and GN are in parenthesis. Persistence is calculated by the Ljung-Box statistics with 10 lags. All series are deflated, in logarithms and detrended with the HP filter applied with a smoothing parameter of 6.25

The finding that discretionary expenditure is not related to the business cycle while automatic expenditure react negatively to the economic activity is common to previous studies for OECD countries. Darby and Melitz (2008) show that not only unemployment compensation, but also age- and health- related social expenditure and incapacity benefits, which are included in the social security benefits, have high elasticity to the output and react to the cycle in a stabilizing manner. Fiorito (1997), analyzing the cyclical fluctuations of public outlays, finds that transfers and the wage component of Government spending are countercyclical and act as a timely cyclical stabilizers. On the other side, Finn (1998) calculate that U.S. cyclical fluctuations of government investments and government consumption, which are contained in the discretionary aggregate, do not comove with the

GDP.

Finally, the correlation between the two components of public spending is null or very weak, suggesting the absence of complementarity between discretionary and automatic expenditure.

All in all, the empirical evidence suggests that we can consider an aggregate of public outlays that is discretionary and exogenous to the economic activity.

3 Discretionary public expenditure during recessions

This section examines the dynamics of discretionary expenditure during recessions to assess how fiscal authorities react during downturns and verify a possible non linear relation between discretionary expenditure and economic activity. The analysis focuses only on US because is the only economy for which the OECD Economic Outlook contains data of fiscal variables at quarterly frequency.

Table 1.3 displays the average of the square of the cyclical deviations during recessions, which are defined as negative variation of real GDP, and during negative cycles, periods characterized by a negative output gap. Although this indicator cannot gauge the sign of the fiscal stance, it evaluates the intensity of the response of discretionary expenditure. For instance, if in recessions the square of deviations is higher than in expansions it means that fiscal interventions are stronger during downturns. Cyclical fluctuations of discretionary expenditure are analyzed and compared during recessions and expansion, with negative and positive output gap and for the all the possible combinations of recessions-expansions and positive-negative output gap. In particular, the business cycles is decomposed in four phases. Phase 1 identifies an expansion with a positive output gap, phase 2 a contraction with a positive output gap, phase 3 a contraction with a negative output gap and phase 4 an expansion with a negative output gap. We also differentiate between mild recessions (GDP growth between 0% and -2%) and strong recessions (GDP growth less than -2%) and between the Great Recession and previous epsiodes of recessions. The OECD countries analyzed experience 74 episodes of recessions and 574 episodes of expansions, while for 308 periods the economy is above its trend and for 340 is below. Deviations from the trend are slightly higher during recessions than during expansions, but the difference is low. Surprisingly the highest values are associated with mild recessions and not with strong recessions or with the Great Recession. Moreover, fiscal policy is more active when the output gap is positive than when it is negative. Decomposing the business cycle in four stages, we can see that deviations of discretionary expenditure from its trend are larger when the economy is contracting and below

Table 1.3: Cyclical deviations of discretionary expenditure during different phases of business cycle

Phase of business cycle	Mean of squares of cyclical deviations (%)	Number of episodes
Recessions	.183	73
Expansions	.148	574
Mild recessions	.276	24
Strong recessions	.137	49
Great recession	.141	27
Negative output gap	.123	339
Positive output gap	.184	308
Phase 1	.187	290
Phase 2	.153	18
Phase 3	.193	55
Phase 4	.109	284

Note: Phase 1 identifies an expansion with a positive output gap, phase 2 a contraction with a positive output gap, phase 3 a contraction with a negative output gap and phase 4 an expansion with a negative output gap.

its trend, but there is not a significant difference with the other phases. All in all, it does not emerge a diverging behavior of fiscal authorities during different business cycle stages.

Figure 1.2 shows the average of discretionary expenditure over GDP around episodes of recessions. When a recession lasts for a longer period of time, only the year with a deeper fall in output is considered, and when an overlapping year belongs to two different spells, we retain the year in the aftermath of a recession. The ratio of discretionary expenditure over GDP does not vary considerably during recessions and the small increase is due mostly to the contraction of GDP.

5

Table 1.4 matches the episodes of discretionary fiscal expansion, defined as an increase in discretionary expenditure by more than 1.5 percent of GDP, with recessions. Only few cases of discretionary fiscal expansions occur in a recessionary year. Similar results are obtained considering the year after a recession to take into account a possible implementation lag in the conduct of fiscal policy.

This empirical analysis highlights that discretionary expenditure does not react strongly to the recessions the recent and past recessions. If this component of public outlay was stable during the Great Recession, what are the drivers for the surge in primary deficit registered in the aftermath of the global financial crisis

⁵We also differentiate between mild recessions and deep recessions and between the Great Recession and previous recessions to verify if the evolution of discretionary expenditure changes during different kinds of episodes. We do not find significant differences.

Figure 1.2: The average of GD / GDP during recessions

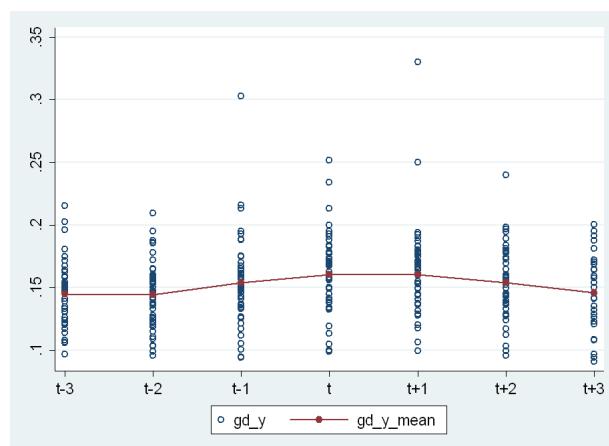


Table 1.4: Fiscal expansions and Recessions

COUNTRY	FISCAL EXPANSIONS
AUSTRIA	2001, 2004
BELGIUM	1983, 2005
DENMARK	1981, 1982
FINLAND	1990
FRANCE	1981, 1982, 1984
ICELAND	1981, 1982, 1983 , 1984, 1985, 1986, 1988 , 1989, 1990, 1991 , 1999, 2001, 2006, 2007, 2008
IRELAND	1982, 1982, 1990, 1999, 2001, 2007, 2008 , 2010
ITALY	1998, 2001
JAPAN	1998 , 2005
NETHERLANDS	1995, 2001, 2002, 2006, 2007, 2008, 2009
NORWAY	1986, 1987
SPAIN	1981 , 1982, 1983, 1984, 1985, 1989, 1990, 1993 , 2004
SWEDEN	1982, 1983, 1989, 1992 , 1999
UK	1981 , 1989, 1990, 2001, 2003, 2008
USA	

Note: In bold the years of recessions

in all the OECD countries analyzed?

Concerning the expenditure side, Tables 1.5 and 1.6 show the evolution of Government spending components in percentage of GDP and in percentage of the total primary public spending from 2007 to 2009. The total primary public spending over GDP ratio increases in all the countries. This variation is mostly due to a rise in the automatic expenditure. Indeed - except in Japan, Netherlands, Sweden and UK - the variation of the discretionary expenditure accounts for less than 50% of the increase in total public expenditure over GDP. Among the components of the discretionary expenditure, less resources are devoted for public

investments whose share declines in all the countries, except in Austria, Norway, Sweden and UK. By contrast, the share of capital transfers increases, especially in Ireland, Iceland, Netherlands, UK and USA because of the rescue plans for the banking system.

In the wake of the global financial crisis, the huge primary deficits in OECD countries that have been threatening the sustainability of public debts, was driven by the automatic stabilizers (total revenues and automatic expenditures), while the weight of the augmentation of discretionary expenditure was lesser. It follows that in most of the OECD countries the recession itself through the action of automatic stabilizer, and not the direct intervention of fiscal authorities was the primary cause of the rise in public deficits.

Table 1.5: Variations of components of discretionary public expenditure 2007 - 2009 (% of GDP)

Country	Δ_{tot}	Δ_{gd}	Δ_{gd}/Δ_{tot}	Δ_{cgnw}	Δ_{igaa}	Δ_{tsub}	Δ_{tkpg}
Austria	4.15	1.37	32.97	0.98	0.12	0.34	-0.08
Belgium	5.07	2.17	42.69	1.31	0.11	0.27	0.48
Denemark	6.64	2.05	30.91	1.32	0.16	0.42	0.14
Finland	7.16	2.44	34.05	1.72	0.36	0.14	0.22
France	3.80	1.41	37.21	0.93	0.14	0.26	0.08
Iceland	4.72	2.18	46.11	2.13	-0.67	0.09	0.63
Ireland	10.35	3.14	30.36	1.01	-0.56	0.10	2.60
Italy	4.25	1.53	35.89	1.12	0.17	0.06	0.17
Japan	5.27	2.72	51.65	1.81	0.29	0.18	0.45
Netherlands	6.62	4.48	67.68	2.56	0.45	0.31	1.16
Norway	5.71	2.25	39.40	1.40	0.54	0.32	-0.01
Spain	6.57	1.79	27.29	1.25	0.42	0.06	0.07
Sweden	4.18	2.46	58.68	1.92	0.48	0.10	-0.04
UK	6.82	3.68	53.91	1.78	0.79	0.01	1.09
USA	5.88	1.81	30.83	0.48	0.37	0.04	0.92

Note: See the Appendix for the definition of public expenditures.

4 The effects of a discretionary spending shock

The series of U.S. government spending used in previous empirical studies based on structural VAR models are total government expenditure and government consumption expenditure, which incorporates both the wage and non wage expendi-

Table 1.6: Variations of components of discretionary public expenditure 2007 - 2009 (% of Total public spending)

Country	Δg_d	Δc_{gnw}	Δi_{gaa}	Δt_{sub}	Δt_{kpg}
Austria	-0.37	0.23	0.04	0.06	-0.70
Belgium	0.71	0.09	-0.17	0.08	0.71
Denemark	0.10	-0.05	-0.21	0.19	0.17
Finland	0.45	0.42	-0.14	-0.18	0.35
France	0.22	0.18	-0.25	0.28	0.01
Iceland	0.27	2.21	-2.93	-0.35	1.34
Ireland	-2.02	-2.55	-4.64	-0.11	5.28
Italy	0.20	0.45	-0.14	-0.10	-0.02
Japan	0.44	-0.05	-0.49	0.23	0.74
Netherlands	2.25	-0.15	-0.20	0.23	2.37
Norway	0.78	0.62	0.12	0.08	-0.05
Spain	-1.94	-0.48	-0.72	-0.32	-0.42
Sweden	2.13	1.89	0.39	-0.06	-0.10
UK	2.68	-0.14	1.02	-0.14	1.94
USA	-0.11	-1.70	-0.60	-0.09	2.28

Note: See the Appendix for the definition of public expenditures.

tures. However, the previous sections have presented evidence that components of government spending present different statistical properties: discretionary expenditure is acyclical, is less persistent and more volatile, suggesting that it is modified more swiftly by fiscal authorities. It follows that innovations to automatic expenditure (for instance retirement benefits and transfers) are more likely to be anticipated as these expenditures are more inertial. In light of these considerations only the discretionary component of public expenditure is used to identify an exogenous government spending shock, avoiding problem of endogeneity and fiscal foresight that would arise in including the automatic expenditure. The analysis of the effect of a government spending shock is carried out only on the U.S. economy since quarterly data on government expenditures are not available for other OECD countries and SVAR models with yearly data can suffer problems of time-varying aggregation as shown by Faust and Leeper (1997).

The data cover the period 1980:I - 2011:III. The choice of the sample takes into account the structural change in the U.S. economy represented by the Great Moderation. Indeed, Perotti (2005) and Bilbiie *et al.* (2008) show that the transmission mechanism of fiscal policy modified after 1980 because of the change in the conduct of monetary policy and the consequence of the increase in asset market participation on private consumption.

The Model

Let Y_t a $(n \times 1)$ vector of endogenous variables including the logarithm of real GDP, y , the logarithm of real discretionary public expenditure, GD , the logarithm of real total revenues, t , the federal fund rate, i , and the inflation rate, π .⁶ The dynamics of Y_t can be described by a system of linear simultaneous equations:

$$AY_t = \alpha'X_t + \epsilon_t \quad , \quad \epsilon_t \sim i.i.d.(0, \Sigma_\epsilon = \text{diag}(\sigma_\epsilon^2)) \quad (1.1)$$

where $X_t = [Y'_{t-1}, \dots, Y'_{t-p}, \bar{Y}'_t]$ is the $(np \times 1)$ vector consisting of lagged observations of endogenous variables, the constant and a quadratic time trend to remove low frequencies, collected in \bar{Y}'_t , α is $(np \times n)$ matrix of coefficients, and ϵ_t is an $(n \times 1)$ vector of structural shocks. A lag length of four quarters is chosen, which is a standard choice in models with quarterly data. An equivalent representation of the dynamics of Y_t is:

$$Y_t = \delta'X_t + B\epsilon_t \quad (1.2)$$

where $\delta = A^{-1}\alpha'$, and $B = A^{-1}$. The reduced form residuals have a variance-covariance matrix Σ_u and they are linear combinations of structural shocks: $u_t = B\epsilon_t$, or:

$$B\Sigma_\epsilon B' = \Sigma_u \quad (1.3)$$

Equation 3 has a solution if at least $n(n-1)/2$ restrictions are imposed. Hence, without restrictions on the parameters in B , the structural model is not identified.

Identification

Three main identification strategies are used in the literature of SVAR model to assess the effects of fiscal policy shocks: the recursive approach, the scheme of Blanchard and Perotti (2002) and sign restrictions.⁷ The recursive approach restricts B to have a lower triangular matrix with unit diagonal, implying a casual ordering of the variables. Fatás and Mihov (2001) order government spending as first variable and tax revenues after GDP, assuming that government spending does not react contemporaneously to shocks of other variables, and output does not react contemporaneously to tax. Blanchard and Perotti (2002) identify the

⁶This set of variables is the same as the ones used by Perotti (2005) and Caldara and Kamps (2008), except for the government expenditure.

⁷The "event study" or "dummy variable approach" introduced by Ramey and Shapiro (1998) avoid the identification problem inherent in SVAR focusing on fiscal episodes considered exogenous with respect to the state of the economy. See Perotti (2007) and Caldara and Kamps (1998) for a more detailed comparison between the "event study" approach and the SVAR approach.

matrix B using zero short-run restrictions and institutional information about tax, transfers and spending programs. They use external information about the output elasticity of government spending and government revenue for the coefficients of the automatic response of government spending and taxes to innovations in output. As they set the output elasticity of government spending to zero, they assume the absence of feedback from economic activity to government spending. As a result, one of the main assumption in these two approaches is that movements in government spending are unrelated to the business cycle. However, Section 2 shows that automatic expenditure comoves negatively with the economic activity. Although *Fatás and Mihov (2001)* and *Blanchard and Perotti (2002)* consider government consumption excluding transfers, they use NIPA data that do not allow for a distinction between purchase of final goods (and services) and compensation of employees. In OECD countries the latter component accounts for a growing proportion of government spending (on average the 29.3 % of total primary spending and the 12.2 % of GDP for the OECD countries considered in this study) and is strongly correlated with the economic activity. The use of more disaggregated data allows to separate public outlays more accurately according to their cyclical properties.

The identification of the structural impact matrix B is achieved via sign restrictions. This approach has been introduced in SVAR methodology by *Uhlig (2005)* to identify monetary policy shocks, and has been applied by *Mountford and Uhlig (2009)* and *Pappa (2009)* to identify fiscal policy shocks.⁸

Five structural shocks are identified: supply, ϵ_t^S , monetary policy, ϵ_t^M , demand non-policy, ϵ_t^D , government spending, ϵ_t^G , and government revenue, ϵ_t^T shocks. The set of restrictions on the structural impact matrix is summarized in the following table. This set of restrictions is sufficient to separate the various shocks from one another, achieving identification.

The benchmark for this identification scheme is *Mountford and Uhlig (2009)* but there are important differences. First, including in the VAR the discretionary expenditure instead of the total government expenditure, makes sure that movements in this fiscal variable are due to a government spending shock and are not the response to other shocks. Second, one additional shock is identified to disentangle the effect of a shock in government expenditure from the shock in demand non-policy on macroeconomic variables. Third, more restrictions to the shocks are imposed. At the cost of further hypotheses, I use more information to increase the precisions of results as stressed by *Paustian (2007)*. Finally, re-

⁸*Canova and De Nicolò' (2002)* impose sign restrictions on the cross-correlations between the variables in response to shocks, rather than directly on the impulse response functions

Table 1.7: Identifying sign restrictions

Variables	Shocks				
	ϵ_t^S	ϵ_t^M	ϵ_t^D	ϵ_t^G	ϵ_t^T
y	+	-	+	+	-
GD				+	
t		-	+	+	+
i		+	+	+	-
π	-	-	+	+	-

This table shows the sign restrictions on the impulse response for each identified shocks. "+" means that the impulse response of the variable in question is restricted to be positive on impact. "-" indicates a negative response. A blank entry indicates that no restrictions have been imposed

restrictions are imposed only on impact and not for four quarters after the shock to leave the dynamics of the variables unconstrained after the shock. Mountford and Uhlig (2009) assume that the government spending does not respond for one year to a fiscal shock to deal with the problem of announcement effect, the possible lag between the announcement and the implementation of changes in fiscal policy. However, I show in the next section that private forecasts do not predict the discretionary government spending shock.

The identification of supply, monetary policy and non-demand policy shocks is close to the scheme applied by Benati (2008). The transitory supply shock is identified as a shock that has a positive impact on GDP and a negative impact on inflation, while fiscal variables are left unconstrained. Monetary policy shock is characterized by a rise in the federal fund rate and a consequent decrease in GDP, Government revenues and inflation. The demand non-policy shock has a positive impact on GDP, Government revenues, the federal fund rate and the inflation. The Government spending shock is characterized as a shock having a positive impact on Government expenditure, GDP, federal fund rate, inflation and tax receipts. The positive effect on GDP and inflation is imposed to distinguish the shock from a systematic spending reaction to a recessionary shock stemming from the private sector. The positive effect on tax revenues means that expenditure is not totally deficit-financed even though I do not impose a balanced budget constraint. Finally, the government revenues shock has a positive impact on government revenues, while has a negative impact on GDP and the federal fund rate.

Estimation

The structural impact matrix B is computed via the procedure introduced by Rubio-Ramirez *et al.* (2010), to ensure that it respects equation (2) and satisfies the imposed pattern of signs. Specifically, let $\Sigma = PDP'$ be the eigenvalue-eigenvector decomposition of the VAR's covariance matrix Σ and let $\tilde{B} = PD^{\frac{1}{2}}$. I draw a $N \times N$ matrix K from the $N(0,1)$ distributions, I take the QR decomposition of K - that is, I compute matrices Q and R such that $K = QR$ - and I compute the structural matrix as $B = \tilde{B}Q'$, with $Q'Q=I$. If the draw satisfies the restrictions I keep it, otherwise I discard it and I repeat the procedure until the restrictions are satisfied.

The VAR coefficients matrices and the variance-covariance matrix are estimated by the Bayesian method adopted by Uhlig (2005). The parameters are drawn jointly from a prior proportional to a Normal-Wishart density. To draw inference from the posterior I take 1000 draws from the VAR coefficients and variance-covariance matrix of the reduced-form residuals. For each draw I calculate the impulse response function, and if the sign restrictions are satisfied I keep the draw, otherwise I proceed to the next. The draws which has been kept are used to calculate errors bands.

5 Results

Generalized impulse response function

Figures 1.3-1.7 display the generalized impulse responses (GIRF) to transitory supply, monetary policy, government expenditure and government revenues shocks. The black line represents the median and red lines the 16% and 84% quantiles. Figure 1.3 shows the effect of a positive supply shock. As restrictions impose, real GDP increases on impact but the effect is temporary as the shock is absorbed after 4 quarters. The reaction of inflation is negative and persistent, suggesting that price adjustment is sluggish. Discretionary expenditure, which is left unconstrained, does not contemporaneously react to a supply shock, confirming that this aggregate of public spending is inelastic to the business cycle. On the other hand, Government revenues track the reaction of GDP, since its elasticity is high

Figure 1.4 shows the effect of a negative monetary policy shock. The tightening of monetary policy has a contractionary effect on GDP in the short term and a persistent negative impact on inflation. The effects of supply and monetary policy shocks on output and inflation are in line with the results of Benati (2008). government revenues react negatively to the tightening of monetary policy, while government expenditure react positively on impact. The response of fiscal vari-

ables to a monetary policy shock is different from Mountford and Uhlig (2009) who find that total primary government spending does not react contemporaneously and government revenues (net the transfers) increases persistently.

Figure 1.6 displays the effect of a positive government spending shock. This shock has an expansionary effect in the short run. GDP increases with a peak after 3 quarters and it reverts after one year. Reversing the sign of the shock, a fiscal adjustment based on spending cuts has a contractionary effect on GDP in the short run. The government spending shock has a positive and transitory impact on inflation that increases for 5 quarters.

Figure 1.7 shows the effect of a positive government revenues shock. The response of GDP is negative in the short run, but after 3 quarters it becomes positive for 12 quarters with a peak in the 6th quarter. The revenue shock causes a reduction in government spending in the second quarter, while inflation decreases persistently for 10 quarters.

The impulse response analysis suggests that a fiscal adjustment based on tax hikes or spending cuts has a contractionary effects on economic activity in the short run.

Figure 1.3: Supply shock

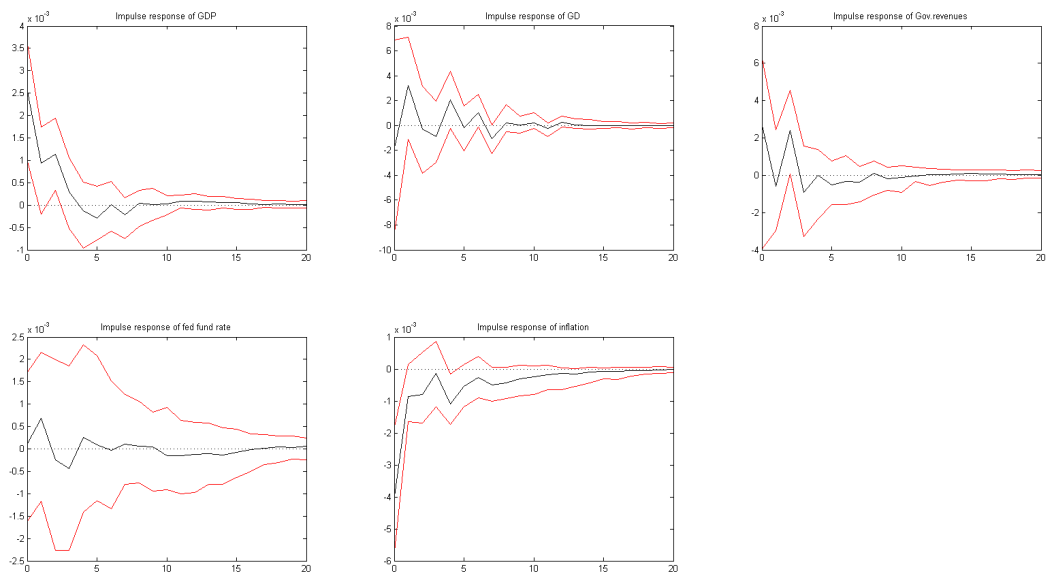


Figure 1.4: Contractionary monetary policy shock

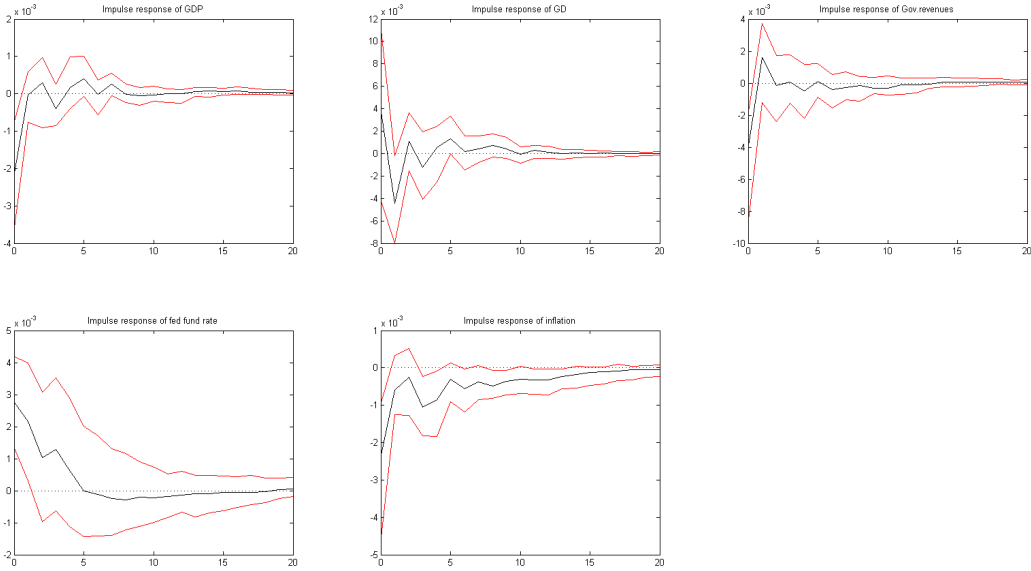


Figure 1.5: Demand non-policy shock

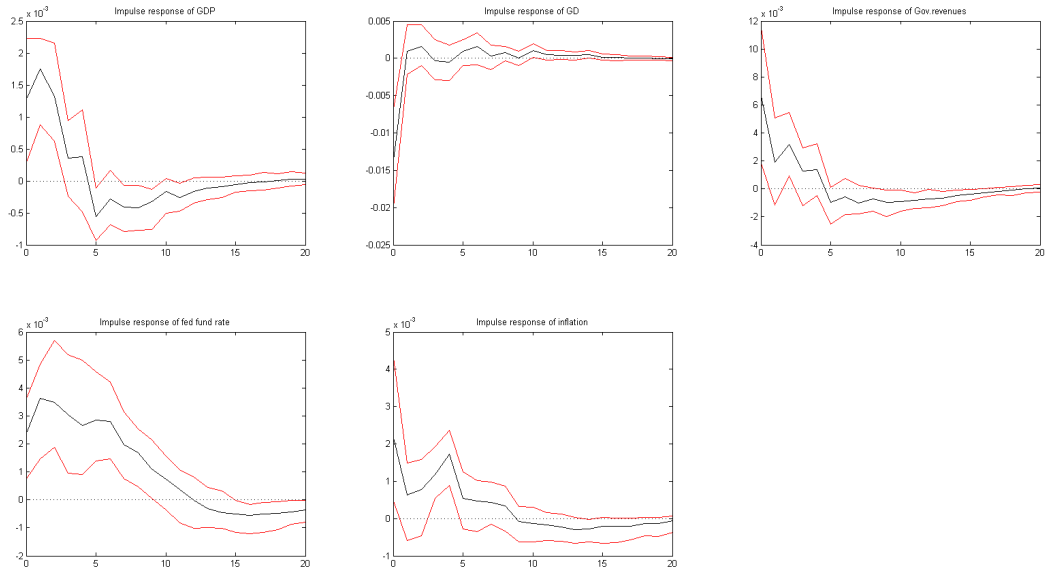


Figure 1.6: Expenditure shock

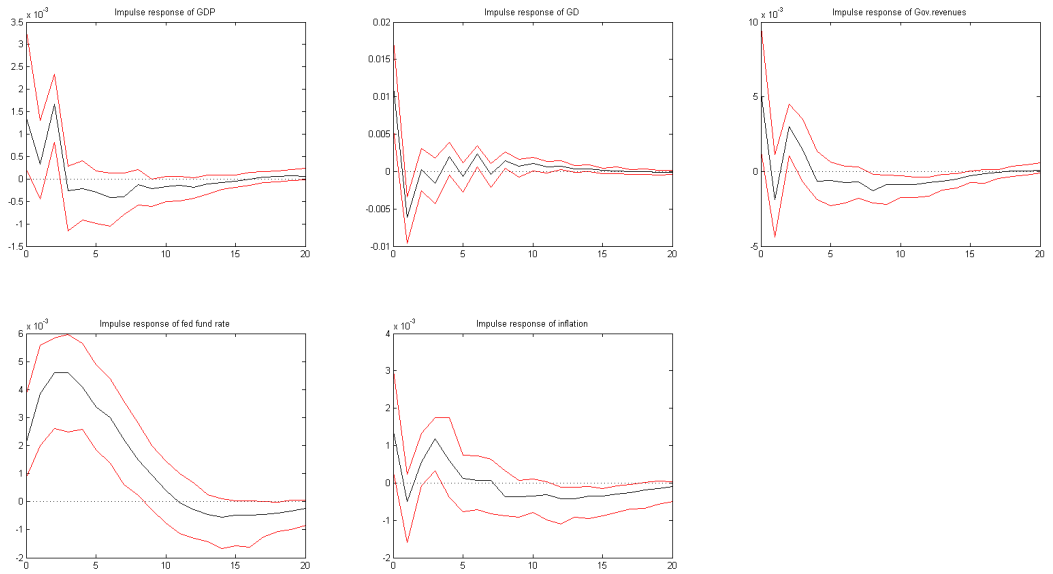
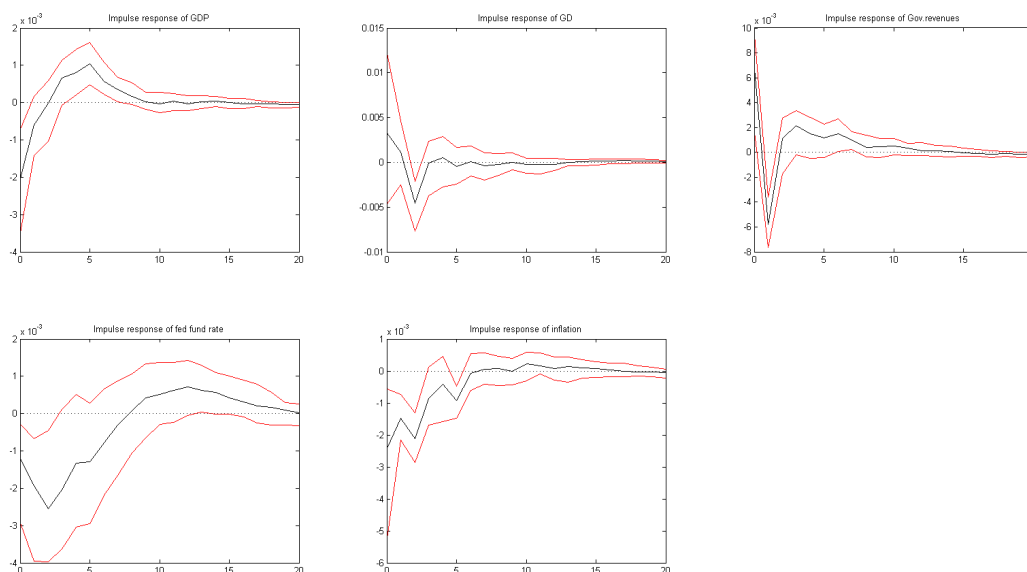


Figure 1.7: Revenue shock



Predictability of Government spending shock

Having assumed sign restrictions on impact in the SVAR identification, it is crucial to verify the predictability of discretionary spending shock. Because of the lag between the legislative decision and the implementation of fiscal measures (outside lag), private agents can anticipate fiscal policy changes, so the estimation of the impact of public spending shock on the economy may be biased. Empirical evidence based on reduced-form and case studies well documents that private agents respond to expected changes of tax rates.⁹ By contrast, government spending foresight has received relatively little attention. Ramey (2009) assess whether the Surveys of Professional Forecasters Granger-causes government spending shock calculated as residual from a VAR model. She concludes that government spending shock is predicted by private forecasts. Analogously, Forni and Gambetti (2010), test if government shock obtained from a structural factor model is Granger-caused by professional forecasts.

Following Ramey (2009), I consider the forecast of government spending growth from the Surveys of Professional Forecasters published by the Federal Reserve Bank of Philadelphia from the third quarter of 1981. I assess if one-quarter ahead professional forecasts Granger-cause the discretionary public spending shock. Table 1.8 shows that professional forecasts do not predict the shock at a con-

⁹See Leeper *et al.* (2009) for a survey.

fidence level of 0.05. This result may suggest that modifications of discretionary public spending are less anticipated than variations in total public spending, as discretionary expenditures are adjusted more swiftly. For example, a modification in the public intermediate consumption is less complex than a reform of the retirement system or transfers, like the American Recovery and Reinvestment Act which was signed in February 2009 after one year of political debate.

Table 1.8: Granger-causality test

H_0 : private forecasts do not Granger-cause discretionary spending shock	
F-stat	critical value
2.9689	3.9229

Note: For the professional forecaster test, the VAR shock in period t is regressed on the forecast made in period $t-1$ of the growth rate of real federal spending from $t-1$ to t . The Number of lags in the model is chosen according to the BIC criterion. Alpha=0.05

6 Conclusions

Primary public expenditure can be divided into two components: discretionary and automatic expenditure. The discretionary spending is more volatile and less persistent, suggesting that it is modified more swiftly and more easily. Moreover, this component is not related to the business cycle neither in expansions nor in recessions. I used this distinction to identify an exogenous government spending shock in a SVAR including the discretionary expenditure and ruling out the automatic expenditure. The impulse response analysis suggests that a fiscal stimulus has an expansionary and inflationary effect in the short run. However, the dominant share of automatic expenditures in the total public outlays may limit the room of manoeuvre for discretionary fiscal intervention during downturn and during the past recessions we do not observe an increase in this component. Further research will estimate a non linear VAR model, following the approach of Auerbach and Gorodnichenko (2010), in order to analyze the effects of disaggregated public outlays in different phases of the business cycle and under different economic environment, such as the zero lower bound condition.

Appendix: Data

Data for government outlays and deflators

The data are from the OECD Economic Outlook No. 90 (December 2011) and they are yearly;

CGNW: Government final non-wage consumption expenditure, value

CGW: Government final wage consumption expenditure, value

IGAA: Government fixed capital formation, value, appropriation account

SSPG: Social security benefits paid by general government, value

TKPG: Capital Transfers paid and other capital payments, value

TSUB: Subsidies, value

PCG: Government final consumption expenditure, deflator

PCGW: Government final wage consumption expenditure, deflator

PCP: Private final consumption expenditure, deflator

PGDP: Gross domestic product, deflator, market prices

PIG: Government fixed capital formation, deflator

PIT: Gross total fixed capital formation, deflator

Data for SVAR

Seasonally adjusted series for real GDP and the GDP deflator (acronyms are GDPC1 and GDPPCTPI respectively) are from the Bureau of Economic Analysis. Quarterly average of effective federal fund rate (acronym is FEDFUNDS) is from the Board of Governors of the Federal Reserve System. Quarterly data for fiscal variables are from the OECD Economic Outlook No. 90. Real discretionary government expenditure is the sum of real Government final non-wage consumption expenditure, real Government fixed capital formation and real capital transfers paid and other capital payments. Subsidies are not included as they are not available in quarterly data. Government revenues are Total receipts, general government (acronym is YRGT). Surveys of Professional Forecasters is from the Federal Reserve Bank of Philadelphia. Data are the mean response on Real Federal Government Consumption Expenditures & Gross Investment (RFEDGOV).

CHAPTER 2

The interaction of Fiscal and Monetary Policy Shocks: A Time Varying Parameters FAVAR Approach

1 Introduction

During the recent financial crisis and the Great Recession policy makers intervened with unprecedented monetary and fiscal policies to stabilize the financial markets and sustain the economic activity. Many central banks, after cutting interest rates to low levels, moved onto unconventional monetary policy operations. In advanced countries fiscal authorities implemented fiscal packages to stimulate aggregate demand before turning to contractionary measures in an effort to contain the public debt. Understanding the consequences of these policy responses requires, therefore, a joint analysis of fiscal and monetary policies. However, the existing empirical studies based on structural vector autoregressions (VARs) separately analyze the impact of either monetary policy shocks or fiscal policy shocks, without examining the effects of their interaction. Hence, they assess the consequences of a certain policy regardless the implementation of other policies that may alter the dynamics of economic variables.

The objective of this paper is to investigate how macroeconomic and financial variables react to a combination of fiscal and monetary policy shocks in the U.S. economy. The impulse response of a monetary policy shock is estimated during periods characterized by different fiscal stances, expansionary or contractionary, identified using the narrative approach. In particular, I focus on the reaction of the financial variables that played a key role in the amplification of the liquidity crisis in 2007 - 2009 in order to assess the effectiveness of different policy mix in stabilizing the financial sector.

Recently, the complementary of macroeconomic measures has been the objective of study of several scholars. For instance, an intense debate has followed about the effect of fiscal policy when monetary policy is constrained by the zero lower bound. Woodford (2011) and Christiano et al. (2011) simulate the impact of a government spending shock when the zero lower bound is binding in a dynamic stochastic general equilibrium (DSGE) model. However, they do not extend the analysis running a structural VAR model, because they argue it may be misleading to compare results in countries where the monetary policy is constrained by the zero lower bound and in countries where the monetary policy is not constrained.

One strand of the literature investigates the coordination of fiscal and monetary policy, identifying alternative fiscal and monetary regimes: passive fiscal and active monetary, active fiscal and passive monetary, both active or passive. Leeper (1991) labels as passive the behavior of the authority which is in charge of debt stabilization as opposed to the active behavior of the authority which can be directed towards different objectives. For instance, a fiscal regime is passive where the fiscal authority is in charge of stabilizing the intertemporal budget con-

straint, i.e. reacts to increasing debt levels by generating higher expected primary surpluses, and is active where the monetary authority is in charge of stabilizing the constraint, i.e. reacts to increasing debt levels by generating higher price levels, whereas the fiscal authority does not show any debt stabilizing motive. Davig and Leeper (2011) analyze the interactions of monetary and fiscal policy in a DSGE model in which the policy rules evolve over time following a Markov chain and they compute the government spending multipliers when monetary and fiscal policy regimes vary. In the same vein, Alfonso and Toffano (2013) assess the existence of fiscal regimes coupled with monetary regimes in the U.K., Germany and Italy using Markov Switching fiscal and monetary rules. This paper does not deal with the problem of policy coordination and aims to focus on the combined effects of fiscal and monetary policy, assuming that fiscal and monetary authorities act independently without strategic complementarities. One can argue that fiscal policy has an indirect effect on the reaction function of monetary policy through a variation in inflation and output, but this dynamics takes place at some lags while in this study fiscal and monetary policy shocks are modeled as occurring simultaneously.

Rossi and Zubairy (2011) compare the impact of monetary and fiscal policy shocks in a structural VAR model. They show that failing to take into account that both monetary and fiscal policy shocks simultaneously affect macroeconomic variables incorrectly attributes some macroeconomic fluctuations to the wrong source. They first estimate a structural VAR ordering the fiscal policy instrument, i.e. government spending, first before macroeconomic variables and the monetary policy instrument, i.e. the federal fund rate, last and identify fiscal and monetary policy shocks with the Cholesky decomposition (this identification scheme is common in the literature and applied also by Fatàs and Mihov (2001), Perotti(2004) and Caldara and Kamps (2006)). They perform a counterfactual analysis considering a structural VAR where alternatively only fiscal policy shocks and the monetary policy shocks are present, assuming that the economy is driven by each individual shock, one at a time, and they compare the effects of the two shocks estimating the GDP that would have been observed if only one shock were present. In this way they evaluate the impact of a policy shock ruling out the effect of the other policy shocks and disentangling the consequences of monetary and fiscal policy shocks, while in this work I assess the impact of a monetary policy shock at the same time when a fiscal policy shock affects the economy.

Few empirical works estimate the consequences of a policy shock taking into account the implementation of other policies. Ilzetzki et al. (2011) assess the impact of a fiscal policy shock under different exchange rate regimes. Using a

panel VAR, they estimate the impulse response function of a fiscal policy shock in economies with a flexible or fixed exchange rate regime.

In this work, in order to study the effects of the interaction of fiscal and monetary policy, the structural VAR methods and the “narrative” approach are combined. External information are used to identify fiscal policy shocks as episodes of large, exogenous and unanticipated variation of fiscal variables, on the basis of two sources: Romer and Romer (2010) and Ramey and Shapiro (1998). Romer and Romer (2010) distinguish endogenous tax variations driven by business cycles from exogenous tax variations motivated by the desire to reduce the public deficit (contractionary tax shocks) or to spur the long run growth (expansionary tax shock), by reading presidential speeches and Congressional reports. Ramey and Shapiro (1998), on the basis of contemporary accounts in the press, identify military spending events in the eve of wars as a proxy for exogenous shocks to government spending. They consider the Vietnam war on June 1950, the Vietnam war on November 1963 and the Carter and Reagan buildup in the wake of the Soviet invasion of Afghanistan on January 1980. Eichenbaum and Fisher (2005) and Ramey (2011) add the Bush buildup after the 9/11. In the same period when the U.S. economy registers a tax shock or a government spending shock, a monetary policy shock is simulated by running a Time Varying Parameters Factor Augmented VAR (TVP FAVAR) model. In other words, the impulse response of a monetary shock is estimated concomitant to a fiscal policy shock.

With respect to structural VARs, the advantage of a FAVAR model is twofold. First, VARs can contain only a small number of variables to conserve degrees of freedom. The small information set in these models can lead to problems of information insufficiency and omitted variables bias, because the variables considered do not convey all of the relevant information about the economy considered by agents and policy makers. In this case the VAR innovations will not span the space of the structural shocks, so the structural shocks cannot in general be deduced from the VAR innovations (see Fernandez-Villaverde et al. (2007) and Forni and Gambetti (2011)). By including in the model a small number of unobserved common factors that produce the observed comovements of economic time series is a solution of these problems. Second, a VAR model allows the impulse response analysis only for the few variables included in the model. So they are unable to provide inference on a large number of variables that may be of interest to policy makers. The FAVAR approach incorporates a huge number of information in a parsimonious way, by including few unobserved factors that summarize hundreds of additional variables and which capture the fundamental economic forces. Sargent and Sims (1977) find that two dynamic factors

may explain more than 80% of the variance of major economic variables. These methods for estimating and analyzing dynamic factor models, combined with the empirical evidence that only few dynamic factors are needed to explain the comovement of macroeconomic variables, has motivated the integration of factor methods into VAR. Bernanke and Boivin (2003) show that the use of factors can improve the estimation of Fed's policy reaction function. Bernanke et al. (2005) find that price and liquidity puzzles present in structural VARs disappear when factors are included, suggesting that a FAVAR model is successful in capturing relevant additional information missing from VARs. Other studies that include factor methods into VAR analysis are Favero and Marcellino (2001), Favero, et al. (2004), Giannone et al. (2002, 2005), and Forni et al. (2004)

One limit of FAVAR models with time invarying parameters is that they abstract from the possibility of changes in the policy transmission mechanism and the way the exogenous shocks change over time. Perotti (2005) and Bilbiie et al. (2008) show that the transmission mechanism of fiscal policy changed after 1980 because of the modification in the conduct of monetary policy and the consequence of the increase in asset market participation on private consumption. Boivin and Giannoni (2006) find that domestic transmission of monetary policy has changed over time. Del Negro and Otreck (2008) is the first paper that combines dynamic factor models and parameter instability in order to capture changes in international business cycle. In their study factors are the means to identify international forces driving business cycles and they interpret a variation in the factor volatility as a change in the importance of global and regional shocks. The factor structure is used to extract comovements at global and regional levels and factor loadings are time varying to allow the sensitivity of each country to global shocks to evolve over time because of changes in policy or in the structure of the economy. Liu et al. (2011) estimate a TVP FAVAR model to analyze the international transmission of money supply, demand and supply shocks. They include factors for foreign real activity, foreign inflation and foreign interest rates extracted from separated blocks of data for each variable. Their model allows for time variation in factor loadings and in the variance covariance matrix. Korobilis (2009) and Eickmeier et al. (2011) use a TVP FAVAR model to analyze how the transmission of monetary policy evolved over time. In this study, the time varying structure of the model is crucial, not to analyze the evolution of the transmission mechanism of a policy shock, but to compare the impulse response function of a monetary policy shocks joint with different fiscal policy shocks.

The remainder of the chapter is organized as follows: Section 2 introduces the TVP FAVAR model and explain the estimation procedure; Section 3 discusses the

identification of fiscal and monetary policy shocks; Section 4 shows the empirical results and Section 5 concludes.

2 Methodology

2.1 The Model

The model is a FAVAR with both time-varying coefficients and multivariate stochastic volatility in the common factors residual covariance matrix composed by a factor equation and a VAR equation. The factor equation is

$$X_t = \Lambda^x F_t^x + \Lambda^y F_t^y + u_t \quad (2.1)$$

$$u_t \sim \mathcal{N}(0, H)$$

where F_t^y is a $(M \times 1)$ vector of observable economic variables assumed to have pervasive effects throughout the economy that form a core VAR. It includes industrial production growth, CPI inflation and the federal fund rate. X_t is a $(N \times 1)$ vector of macroeconomic and financial variables ($N \gg M$). This additional information set can be summarized by a $(K \times 1)$ vector of few unobserved factors F_t^x , which represent forces that affect economic variables included in X_t simultaneously. The total number of time series is denoted by $N = (M + K)$ and $F_t = [F_t^x, F_t^y]$ of dimension $(N \times 1)$. Λ^x and Λ^y are factor loading matrices of respective dimensions $(N \times K)$ and $(N \times M)$ relating F_t^x and F_t^y to X_t . The time t observation residual is denoted by the vector $u_t = [u_t^m, 0_{m \times 1}]$. The innovation term u_t has mean 0 and covariance H , which is assumed to be diagonal and including zero elements for the variances of the core VAR process F_t^y in the FAVAR. Hence, the error terms of the observable variables are mutually uncorrelated at all leads and lags, namely

$$E[u_{i,t} F_t] = 0$$

$$E[u_{i,t} u_{j,s}] = 0$$

for all $i, j=1, \dots, N \wedge t, s=1, \dots, T$ and $i \neq j \wedge t \neq s$. The working hypothesis of the FAVAR model is that while a narrow set of variables F_t^y , notably the policy instrument of the central bank, are perfectly observable and have pervasive effects on the economy, the underlying dynamics of the economy are less perfectly observable, and hence a VAR in just a few key variables would potentially suffer from omitted variable bias. As increasing the size of a VAR is impractical due to problems of dimensionality, the FAVAR approach aims to extract the common

dynamics from a wide information set X_t , and to include these in the VAR, represented by a small number of factors F_t^x . The information set X_t is assumed to be driven by observable variables with pervasive effects on the economy, F_t^y , and a small number of unobservable common factors, F_t^x , which together represent the main driving forces of the economy, and an idiosyncratic component u_t .

The joint dynamics of the factors F_t are given by the following VAR(P) process with drifting parameters and volatilities

$$F_t = \Phi_{1,t}F_{t-1} + \dots + \Phi_{p,t}F_{t-p} + v_t \quad (2.2)$$

$$v_t \sim \mathcal{N}(0, \Omega_t)$$

where

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' (A_t')^{-1}$$

$$v_t = A_t^{-1} \Sigma_t \epsilon_t$$

$$E[\epsilon_t \epsilon_t'] = I_K$$

where u_t is the time t vector of innovations and ϵ_t is the time t vector of structural shock both of dimension $(K \times 1)$, where $K = [K_x + K_y]$ denotes the total number of factors and observed variables. The contemporaneous relations of the shocks and the factors are represented through the matrix A_t of dimension $(K \times K)$. From the above triangular reduction it follows that

$$A_t = \begin{bmatrix} 1 & 0 & \dots & 0 \\ \alpha_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{K1,t} & \dots & \alpha_{KK-1,t} & 1 \end{bmatrix} ; \quad \Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \dots & 0 \\ 0 & \sigma_{2,t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_{K,t} \end{bmatrix}$$

Equation (2) can be rewritten in a more compact way:

$$F_t = Z_t' \Phi_t + A_t^{-1} \Sigma_t \epsilon_t \quad (2.3)$$

$$Z_t' = I_n \otimes [F_{t-1}, \dots, F_{t-p}]$$

Let α_t the vector of non-zero and non-one elements of matrix A_t and σ_t the vector of the diagonal elements of the matrix Σ_t . Parameters Φ_t and α_t evolve as driftless random walks and σ_t as geometric random walk ¹

¹This is a common specification in time varying parameter models, see e.g. Nyblom (1989). Giordani and Kohn (2008), Koop at al. (2009) and Korobilis (2009) use the mixture innovation

$$\Phi_t = \Phi_{t-1} + \eta_t^\Phi \quad , \quad \eta_t^\Phi \sim \mathcal{N}(0, Q) \quad (2.4)$$

$$\alpha_t = \alpha_{t-1} + \eta_t^\alpha \quad , \quad \eta_t^\alpha \sim \mathcal{N}(0, S) \quad (2.5)$$

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t^\sigma \quad , \quad \eta_t^\sigma \sim \mathcal{N}(0, W) \quad (2.6)$$

The vector of all innovations in the model is given by $e_t = (u_t, \epsilon_t, Q_t, S_t, W_t)$ and is assumed to be jointly normally distributed given by

$$e_t = \mathcal{N} \left(\begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} u_t & 0 & 0 & 0 & 0 \\ 0 & \epsilon_t & 0 & 0 & 0 \\ 0 & 0 & Q_t & 0 & 0 \\ 0 & 0 & 0 & S_t & 0 \\ 0 & 0 & 0 & 0 & W_t \end{bmatrix} \right)$$

where Q, S, W are positive definite matrices. Following Primiceri (2005), S is restricted to be block diagonal, where each block corresponds to parameters belonging to separate equations. In other words, the coefficients of the contemporaneous relations among variables are assumed to evolve independently in each equation.

2.2 Estimation

2.2.1 Estimation strategy

The model can be represented in a state-space form in which the measurement equation is the factor equation and the state equation is the VAR equation. Equation (2.1) and (2.2) can be written in the following way:

$$\tilde{X}_t = L F_t + u_t \quad (2.7)$$

$$F_t = \Phi(L)F_{t-1} + v_t \quad (2.8)$$

where $\tilde{X}_t = [X_t', F_t']$ and $L = \begin{bmatrix} \Lambda^x & \Lambda^y \\ 0 & I_K \end{bmatrix}$ is a block matrix of factor loadings.

approach for the dynamics of parameters instead of normal innovations. In this set up the random walk is augmented with a mixture innovation specification and one component follows a 0/1 Markov process allowing the model to be time varying at some points and constant at other ones. Another alternative consists in modeling time variation as the result of switching across regimes, as in Sims and Zha (2006), or as structural breaks as in Doyle and Faust (2005).

The model is estimated in two stages. The first stage involves estimating the unobserved factors F_t as first principal components of X_t in equation (2.7), obtaining \hat{F}_t . Hence, common factors are treated as data and included in equation (8) with F_t replaced by \hat{F}_t . The second stage consists in estimating the parameters of the TVP FAVAR model in equation (8) via Bayesian methods.

Principal components can be easily computed when the cross-sectional dimension N is large. Forni et al. (2000) and Stock and Watson (2002) show that principal components are consistent estimators of the common factors for both the cross-sectional dimension N and the sample size T going to infinity for any path of N and T . Principal component estimators are consistent even if there is some time variation in the loading parameters, as argued by Stock and Watson (2009). An alternative approach consists in estimating equation (10) and equation (11) simultaneously by Gaussian maximum likelihood (ML) or by Quasi ML using the Kalman filter. Doz et al. (2011) show that ML estimates of the common factors are also consistent for N and T going to infinity along any path, however the estimation by ML estimator is cumbersome for large N .² In this study the two-step approach is more suitable as it is computationally less burdensome, considering the high number of parameters to estimate, and it requires weaker distributional assumptions of residuals. Moreover, Bayesian methods deal efficiently with the nonlinearities of the model splitting the original estimation problem in smaller and simpler ones.

In order to determine the number of factors to estimate, I computed the panel criteria proposed by Bai and Ng (2002) applied to the X_t matrix. Table 2.1 displays the results for different criteria and suggests the presence of three factors. The test is computed with maximum 3 factors because the size of the Z_t matrix increases exponentially with the number of variables leading to the curse of dimensionality.³ The principal components are then estimated using the singular value decomposition.

In order to uniquely identify factors against rotational, scale and sign indeterminacy restrictions are imposed to model. Factors are restricted by $T^{-1}F'F = I_n$, obtaining $\hat{F} = \sqrt{T}\hat{Z}$, where \hat{Z} is the matrix of eigenvectors associated with the r largest eigenvalues of the sample variance matrix of X_t , $\hat{\Sigma}_X = T^{-1} \sum_{t=1}^T X_t X_t'$, sorted in descending order to deliver the common components $F\Lambda^{f'}$ and the factor space.

²To measure the effects of monetary policy Bernanke et al. (2005) estimate a FAVAR model using both the two-step principal components approach and the single-step likelihood method and obtain essentially the same results. Liu et al. (2009) and Mumtaz and Surico (2011) follow the one-step strategy proposed by Bernanke et al. (2005) based on Gibbs sampling for the estimation of TVP FAVAR models. Instead, Korobilis (2009) and Eickmeier et al. (2011) estimate the factors as first principal components.

³See Bai and Ng (2002) for more details about the information criteria and their properties.

The model is estimated by simulating the distribution of the parameters of interest, given the data. I apply a Gibbs sampling algorithm with the conditional prior and posterior distributions described below.

2.2.2 Prior distributions and initial values

The choice of the prior distributions follows Bernanke et al. (2005) and Korobilis (2009) for the measurement equation and Primiceri (2005) for the state equation. In equation (2.7) an uninformative prior distribution is used for the matrix of loadings $L = \begin{bmatrix} \Lambda^f & \Lambda^y \\ 0 & I \end{bmatrix}$ and the inverse gamma distribution for the diagonal elements of H :

$$L_0 \sim N(0, 4I)$$

$$H_0 \sim iG(a_0, b_0)$$

where $a_0 = 0.01$ and $b_0 = 0.01$ denote the scale parameter and the shape parameter respectively. In equation (8) diffuse priors based on OLS estimations on the overall sample are used and initial states for all the parameters are independent. In particular, for Φ_t and A_t Normal priors are considered and the mean and variance are chosen to be OLS point estimates and four times its variance in a time invariant VAR. Elements of Σ_t are assumed to follow a log Normal distribution. The mean of the distribution is chosen to be logarithm of the OLS point estimates of the standard errors of the same time invariant VAR, while the variance covariance matrix is assumed to be the identity matrix. The priors for the hyperparameters Q_t , W_t and S_t are assumed to be distributed as independent inverse-Wishart. Summarizing, the priors in the state equation take the following forms:

$$\Phi_0 \sim N(\hat{\Phi}, 4V(\hat{\Phi}))$$

$$A_0 \sim N(\hat{A}, 4V(\hat{A}))$$

$$\log \sigma_0 \sim N(\log \hat{\sigma}, I_n)$$

$$Q \sim iW(k_\Phi^2 \cdot (1 + n_\Phi) \cdot V(\hat{\Phi}), 1 + n_\Phi)$$

$$S \sim iW(k_\alpha^2 \cdot (1 + n_\alpha) \cdot V(\hat{I}_n), 1 + n_\alpha)$$

$$W \sim iW(k_\sigma^2 \cdot (1 + n_\sigma) \cdot V(\hat{A}), 1 + n_\sigma)$$

where n_θ denotes the number of elements on each state vector $\theta = \Phi, \alpha, \sigma$; k_θ are tuning constant: $k_\Phi = 0.07$; $k_\alpha = 0.1$; $k_s = 0.01$.

2.2.3 Simulating the posterior distributions

The factor loadings in equation (2.7) are sampled from the following Normal distribution:

$$L_i \sim N(L^*, M^*)$$

where $L^* = M^* + H_{i,i}^{-1} \cdot FY' \cdot X_{i,t}$ and $M^* = (4I + H_{i,i}^{-1} + FY' \cdot FY)^{-1}$. $H_{i,i}$ denotes variance parameter in the prior on the coefficients of the i -th equation, L_i . Since the errors are assumed uncorrelated and the variance covariance matrix is diagonal, OLS are applied equation by equation to obtain the matrix of factor loadings \hat{L} and the residuals $\hat{\epsilon}$. The diagonal elements $H_{i,i}$ are drawn from the following inverse gamma distribution:

$$H_{i,i} \sim iG(a^*, b^*)$$

where $a^* = \frac{a_0}{2} + \frac{T}{2}$ and $b^* = \frac{b_0}{2} + \hat{\epsilon}'_i \hat{\epsilon}_i$. For equation (7) a Gibbs sampling procedure is applied drawing sequentially time varying coefficients (Φ_t), simultaneous relations (A_t), volatilities (Σ_t) and hyperparameters (Q_t , W_t and S_t), conditional \tilde{X}_t and all other parameters. This amounts to reducing a complex problem into a sequence of tractable ones, sampling from conditional distributions for a subset of parameters conditional on all the other parameters. In the first block Φ_t is drawn conditional on $\tilde{X}_t, A_t, \Sigma_t$ and hyperparameters. In the second block A_t is drawn conditional on $\tilde{X}_t, \Phi_t, \Sigma_t$ and hyperparameters. In the third block Σ_t is drawn conditional on \tilde{X}_t, Φ_t, A_t , and hyperparameters. Finally, the hyperparameters Q_t , W_t and the diagonal blocks in S_t are drawn from inverse-Wishart posterior distributions independent each other conditional on and FY_t, Φ_t, A_t and Σ_t .⁴ In the first three blocks I reduce the problem into three state space linear and Gaussian forms and apply the Carter and Kohn (1994) algorithm.⁵

The first step consists in drawing coefficient states Φ_t from the linear and Gaussian state space form given by equations (2.3) and (2.4) using Kalman filter and backward recursion. The second step consists in drawing the covariance states, considering equation (2.3) as the following:

$$A_t(\tilde{Y}_t - Z'_t \Phi_t) = A_t \hat{y}_t = \Sigma_t \epsilon_t \tag{2.9}$$

⁴I use 20,000 replications in these Gibbs runs discarding the first 2,000 as burn-in.

⁵See the appendix B for a complete description of the algorithm.

Since A_t is a lower triangular matrix with ones on the main diagonal, equation (2.9) can be written as

$$\hat{y}_t = \tilde{Z}_t \alpha_t + \Sigma_t \epsilon_t \quad (2.10)$$

where α_t is defined in equation (2.5). \tilde{Z}_t is the following matrix

$$\tilde{Z}_t = \begin{bmatrix} 0 & \dots & \dots & 0 \\ -\hat{y}_{1,t} & 0 & \ddots & 0 \\ 0 & -\hat{y}_{[1,2],t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & -\hat{y}_{[1,\dots,n-1],t} \end{bmatrix}$$

where $\hat{y}_{[1,\dots,i],t}$ denotes the row vector $[\hat{y}_{1,t}, \hat{y}_{2,t}, \dots, \hat{y}_{i,t}]$. Intuitively, equation (10) is equivalent to regressing the error term of the VAR on other error terms according to the lower triangular structure. Equations (2.10) and (2.5) form a Gaussian but non linear state space model. However, under the additional assumption of S block diagonal, this problem can be solved by applying the Kalman filter and backward recursion equation by equation.

The third step consists in drawing covariance states. Consider the system of equations

$$A_t(\tilde{Y}_t - Z_t' \Phi_t) = y_t^* = \Sigma_t \epsilon_t \quad (2.11)$$

where, taking Φ_t and A_t as given, y_t^* is observable. This system of nonlinear measurement equations is converted in a linear one, by squaring and taking logarithm of every elements of equation (2.11). A constant \bar{c} is used to make the estimation procedure more robust. I obtain the following state space form

$$y_t^{**} = 2h_t + e_t \quad (2.12)$$

$$h_t = h_{t-1} + \xi_t \quad (2.13)$$

where $y_{i,t}^{**} = \log[(y_{i,t}^*)^2 + \bar{c}]$; $e_{i,t} = \log(e_{i,t}^2)$; $h_{i,t} = \log \sigma_{i,t}$; $E[e_t, \xi_t] = 0$. Since $e_t \sim \log \chi^2(1)$ the system is linear but not Gaussian. In order to convert the system in a Gaussian one, a mixture of seven Normals approximation for any elements of e is used as the variance covariance matrix of e_t is diagonal, following the approach in Kim, Shephard and Chib (1998).

3 Identification of Monetary and Fiscal Policy Shocks

The identification of monetary and fiscal policy shocks is achieved by combining the narrative approach and the structural VAR methods. The monetary policy shock is identified following the strategy of Bernanke, Boivin and Elias (2005). Their scheme entails partitioning the series into three groups: slow-moving variables, federal fund rate and fast-moving variables. The economic intuition is that the slow-moving variables, such as employment and prices, are assumed to be unaffected within the month by the monetary policy shock or by shocks to financial markets. The shocks to slow variables are assumed to be observed by the monetary authority, so that the monetary policy instrument (the federal fund rate) is a function of the shock to slow variables, the monetary policy shock and an idiosyncratic disturbance. Finally, the remaining fast-moving variables, such as stock returns, other interest rates and exchange rates, are assumed to be affected by the slow and monetary policy shocks instantaneously. In order to implement this scheme, first, principal components (\hat{C}_t^s) are extracted from slow-moving variables. Then, principal components (\hat{C}_t) extracted from the overall information set are regressed on the slow moving factors and the federal fund rate (r_t):

$$\hat{C}_t = b_c \hat{C}_t^s + b_r r_t + e_t \quad (2.14)$$

Finally, \hat{F}_t^x is obtained from $\hat{C}_t - \hat{b}_r r_t$ to control for the part of \hat{C}_t that correspond to the federal fund rate. Cholesky identification is employed imposing a contemporaneous recursive structure where the estimated factors \hat{F}_t^x are ordered first before the core VAR factors F_t^y . In the core VAR industrial production growth is ordered first before CPI inflation and the monetary policy instrument is ordered last in F_t^y . A drawback of the recursive scheme is the assumption that components of estimated factors respond to the monetary and fiscal policy shocks at one lag. An alternative identification is to extract slow-moving and fast moving factors from the respective blocks of data and order slow-moving factors before the observed factors and fast-moving factors last. However, the first principal component of fast-moving variables turn out to be highly correlated with the federal fund rate (the coefficient of correlation = 0.973) and this would introduce collinearity in the system.

Fiscal policy shocks are identified following the narrative approach, which is an alternative methodology for the identification of policy shocks through non-statistical procedures, by extracting information from historical records, such as government reports and speeches, monetary policy committee, documents and IMF reports. This procedure allows to isolate episodes of exogenous varia-

tions of fiscal and monetary variables from endogenous movements induced by business cycles and other non-policy influences. Romer and Romer (1989) introduced this methodology to construct monetary policy innovations, consulting the transcripts from FOMC meetings. Ramey and Shapiro (1998), on the basis of contemporary accounts in the press, identify military spending events as a proxy for exogenous shocks to government spending. They argue that fiscal policy shocks identified via SVAR model, such as in Fatàs and Mihov (2001) and Blanchard and Perotti (2002), are largely anticipated by the private sector because of the delay between the policy decision and the policy implementation. They isolate the deviation from the normal path of the endogenous variables caused by military buildups driven by foreign policy, therefore not related to the business cycle. They identify three episodes of expansionary defense spending interpreted as exogenous and unforeseen: the Korean war, the Vietnam war, and the Carter-Reagan buildup. Eichenbaum and Fisher (2004) and Ramey (2011) add the Bush buildup after the 9/11. Romer and Romer (2010) employ the narrative approach to distinguish between endogenous and exogenous tax variations. Endogenous tax changes are those countercyclical or undertaken because government spending was changing. Exogenous tax changes are those taken to reduce an inherited budget deficit and spur the long run growth. Devries et al. (2011) follow a similar procedure to identify episodes of fiscal consolidation for OECD countries. Using the records available in the official documents, they examine policy makers' intentions and actions as described in contemporaneous policy documents, that represent a response to past decisions and economic conditions rather than to current or prospective conditions and identify the size, timing and principal motivation for the fiscal actions taken by each country.

For the purpose of this study I consider three episodes of fiscal policy shocks. A contractionary tax shock, an expansionary tax shock and an expansionary government spending shock. Tax shocks are selected from those identified by Romer and Romer (2010) and reported in Romer and Romer (2009). I consider two shocks that are the largest in their sample, exogenous and unanticipated. In addition, the choice has been restricted among those occurred during the Great Moderation to avoid structural changes in the U.S. economy that may affect the impulse response of a monetary policy shock. For this reason, shocks in the early 1980s and after the global financial crises have not been considered. On the basis of these criteria the *Omnibus Budget Reconciliation Act of 1993* is selected for contractionary tax changes and the *Jobs and the Growth Tax Relief Reconciliation Act of 2003* for expansionary tax changes.⁶

⁶Another important episode of tax hikes was the *Omnibus Budget Reconciliation Act of 1987*,

The *Omnibus Budget Reconciliation Act of 1993* was enacted on August 10. “The motivation for this tax change was deficit reduction. In a speech to Congress describing his economic proposals, President Clinton called for a deficit reduction program that will increase the savings available for the private sector to invest, will lower interest rates, will decrease the percentage of the Federal budget claimed by interest payments, and decrease the risk of financial market disruptions that could adversely affect the economy. [...] A desire to offset short-term cyclical factors was never mentioned as a reason for the changes. Thus, this tax change is clearly an exogenous, deficit-driven action. [...] The bill also included provisions calling for substantial spending cuts. The administration estimated the reductions, including lower interest payments because of lower deficits, at \$255 billion over five years. CBO estimated the reductions, excluding reduced interest payments, as \$146 billion over the same period. [...] Roughly two-thirds of the additional revenues came from higher marginal rates on high-income individuals (from both the regular income tax and the repeal of the cap on income subject to the Medicare tax). The remaining third came from a wide array of sources. The changes were almost all intended to be permanent.”⁷

The *Jobs and the Growth Tax Relief Reconciliation Act* was signed on May 28 2003. “The tax cuts were motivated by both long-run and short-run considerations. The long-run motivation for the tax cut was the belief that lower marginal tax rates and lower taxes on capital income would increase long-run growth. But short-run considerations were also a crucial motivation for the tax cuts. [...] What is harder to determine is whether the short-run goal was to offset prospective economic weakness or to achieve above-normal growth in order to bring output closer to potential and reduce unemployment. [...] Although Bush’s statements do not make it clear whether the short-run motivation for the plan was to return growth to normal or to achieve above-normal growth, two other administration documents provide strong support for the view that the goal was to produce above-normal growth. [...] As this discussion makes clear, the bill made several major changes to the tax code. Most notably, it reduced marginal rates, lowered taxes on dividends, and increased investment incentives. The investment incentives were clearly intended to be temporary. The other provisions were legislated as temporary

motivated by deficit reduction and putting the social security system on a sustainable footing. The tax hike had an estimated budgetary impact of \$10.8 billion (p. 77). However, these tax hikes were partly offset by a tax cut associated with the *Tax Reform Act of 1986*. As Romer and Romer (2009) explain, this tax cut was motivated by the need to simplify the tax system, and not in response to short-term economic developments, and the budgetary impact was \$7.2 billion. Therefore, the net tax hike amounted to \$3.6 billion (10.8, -7.2) in 1988. For this reason I do not include this episode.

⁷Romer and Romwer (2009).

(although the dividend cuts were scheduled to last a substantial time), but it is clear that their supporters intended them to be permanent. In 2003Q3 the tax cut amounted to \$126.4 billions.”⁸

To the sake of comparison, the American Recovery and Reinvestment Act (ARRA), enacted in February 2009, is the biggest fiscal stimulus of the U.S. history, but is highly endogenous to the state of the economy and largely anticipated by economic agents, because preceded by a long-lasting debate and it cannot be considered as an exogenous and unexpected fiscal shock.

The expansionary government spending shock is identified using the military date variables. I consider the government spending shock in 9/11 because its effects are more comparable with those of tax shocks since they occurred in a short spell of time. Figure 2.3 shows the magnitude of these shocks on total government spending. Not only defense spending growth but also total public spending growth peaks following the military buildups episodes, suggesting that variations in military spending account for a large part of variations in total government spending.⁹

Finally, to compare the impulse response function of a monetary policy shock combined with a fiscal policy shock we consider the 06:2006 as a benchmark. There are no economic reasons for the choice of this period, except that no fiscal and monetary policy shocks are registered in U.S. economy in this time, and is also selected by Korobilis (2009) to analyze the evolution of the transmission mechanism of a monetary policy shock.

4 Results

Figures 2.4-2.7 display the median of the posterior distributions of the impulse responses to a negative monetary policy shock combined with different fiscal policy shocks. Figure 2.4 compares the impact of a monetary policy shock on macroeconomic variables with and without an expansionary government spending shock. In both cases inflation surges after one month and then decreases persistently. The price puzzle present in the TVP VAR of Primiceri (2005) strongly reduces when the VAR model is augmented with principal components extracted from

⁸Romer and Romer (2009).

⁹A criticism of this identification concerns the assumption that military spending is completely exogenous to the business cycle and that the transmission mechanism of fiscal policy during wartime and peaceful is similar. As the data used in this analysis are monthly to trace the reaction of financial markets to policy changes and avoid problem of time aggregation, the employ of military dates is more suitable to capture exogenous shifts in fiscal policy. Moreover, it allows to examine the reaction of financial markets to unexpected fiscal news.

of a large information set. Interestingly, the response of industrial production differs in the two scenarios. In "normal times" a tightening in monetary policy leads to a contraction in economic activity. However, when a negative policy shock is combined with a positive government spending shock the response of industrial production is positive for 11 months and then becomes negative. Two main conclusions can be derived. First, the impact of a change in monetary policy on the industrial production varies under different fiscal policy regimes. Second, the contractionary effect of a negative monetary policy shock is offset by the expansionary effect of a positive government spending shock. Inverting the sign of the shocks, we can infer that an accommodative monetary policy cannot stimulate the economic activity in the short run if combined with a fiscal adjustment based on spending cuts.

Figure 2.5 shows the effects of a monetary policy shock on macroeconomic variables joint with an expansionary tax shock and a contractionary tax shock. The response of inflation is negative, in all the scenarios. Industrial production declines, but with different shapes in the three cases. The reduction of the economic activity is larger with a negative tax shock than with an expansionary tax shock. Comparing the consequences of a negative monetary policy shock on economic activity combined with a positive tax shock and a positive government spending shock, we can note that in the latter case the policy mix is more effective in sustaining the economic activity.

Figure 2.6 plots the response of financial variables to a negative monetary policy shock combined with a positive government spending shock. Small differences emerge in the impulse response function of a monetary policy shock on financial variables with and without a government spending shock, except for the equity prices. The S&P 500 Stock Price Index slightly fall on impact and after two months it rises, but it is dampened with the occurrence of a positive government spending shock. The response of the 10-year Treasury rate, closely tracks the one of the federal fund rate. Figure 2.6 also compare the impact of a monetary policy shock on three different spreads: the BAA-AAA spread, the TED spread and the external risk premium. Figure 2.2 displays the sudden rise in these spreads during the recent financial crisis. Taken together, these indicators are a proxy of financial conditions. The BAA-AAA spread, the difference between the BAA corporate bond yields and the AAA corporate bond yields, is a measure of credit spread which indicates that the BAA securities become less liquid. Hence, a spike of this index suggests a period of stress in credit markets. The TED spread is the difference between the risky 3-month LIBOR rate and the risk-free 3-month Treasury bill rate and is a proxy for U.S. liquidity pressure. Further, Treasury

bonds become more attractive, as banks want to get first-rate collateral, and the Treasury bond yield fall. Figure 2.2 shows that in times of financial stress the TED spread widens because banks charge higher interest for unsecured loans, which increases the LIBOR rate. This happened in August 2007 and in October 2008 after the collapse of Lehman Brother, showing signs of credit market deteriorations. The external finance premium, the difference between the bank prime loan and the 3-month Treasury bill rate, measures the premium that firms pay when raise funds externally asking a credit to banks. The BAA-AAA spread and the external finance premium spike on impact but after 2 months the effect is negative and persistent. The reaction of the TED spread to a monetary policy shock is positive and revert to its initial level slowly. The response of spreads to a negative monetary policy shock seems not affected by the occurrence of a positive government spending shock.

Figure 2.7 displays the impact of a negative monetary policy shock on financial variables with an expansionary tax shock and a contractionary tax shock. The reaction of equity prices to a monetary policy shock is positive with an expansionary tax shock and contractionary with a negative tax shock, suggesting that the sign of the impulse response function depends on the stance of fiscal policy. The response of the other financial variables, is similar when the monetary policy shock is combined with an expansionary tax shock and a contractionary tax shock, except for the reaction of the BAA-AAA spread and TED spread to a policy mix of negative monetary policy and positive fiscal policy. In this case spreads are higher than with a neutral and an expansionary fiscal policy.

To sum up we observe that the reaction of economic activity to a monetary policy shock varies when combined with different fiscal policy shocks. In particular, the contractionary effect of a negative monetary policy shock is mitigated by a positive tax shock. Moreover, a policy mix based on a tightening in monetary policy and an increase in government spending seems more expansionary than with a fall in tax rates. The response of financial variables to a negative monetary policy shock is similar with different fiscal stances, except equity prices, which increase with a a positive government spending shock and a negative tax shock and fall with a positive tax shocks.

5 Conclusions

A strand of the empirical literature examines the evolution of monetary policy over the past years applying econometric models with time varying parameters. This paper using a Time Varying Parameters FAVAR model studies the interaction

of fiscal and monetary policies in the U.S economy. The time varying structure of the model allows to simulate the impact of a monetary policy shock, identified with Structural VAR methods, in the same period of a fiscal policy shock, identified with the narrative approach. This procedure permits to analyze the effects of a combination of fiscal and monetary policy shocks on real and financial variables. A second main contribution of this paper is that, by including factors in the model, extends the impulse response analysis on several financial variables, which played a key role in the propagation and amplification of a financial shock during the recent crisis. Assessing the reaction of financial variables to different policy mix provide new insights on the transmission mechanism of monetary and fiscal policy.

Results show that the contractionary effect of a negative monetary policy shock on economic activity can be offset by a positive government spending shock or a positive tax shock. They also suggest that a loose monetary policy cannot stimulate the economy in the short run when combined with a fiscal adjustment, especially if based on spending cuts, which is the policy mix currently adopted in most of the European countries. However, it can alleviate tensions in financial markets.

An extension of this work will be considering the case of a small open economy, such as Canada, to investigate whether the effects of different policy mix are different from a big closed economy, consistent with the Mundell-Fleming model.

Figures and tables

Table 2.1: Number of common factors

Number of factors	IC_1	IC_2	IC_3	PC_1	PC_2	PC_3	BIC_3	AIC_3
0	-0.0021	-0.0021	-0.0021	0.9979	0.9979	0.9979	0.9979	0.9979
1	-0.2489	-0.2465	-0.2566	0.7680	0.7692	0.7639	0.8059	0.7531
2	-0.4304	-0.4257	-0.4458	0.6412	0.6437	0.6330	0.7168	0.6114
3	-0.4845	-0.4774	-0.5076	0.6095	0.6133	0.5973	0.7227	0.5648

Test Bai-Ng (2002)

Figure 2.1: Principal components

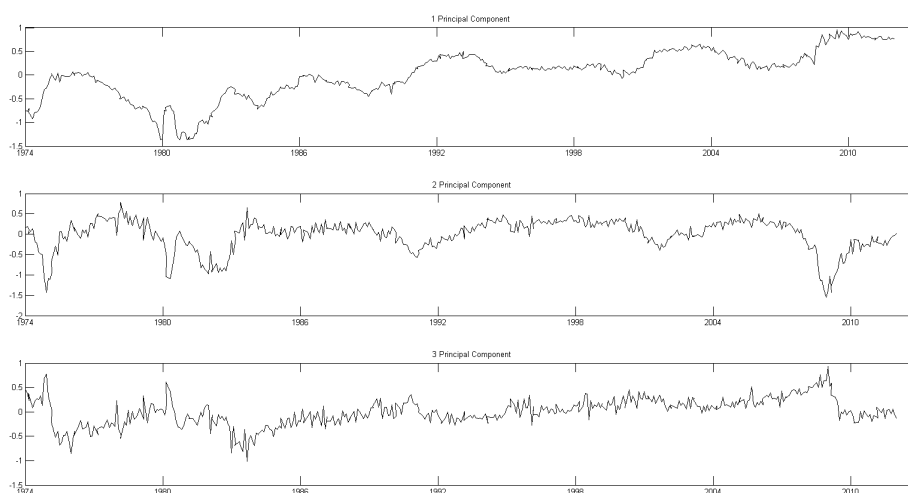


Figure 2.2: Financial variables during the crisis

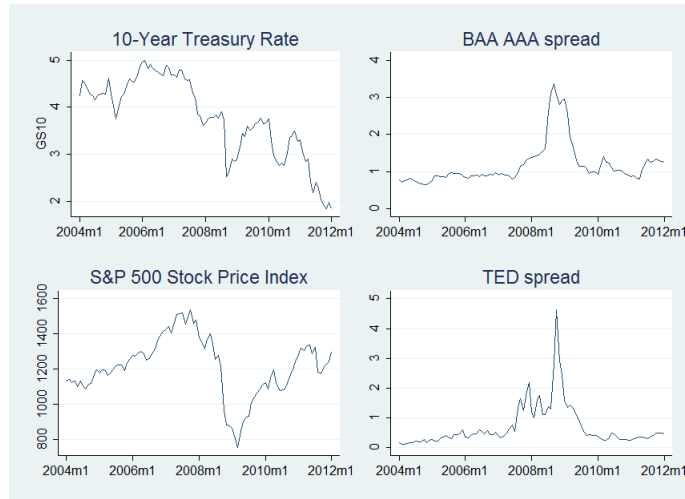
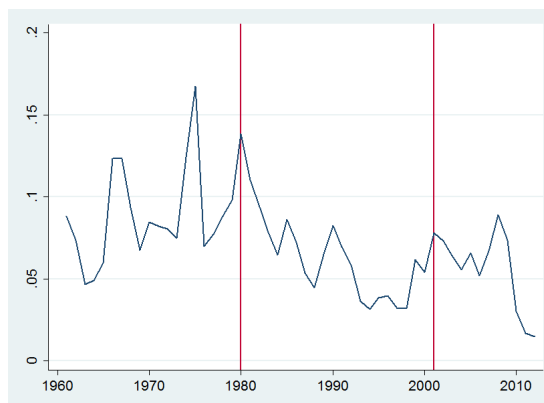
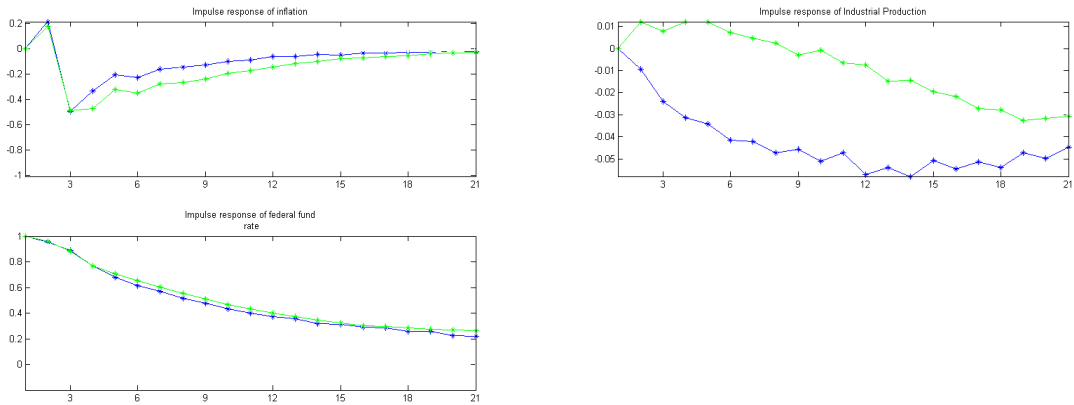


Figure 2.3: Military buildups and government spending growth.



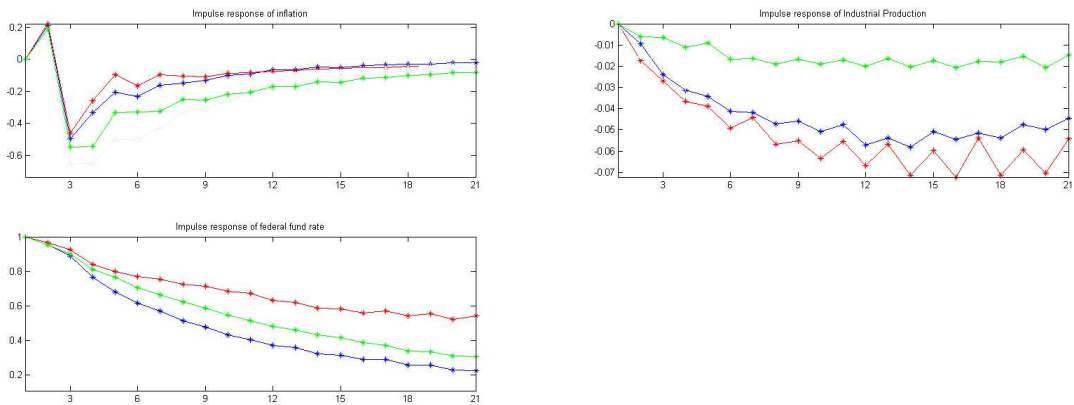
The red lines indicate the episodes of military buildups in 1980 and 2001.

Figure 2.4: Impulse responses of macroeconomic variables to a negative monetary policy shock with and without a government spending shock



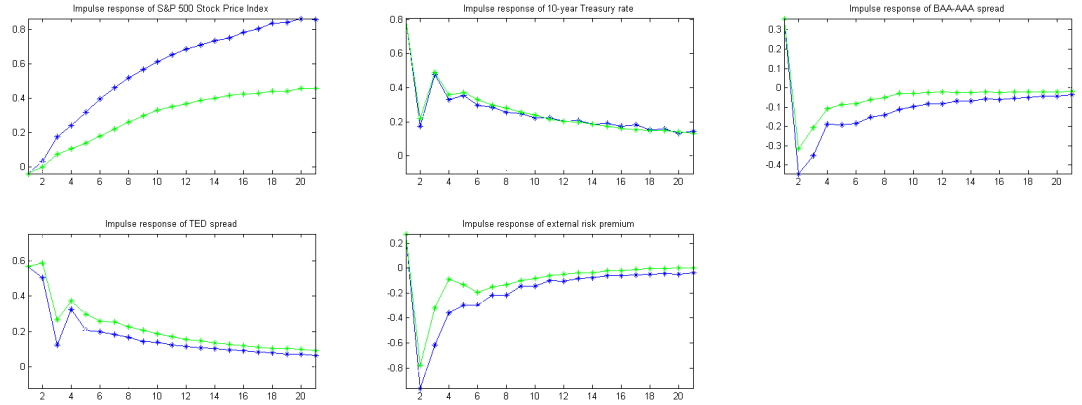
Note: the green line represents the impulse response with an expansionary government spending shock (2001:10) and the blue line without a government spending shock (2006:06).

Figure 2.5: Impulse responses of macroeconomic variables to a negative monetary policy shock with and without a tax shock



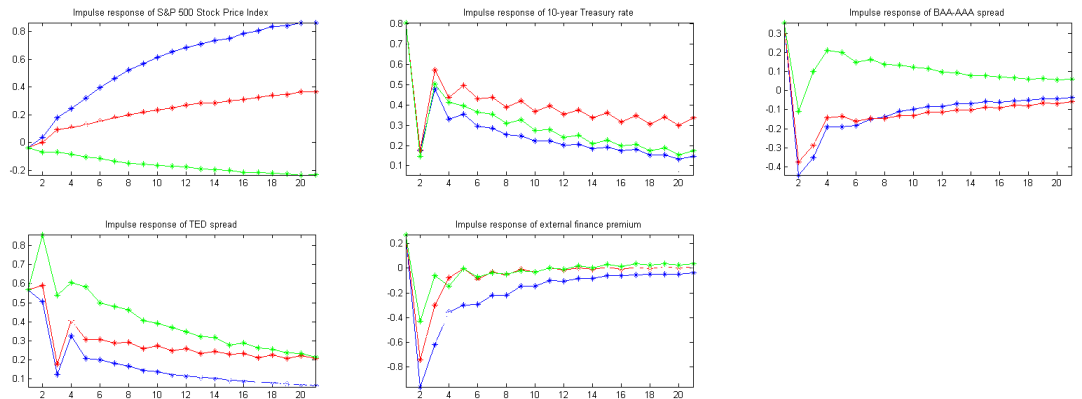
Note: the green line represents the impulse response with a contractionary tax shock (1993:11), the red line with an expansionary tax shock (2003:06) and the blue line without a tax shock (2006:06).

Figure 2.6: Impulse responses of financial variables to a negative monetary policy shock with and without a government spending shock



Note: the green line represents the impulse response with an expansionary government spending shock (2001:10) and the blue line without a government spending shock (2006:06)

Figure 2.7: Impulse responses of financial variables to a negative monetary policy shock with and without a tax shock.



Note: the green line represents the impulse response with a contractionary tax shock (1993:11), the red line with an expansionary tax shock (2003:06) and the blue line without a tax shock (2006:06)

Appendix A: Data

The dataset contains macroeconomic and financial variables spanning from 01:1973 to 01:2012. All series are downloaded from St. Louis' FRED database and they are seasonally adjusted (either by taking seasonally adjusted from the original sources or by applying the X-12-ARIMA seasonal adjustment program of the U.S. Census Bureau). Spreads are calculated by the author. All variables are transformed to be approximate stationary. The transformation codes are: 1 - no transformation; 2 - first difference; 4 - logarithm; 5 - first difference of logarithm. Following Bernanke et al. (2005), the fast moving variables are interest rates, stock returns, exchange rates, monetary aggregates and loans. Slow = 1 indicates that a variable is slow-moving. All variable descriptions and pneumonics are from the original source, except spreads.

Table 2.2: Information set

No.series	Mnemonic	Slow	Transformation	Description
1	AHETPI	1	5	Aver. Hourly Earn. of Prod. and Nonsuperv. Employees
2	AMBSL	0	5	St. Louis Adjusted Monetary Base
3	CANDH	1	1	Chicago Fed Nat. Act. Index: Personal Consumpt. and Hous.
4	CFNAI	1	1	Chicago Fed Nat. Act. Index
5	DSPI	1	5	Disposable Personal Income
6	EMRATIO	1	1	Civilian Employment-Population Ratio
7	HOUST	0	4	Housing Starts: Total: New Priv. Owned Housing Units Started
8	HOUST1F	0	4	Privately Owned Housing Starts: 1-Unit Structures
9	HOUST2F	0	4	Housing Starts: 2-4 Units
10	HOUST5F	0	4	Privately Owned Housing Starts: 5-Unit Structures or More
11	M1SL	1	5	M1 Money Stock
12	M2SL	1	5	M2 Money Stock
13	PANDI	1	1	Chicago Fed National Activity Index: Production and Income
14	PAYEMS	1	5	All Employees: Total nonfarm
15	PCE	1	5	Personal Consumption Expenditures
16	PCEDG	1	5	Personal Consumption Expenditures: Durable Goods
17	PCEND	1	5	Personal Consumption Expenditures: Nondurable Goods
18	PCES	1	5	Personal Consumption Expenditures: Services
19	PERMIT	1	4	New Private Housing Units Authorized by Building Permits
20	SOANDI	1	1	Chicago Fed National Activity Index: Sales, Orders and Invent.
21	TCU	1	1	Capacity Utilization: Total Industry
22	UNEMPLOY	1	5	Unemployed
23	UNRATE	1	1	Civilian Unemployment Rate
24	USEHS	1	5	All Employees: Education & Health Services
25	USFIRE	1	5	All Employees: Financial Activities
26	USGOVT	1	5	All Employees: Government
27	USINFO	1	5	All Employees: Information Services
28	USLAH	1	5	All Employees: Leisure & Hospitality
29	USPRIV	1	5	All Employees: Total Private Industries
30	USSERV	1	5	All Employees: Other Services
31	USTRADE	1	5	All Employees: Retail Trade
32	USWTRADE	1	5	All Employees: Wholesale Trade
33	SP500	0	5	S&P 500 Stock Price Index
34	DJIA	0	5	Dow Jones Industrial Average
35	DJUA	0	5	Dow Jones Utility Average
36	DJCA	0	5	Dow Jones Composite Average
37	NFCI	0	1	Chic. Fed Nat. Financ. Condit. Index
38	NFCICREDIT	0	1	Chic. Fed Nat. Financ. Condit. Credit Subindex
39	NFCILEVERAGE	0	1	Chic. Fed Nat. Financ. Condit. Leverage Subindex
40	NFCIRISK	0	1	Chic. Fed Nat. Financ. Condit. Risk Subindex
41	NFCINONFINLEVERAGE	0	1	Chic. Fed Nat. Financ. Condit. Index Nonf. Lederal Subindex
42	CONSUMER	0	5	Consumer Loans at All Commercial Banks
43	TOTALSL	0	5	Total Consumer Credit Owned and Securitized, Outstanding
44	DED3	0	2	3-Month Eurodollar Deposit Rate (London)
45	EXCRESNS	0	5	Excess Reserves of Depository Institutions
46	CPILFESL	1	5	C.P.I. for All Urban Consumers: All Items Less Food & Energy
47	CPIULFSL	1	5	C.P.I. for All Urban Consumers: All Items Less Food
48	CPILEGS	1	5	C.P.I. for All Urban Consumers: All Items Less Energy
49	CPIENGSL	1	5	C.P.I. for All Urban Consumers: Energy
50	CPIUFDSL	1	5	C.P.I. for All Urban Consumers: Food
51	PPICPE	1	5	Producer Price Index: Finished Goods: Capital Equipment

No.serie	Transformation	Mnemonic	Slow	Description
52	PPICRM	1	5	Producer Price Index: Crude Materials for Further Processing
53	PPIFCG	1	5	Producer Price Index: Finished Consumer Goods
54	PPIFGS	1	5	Producer Price Index: Finished Goods
55	SRVPRD	1	5	All Employees: Service-Providing Industries
56	USGOOD	1	5	All Employees: Goods-Producing Industries
57	USPRIV	1	5	All Employees: Total Private Industries
58	CE16OV	1	5	Civilian Employment
59	CLF16OV	1	5	Civilian Labor Force
60	CIVPART	1	1	Civilian Labor Force Participation Rate
61	AWOTMAN	1	1	Aver. Weekly Overtime Hours of Prod. and Nonsup. Employees: Manufact.
62	AWHMAN	1	1	Aver. Weekly Hours of Production and Nonsupervisory Employees: Manufact.
63	IPNCONGD	1	5	Industrial Production: Nondurable Consumer Goods
64	IPMAT	1	5	Industrial Production: Materials
65	IPFINAL	1	5	Industrial Production: Final Products (Market Group)
66	IPDCONGD	1	5	Industrial Production: Durable Consumer Goods
67	IPCONGD	1	5	Industrial Production: Consumer Goods
68	IPBUSEQ	1	5	Industrial Production: Business Equipment
69	UEMP5TO14	1	5	Civilians Unemployed for 5-14 Weeks
70	UEMP15OV	1	5	Civilians Unemployed - 15 Weeks & Over
71	UEMP15T26	1	5	Civilians Unemployed for 15-26 Weeks
72	UEMP27OV	1	5	Civilians Unemployed for 27 Weeks and Over
73	TB3M	0	1	3-Month Treasury Bill: Secondary Market Rate
74	AAA'	0	1	AAA Moody, 3-Seasoned Aaa Corporate Bond Yield
75	BAA'	0	1	Moody, 3-Seasoned Baa Corporate Bond Yield
76	CD3M'	0	1	3-Month Certificate of Deposit: Secondary Market Rate
77	CD6M'	0	1	6-Month Certificate of Deposit: Secondary Market Rate
78	EXCAUS	0	5	Canada / U.S. Foreign Exchange Rate
79	EXJPUS	0	5	Japan / U.S. Foreign Exchange Rate
80	EXSDUS	0	5	Sweden / U.S. Foreign Exchange Rate
81	EXSZUS	0	5	Switzerland / U.S. Foreign Exchange Rate
82	GS1	0	1	1-Year Treasury Constant Maturity Rate
83	GS10	0	1	10-Year Treasury Constant Maturity Rate
84	GS3	0	1	3-Year Treasury Constant Maturity Rate
85	GS5	0	1	5-Year Treasury Constant Maturity Rate
86	MED1	0	1	1-Month Eurodollar Deposit Rate (London)
87	MED3	0	1	3-Month Eurodollar Deposit Rate (London)
88	MED6	0	1	6-Month Eurodollar Deposit Rate (London)
89	MORTG	0	1	30-Year Conventional Mortgage Rate
90	MPRIME	0	1	Bank Prime Loan Rate
91	TB6MS	0	1	6-Month Treasury Bill
92	sTB6MS	0	1	sTB6MS Spread 6-Month Treasury Bil - Federal Fund Rate
93	sGS1	0	1	Spread 1-Year Treasury Constant Maturity Rate - Fed Fund Rate
94	sGS10	0	1	Spread 10-Year Treasury Constant Maturity Rate - Fed Fund Rate
95	sGS3	0	1	Spread 3-Year Treasury Constant Maturity Rate - Fed Fund Rate
96	sGS5	0	1	sGS5 Spread 5-Year Treasury Constant Maturity Rate - Fed Fund Rate
97	sMPRIME	0	1	Spread Bank Prime Loan Rate - Fed Fund Rate
98	sAAA	0	1	Moody, 3-Seasoned Aaa Corporate Bond Yield - Fed Fund Rate
99	sBAA	0	1	sBAA Moody, 3-Seasoned Aaa Corporate Bond Yield - Fed Fund Rate
100	BUSLOANS	0	5	Commercial and Industrial Loans at All Commercial Banks
101	INVEST	0	5	Total Investments at All Commercial Banks
102	LOANINV	0	5	Bank Credit at All Commercial Banks
103	LOANS	0	5	Loans and Leases in Bank Credit
104	REALLN	0	5	Real Estate Loans at All Commercial Banks
105	USGSEC	0	5	Treasury and Agency Securities at All Commercial Banks
106	OTHSEC	0	5	Other Securities at All Commercial Banks
107	BAA-AAA	0	1	Default Rate Spread
108	MPRIME-TB3MS	0	1	External Finance Premium
109	LIBOR3M-TB3M	0	1	TED spread

Appendix B: The Markov Chain Monte Carlo algorithm

This section presents the Gibbs sampling procedure applied to estimate the time varying parameters. This method follows Primiceri (2005) and it is described in Kim and Nelson (1999). Consider a linear and Gaussian state space form:

$$\begin{aligned} y_t &= Z\beta_t + e_t \\ \beta_t &= T\beta_{t-1} + v_t \\ e_t &\sim i.i.d.\mathcal{N}(0, Q) \\ v_t &\sim i.i.d.\mathcal{N}(0, H) \\ E(e_t, v_t') &= 0 \end{aligned}$$

Let $\beta_{t|s} = E(\beta_t|Y^s, H^s, R^s, Q)$ and $V_{t|s} = Var(\beta_t|Y^s, H^s, R^s, Q)$. Then, given $\beta_{0|0}$ and $V_{0|0}$, a standard Kalman filter delivers:

$$\begin{aligned} \beta_{t|t-1} &= T\beta_{t-1|t-1} \\ P_{t|t-1} &= TP_{t-1|t-1}T' + Q \\ v_t &= y_{t|t-1} - Z\beta_{t|t-1} \\ F_{t|t-1} &= ZP_{t|t-1}Z' + H \\ \beta_{t|t} &= \beta_{t|t-1} + P_{t|t-1}Z'F_{t|t-1}^{-1}v_t \\ P_{t|t} &= P_{t|t-1} - P_{t|t-1}Z'F_{t|t-1}^{-1}ZP_{t|t-1} \end{aligned}$$

The last elements of the recursion are $\beta_{T|T}$ and $V_{T|T}$, which are the mean and the variance of the normal distribution used to make a draw for β_T . The draw of β_T and the output of the filter are now used for the first step of the backward recursion, which provides $\beta_{T|T-1}$ and $V_{T|T-1}$, used to make a draw of β_{T-1} . The backward recursion continues until time zero. For a generic time t , the updating formulas of the backward recursion are:

$$\begin{aligned} \beta_{t|t+1} &= \beta_{t|t}P_{t|t}F_{t+1|t}^{-1}(\beta_{t+1} - T\beta_{t|t}) \\ V_{t|t+1} &= V_{t|t} - V_{t|t}F_{t+1|t}^{-1}FV_{t|t} \end{aligned}$$

CHAPTER 3

Repurchase Agreements, Margin Calls and Sovereign-Debt Crises

1 Introduction

The liquidity crisis of 2007-2009 in US has highlighted the growing importance of the shadow banking system in intermediary activities and credit supply to investment banks through short-term collateralized debt and, in particular, repurchase agreements (repos), which have become a primary source of liquidity for these financial institutions. Although there are no official statistics on the size of the US repo market, it is estimated to be about \$12 trillion, compared to the total assets in the US banking system of \$10 trillion and, according to Hördahl and King (2008), the top US investment banks funded roughly half of their assets using repo contracts. Several authors have analyzed the role of the repo market in the propagation and amplification of the liquidity crisis.

Adrian and Shin (2009, 2010) show that the leverage of investment banks is procyclical and that they adjust their balance sheets by increasing or reducing the amount of repos. Brunnermeier (2009) argues that prior to the crisis both commercial and investment banks were heavily exposed to maturity mismatch through their increased reliance on overnight and short-term repos and asset-backed commercial papers (ABCPs), this being considered as a sign of the financial system vulnerability. Gai et al. (2011) point out that collateral lending has contributed to the rise in the systemic risk by splitting up liquidity transformation, lengthening credit chains and expanding the number of connections among intermediaries. Gorton and Metrick (2012) argue that the recent financial crisis was a run in the securitized-banking system characterized by a rise in repo haircuts which reduced the liquidity of banks in a similar way of traditional deposit runs. Nevertheless, Copeland et al. (2010) report that in tri-party repo market the haircuts and the amount of funding was stable between the period from July 2008 to early 2010. Moreover, Krishnamurthy et al. (2013) find that before the crisis the short-term funding of securitized asset through ABCPs was larger than the repo funding and that during the crisis the contraction in ABCPs was bigger than the one in repos, arguing that the collapse of ABCP market was the primary cause of the liquidity crisis more than the contraction of repo market.

While the characteristics and the evolution of the US repo market in the last years have been deeply investigated and are at the center of the debate about the financial crisis, few studies analyze the repo market in Europe and its implication for the sovereign-debt crises. Because of the paucity of data we know little about these questions: How important is the repo funding for the European banking system? How did it evolve during the recent financial crisis? What is the source of repo funding for European banks? What is the composition of collateral in European repos? What is the impact of sovereign debt crises on the collateral

availability and the interbank repo lending?

The objective of this paper is to fill this gap using novel data and to investigate the role of the repo market in the European “twin crises”, the combination of banking and sovereign-debt crises that are affecting countries in the periphery of the Eurozone. To the best of my knowledge, Hördahl and King (2008) is the only study that explores the development of the repo market in the Euro area and compares its evolution with the dynamics of the US and UK repo markets during the onset of the global financial crisis. However, it does not cover the recent period characterized by tensions in sovereign-debt markets.

The analysis proceeds in two steps. To begin with, I set the stage by examining the size and the evolution of the European repo market, in particular after the collapse of Lehman Brother and the first signs of stress in the sovereign debt market. I compare the features of repo markets in US and Europe and analyze the types, the counterparties, the underlying collaterals and the maturities of European repos. I find three main evidences. First, European banks rely increasingly on repos for their funding needs. In particular, after the global financial crises they have been shifting from unsecured to secured interbank lending because of the rise in counterparty risk. Second, a large fraction of repos in the liability side of European banks’ balance sheets are invested by non-Eurozone financial institutions, especially from the US. Third, European repos are collateralized to a large extent by government bonds.

These empirical findings suggest that the repo market may have tightened the link between banking and sovereign debt crises in Europe amplifying the tensions on the sovereign debt markets in the periphery of the Eurozone. Prior to the global financial crisis, bonds issued by governments in the Euro area were considered risk-free and used as collateral in interbank repo transaction and in monetary policy operations of the ECB with very low haircuts. As a result, European banks hoarded both domestic and non-domestic government bonds not only for their maturity value but also for their exchange value since they could easily borrow against them; in other words their funding liquidity was high.

Nevertheless, in 2010 when signs of stress showed up in the sovereign debt markets of countries in the periphery of the Eurozone, repo haircuts on government bonds issued by these countries began to increase. Additionally, the ECB introduced graduated valuation haircuts for lower-related assets in its risk management, comprising government securities.¹ These fluctuations of haircuts

¹From the ECB Press Release, 8 April 2010: “the Governing Council has decided to apply, as of 1 January 2011, a schedule of graduated valuation haircuts to the assets rated in the BBB+ to BBB-range (or equivalent). This graduated haircut schedule will replace the uniform haircut add-on of 5% that is currently applied to these assets”.

triggered the “margin spiral”, described in Geanakoplos (2003) and Brunnermeier and Pedersen (2009). Haircuts were increased in response to an initial loss of confidence or a large variation in the value of collateral, which in turn reduced the funding liquidity of the assets used as collateral in repo transactions. This led investors to sell the illiquid security and buy the more liquid ones, causing a fire-sale of illiquid assets and resulting in new rises in haircuts. When the collateral of repo transactions is government bonds, this vicious spiral may create situations of multiple equilibria in the sovereign-debt market and entail unsustainable high cost of borrowing for governments.

This mechanism is documented in the second step of the analysis. I collect data on the repo haircuts of Irish and Portuguese 10-year government bonds applied by the LCH Clearnet Ltd., one of the most important clearing houses in Europe. The haircuts applied on these bonds reached the 80% in 2011. Subsequently, I assess the impact of a rise in the haircuts on the yields of government bonds via a Bayesian VAR. The impulse response function is estimated for liquidity shock and a credit risk shock to disentangle the two channels. Both shocks have a negative effect on the government bonds yields confirming the negative impact of an increase in haircuts on the value of bonds.

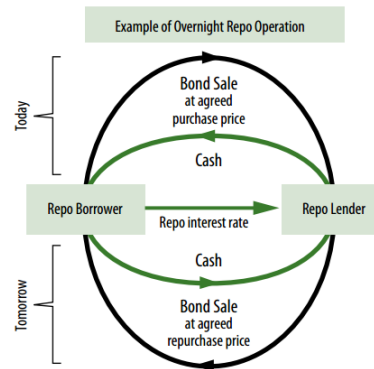
The remainder of the paper is organized as follows: Section 2 defines the terms commonly employed for the market of repurchase agreements and describes the data used in the analysis; Section 3 illustrates the structural characteristics of the European repo market and its developments during the recent financial crisis; Section 4 explains the amplification mechanism of a negative liquidity spiral on government bonds; Section 5 examines the impact of a rise in haircuts on the government bond yields and Section 6 concludes.

2 Repurchase Agreements: definitions and data

This section explains the main features of repurchase agreements, important in understanding the results of the analysis, and describes the data used to investigate the European repo market. A repo transaction is an agreement between two parties on the sale and subsequent repurchase of securities at an agreed price. In economic terms, a repo is equivalent to a loan secured by securities (collateral) and typically involves overcollateralization, as the buyer (lender) receives securities as collateral from the seller (borrower), whose value exceeds the loan.

The difference between the value of the cash and the value of the collateral is defined as the haircut (or initial margin), which is generally expressed as a

Figure 3.1: Repurchase Agreement



Source: *Global Financial Stability Report (October 2010)*, IMF

percentage.² For instance, if \$100 of securities collateralizes a loan of \$90, the haircut is 10 percent. The haircut is also a measure of the inverse of the leverage. To hold \$100 the borrower must come up with \$10 of equity, thus the maximum permissible leverage is 10. Hence, the lower is the haircut, the higher is the leverage. The purpose of the haircut is to protect the lenders from a decrease in the value of collateral and its level typically reflects the quality of the collateral, but may also vary by counterparty, reflecting the borrower's creditworthiness. In particular, haircuts take account of the unexpected loss that the lender in a repo may face due to the difficulty of selling that security in response to a default by the borrower. So it can be considered at the same time as an indicator of the funding liquidity from the standpoint of the cash borrower and of market liquidity from the standpoint of cash lender.

According to the involvement of intermediaries between the lender and the borrower, repos can be distinguished in two types. In bilateral repos the lender and the borrower transact directly with each other, selecting the collateral, initiating the transfer of cash and securities, and conducting collateral valuation. In tri-party repos, however, a third party enters into a tripartite agreement with the two counterparties in the transaction. The tri-party repo service provider is responsible for the administration of the transaction, in particular, the selection and valuation of collateral securities. Both types of repos can be combined with central clearing counterparties (CCP).

In order to investigate the European repo market two sources are used:

²The haircut is distinct from margin which refers to maintaining the value of collateral should market prices adversely change after the contract is signed. Both serve as security in the event that a counterparty fails to perform on its obligations and are designed to buffer against potential price volatility in the underlying exposure. But while margining occurs during the whole period of the transaction, the haircut is set when the contract is initially signed.

Bankscope and the European Repo Survey (ERP).³ Bankscope provides data on repos at a disaggregated bank level. However, it presents three limits: first, it lacks of important breakdowns, such as counterparty, maturity and currency, preventing a more granular analysis of the European repo market and it does not separate private repos from repos issued by the ECB as conventional measures in its monetary policy. Second, the database covers a recent period starting from 2006. Lastly, it lacks data on repos for several banks. This prevents to compute the amount of repos in the overall European banking system, by aggregating the individual banks' balance sheets. The advantage of this database is that it allows to compare different sources of funding of European financial institutions during financial crises.

The ERP provides information on the size and composition of the European repo market, including the types of repos traded, the rates, the collaterals, the cash currency and the maturity. It is a semi-annual survey conducted by the International Capital Market Association. The survey asks a sample of financial institutions in Europe for the value of their repo contracts that were still outstanding at close of a business days excluding the value of repos transacted with central banks as part of official monetary policy operations. On the one hand, measuring the stock of transactions at one date, rather than the flow between two dates, permits a deeper analysis. On the other hand, it can miss peaks and troughs in business between survey dates, especially of very short-term transactions. However, it is an important source to evaluate the evolution of repos in the last decade. The questionnaire also asks financial institutions to analyze their business in terms of the currency, the type of counterparty, contract and repo rate, the remaining term to maturity, the method of settlement and the origin of the collateral, providing more information on the European repo market.

The ERP also reports the average of haircuts in tri-party repos for various categories of collateral (governments bonds, public agencies, corporate bonds, covered bonds, mortgage-back securities, other asset-backed securities, convertible bonds, equity). However, the survey does not provide information on haircuts for government bonds divided by nationality. In order to monitor the variation of haircuts for different government securities during the recent sovereign debt crises, I constructed time series of haircuts set by the LCH.Clearnet Ltd, a clearing house operating in the euro area and providing clearing services covering Austrian, Belgian, Dutch, German, Irish, Finnish, Portugese, Slovakian, Slovenian, Spanish and UK government debts, on cash and repos transactions (cash bonds

³The ECB website also provides yearly data on CCP repos but they are divided by clearing house.

and repo trades in Italian and French markets are cleared by LCH.Clearnet SA).⁴ The data on haircuts for Irish and Portuguese bonds are extracted by reading the communications of LCH.Clearnet Ltd.

3 Key features of the European repo market

3.1 Structural characteristics

Before analyzing the European repos, I start by broadly illustrating the funding structure of the European banking system. Figure 3.2 shows the average of total customer deposits, short-term funding and long-term funding for the 32 biggest European commercial banks in terms of total assets. Short-term funding is the sum of interbank deposits, repos and other short-term deposits with maturity shorter than one year. Long-term funding includes the debts with maturity longer than one year. Banks' balance sheets data are reported for the year 2010 to exclude the two three-year LTROs with full allotment implemented by the ECB in December 21, 2011 and February 29th 2012, which altered the funding structure of European banks since the data do not distinguish private repos from ECB repos. Total customer deposits represent the largest share in the funding structure of European commercial banks (44.8% of the total). Short-term debt constitutes a considerable share (32.5%), larger than long-term debt (22.6 %). This suggests that the funding structure of the European commercial banks is similar to U.S. investment banks and that European banks have to roll over their debt frequently.⁵

Table 3.1 displays the funding structure of the banks for which bankscope reports data on repurchase agreements, separating interbank deposits and repos. Figures 2-6 in appendix A show visually the same data ordering the bank following a geographical criterion. As the European banking system is highly concentrated (the first biggest 20 financial institutions hold 80% of total assets), this sample can be representative for the overall system. The banks in the countries of the Core Europe (Germany, France, Switzerland, Belgium) show a large fraction of repos, which is bigger than interbank deposits, except for CrÈdit Agricole Corporate and Commerzbank. Moreover, for most of the banks in the Core Europe, repos constitute a more important source of funding than long-term debt. By contrast, Italian, Spanish and Nordic banks have a longer maturity structure of

⁴In 2012 LCH.Clearnet cleared approximately 50% of the global interest rate swap market, and is the second largest clearer of bonds and repos in the world.

⁵The chapter 2 of the Global Financial Stability Report (October 2010) carries out a comparison between U.S. investment and commercial banks using the same database employed for this analysis.

Figure 3.2: Funding structure of European banks



Note: Average funding structure of the 32 biggest European commercial banks in 2010 (millions of euro)
Source: Bankscope

Table 3.1: Quantity of Repos in European Commercial Banks in 2010

Bank	Deposit	Interbank	Repos	LT debt	Liab	% Repos/Liab
BNP Paribas	523124	138863	206058	121748	1888313	10.91
Barclays Bank Plc	366045	92085	207292	154606	1498292	13.84
Banco Santander	563692	58722	120157	211726	1177375	10.21
SociÈtÈ Generale	289116	90026	113182	103213	1135908	9.96
UBS AG	342409	30201	177679	142551	1365669	13.01
UniCredit SpA	398379	100363	31444	157136	871971	3.61
Credit Agricole Corporate	103317	76096	40172	4987	701293	5.73
Intesa Sanpaolo	197165	65954	12690	178898	591463	2.15
Banco Bilbao	261702	35904	53122	84658	557630	9.53
Commerzbank AG	227135	79496	47194	90798	639647	7.38
Danske Bank	795275	177592	269515	947097	3298548	8.17
Skandinaviska Enskilda Banken	837624	174957	50375	330635	2256642	2.23
Bankia	111382	10393	35022	89642	290353	12.06
Svenska Handelsbanken	716887	197834	12056	742977	2359842	0.51
Fortis Bank	143295	26717	14968	19143	328365	4.56
Abbey National Treasury Services	7061	134205	35071	33990	249897	14.03
KBC	140457	20351	23610	29273	262580	8.99
Banca Monte dei Paschi	79029	22981	24094	59988	228802	10.53

Note: in millions of national currency. Deposits=customer deposits, Interbank=interbank deposits, LT debt=long-term debt, Liab=total liabilities

Source: Bankscope and author's calculations

their debt, relying more on long-term funding. In particular, Nordic banks show a little share of repos, except Danske Bank. Table 1 also compares the ratio of repos to the total liabilities for European banks. The six largest commercial banks in the sample (BNP Paribas, Barclays Bank, Banco Santander, SociÈtÈ GÈnerale and UBS) display a relatively high fraction of repos, which is around 10% of total liabilities. All in all, repurchase agreements represent a significant source of funding for the European banking system, in particular for the biggest commercial banks.

The geographical composition of counterparties in the European repo market is then analyzed from June 2007. Figure 3.3 shows that the domestic business is the largest share of repos, which consists between 30% and 35% of the total during the period considered. The share of cross-border business involving one non-Eurozone counterparty represents around one third of the total. The share of cross-border business involving Eurozone counterparties is around 26%, growing from 20% in December 2009. This is probably due to a shift from unsecured to secured interbank lending observed in Europe during the recent financial crisis.⁶

Figure 3.3: Geographical analysis of the European repo market

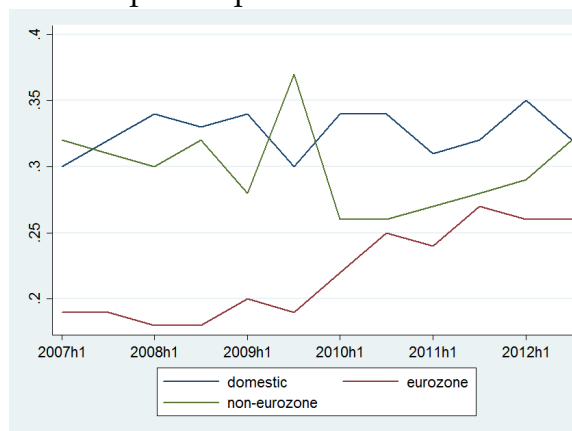
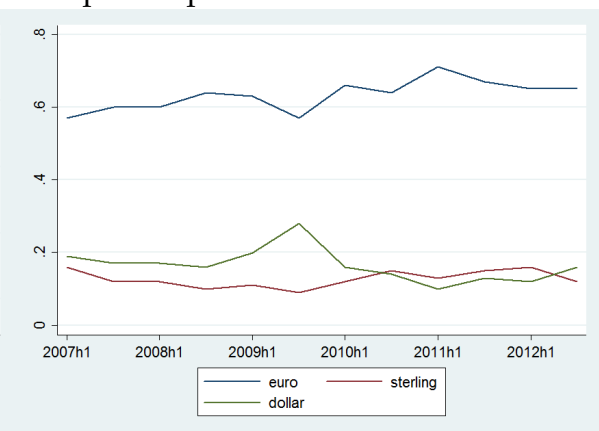


Figure 3.4: Currency analysis of the European repo market



Note: in percent of the total

Source: European Repo Survey (from June 2007 to December 2012)

Figure 3.4 displays the cash currency analysis of the European repo market. More than 60% of repo transactions are denominated in euro and roughly 20% are in U.S. dollar and in British pound sterling respectively. Matching figures 3.3 and 3.4 we can see that the share of non-Eurozone repos and the share of repos in dollar strongly comove. The correlation between the two series is 0.79, while the correlation of the share of non-Eurozone repos and the share of repos in British pound is -0.49. This is line with the existing literature (Chernenko and Sunderam 2013, Krishnamurthy et al. 2011, Shin 2010) that show that US Money Market Funds have invested massively in European banks. This suggests that U.S. financial intermediaries, such as Money Market Funds, have a large exposure to the Eurozone banks and is in line with the findings of Chernenko and Sunderam (2013) and Krishnamurthy et al. (2011). Moreover the fact that the biggest European banks hold the largest amount of repos is also consistent with the concept of “European global banks”, elaborated by Shin (2010) to indicate the European financial institutions that rely on the U.S. wholesale market to finance their activities.

⁶See also Hördahl and King (2008) and Allen and Moessner (2012 b).

One structural feature that differentiates the European from the US repo markets is the low share of tri-party repos in the European market which is around 10% of the total amount of repos. A larger fraction, more than 30%, is represented by repos involving central clearing counterparties, CCPs (including those transacted on an automatic trading system (ATS) and automatically cleared across a CCP, but also those transacted directly with a counterparty or via a voice-broker, and then registered with a CCP post trade). By contrast, most of the repos in U.S. are managed by a tri-party repo service provider.⁷ A key difference between the two types of repos is the risk management of collateral: in markets where a CCP is involved, the CCP effectively standardizes the margins and the haircuts as it becomes the counterparty to every cash lender, bearing most of the credit risk. In contrast, tri-party repos service providers only implement the margins and haircuts agreed upon by the counterparty. It follows that counterparty credit risk is lower in markets in which operate the CCP, but also that a change in the margins or haircuts decided by a CCP affect simultaneously more counterparties which trade with the same CCP. In tri-party repos haircuts are more sensitive to counterparty than to collateral.

Another significant difference between the European and the US markets concerns the collateral in the repo transactions. Table 3.2 shows that in December 2012 the fraction of government bonds within the pool of collateral is 81.8%. This share barely moved during the last years with a slight reduction between December 2008 and December 2011, suggesting that a structural characteristics in the European market is represented by the high quantity of repo transactions collateralized by government securities, which is in contrast to the US market where private assets and structured securities represent a larger share in the collateral of repos.

Fitch Ratings shows that in US Treasuries are less than one third of the total of repo collateral. Agency and Treasury securities account for roughly 50% of the collateral in Securities Lender repos and represent a larger fraction in Money Market Fund repos, around 80%. However this share was around 50% before the financial crisis increased sharply following the flight to quality on collaterals.

3.2 Developments during the crisis

After having highlighted the structural characteristics of the European repo market, this section examines the elements that underwent deep modification during the recent financial crisis, in particular quantity, maturity and collateral. Figure 3.5 shows the expansion of the repos in Europe from June 2001. To overcome

⁷See the BIS Working Paper “Strengthening repo clearing and settlements arrangements” (September 2010).

Table 3.2: Share of government bonds within the pool collateral

	Dec-08	Dec-09	Dec-10	Dec-11	Jun-12	Dec-12
Austria	1.00	0.80	1.00	1.40	1.10	0.90
Belgium	2.60	1.60	2.20	3.20	3.10	2.70
Denmark	0.20	0.20	0.40	0.50	0.60	0.40
Finland	0.30	0.30	0.30	0.60	0.50	0.60
France	8.40	6.50	7.30	8.10	7.30	9.60
Germany	23.80	20.90	18.70	15.40	14.20	16.70
Greece	2.30	2.00	0.50	0.20	0.10	0.10
Ireland	0.30	0.60	0.30	0.20	0.10	0.10
Italy	11.80	10.30	9.80	6.40	7.80	8.30
Luxembourg	0.20	0.20	0.10	0.10	0.30	0.10
Netherlands	2.20	1.70	1.70	2.90	2.60	2.60
Portugal	1.10	0.90	0.80	0.30	0.10	0.20
Spain	3.60	3.20	3.90	5.30	4.30	4.20
Sweden	0.50	0.60	0.80	0.70	0.90	0.80
UK	10.60	7.70	8.00	10.60	12.80	12.40
US	2.90	3.10	3.10	3.10	3.30	2.60
Poland	0.10	0.20	0.20	0.20	0.20	0.20
Other	11.30	13.40	17.60	18.50	16.80	19.30
Total	83.30	74.50	76.80	77.90	76.50	81.80

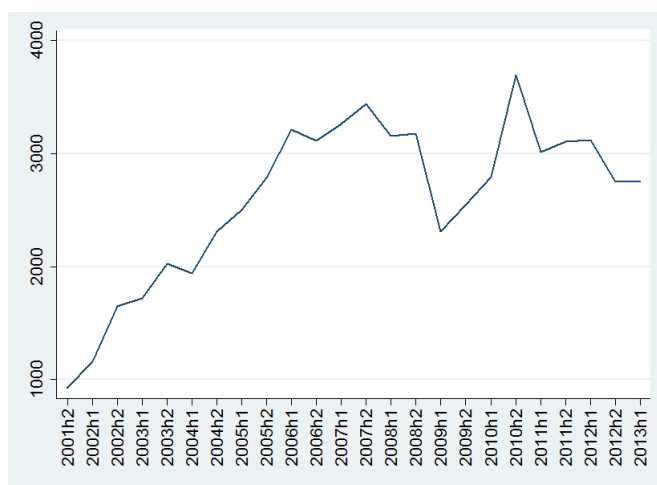
Source: European Repo Survey (from December 2008 to December 2012)

the problems caused by changes in the sample of survey participants, the ERS compares the aggregate outstanding contracts reported only by the 57 institutions which have participated continuously in all the surveys. Although the data cover a subsample of banks, they provide insight on the rapid expansion of repos, which tripled in less than a decade from 924 billions of euro in June 2001 to 3.697 billions of euro in June 2010. The quantity of repos declined during the recent financial crisis, but recovered rapidly from June 2009.

Table 3.3 compares the yearly rate of growth of repos, customer deposits, interbank deposits and long-term debt and shows that the spectacular increase in repos is not the result of the growth in banks' balance sheets. Before the crisis repos evolved faster than customer deposits, long-term debt and interbank deposits. In 2005 and 2006 we observe a rate of growth of repos close of 28.91% and 28.23%, respectively. During the first stage of the global financial crisis repos decreased contracting by 3.29% in 2008 and 26.67% in 2009. In 2010 and 2011 repos recovered (20.72% and 7.96% respectively), while interbank deposits continued to fall (-10.14% and -4.03%), confirming a shift in the interbank market from unsecured to secured loans.⁸ The quick diffusion of repurchase agreements in

⁸Allen and Moessner (2012 b) argue that uncollateralized debt was replaced also with collat-

Figure 3.5: Evolution of European repos



Note: in billions of euro. Repos reported by institutions which have participated continuously in all the surveys.

Source: European Repo Survey (from December 2001 to December 2012).

Europe in the last years seems the consequence of a transformation in the business model of European banks, which relies more massively on short-term debt as a source of funding for their activities and relatively less on traditional deposits and long-term debt.

Table 3.3: Annual growth of funding structure of European commercial banks

year	customer deposits	long-term debt	interbank deposits	repos
2005	-1.67	1.43	-7.78	28.91
2006	10.46	13.81	3.39	28.23
2007	4.29	3.61	-3.81	1.49
2008	2.03	-1.18	-9.49	-3.29
2009	-0.45	-10.10	-24.26	-26.67
2010	3.48	8.81	-10.14	20.72
2011	4.20	0.42	-4.03	7.96

Note: in percent of the total.

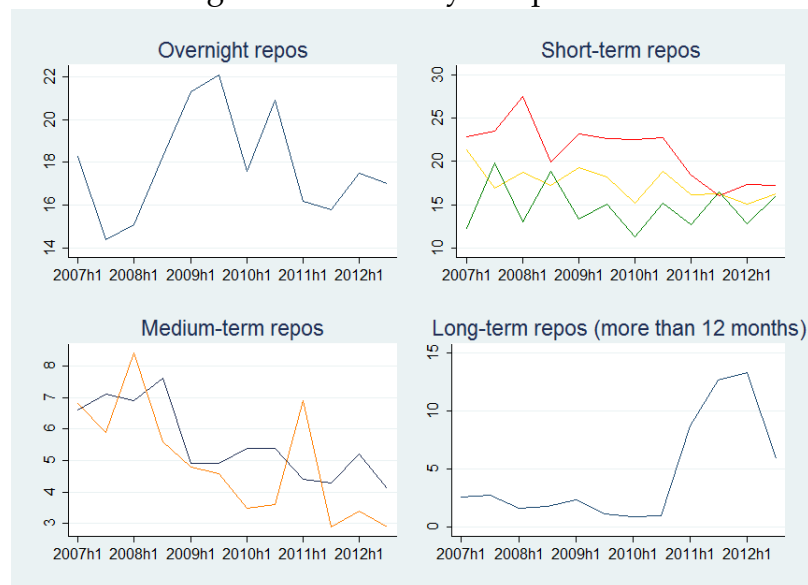
Source: Bankscope and European Repo Survey

The recent financial crisis affected the composition of government bonds within the pool of collateral. Table 3.2 shows that the share of government securities issued by countries in the Periphery of the Eurozone declined between December 2009 and December 2011. In particular, the reduction is stronger during the periods of major tensions in the sovereign debt markets (in Greece and Ireland 2010 and in Italy and Portugal 2011), despite the ECB relaxed its own collateralized borrowing from the ECB contributing to the collateral squeeze.

collateral eligibility rules (for instance it suspended the application of its normal minimum credit rating requirement to Greek, Irish and Portuguese bonds in May 2010, March 2011 and July 2011). Two interesting findings emerge from the table 3.3: first, the share of Spanish government bonds in the pool of collateral slightly increased in 2010 and 2011, second, the fraction of government bonds that increased the most during the financial crisis are Holland, UK and issued by other OECD countries, while German bonds also reduced. This is not consistent with the theory of flight to quality of collateral. However it can be explained by the collateral squeeze in the Euro area during the Global financial crisis which reduced the availability of collateral (See Allen and Moessner (2012 b)).

Figure 3.6 displays the shares of repos divided by maturity. Overnight repos represent an important fraction of the total, around 17% in December 2012. This share expanded during the most acute phase of the European crisis between 2009 and 2012 peaking a record as high as 22% in December 2012. It follows that more than 1/5 of repos held in their balance sheets were rolled on a daily basis, this way facing an increasing funding risk.

Figure 3.6: Maturity comparison



Note: in percent of the total. For short-term repos the yellow line indicates the repos with maturity between 2 days and one week, the red line the repos with maturity between 1 week and 1 month and the green line the repos with maturity between 1 month and 3 months. For medium-term repos the dark blue line indicates the repos with maturity between 3 months and 6 months and the orange line the repos with maturity between 6 months and 12 months.

Source: European Repo Survey.

Short-dated repos represent the largest share of the total. Repos with maturity between 2 days and two weeks, with maturity between 1 week and 1 month and with maturity between 1 and 3 months were 16.3%, 17.2% and 16% respectively

in the last period of the sample. The share of the repos with maturity less than one month sharply declined from December 2010 (22.7%).⁹ Medium-dated repos constitute a small fraction of the total. Repos with maturity between 3 months and 6 months and with maturity between 6 months and 12 months are 4.1% and 2.9% of the total respectively, reducing from 6.9% and 8.4% in June 2008. Long-dated repos with maturity more than 1 year dropped back sharply to 5.9% from a record high of 13.3% in June 2012. This reduction may reflect the availability of alternative longer-term funding from the 3-year LTROs.

All in all, we observe a shift in maturities during the global financial crisis. As a consequence of the rise in counterparty risk in the European interbank market, overnight repos expanded substantially, while medium-dated repos contracted sharply. On the other hand, starting from December 2010 the repo transactions with maturity more than one year increased before falling back in mid-2012.

4 The negative liquidity spiral in Europe

From the overview of the European repo market analyzed in the previous section we can draw three main conclusions. First, in the last decade repos steadily increased and now account for a large share in the funding structure of European commercial banks. Moreover, after the onset of the global financial crisis secured lending have replaced unsecured lending in the interbank market. Second, an important fraction of repos in the European banks' balance sheets is lent by non-Eurozone financial intermediaries and in particular by US money market funds. Third, government bonds represent the predominant share within the pool of collateral in European repos and the fraction of government bonds issued by countries in the periphery of the Eurozone fell after the onset of the sovereign debt crises in Europe.

The last point represents a key difference with the US financial market entailing deep economic implications on the causes and consequences of variations of haircuts. Gorton and Metrick (2010) argue that an increase in the haircuts is a way to protect against the endogenous adverse selection since in a repo transaction cash borrower may be better informed about the value of collateral than the cash lender. They show that in 2008 and 2009 repo haircuts increased far more on subprime-related asset classes than on non-subprime-related ones, but this large difference was not mirrored in the prices, suggesting that diverse haircuts cannot

⁹The European Commission proposed to oblige the European money market funds to hold at least 10% of assets in instrument that mature on a daily basis and an additional 20 per cent in assets that mature in a week to reduce the systemic risk. See the Financial Times "EU clamps down on money market funds", 4 September 2013.

be explained by the changes in riskiness, but with the idea that depositors want collateral that is immune to adverse selection. Dang et al. (2011) develop a model in which the haircuts on securities offered as collateral are a function of the “information acquisition sensitivity” (IAS) of a security and the probabilities of default of both parties to a repo. IAS measures the “tail risk” of a security, that is, the expected losses on a collateral security when its liquidation value has fallen below the outstanding repurchase price. The arrival of bad economic news increases the IAS of collateral and the repo haircut, which may trigger a negative feedback loop that amplifies the initial shock: higher haircuts reduce the amount of lending to the borrower and augments its default probability which, in turn, increase haircuts again.

While phenomena of adverse selection and information acquisition sensitivity may partly explain the run on repo in the US market because of the large share of structured securities in the pool of collateral, these mechanisms are less likely to be at play in the European market in which repos are collateralized to a large extent by government securities that are less information acquisition sensitive and this reduces the asymmetric information between borrowers and lenders about the value of collateral. Nevertheless, fluctuations in haircuts may have negatively affected the price of government securities in the countries of the Periphery of the Eurozone, tracing a channel through which banking crises reinforce sovereign debt crises. This mechanism is based on the model of Brunnermeier and Pedersen (2009) which describes the liquidity spiral as the interaction between the margin and loss spirals that force investors to delever in times of crisis and that can lead to multiple equilibria.

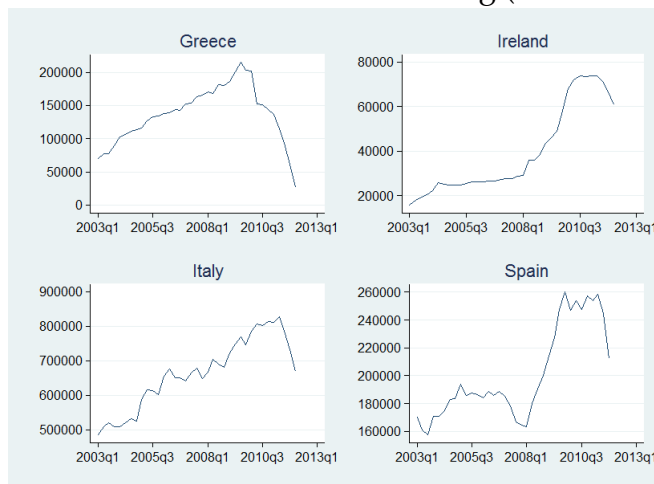
The loss spiral is triggered when a negative shock in the asset value reduces the net worth of leveraged investors, who are obliged to fire-sell their assets reducing the asset value even further. In the example of a repo contract in Section 2, an investor who buys \$100 of securities on 10 percent haircut, borrows \$90 and finances \$10 with its own capital with a leverage of 10. If the value of acquired asset falls to \$95, the investor has \$5 of its own capital remaining. Holding the leverage constant, he has to reduce the overall position to \$50 selling \$45 of assets, depressing the price further and inducing more selling. The loss spiral is akin to financial accelerator, the amplification mechanism that also arise in Kiyotaki and Moore (1997) and Bernanke, Gertler and Gilchrist (1999).

The margin spiral is an adverse feedback loop between margins and prices. Not only a decrease in the price of asset depresses the value of collateral, but also the consequent rise in haircuts reduces the investors’ leverage, so they have to sell even more and, if more investors face the same constraints, the liquidity shortage

may lead to fire-sale externalities and solvency problems.

Now suppose that investors dispose of two assets, say a blue paper and a red paper, and the red paper may be subject to a negative liquidity shock, while the blue one not. In this case if a liquidity spiral arises for the red papers they will sell them and will buy the blue papers. This seems to be the situation that experienced banks in the Core of the Eurozone, which before the global financial crises hoarded government bonds issued by countries of the Periphery, but after the onset of crisis they sold massively these securities, not only because of the rise in credit risk and in the probability of defaults, but also because of the lesser funding liquidity of these assets, red papers, compared to the government securities of the Core, blue papers (see figure 3.7).

Figure 3.7: Non-resident bonds holding (billions of euro)

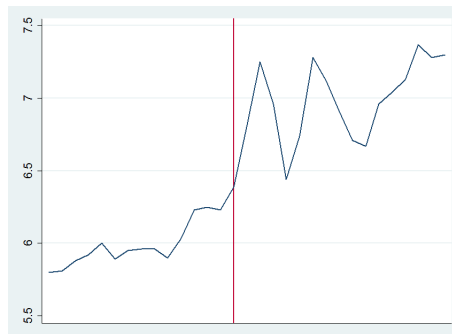


Source: Bruegel database of sovereign bond holding (Merler and Pisani 2012)

The case of Italy in November 2011 is significant to highlight how the funding liquidity of an asset affects its value and the impact of a variation in haircuts on the price of collateral. On 8 November 2011 the clearing house LCH Clearnet SA decided to increase collateral margins on unsettled trades, including repos, in Italian government securities by between 3 and 5.5 percentage points. On 9 November the haircut on the 10-year Italian government bond increased from 6.65 to 11.65 percentage points. Figure 3.8 shows that from 7 November 2011 to 9 November 2011 the yields of the 10-year Italian government bond increased from 6.39 to a high record level of 7.25. Even though other factors may have caused this rise, the run on Italian bonds by foreign banks following the increase in haircuts seems to be the main driver.¹⁰

¹⁰See also FT Alphaville "Why Italy is 'Oh, so special'", 11 November 2011.

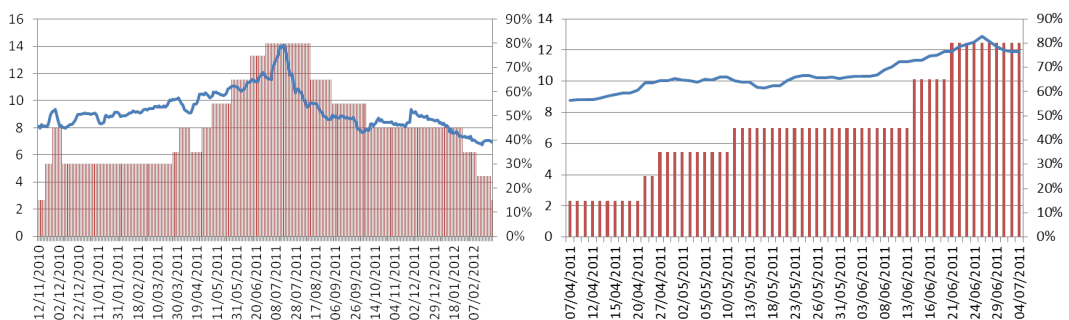
Figure 3.8: Yields of 10-year Italian government bonds (from 14/10/2011 to 29/11/2011)



Note: the red lines indicates the announcement of an increase in haircut on 10-year government bonds from 6.65% to 11.65% on 07/11/2011

In order to study the interaction between haircuts and yields of government bonds I constructed a novel time series of haircuts for Irish and Portuguese 10-year government bonds, by reading the communications of LCH.Clearnet Ltd. Figure 3.9 shows the dynamics of haircuts and yields of the two bonds. The two series strongly comove, because the LCH.Clearnet Ltd systemically increased the haircut when the spread with the German government bonds exceeded 450 basis points. The haircut on Irish government bonds reached 80% on June 2011 and decreased on August 2011 following the decline in yields. The haircut on Portuguese bonds augmented up to 80% in June 2011. As a consequence, the liquidity of these securities dried up almost completely.

Figure 3.9: Yields and haircuts on 10-year government bonds issued by Ireland (left) and Portugal (right)



Note: Blue line: yields (LHS), red bars: LCH Clearnet haircuts (RHS)

Sources: Global finance data and LCH clearnet website.

5 The impact of a rise in haircuts on government bond yields

I evaluate the dynamic interaction between haircuts and government bond yields and I assess the effect of fluctuations of haircuts on the value of government securities. In order to analyze the dependence structure of these variables, I start by studying the copula function. The marginal cumulative distribution function and the joint cumulative distribution functions are estimated non parametrically by kernel methods. Figure 3.10 displays the scatter of haircuts and government bond yields for Ireland because more observations are available. There is a strong and positive link between the two variables, in particular for the upper-tail probabilities as we can see at the top-right corner of the graph. This is confirmed by the coefficient of linear correlation parameter of copula which is 0.59.

I compare the credit risk and liquidity effects on government bond yields estimating a granger causality test and the impulse response function of a structural VAR. Credit risk is measured by credit default swap (CDS) premium and funding liquidity by haircuts. The data of CDS premium are taken from datastream and the data of government bond yields from the Global Finance database. All the data are at daily frequency. The Granger causality test is estimated for Ireland and Portugal (see tables 3.4 and 3.5). For Ireland both CDS premium and haircuts Granger cause the yields of government bonds. In addition, they are Granger caused by the yields. It follows that both the indicator of liquidity and of credit risk have a significant prediction power on the government bond yields and vice versa. For Portugal CDS premium and haircuts also Granger cause the yields, but they are not Granger caused. Since the clearing house sets the haircuts as a function of the yields, a possible explanation is that variations in spreads do not mirror completely variations in yields.

Table 3.4: Granger causality tests (Ireland)

Test	F-statistic	critical value
yields → haircut	9.582	0.908
haircut → yields	3.305	0.456
yields → CDS	6.222	0.456
CDS → yields	9.205	0.695

Note: The lag length selection is chosen using the Bayesian Information Criterion considering a maximum of 12 lags. The significance level is 0.05. Yields are taken as difference of logs to be stationary.

Figure 3.10: Copula of the kernel distributions of yields and haircuts (Ireland)

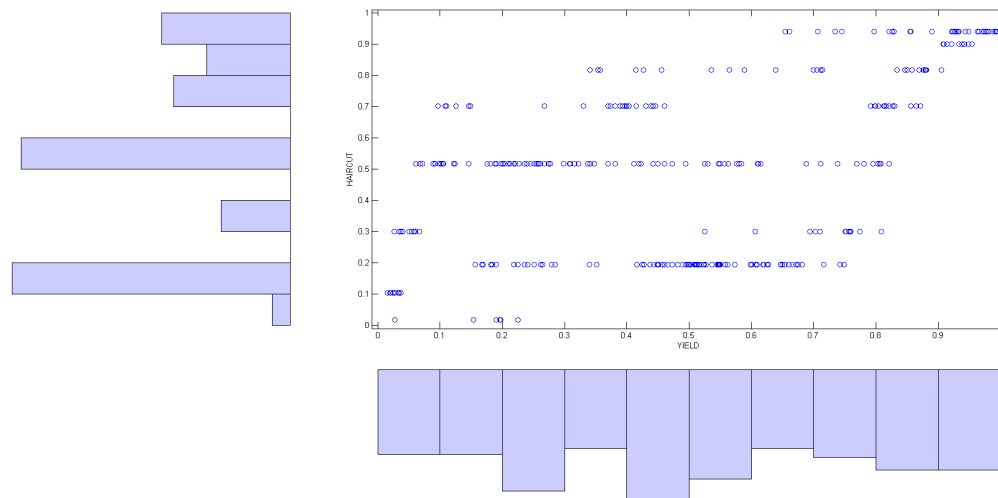


Table 3.5: Granger causality tests (Portugal)

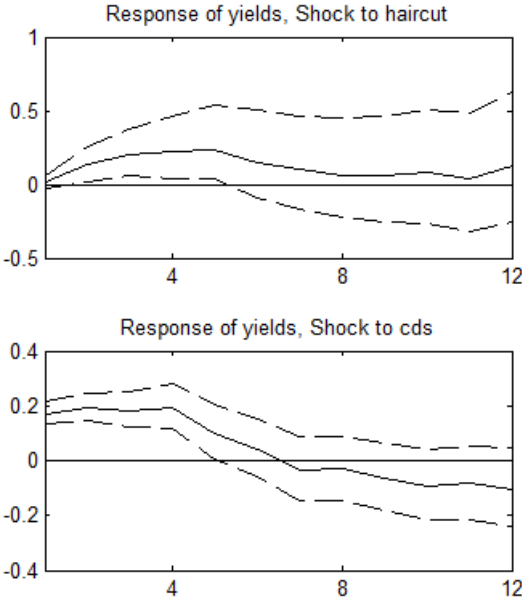
Test	F-statistic	critical value
yields \rightarrow haircut	0.228	0.459
haircut \rightarrow yields	1.129	0.459
yields \rightarrow CDS	0.399	0.459
CDS \rightarrow yields	6.001	0.700

Note: The lag length selection is chosen using the Bayesian Information Criterion considering a maximum of 12 lags. The significance level is 0.05. Yields are taken as difference of logs to be stationary.

In order to assess the impact of a rise in haircuts on government bond yields avoiding endogeneity problems and reverse causality issues, I estimate a Bayesian SVAR for Ireland which comprises haircuts, CDS premiums and yields. The data are at daily frequency. Structural shocks are recovered using the triangular Cholesky decomposition. The main assumption of this identification scheme is that haircuts respond to yields with one lag. This is due to the one-day delay between the communication of the clearing house of variations in haircuts and the implementation of this decision. Figure 3.10 compares the impulse response function of a shock of haircut and a shock of CDS premium on the yields of Irish government bonds to disentangle the liquidity and credit channels.

Yields rise significantly for five days following a negative liquidity shock and a negative credit risk shock, suggesting that the two channels are important for the dynamics of the yields. In particular, this seems to confirm the mechanism of margin spiral for Irish government securities during the most acute phase of tensions in the sovereign-debt market in 2011 and a negative feedback loop between the price of government bonds and the haircuts.

Figure 3.11: Impulse response function of a liquidity shock and a credit risk shock



6 Related literature and final remarks

Countries in the periphery of the Euro area are experiencing a combination of banking crises and sovereign debt crises which prevents the economic recovery after the global financial crisis is threatening the European Monetary Union. A strong link between banking crises and sovereign default across the economic history of advanced and emerging countries is showed empirically by Reinhart and Rogoff (2011). They find that boom-bust cycles in private debt, fueled by both domestic banking credit growth and external borrowing, are a recurring antecedent to domestic banking crises, which precede or accompany sovereign debt crises. One reason for this temporal sequence is that government takes on massive debts from the private banks, thus undermining its own solvency. The contingent liability argument is emphasized by Diaz Alejandro (1985) and formalized in Velasco (1986). Reinhart and Rogoff (2009) show that, even absent large-scale bailouts government debts typically rise about 86 percent in the three years, largely owing to collapsing revenues.

The literature points out two main channels through which banking crises have spilled over to sovereign debt crises in Europe. First, Acharya et al. (2011) find empirical evidence of a two-way feedback between financial and sovereign credit risk. In the short-run, bailouts are funded through the issuance of government bonds. A high level of issuance helps to fund the bailout but dilutes existing bondholders and introduces credit risk into the government bond price. This deterioration of sovereign's creditworthiness feeds back onto the financial sector, reducing the value of its guarantees and existing bond holdings and increasing its sensitivity to future sovereign shocks. Second, European banks took on excessive exposure to their own sovereign credit risk assuming sovereign debt as risk free. In countries where sovereign debt was perceived to be riskier, bank stock plunged, leading to expectations of a public bail out, further increasing the perceived credit risk in government bonds. This generated the "diabolic loop" described by Brunnermeier et al (2011).

Both these mechanisms are based on the credit risk in government bonds. This paper has analyzed the European market of repurchase agreements, which may represent an other channel in the transmission of banking and sovereign-debt crises hinged on the liquidity of government bonds. A reduction in the value of these assets, largely used as collateral in repo transactions, along with rises in haircuts may trigger a margin spiral which forces European banks to delever causing fire-sales of illiquid government bonds which depress the value of bonds even more and cause new increases in haircuts. This vicious cycle can lead to unsustainable high cost of borrowing for governments.

Therefore, variations in haircuts not only exacerbate the procyclicality of financial system, boosting liquidity in good times and draining it in bad times, but are also a source of systemic risk. This raises relevant questions for regulators about margin and haircuts practices to preserve the financial stability without contracting the liquidity of financial markets.

Appendix A: Figures

Figure 3.12: Funding structure of French banks in 2010 (millions of national currencies)

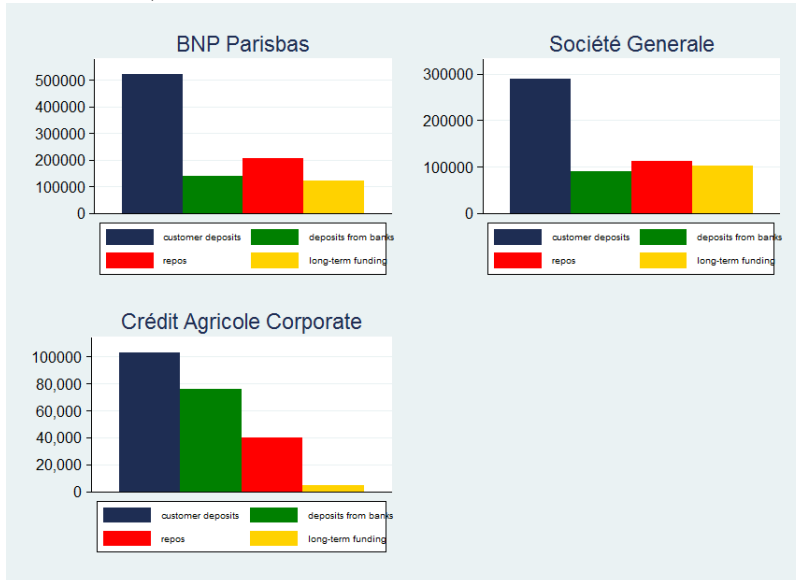


Figure 3.13: Funding structure of Swiss, German and Belgian banks in 2010 (millions of national currencies)

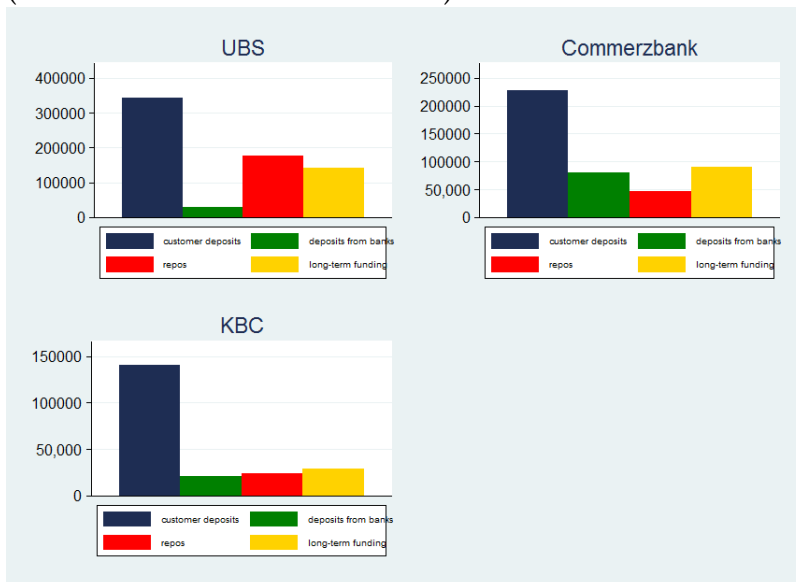


Figure 3.14: Funding structure of Italian banks in 2010 (millions of national currencies)

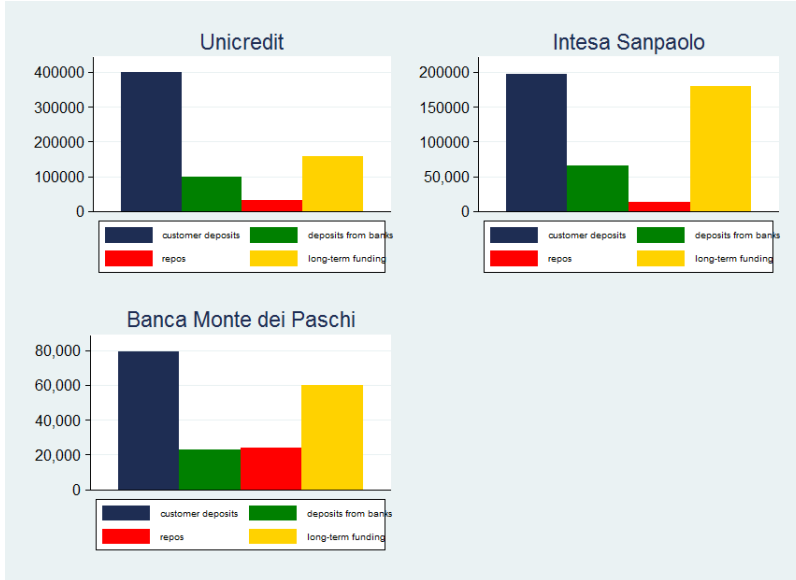


Figure 3.15: Funding structure of Spanish banks in 2010 (millions of national currencies)

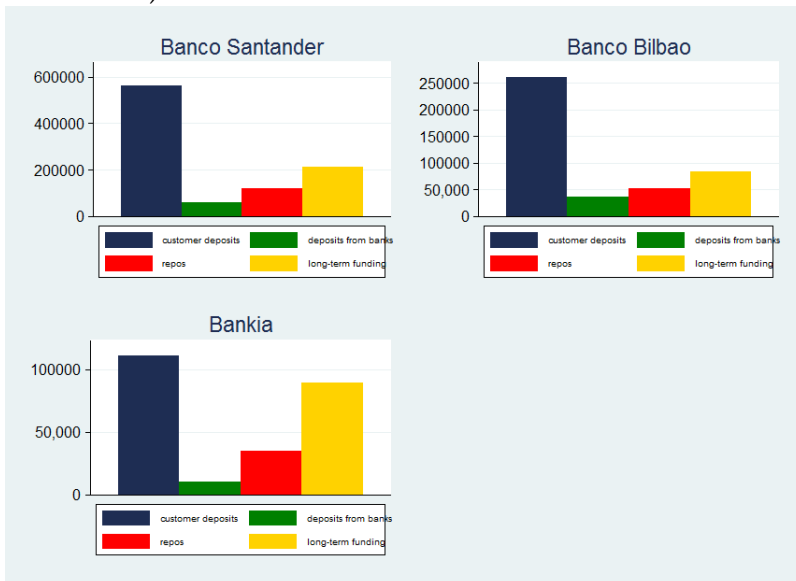
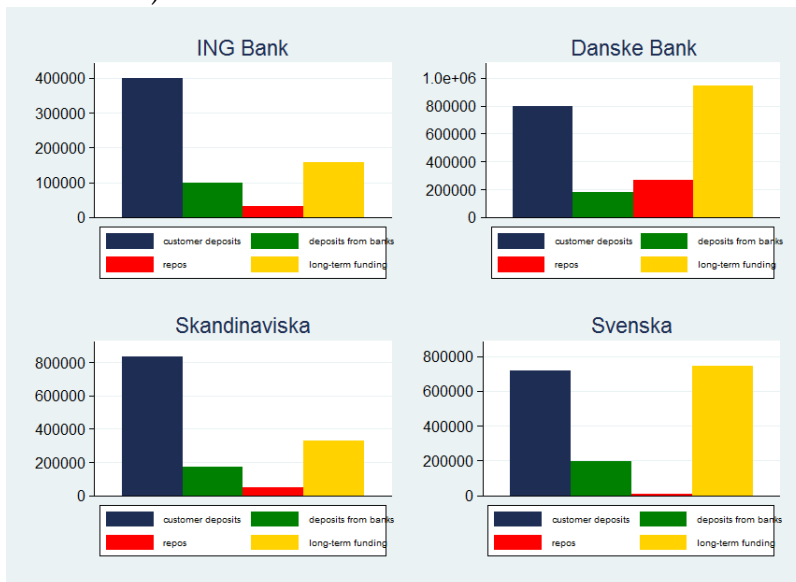


Figure 3.16: Funding structure of Nordic banks in 2010 (millions of national currencies)



Appendix B: Bayesian VAR

Consider a VAR(p) model

$$Y_t = \alpha_0 + \sum_{j=1}^p A_j y_{t-j} + \epsilon_t \quad (3.1)$$

where y_t is $(M \times 1)$ vector, α_0 is a $(M \times 1)$ vector of intercepts, A_j is a $M \times M$ matrix of coefficients, ϵ_t is a $(M \times 1)$ vector of residuals and ϵ_t is i.i.d. $N(0, \Sigma)$.

An alternative way to write the VAR is the following. Let y be $MT \times 1$ vector ($y = (y'_1, \dots, y'_T)$) and ϵ stacked conformably. Let $x_t = (1, y'_{t-1}, \dots, y'_{t-p})$ and $X' = [x_1, x_2, \dots, x_T]$. $K = 1 + Mp$ is the number of coefficients in each equation of VAR and X is a $T \times K$ matrix.

The VAR can be rewritten as:

$$y = (I_M \otimes X)\alpha + \epsilon \quad ; \quad \epsilon \sim N(0, \Sigma \otimes I_M) \quad (3.2)$$

Conjugate priors with Normal and Inverse Gamma distributions are used for the estimation of α and ϵ .

$$\alpha | \Sigma \sim N(\alpha^*, \Sigma \otimes V^*) \quad (3.3)$$

$$\Sigma^{-1} \sim W(S^{-1*}, \nu^*) \quad (3.4)$$

where $\alpha^*, V^*, S^{-1*}, \nu^*$ are the hyperparameters set

The posterior distributions have the form

$$\alpha | \Sigma \sim N(\bar{\alpha}, \Sigma \otimes \bar{V}) \quad (3.5)$$

$$\Sigma^{-1} | y \sim W(\bar{S}^{-1}, \bar{\nu}) \quad (3.6)$$

where

$$\bar{V} = [V^{-1*} + X'X]^{-1}$$

$$\bar{A} = \bar{V}[V^{-1*}A^* + X'X\hat{A}]$$

$$\bar{S} = S + S^* + \hat{A}'X'X\hat{A} + A^*V^{-1}A^* - \bar{A}'(V^{-1*} + X'X)\bar{A}'$$

$$\bar{\nu} = T + \nu^*$$

CHAPTER 4

Liquidity, Government Bonds and Sovereign-Debt Crises

1 Introduction

One of the most striking features of the recent financial crisis in Europe is the spectacular rise in the yield spreads of Government bonds which has undermined the capacity of countries in the periphery of the Eurozone to repay the public debt and required the intervention of the IMF, European Commission and ECB as lenders of last resort in Greece, Ireland and Portugal. Once eliminated the exchange rate risk through the creation of a monetary union, intra-euro spreads reflect mainly two components: credit risk and liquidity. Credit risk derives from the probability of default of the issuer. Weak fundamentals of a country may induce investors to evaluate that the probability of default and the expected loss increase and they ask a higher compensation for holding this risk. As a consequence, the price of Government bonds falls and the yields surge. Moreover, the fears of default, by driving up the yields, can themselves trigger default in countries that do not have their own currency and cannot press new currency. Therefore, according to this theory sovereign-debt crises may be driven by self-validating expectations in countries that do not control the currency in which they issue their debt and sovereign-debt market could be characterized by multiple equilibria. Calvo (1988), Cole and Kehoe (2000) and Corsetti and Dedola (2012) propose an analytical framework for self-fulfilling debt crises that captures the problem faced by a country having a small probability of default in which authorities can repudiate public debt by imposing haircuts on debt holders.

Liquidity is an ambivalent concept which is related to the capacity of an asset to provide cash to the holder when it is sold. Brunnermeier and Pedersen (2009) divide the liquidity into two categories: market liquidity and funding liquidity. Market liquidity is the ease to raise money by selling an asset. Funding liquidity is the ease to raise money by borrowing against the asset. Empirical studies try to disentangle the credit and liquidity effects in bonds price and there is compelling evidence that yields and spreads are affected by liquidity concerns (see, e.g., Longstaff (2004), Acharya and Pedersen (2005)), Chen et al. (2007), Kempf et al. (2012)), and that liquidity effect significantly contributes to the dynamics of intra-euro spreads (see Favero et al. (2010), Manganelli and Wolswijk (2009) and Monfort and Renne (2013)). In many ways, the ongoing financial crisis has illustrated that, along with credit risk, liquidity risk matters and should not be underestimated.

In this paper we emphasize the role of funding liquidity of Government bonds which are used to a large extent as collateral in repurchase agreements (repos), a form of collateralized short-term debt through which European banks fund increasingly their activities. In these transactions the cash borrower cannot borrow

up to the entire price of the collateral. The difference between the price of collateral and the amount of cash he can obtain is the haircut or initial margin, which provides a measure of the funding liquidity of an asset or its pledgeability. The lower is the haircut, the higher is the pledgeability of the asset used as collateral.

Before the onset of the recent financial crises haircuts on repos collateralized by Government bonds were generally low, but after the first signs of stress in the sovereign-debt markets, haircuts on Government bonds issued by countries of the Periphery started to increase (see Figure 1). In addition, the ECB introduced graduated valuation haircuts for lower-related assets in its risk management, comprising Government securities.

Building on Del Negro, Eggerston, Ferrero and Kiyotaki (2012), hereafter DEFK, we analyze the effects of fluctuations in haircuts through a DSGE model with liquidity frictions. In this framework an increase in haircut is equivalent to a negative liquidity shock which is modeled as a tightening of the resaleability constraint on Government bonds.

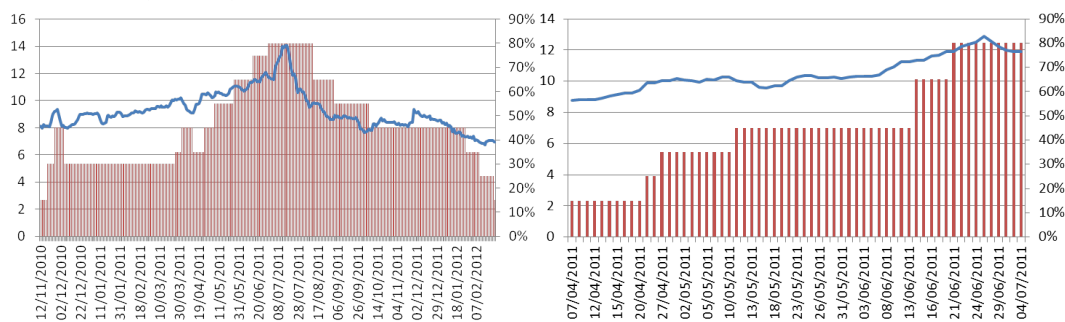
Kiyotaki and Moore (2012), hereafter KM, propose the seminal paper which combines a resaleability constraint with a borrowing constraint. In their model investing entrepreneurs can borrow only up to a fraction of the value of the investment (borrowing constraint) and can sell only a fraction of equity in their portfolio (resaleability constraint), while can dispose of the entire holding of money to finance the investment. This introduces heterogeneity in the liquidity of assets which is associated with differences in returns on assets. Although the returns on money are lower than the returns on equity, agents have an incentive to hold money because of the “liquidity premium”, the fact that in case they face an investment opportunity they can employ entirely the liquid assets to purchase investment goods. Shi (2012) simplifies the KM model by ruling out the heterogeneity of agents and assuming that entrepreneurs and workers are members of the same household that allows the use of a representative household. DEFK adopt this framework to analyze the impact of a negative liquidity shock of equity and the credit facilities implemented by the FED during the recent financial crisis which consisted in exchanging Government liquidity for private financial assets through direct purchase or collateralized short-term loans (for instance the Term Auction Facility, the Primary Dealer Credit Facility and the Term Securities Lending Facilities). In their model the liquid assets are Government bonds instead of money and the open market operations of Government can make the agents’ portfolio more liquid. This model captures the idea that in US private assets, such as ABS and MBS, were highly liquid before the crisis and allows to study the effect of credit facilities to alleviate the shortage of liquidity in these markets.

We propose a modified version of the model of DEFK to take into account the diversities between European and US markets and to evaluate the impact of a liquidity shock on European Government bonds. The European financial market differ from the US financial market in two dimensions. First, in Europe Government bonds issued by different countries were considered not only risk-free but also the most liquid instrument for savings and private assets were far less liquid than in US. As a result, Government bonds were almost as liquid as money and were held by banks not only for their maturity value but also for their exchange value and for their pledgeability in collateralized interbank loans. Second, the liquidity shock hit not the private assets but the Government bonds issued by the countries in the Periphery of the Eurozone reducing the circulation of these assets and their capacity to be used as collateral.

This model departs from DEFK as private papers are completely illiquid and public papers are partially liquid and subject to a resaleability constraint. A tightening in this constraint reduces the quantity of cash that an entrepreneurs can obtain from selling the bonds and is equivalent to a rise in the haircut of repos. It compares the effect of this liquidity shock in a laissez-faire economy and in an economy in which the Government reacts with an unconventional policy intervention which consists in issuing a one-period Government bonds which is completely liquid and not subject to the resaleability constraint and that represents an alternative liquid means of saving. The model incorporates the same nominal and real rigidities as in DEFK that guarantee comovements of investment and consumption in the response to a liquidity shock.

The remainder of the paper is organized as follows: Section 2 describes the model and Section 3 its calibration. Section 4 illustrates the impact of a liquidity shock, Section 5 shows the effects of the policy intervention and Section 6 concludes.

Figure 4.1: Yields and haircuts on 10-year Government bonds issued by Ireland (left) and Portugal (right)



Blue line: yields (LHS), red bars: LCH Clearent haircuts (RHS)

Note: Sources: Global finance data and LCH clearent website

2 The Model

2.1 The model environment

Consider an infinite-horizon economy with discrete time. The economy is populated by a continuum of households of measure one and the members of each representative household are either entrepreneurs or workers. The other actors in the model are the Government, intermediate and final goods firms, labor agencies and capital producers. In the economy there are three assets: equity, which cannot be sold in a secondary market and is completely illiquid, long-term Government bonds, which are subject to a resaleability constraint and are partially liquid and short-term bonds which are completely liquid. The production process and the labor market are characterized by the presence of intermediaries which introduce nominal rigidities in the model. We also assume adjustment costs in the investment function. The Government conducts conventional monetary policy via de control of the nominal interest rate, fiscal policy via taxes to stabilizes the public debt and unconventional monetary policy which consists in issuing the short-term bond.

2.2 Households

Household structure. The economy is composed by a continuum of representative households of measure one and each household consists of a continuum of members indexed by $j \in [0,1]$. Each period, household members receive an idiosyncratic shock that determines their profession during all the period. With probability χ , they become entrepreneurs and with probability $(1-\chi)$ they become workers. By the law of large number, χ also represents the fraction of entrepreneurs in the households. Entrepreneurs and workers are differentiated because each entrepreneur $j \in [0,\chi)$ invests, but does not work and each worker $j \in (\chi, 1]$ supplies labor. At the end of each period all members share consumption goods and asset, but within the period the two groups are completely separated and resources cannot be reallocated among household members.¹

Preferences. Households maximize the utility function

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{C_s^{1-\sigma}}{1-\sigma} - \frac{\omega}{1+\nu} \int_{\chi}^1 H_s(j)^{1+\nu} dj \right] \quad (4.1)$$

¹This separation ensures that households cannot shift funds from workers to entrepreneurs to the finance investment projects of entrepreneurs and circumvent the liquidity constraints.

where $\beta \in (0, 1)$ is the subjective discount factor, $\sigma > 0$ is the coefficient of relative risk aversion, $\nu > 0$ is the inverse Frisch elasticity of labor supply, $\omega > 0$ is a parameter that pins down the steady-state level of hours. C_t is the aggregate consumption and $H_s(j)$ is the individual labor supply.

Portfolio. Households hold physical capital K_t which has a unit value q_t and earns a dividend stream r_t^k . There is a claim to the return of every unit of capital, which is either retained by households or sold to outside investors at unit price q_t . Hence, households own N_t^O claims on other households' capital and their liabilities consists on claims on capital sold to other households N_t^I . In addition, households invest in risk-free nominal bonds issued by the Government. There are two types of bonds: a short-term bond, with price Q^S , which pays 1 in the future period (t+1) and a long-term bond, with price Q^L , paying the return stream 1 in t+1, λ in t+2, λ^2 in t+3 and so on. Table 4.1 summarizes the households' balance sheet at the beginning of period t

Table 4.1: Household's balance sheet

Assets	Liabilities
Capital stock: $q_t K_t$	Equity issued: $q_t N_t^I$
Others' equity: $q_t N_t^O$	
Long-term bonds: $Q_t^L B^L / P_t$	
Short-term bonds: $Q_t^S B^S / P_t$	Net worth: $q_t N_t + B^S / P_t + B^L / P_t$

Households also own a fully-diversified, non-tradable portfolio of intermediate-goods-producing firms and capital-producing firms, which pay the per-period profits D_t and D_t^I , respectively. Finally, households pay lump-sum taxes T_t to the Government. At the beginning of each periods all of these income flows are evenly distributed across members.

We assume that an identical fraction of previously uncommitted returns to own physical capital ($K_t - N_t^I$) can be remortgaged and that the holding of other entrepreneurs' equity (outside equity) and unmortgaged capital stock (inside equity) can be lumped together as "net equity", N_t . This simplification implies that both assets yield the same returns, have the same liquidity and depreciated at the same rate (λ), so it allows to reduce the number of assets in this model.

$$N_t = N_t^O + K_t - N_t^I \tag{4.2}$$

The key assumption of this portfolio structure is that the assets have different liquidity: equity is completely illiquid and cannot be sold, long-term bonds are

partially liquid and subject to a liquidity constraint and short term bonds are completely liquid and can freely circulate.

Two financial frictions constraints the financing of new investment projects by entrepreneurs and the evolution of the balance sheets. The first one is the borrowing constraint that implies that any entrepreneur can issue an equity claim to the future output from the investment, but only a fraction $\theta \in (0, 1)$ of the investment can be issued.² The second one is the resaleability constraint that prevents the entrepreneur to trade all the long-term bonds in its portfolio and he can sell only a fraction ϕ of them. A decrease in ϕ limits the amount of liquidity that an entrepreneurs can obtained from disposing of bonds.

$$N_{t+1}(j) \geq (1 - \theta)I_t(j) + \lambda N_t \quad (4.3)$$

$$B_{t+1}^L(j) \geq (1 - \phi_t)B_t^L \quad (4.4)$$

The interpretation of equation 4.3 and 4.4 is that the entrepreneur has to finance a fraction $(1 - \theta)$ of the investment project with his own equity and he cannot sell the existing equity to acquire resources from the market. In addition he cannot sell the entire long-term bond holding and has to keep a fraction $(1 - \phi)$ of them in its portfolio. Finally, short-term bonds are assumed to be fully liquid and that private agents cannot issue Government bonds.

$$B_{t+1}^S(j) \geq 0 \quad (4.5)$$

To characterize the different liquidity of assets it is possible to think that $\phi = 0$ for equity and $\phi = 1$ for short-term bonds. The budget constraint of the typical household member j can be written as the following.

$$\begin{aligned} C_t(j) + p_t^I I_t(j) + q_t [N_{t+1}(j) - I_t(j) - \lambda N_t] + Q_t^L \left[\frac{B_{t+1}^L(j)}{P_t} - \lambda \frac{B_t^L}{P_t} \right] + Q_t^S \frac{B_{t+1}^S(j)}{P_t} \quad (4.6) \\ = r_t^k N_t + \frac{B_t^L}{P_t} + \frac{B_t^S}{P_t} + \frac{W_t(j)}{P_t} H_t(j) + D_t + D_t^I - \tau_t \end{aligned}$$

where P_t denotes the price level, $H_t(j)$ and $W_t(j)$ the working hours for workers j and nominal wage for type- j labor, respectively. p_t^I is the cost of a unit of new capital in terms of the consumption goods, differing from 1 because of the capital adjustment cost. Households members allocate their resources (LHS) between

²This follows from the assumption that there is not insurance market against having an investment opportunity, so that the market is incomplete. If $\theta = 1$ any investment opportunities can be shared across entrepreneurs, then the market is complete.

purchase of non-storable consumption good, investment in new capital, if they are entrepreneurs, and savings in different assets (equity, long-term bonds and short-term bonds). They finance their activities (RHS) with returns on equity, on long-term bonds, short-term bonds, wages, if they are workers, and the dividends of final and intermediate firms net to taxes. Next, we can take into account the specific functions of workers and entrepreneurs and their budget constraints.

2.3 Workers

Worker $j \in [\chi, 1]$ does not invest, so $I_t(j) = 0$. He supplies labor as demanded by firms at a fixed wages, as the union who represents each type of worker sets wages on a staggered basis. As a consequence, households decide N_{t+1} , B_{t+1}^L , B_{t+1}^S and C_{t+1} , taking wages and hours as given. The budget constraint of workers is

$$\begin{aligned} C_t(j) + q_t [N_{t+1}(j) - I_t(j) - \lambda N_t] + Q_t^L \left[\frac{B_{t+1}^L(j)}{P_t} - \lambda \frac{B_t^L}{P_t} \right] + Q_t^S \frac{B_{t+1}^S(j)}{P_t} \quad (4.7) \\ = r_t^k N_t + \frac{B_t^L}{P_t} + \frac{B_t^S}{P_t} + \frac{W_t(j)}{P_t} H_t(j) + D_t + D_t^I - \tau_t \end{aligned}$$

2.4 Entrepreneurs

Entrepreneur $j \in [0, \chi]$ does not supply labor, so $H_t(j) = 0$. The budget constraint of entrepreneurs reduces to

$$\begin{aligned} C_t(j) + p_t^I I_t(j) + q_t [N_{t+1}(j) - I_t(j) - \lambda N_t] + Q_t^L \left[\frac{B_{t+1}^L(j)}{P_t} - \lambda \frac{B_t^L}{P_t} \right] + Q_t^S \frac{B_{t+1}^S(j)}{P_t} \quad (4.8) \\ = r_t^k N_t + \frac{B_t^L}{P_t} + \frac{B_t^S}{P_t} + D_t + D_t^I - \tau_t \end{aligned}$$

We now make the assumption that $q_t > p_t^I$. If the price of equity is greater than the price of newly produced capital p_t^I , entrepreneurs will use all the available liquid resources for new investment projects to maximize the households' utility. In equilibrium, constraints (4.3), (4.4) and (4.5) are all binding. Furthermore, the entrepreneur spend no resources on consumption goods:

$$N_{t+1}(j) = (1 - \theta)I_t(j) + \lambda N_t \quad (4.9)$$

$$B_{t+1}^L(j) = (1 - \phi_t)B_t^L \quad (4.10)$$

$$B_{t+1}^S(j) = 0 \quad (4.11)$$

$$C(j) = 0 \quad (4.12)$$

Plugging equations (4.9), (4.10), (4.11) and (4.12) into equation (4.8), it is possible to derive the function of investment for entrepreneurs

$$I_t(j) = \frac{r_t^K N_t + \left[1 + \lambda \phi_t Q_t^L\right] \frac{B_t^L}{P_t} + Q_t^S \frac{B_t^S}{P_t} + D_t + D_t^I - \tau_t}{p_t^I - \theta q_t} \quad (4.13)$$

The nominator represents the maximum liquidity available for the entrepreneurs deriving from the return on papers (equity and long-term bonds), sales of the re-saleable fraction of long-term bonds after depreciation, sales of short-term bonds and the dividends net taxes. $p_t^I - \theta q_t$ measures the amount of own resources that entrepreneurs have to use to finance one unit of investment. The lower is this gap the greater is the investment and $\frac{1}{p_t^I - \theta q_t}$ can be considered as a measure of leverage. Therefore, investments are a function of net worth and leverage. Aggregate investment is

$$I_t = \int_0^x I_t(j) dj = \chi \frac{r_t^K N_t + \left[1 + \lambda \phi_t Q_t^L\right] \frac{B_t^L}{P_t} + Q_t^S \frac{B_t^S}{P_t} + D_t + D_t^I - \tau_t}{p_t^I - \theta q_t} \quad (4.14)$$

2.5 Households' problem

We now consider the aggregation of household members to all workers and all entrepreneurs, keeping the assumption that $q_t > p_t^I$ for the rest of the model. The households budget constraint is

$$\begin{aligned} C_t(j) + p_t^I I_t(j) + q_t [N_{t+1}(j) - I_t(j) - \lambda N_t] + Q_t^L \left[\frac{B_{t+1}^L(j)}{P_t} - \lambda \frac{B_t^L}{P_t} \right] + Q_t^S \frac{B_{t+1}^S(j)}{P_t} \\ = r_t^K N_t + \frac{B_t^L}{P_t} + \frac{B_t^S}{P_t} + \int_\chi^1 \frac{W_t(j)}{P_t} H_t(j) + D_t + D_t^I - \tau_t \end{aligned} \quad (4.15)$$

Households maximize the utility function (4.2) by choosing C_t , N_{t+1} , B_{t+1}^L and B_{t+1}^S subject to the budget constraint (4.15) and the investment constraint (4.13). The first order conditions for equity, long-term bonds and short-term bonds are respectively:

$$C_t^{-\sigma} = \beta \mathbb{E}_t \left\{ C_{t+1}^{-\sigma} \left[\frac{r_{t+1}^K + \lambda q_{t+1}}{q_t} + \frac{\chi(q_{t+1} - p_{t+1}^I) r_{t+1}^K}{p_{t+1}^I - \theta q_{t+1}} \frac{1}{q_t} \right] \right\} \quad (4.16)$$

$$C_t^{-\sigma} = \beta \mathbb{E}_t \left\{ C_{t+1}^{-\sigma} \left[\frac{1}{Q_t^L \pi_{t+1}} + \frac{\chi(q_{t+1} - p_{t+1}^I) (1 + \lambda \phi_{t+1} Q_{t+1}^L)}{p_{t+1}^I - \theta q_{t+1}} \frac{1}{Q_t^L \pi_{t+1}} \right] \right\} \quad (4.17)$$

$$C_t^{-\sigma} = \beta \mathbb{E}_t \left\{ C_{t+1}^{-\sigma} \left[\frac{1}{Q_t^S \pi_{t+1}} + \frac{\chi(q_{t+1} - p_{t+1}^I) Q_{t+1}^S}{p_{t+1}^I - \theta q_{t+1}} \frac{1}{Q_t^S \pi_{t+1}} \right] \right\} \quad (4.18)$$

where π_t is the inflation rate defined as $\pi_t = \frac{P_{t+1}}{P_t}$. Euler equations mean that reducing one unit of consumption today to increase consumption tomorrow by holding a paper gives a payoff which is composed by two parts. The first is the returns on papers: $\frac{r_{t+1}^K + \lambda q_{t+1}}{q_t}$ for equity, $\frac{1}{Q_t^L \pi_{t+1}}$ for long-term bonds and $\frac{1}{Q_t^S \pi_{t+1}}$ for short-term bonds. The second part can be considered as a “liquidity premium”, deriving from the fact that the paper provides extra liquidity for entrepreneur that relaxes its investment constraint. $\frac{1}{p_{t+1}^I - \theta q_{t+1}}$ is the leverage and captures the additional investment that the entrepreneur can do using one extra unit of liquidity. The difference $q_t - p_t^I$ is a measure of the value of relaxing the constraint. The greater the distance, the more valuable for the household to acquire capital by investing and pay p_t^I , rather than paying q_t on the market. However, this premium applies differently across the papers: for equity only to the dividend, for long-term bonds to the liquid part of returns and for the short-term bonds to the entire returns. Therefore, the different liquidity of papers is reflected by different premiums.

2.6 Firms

2.6.1 Final and intermediate goods producers

Competitive final-goods producers combine intermediate goods Y_{it} where $i \in [0, 1]$ indexes intermediate-goods-producing firms, to sell a homogeneous final good Y_t according to the technology

$$Y_t = \left[\int_0^1 Y_{it}^{\frac{1}{1+\lambda_f}} di \right]^{1+\lambda_f} \quad (4.19)$$

where $\lambda_f > 0$. Their demand for the generic i^{th} intermediate good is

$$Y_{it} = \left[\frac{P_{it}}{P_t} \right]^{-\frac{1+\lambda_f}{\lambda_f}} Y_t \quad (4.20)$$

where P_{it} is the nominal price of good i . The zero profit condition for competitive final goods producers implies that the aggregate price level is

$$P_t = \left[\int_0^1 P_{it}^{-\frac{1}{\lambda_f}} di \right]^{-\lambda_f} \quad (4.21)$$

The intermediate-goods firm i uses K_{it} units of capital and H_{it} units of composite labor to produce output Y_{it} according to the production technology

$$Y_{it} = A_t K_{it}^\gamma H_{it}^{1-\gamma} \quad (4.22)$$

where $\gamma \in (0, 1)$ and A_t is an aggregate productivity shock. Intermediate-goods firms operate in a monopolistic competition and set prices on staggered basis à la Calvo (1983), taking the real wage $\frac{w_t}{P_t}$ and the rental rate of capital r_t^K as given. With probability $1 - \zeta_p$, the firms can reset its price and with probability ζ_p they cannot. By the law of large number, the probability of changing the price corresponds to the fraction of firms that reset the price and they choose the price \tilde{P}_{it} to maximize the present discounted value of profits

$$D_{it+k} = P_{it+k} Y_{it+k} - w_{t+k} H_{it+k} - r_{t+k}^K K_{it+k} \quad (4.23)$$

subject to the demand for its own goods (4.20) and conditional on not changing its price. The problem of intermediate goods producers can be solved in two step. First, they choose the optimal amount of inputs (capital and labor) and they minimize the costs, $w_t H_{it} - r_t^K K_{it}$, subject to the production of intermediate goods (4.22). The first order condition is

$$\frac{K_{it}}{H_{it}} = \frac{\gamma}{1-\gamma} \frac{w_t}{r_t^K} = \frac{K_t}{H_t} \quad (4.24)$$

Since the capital-labor ratio at the firm-level is independent of firm-specific variables, then the marginal cost mc_{it} , i.e. the Lagrange multiplier on the constraint, is also independent of firm-specific variables

$$mc_{it} = \frac{1}{A_t} \left(\frac{r_t^K}{\gamma} \right)^\gamma \left(\frac{w_t}{1-\gamma} \right)^{1-\gamma} = mc_t \quad (4.25)$$

In the second step the $(1 - \zeta_p)$ firms that can change the price, will choose \tilde{P}_{it} to maximize

$$E_t \sum_{s=t}^{\infty} (\beta \zeta_p)^{s-t} C_s^{-\sigma} \left[\frac{\tilde{P}_{it}}{P_s} - (1 + \lambda_f) mc_s \right] Y_s(i) = 0 \quad (4.26)$$

We focus on a symmetric equilibrium in which all firms choose the same price

$\tilde{P}_{it} = \tilde{P}_t$. Let $\tilde{p}_t = \tilde{P}_t/P_t$ the optimal relative price. The first order condition for optimal price settings becomes

$$E_t \sum_{s=t}^{\infty} (\beta \zeta_p)^{s-t} C_s^{-\sigma} \left[\frac{\tilde{p}_t}{\pi_{t,s}} - (1 + \lambda_f) mc_s \right] \left(\frac{\tilde{p}_t}{\pi_{t,s}} \right)^{-\frac{1+\lambda_f}{\lambda_f}} Y_s = 0 \quad (4.27)$$

By the law of large number, the probability of changing the price coincides with the fraction of firms who change the price in equilibrium. From the zero profit condition (4.21), inflation depends on the optimal reset price according to

$$1 = (1 - \zeta_p) \tilde{p}_t^{-\frac{1}{\lambda_f}} + \zeta_p \left(\frac{1}{\pi_t} \right)^{-\frac{1}{\lambda_f}} \quad (4.28)$$

Finally, since the ratio of capital-output is independent of firm-specific factors, the aggregate production function is

$$A_t K_t^\gamma H_t^{1-\gamma} = \int_0^1 Y_{it} di = \sum_{s=0}^{\infty} \zeta_p (1 - \zeta_p)^{t-s} \left(\frac{\tilde{p}_{t-s}}{\pi_{t-s,t}} \right)^{-\frac{1+\lambda_f}{\lambda_f}} Y_t \quad (4.29)$$

where $K_t = \int_0^1 K_{it} di$ and $H_t = \int_0^1 H_{it} di$

2.6.2 Labor Agencies

Competitive labor agencies combine j -specific labor inputs into a homogeneous composite H_t according to

$$H_t = \left[\left(\frac{1}{1-\chi} \right)^{\frac{\lambda_\omega}{1+\lambda_\omega}} \int_\chi^1 H_t(j)^{\frac{\lambda_\omega}{1+\lambda_\omega}} dj \right]^{1+\lambda_\omega} \quad (4.30)$$

where $\lambda_\omega > 0$. Labor agencies provide the labor input to firms at the wage W_t and remunerate the households for the labor supplied. Labor agencies do not have profit for their intermediation:

$$W_t H_t = \int_\chi^1 W_t(j) H_t(j) dj \quad (4.31)$$

where W_t is the aggregate wage index. Labor agencies maximize the profit function (4.31) subject to (4.30), taking wages $W_t(j)$ as given. The first order condition determines the demand for the j^{th} labor input

$$H_t(j) = \frac{1}{1-\chi} \left[\frac{W_t(j)}{W_t} \right]^{-\frac{1+\lambda_\omega}{\lambda_\omega}} H_t \quad (4.32)$$

where $W_t(j)$ is the wage specific to the labor input j . From the zero profit

condition for labor agencies the aggregate wage index is

$$W_t = \left[\frac{1}{1-\chi} \int_{\chi}^1 W_t(j)^{-\frac{1}{\lambda_\omega}} dj \right]^{-\lambda_\omega} \quad (4.33)$$

Labor agencies set wages on a staggered basis, taking as given the demand for their specific labor input. Each period, labor agencies are able to reset the wage $W_t(j)$ with probability $1 - \zeta_\omega$ and with probability ζ_ω they cannot and the wage remains fixed. By the law of large number, the probability of changing the wage corresponds to the fraction of workers whose wages change. Households supply whatever labor is demanded at that wage. If labor agencies can modify the wage, they will chose the wage \tilde{W}_t to maximize

$$E_t \sum_{s=t}^{\infty} (\beta \zeta_\omega)^{s-t} \left[\frac{C_s^{1-\sigma}}{1-\sigma} - \frac{\omega}{1+\nu} \int_{\chi}^1 H_s(j)^{1+\nu} dj \right] \quad (4.34)$$

subject to (4.15) and (4.32). The first order condition for this problem is

$$E_t \sum_{s=t}^{\infty} (\beta \zeta_\omega)^{s-t} C_s^{-\sigma} \left[\frac{W_{t+s}(j)}{P_s} - (1 + \lambda_\omega) \frac{\omega H_s(j)^\nu}{C_s^{-\sigma}} \right] H_s(j) = 0 \quad (4.35)$$

We focus on a symmetric equilibrium in which all agencies choose the same wage. Let $w_t = W_t/P_t$. From equation(4.33) the law of motion of real wage is

$$w_t^{-\frac{1}{\lambda_\omega}} = (1 - \zeta_\omega) w_{t+s}^{-\frac{1}{\lambda_\omega}} + \zeta_\omega \left(\frac{w_{t-1}}{\pi_t} \right)^{-\frac{1}{\lambda_\omega}} \quad (4.36)$$

2.6.3 Capital-goods producers

Competitive capital-goods producers transforms consumption goods into investments goods. They choose the amount of investment goods to maximize the profits taking the price of investment goods p_t^I as given

$$D_t^I = \left\{ p_t^I - \left[1 + S \left(\frac{I_t}{I} \right) \right] \right\} I_t \quad (4.37)$$

The price of investment goods differ from the price of consumption goods because of the adjustment costs, which depends on the deviations of actual investment from its steady-state value. In steady state adjustment costs are zero, $S(1) = 0$ and as well as its first derivative, $S'(1) = 0$, while its second derivative is positive, $S''(1) > 0$. The first order condition for this problem is

$$p_t^I = 1 + S \left(\frac{I_t}{I} \right) + S' \left(\frac{I_t}{I} \right) \frac{I_t}{I} \quad (4.38)$$

The law of motion of capital is

$$K_{t+1} = \lambda K_t + I_t \quad (4.39)$$

and we consider the following identity equation between capital and net equity

$$K_{t+1} = N_{t+1} \quad (4.40)$$

The resource constraint can be expressed as

$$Y_t = C_t + \left[1 + S\left(\frac{I_t}{I}\right)\right] I_t \quad (4.41)$$

Finally, considering the aggregate expression for D_t for the whole economy and D_t^I in equations (4.23) and (4.37), the investment function can be rewritten as:

$$I_t = \chi \frac{r_t^K N_t + \left[1 + \lambda \phi_t Q_t^L\right] \frac{B_t^L}{P_t} + Q_t^S \frac{B_t^S}{P_t} + Y_t - w_t H_t - r_t^K + p_t^I I_t - I_t \left[1 + S\left(\frac{I_t}{I}\right)\right] - \tau_t}{p_t^I - \theta q_t} \quad (4.42)$$

2.7 The Government

The Government conducts conventional and unconventional monetary policy and fiscal policy following exogenous policy rules.³ The conventional monetary policy consists in setting the nominal interest rate following the feedback rule

$$R_t = \psi_\pi \pi_t \quad (4.43)$$

where $\psi_\pi > 1$. Unconventional monetary policy consists in issuing a short term bond as a function of the liquidity of long-term bond.

$$\frac{B_{t+1}^S}{K_t} = \psi_B \left(\frac{\phi_t}{\phi} - 1 \right) \quad (4.44)$$

While in DEFK the unconventional policy corresponds to Government purchase of private papers, in this framework the Government may alleviate the shortage of liquidity in Government bonds by increasing the issue of one-period bonds when the liquidity of long-term bonds dries ups. This policy provides an alternative liquid means of savings for entrepreneurs that makes their portfolio more liquid. In the first period, the portfolio composition of the private sector is predetermined and on impact the intervention is effective only via its impact on expectations and prices.

³See Cui and Guillen (2013) for a study of optimal policy in a model with liquidity frictions.

The price of the nominal short-term bond is the inverse of the nominal rate ⁴

$$Q_t^S = \frac{1}{R_t} \quad (4.45)$$

The Government budget constraint is given by

$$Q_t^L \left(\frac{B_{t+1}^L}{P_t} - \lambda \frac{B_t^L}{P_t} \right) + Q_t^S \frac{B_{t+1}^S}{P_t} + T_t = \frac{B_t^S}{P_t} + \frac{B_t^L}{P_t} \quad (4.46)$$

The debt repayment is financed by the issue of new debt and a net taxes (or equivalently it can be interpreted as primary surplus). A fiscal rule ensure the Government intertemporal solvency

$$T_t - T = \psi_T \left(\frac{B_t^L}{P_t} - \frac{B^L}{P} \right) \quad (4.47)$$

where $\psi_T > 0$. T and $\frac{B^L}{P}$ are steady-state taxes and beginning-of-period public debt. Therefore, Government adjusts taxes, in term of deviations from steady state, to be proportional to the debt position.

3 Calibration

The model is calibrated at quarterly frequency. We assume that productivity and liquidity (A_t, ϕ_t) follow independent AR(1) processes with autoregressive coefficients $\rho_A = \rho_\phi = 0.95$. The innovations of the two processes are assumed to have mean zero and to be mutually independent. Tables 2 reports the values of parameters in the model. Some of them are standard in the business cycle literature. We set the subjective discount factor β to 0.99 and the inverse Frish elasticity of labor supply ν to 1. The capital share γ of 0.4 and the share of non depreciated capital λ (one minus depreciation rate) of 0.975. The arrival rate of investment opportunity in each quarter χ is 0.05. This is the number to match investment spikes observed from US manufacturing plants (see Doms and Dunne (1998) and Gourio and Kashyap (2007)). The degree of monopolistic competition in labor and product markets are calibrated symmetrically assuming a steady state markup of 10% ($\lambda_p = \lambda_w = 0.1$). The average duration of price and wage contracts is 4 quarters ($\zeta_p = \zeta_w = 0.75$).

⁴This is similar to the model of Lorenzoni (2009), in which the Central Bank chooses the nominal interest rate by following a rule which responds only to inflation and by deciding the nominal interest rate it sets also the price of the one-period nominal bond.

Table 4.2: Calibration

β	0.99	Discount factor
σ	1	Relative risk aversion
χ	0.05	Probability of investment opportunity
λ	0.975	Inverse depreciation rate
γ	0.4	Capital share
$S''(1)$	1	Adjustment cost parameter
ν	1	Inverse Frish elasticity
$\zeta_p = \zeta_w$	0.75	Price and wage Calvo probability
$\lambda_p = \lambda_w$	0.1	Price and wage steady state mark-up
θ	0.19	Borrowing constraint
ϕ	0.75	Resaleability constraint
L	0.4	Steady-state liquidity/GDP
ψ_π	1.5	Monetary policy rule coefficient
ψ_T	0.1	Transfer rule coefficient
ψ_B	-0.127	Government intervention coefficient
$\rho_A = \rho_\phi$	0.95	Autoregressive coefficient in the productivity and liquidity

ϕ and θ are the steady-state values of the parameters capturing the financial frictions. θ can be thought as a measure of financial developments and following DEFK is set to 0.19. ϕ is the key parameter of the model and its value is 0.75. This means that the entrepreneur can sell up to 75% of the long-term bond holding within a quarter, so the liquidity he can obtain is 75% of the value of long-term bond. Thinking about a repo contract, this is equivalent to a repo collateralized by a government bond with a haircut of 25% which gives the investor liquidity for 75% of the value of the government bond used as collateral. Before the crisis, the haircuts on repos collateralized by 10-year bonds issued by Portugal and Ireland was 0.25% as showed by figure 1. For this reason, we set $\phi = 0.75$.⁵ Following DEFK the quarterly liquidity share in the economy L is 0.4. This is a measure of the fraction of total liquid assets over GDP in the economy.

Concerning the policy rules, feedback coefficient on inflation in the monetary

⁵DEFK set $\phi = \theta = 0.19$. This is because they choose a value of ϕ as a function of the steady-state share of liquidity observed in the data.

policy rule ψ_π is 1.5 to guarantee a uniquely determined equilibrium. Transfers slowly adjust to the government debt ($\psi_T = 0.1$). We then compare this economy with the one in which the government reacts more to the debt ($\psi_T = 0.7$). Finally the coefficient of the intensity of government intervention ψ_B is -0.127. This is the value adopted by DEFK to capture the intervention of the FED in open market operations.

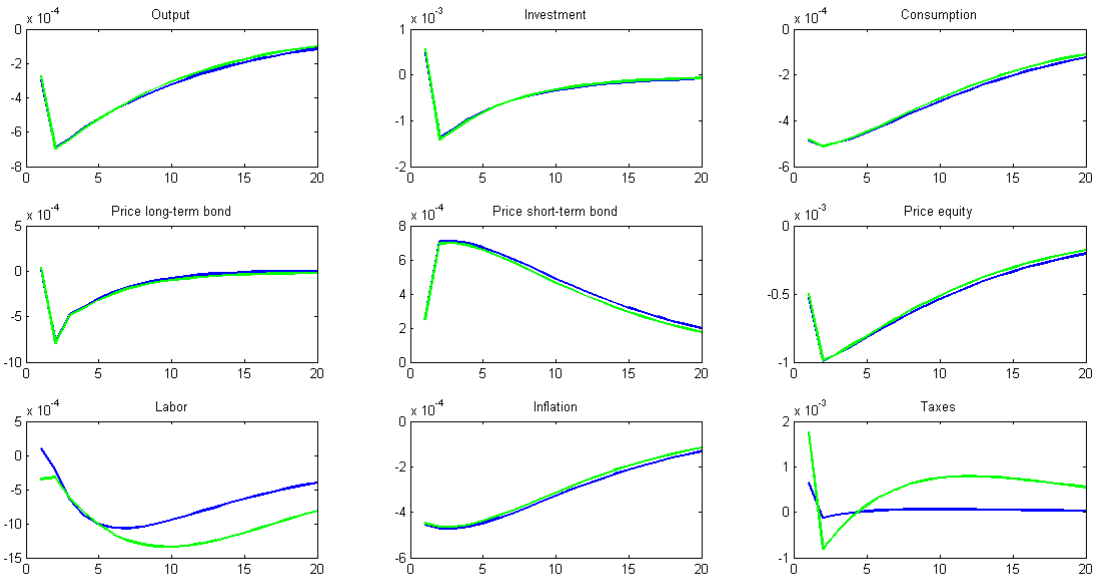
4 Results

4.1 The impact of a liquidity shock

Figure 4.2 shows the response of output, investment, consumption, price of equity, price of short- and long-term bond, hours, inflation and taxes to a 1% increase in ϕ_t (blue line). We first analyze the economy in which the government does not intervene with the unconventional policy, so $\psi_B = 0$. Output, investment and consumption all drop following a negative liquidity shock and recover slowly. A tightening in the resaleability constraint of long-term bonds reduces investment because investors dispose of less liquidity from selling their bond holdings. As a consequence, capital stock also declines. The presence of nominal rigidities avoids the fall in real interest rate that would lead to a rise in consumption. Indeed, in the model of KM with flexible price, a negative liquidity shock has a positive effect on consumption.

Long-term bonds are less attractive than short-term bonds as means of saving, because the entrepreneur can resale a smaller fraction of the bond holding for the investments. On one side, the value of short-term bond increase following a “flight to liquidity” towards the most liquid papers. On the other side, the price of long-term bond decreases. Hours and inflation decrease and because of the monetary policy rule also the nominal interest rate falls. We compare the effect of a liquidity shock with a different calibration of the tax rule. We set $\psi_T = 0.7$ to study an economy in which fiscal policy reacts more strongly to an increase in the debt (green line). Figure 4.2 shows that except for taxes, the impulse response of a liquidity shock does not change.

Figure 4.2: Impulse Responses to a Negative Liquidity Shock

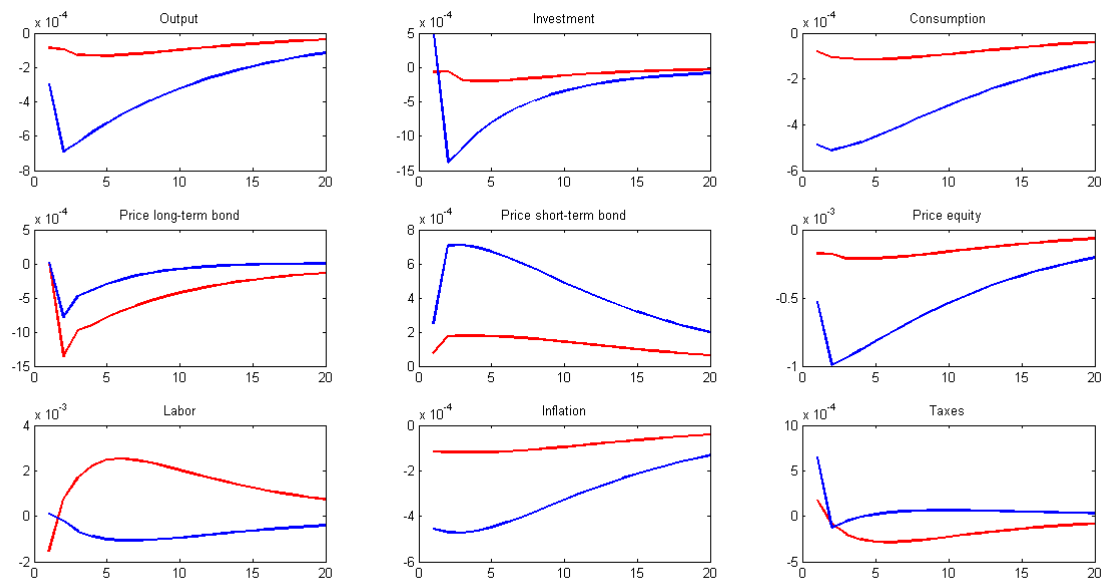


4.2 The effect of the policy intervention

We analyze the effects of a negative liquidity shock in an economy in which the government reacts by issuing more short-term bonds in order to restore the liquidity of entrepreneurs. Figure 4.3 compares the impulse responses to a negative liquidity shock with and without the unconventional policy response (red and blue lines respectively). The unconventional policy reduces the drop in output by more than three times. Looking at its components, the fall in investment is low with the policy intervention, while in a *laissez-faire* economy it falls more than 10 times. The presence of an alternative means of saving makes the entrepreneur's portfolio more liquid and he can therefore invest more. Capital stock and output also fall less.

The unconventional policy has a strong impact on the prices of assets. On one side, a greater availability of short-term bonds increases the flight to quality from long-term bonds to short-term bonds and the price of long-term bonds falls more. On the other side, the increase in the supply of short-term bonds reduces the pressure on the demand of these papers and the impact of the liquidity shock on the price of short-term bond is weaker. In addition, the fall in inflation is less pronounced and the labor supply increases with the policy intervention.

Figure 4.3: The Effect of Policy Intervention



5 Conclusions

This paper has proposed a model to analyze the effect of a reduction in the liquidity of government bonds which is characterizing the sovereign-debt crisis in the Periphery of the Euro area via increases in haircuts of repos collateralized by government bonds. The model incorporates a resaleability constraint on bonds and analyze the consequences of policy intervention which consists in issuing a liquid short-term bond.

Results suggest that a tightening of the resaleability constraint of Government bonds has a negative impact on output, investment and consumption. The negative effect of the liquidity shock can be alleviated by the policy intervention that provide the economy of a liquid means of saving that reduces the fall in investment.

An extension of this model will be to consider an open economy with two countries conducting an independent fiscal policy and sharing the monetary policy in which the liquidity shock hits only the Government bond issued by one country. This would represent the scenario of the Euro area where the Government bonds issued by the Periphery have become less liquid than the ones issued by the Core. It will also allows to study the effect of issuing a liquid bond by the common monetary authority, such as “Eurobond”.

Appendix: Solving the model

A. Equilibrium conditions

To solve the model we define $L_{t+1} = B_{t+1}^L/P_t$, as real long-term bonds. The total factor productivity and resaleability constraint (A_t, ϕ_t) follow an exogenous Markov process and there are 4 endogenous state variables: the aggregate capital stock, the nominal short-term bond, the real long-term bond and the real wage rate from the previous period $(K_t, B_t^S, L_t, w_{t-1})$. The recursive competitive equilibrium is defined as 9 endogenous quantities $(I_t, C_t, Y_t, H_t, K_{t+1}, N_{t+1}, B_{t+1}^S, L_{t+1}, T_t)$ and 11 prices $(q_t, Q_t^L, Q_t^S, p_t^l, \tilde{w}_t, w_t, \tilde{p}_t, \pi_t, r_t^K, mc_t, R_t)$ as a function of state variables $(K_t, B_t^S, C_t, Y_t, L_t, w_{t-1}, A_t, \phi_t)$, which satisfies the 19 equilibrium conditions (4.16, 4.17, 4.18, 4.35, 4.36, 4.24, 4.25, 4.26, 4.27, 4.38, 4.39, 4.40, 4.41, 4.42, 4.43, 4.44, 4.45, 4.46, 4.47). Once all the market clearing condition and the government budget constraints are satisfied, the household budget constraint is satisfied by Walras' Law.

B. Steady states

In the steady-state economy there is no change in the total factor productivity, resaleability, nominal price level, prices and endogenous quantities. The steady-state versions of the Euler conditions are respectively

$$\beta^{-1} = \frac{r^k + \lambda q}{q} + \frac{\chi(q-1)r^k}{q(1-\theta q)} \quad (4.48)$$

$$\beta^{-1} = \frac{1}{Q^L} + \frac{\chi(q-1)}{1-\theta q} \frac{1 + \lambda Q^L \phi}{Q^L} \quad (4.49)$$

$$\beta^{-1} = \frac{1}{Q^S} + \frac{\chi(q-1)}{1-\theta q} \quad (4.50)$$

where in steady state $p^l = 1$ because $S(1) = S'(1) = 0$ from equation (4.38). No arbitrage condition in steady state is

$$\frac{1}{Q^S} = \frac{1 + \lambda Q^L}{Q^L} \quad (4.51)$$

The capital-labor ratio is given by condition (4.24)

$$\frac{K}{H} = \frac{\gamma}{1-\gamma} \frac{w}{r^k} \quad (4.52)$$

Since in the steady state all firms charge the same price, $\tilde{p} = 1$ and the real marginal cost is equal to the inverse of markup

$$mc = \frac{1}{A} \left(\frac{r^k}{\gamma} \right)^\gamma \left(\frac{w}{1-\gamma} \right)^{(1-\gamma)} = \frac{1}{1+\lambda_f} \quad (4.53)$$

Plugging these two equations into the production function (4.37) at the steady state we obtain the capital-output ratio which is a function of the rental rate of capital.

$$\frac{Y}{K} = \frac{(1+\lambda_f)r^k}{\gamma} \quad (4.54)$$

Equation (4.53) can be rewritten as a function of the rental rate

$$w = (1-\gamma) \left(\frac{A}{1+\lambda_f} \right)^{\frac{1}{1-\gamma}} \left(\frac{\gamma}{r^k} \right)^{\frac{\gamma}{1-\gamma}} \quad (4.55)$$

In steady state, the real wage is equal to a markup over the marginal rate of substitution between labor and consumption

$$w = (1+\lambda_w) \frac{[H/(1-\chi)]^\nu}{C^{-\sigma}} \quad (4.56)$$

Assuming that $B^S = 0$ and considering $K=N$, the investment function in steady state is

$$I = \chi \frac{r^k K + (1-\lambda p^B \phi) B^L + \frac{\lambda_f}{1+\lambda_f} Y - T}{1-\theta q} \quad (4.57)$$

Steady-state investment are also the depreciated steady-state capital

$$\frac{I}{K} = (1-\lambda) \quad (4.58)$$

The resource constraint is

$$Y = C + I \quad (4.59)$$

Finally, from the Government budget constraint the steady-state tax is

$$T = B(p^B - \lambda p^B - 1) \quad (4.60)$$

C. Log-linear approximation

Define $\hat{x}_t = \log\left(\frac{x_t}{x}\right)$ where x is the steady-state value of x_t . The log-linearized equilibrium conditions are the following:

Investments:

$$(1 - \chi)\lambda\hat{p}_t^I + (1 - \theta q)\lambda\hat{I}_t - \theta\lambda q\hat{q}_t - \chi\lambda\phi q\hat{\phi}_t - \chi\lambda\phi q\hat{Q}_t^L - \chi(1 + \lambda\phi Q^L)\frac{L}{K}\hat{L}_t + \chi(1 + \lambda\phi Q^L)\frac{L}{K}\hat{\pi}_t - \chi Q^S\frac{\hat{B}^S}{K} - \chi\frac{T}{K}\hat{r}_t^k - \chi\frac{N}{K}\hat{N}_t - \chi\frac{Y}{K}\hat{Y}_t + \chi\frac{(1 - \gamma)r^k}{\gamma}(\hat{w}_t + \hat{H}_t) + \chi r^k\hat{K}_t = 0 \quad (4.61)$$

Euler equation for equity:

$$-\sigma\hat{C}_t = -\sigma\mathbb{E}_t[\hat{C}_{t+1}] - \hat{q}_t + \beta\frac{r^k}{q}(1 + \chi\frac{q-1}{1-\theta q})\mathbb{E}_t[\hat{r}_{t+1}^k] \\ + \beta\chi r^k\frac{1 - \theta}{(1 - \theta q)^2}\mathbb{E}_t[\hat{q}_{t+1}] - \beta\chi r^k\frac{1 - \theta}{(1 - \theta q)^2}\mathbb{E}_t[\hat{p}_{t+1}^I] \quad (4.62)$$

Euler equation for long-term bonds:

$$-\sigma\hat{C}_t = -\sigma\mathbb{E}_t[\hat{C}_{t+1}] - \hat{Q}_t^L - \mathbb{E}_t[\hat{\pi}_{t+1}] + \beta\lambda\chi\frac{q-1}{1-\theta q}\phi\mathbb{E}_t[\hat{\phi}_{t+1}] + \beta\chi\lambda\phi\frac{q-1}{1-\theta}\mathbb{E}_t[\hat{Q}_{t+1}^L] \\ + \beta[\chi(\frac{1}{Q^L} + \lambda\phi)\frac{1 - \theta}{(1 - \theta q)^2}]\mathbb{E}_t[\hat{q}_{t+1}] - \beta[\chi(\frac{1}{Q^L} + \lambda\phi)\frac{(1 - \theta)q}{(1 - \theta q)^2}]\mathbb{E}_t[\hat{p}_{t+1}^I] \quad (4.63)$$

Euler equation for short-term bonds:

$$-\sigma\hat{C}_t = -\sigma\mathbb{E}_t[\hat{C}_{t+1}] - \hat{Q}_t^S - \mathbb{E}_t[\hat{\pi}_{t+1}] + \beta\chi\frac{q-1}{1-\theta q}\mathbb{E}_t[\hat{Q}_{t+1}^S] \\ + \beta\chi\frac{(1 - \theta)q}{(1 - \theta q)^2}\mathbb{E}_t[\hat{q}_{t+1}] - \beta\chi\frac{(1 - \theta)q}{(1 - \theta q)^2}\mathbb{E}_t[\hat{p}_{t+1}^I] \quad (4.64)$$

Resource constraints:

$$\hat{Y}_t = \frac{I}{Y}\hat{I}_t + \frac{C}{Y}\hat{C}_t \quad (4.65)$$

The resource constraint:

$$\hat{m}c_t = (1 - \gamma)\hat{w}_t + \gamma\hat{r}_t - \hat{A}_t \quad (4.66)$$

The Phillips curve:

$$\pi_t = \frac{(1 - \zeta_f\beta)}{(1 - \zeta_f)}\hat{m}c_t + \beta\mathbb{E}_t[\hat{\pi}_{t+1}] \quad (4.67)$$

The capital-labor ratio:

$$\hat{K}_t = \hat{w}_t - \hat{r}_t^k + \hat{H}_t \quad (4.68)$$

The law of motion for aggregate wages:

$$\hat{w}_t = (1 - \zeta_w)\hat{w} + \zeta_w(\hat{w}_{t-1} - \hat{\pi}_t) \quad (4.69)$$

Wage-setting decision:

$$\begin{aligned} & \left(1 + \nu \frac{1+\lambda_w}{\lambda_w}\right)\hat{w}_t - (1 - \zeta_w\beta)\nu \frac{1+\lambda_w}{\lambda_w}\hat{w}_t \\ & = (1 - \zeta_\beta)(\nu\hat{H}_t + \sigma\hat{C}_t) + \zeta_w\beta \left(1 + \nu \frac{1+\lambda_w}{\lambda_w}\right)\mathbb{E}_t(\hat{w}_{t+1} + \hat{\pi}_{t+1}) \end{aligned} \quad (4.70)$$

Aggregate production function:

$$\hat{Y}_t = \hat{A}_t + \gamma\hat{K}_t + (1 - \gamma)\hat{H}_t \quad (4.71)$$

The first order condition for capital producers:

$$\hat{p}_t^I = S''(1)\hat{I}_t \quad (4.72)$$

Identity condition equity and capital:

$$\hat{K}_{t+1} = \hat{N}_{t+1} \quad (4.73)$$

Law of motion of capital:

$$\hat{K}_{t+1} = (1 - \lambda)\hat{I}_t + \lambda\hat{K}_t \quad (4.74)$$

Government budget constraint:

$$\frac{T}{K}\hat{T}_t = \frac{L}{K}(1 + \lambda Q^L)\hat{L}_t - \frac{L}{K}(1 + \lambda Q^L)\hat{\pi}_t + \hat{B}_t^S + (1 - \lambda)(Q^L \frac{L}{K})\hat{Q}_t^L + Q^L \frac{L}{K}\hat{L}_{t+1} + Q^S \hat{B}_{t+1}^S \quad (4.75)$$

Tax rule:

$$\frac{T}{K}\hat{T}_t = \psi_t \left[\frac{L}{K}(\hat{L}_t - \hat{\pi}_t) \right] \quad (4.76)$$

The interest rate rule:

$$\hat{R}_t = \psi_\pi \hat{\pi}_t \quad (4.77)$$

Government intervention:

$$\hat{B}_t^S = \psi_k \hat{\phi}_t \quad (4.78)$$

Price of short-term bond

$$\hat{R}_t = -\log(Q^S) \quad (4.79)$$

Conclusion

In the aftermath of the Great Depression fiscal policy had been seen as the central macroeconomic tool. The fiscal interventions during the global financial crisis and the Great Recession has generated new interest on fiscal policy and on the consequences of fiscal interventions. What is the effect of fiscal stimuli implemented in the wake of financial crisis? What are the consequences of unconventional monetary policy? How fiscal adjustments affect the economy recovery? How to guarantee the sustainability of growing public debts? How fiscal weakness spreads over the banking system? How banks' fragility impacts the sovereign risk? These interrogatives are at the center of the economic debates and represents areas of interest for the present and future academic research.

This dissertation has addressed some of these issues and raised new questions. The first chapter has analyzed the impact of a fiscal stimulus on the economy suggesting an alternative approach for the identification of a Government spending shock based on a two-step approach which consists in separating discretionary and automatic components of public spending on the basis of their statistical properties and in including discretionary expenditure in a structural VAR to reduce the problem of endogeneity.

The second chapter showed how fiscal stance affects the transmission mechanism of monetary policy shocks and the importance to take into account the complementary of macroeconomic measures in order to provide policy recommendations. In particular, fiscal adjustments reduce the effectiveness of monetary policy to stimulate the economic activity. This raises some doubts on the current policy mix adopted in most of the European countries to recover economic activity after the global financial crisis.

The third chapter has explored the European market of repurchase agreements, which is a "black box" because of the paucity of the data and has highlighted that this market represents a channel for the banking and sovereign-debt crises in the periphery of the Eurozone, because of the role of government securities as collateral in these transaction.

The fourth chapter has presented a DSGE model to analyze the impact of a liquidity shock on government bonds on the economy and how public authorities may restore the liquidity in the market via a non conventional policy which consists in issuing a liquid short-term bond.

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Chapter 2

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