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Financial innovations and macroeconomic stability : an assessment of contingent convertible bonds

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PARIS 1 PANTHÉON-SORBONNE UNIVERSITY

Centre d'Economie de la Sorbonne

&

BIELEFELD UNIVERSITY

Bielefeld Graduate School of Economics and Management

Financial innovations and macroeconomic stability: an assessment of contingent convertible bonds

Thèse présentée et soutenue par

Elise KREMER

le 16 décembre 2022 à l'Université Paris 1 Panthéon-Sorbonne dans le cadre d'une cotutelle

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Financial innovations and macroeconomic stability: an assessment of contingent convertible bonds

This thesis was written and defended by

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Financial innovations and macroeconomic stability: an assessment of contingent convertible bonds

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ABSTRACT

In the period prior to 2008, balance sheets increased so rapidly that the banking sector lent to households that could not repay. This resulted in a financial crisis that then spread to the real sector via other balance sheet effects (a drop in the net worth of the household sector and therefore in its consumption, a sharp contraction in credit etc.). To prevent this from happening again, regulators are demanding that banks be able to deal with this type of problem ex ante by setting aside larger and higher quality capital and by relying more on bail-in mechanisms. As a result, the banking sector has created a new type of asset: contingent convertible bonds (CoCos). When the banks' ratio of assets and liabilities exceed a certain threshold, these bonds either convert into shares, which then boosts the capitalization of the bank, or are written off. These contingent convertible bonds are intended to strengthen the stability of the banking system and to ensure that the government is not required to fully assume the bailout of banks in the event of a new financial crisis.

As no CoCo bond has yet been activated, their effectiveness remains hypothetical. The main question in this thesis is whether or not they could fulfil their mission of stabilising the banking sector. What other effects can be expected? Given that CoCos holders might endure a total write-down of what they were supposed to earn what kind of behaviour can be expected in the event of an activation? How does this risk shifting translate for the whole economy versus a system without coco bonds? Could the costs of such bail-ins outweigh their benefits in some situations? Will CoCos play a stabilizing or destabilizing role in the event of another financial crisis?

This thesis aims at incorporating in a stock-flow consistent agent-based model (more precisely the JMAB model developed by Caiani et al. (2016)) the contingent convertible bonds issued by the banking sector since the 2008 crisis, allowing them to build up capital buffers that can be mobilized in the context of bail-ins when their balance sheet deteriorates too strongly. Since these bonds have never been triggered on a large scale, I propose a counterfactual analysis of what would happen in case of activation, based on an SFC-AB model. My work consists in extending the JMAB model by adding: 1. a new class of financial assets, 2. learning behaviors on the part of investors, 3. a variable opinion component (alternating between optimism and pessimism/prudence on the part of issuing banks and investors) allowing to take into account possible financial contagion effects through information spillovers.

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ZUSAMMENFASSUNG

In der Zeit vor 2008 stiegen die Bilanzen so schnell an, dass der Bankensektor Kredite an Haushalte vergab, die diese nicht zurückzahlen konnten. Dies führte zu einer Finanzkrise, die dann über andere Bilanzeffekte auf den realen Sektor übergriff (Rückgang des Nettowertes des Haushaltssektors und damit des Konsums, starker Rückgang der Kredite usw.). Um dies zu verhindern, verlangen die Regulierungsbehörden, dass die Banken in der Lage sind, diese Art von Problemen ex ante zu bewältigen, indem sie größeres und hochwertigeres Kapital zurücklegen und sich stärker auf Bail-in-Mechanismen verlassen. Infolgedessen hat der Bankensektor eine neue Art von Vermögenswerten geschaffen: bedingte Pflichtwandelanleihe (CoCos). Wenn das Verhältnis von Aktiva und Passiva der Banken einen bestimmten Schwellenwert überschreitet, werden diese Anleihen entweder in Aktien umgewandelt, was die Kapitalisierung der Bank erhöht, oder abgeschrieben. Diese bedingten Pflichtwandelanleihen sollen die Stabilität des Bankensystems stärken und sicherstellen, dass der Staat im Falle einer neuen Finanzkrise nicht vollständig für die Rettung der Banken aufkommen muss.

Da bisher noch keine CoCo aktiviert wurden, bleibt ihre Wirksamkeit hypothetisch. Die Hauptfrage in dieser Doktorarbeit ist, ob sie ihre Aufgabe, den Bankensektor zu stabilisieren, erfüllen können oder nicht. Welche anderen Auswirkungen sind zu erwarten? Wie werden sich die Inhaber von CoCos im Falle einer Aktivierung verhalten, wenn sie einen Totalverlust ihrer erwarteten Einnahmen hinnehmen müssen? Wie wirkt sich diese Risikoverlagerung im Vergleich zu einem System ohne CoCos auf die gesamte Wirtschaft aus? Könnten die Kosten solcher Bail-ins in manchen Situationen ihre Vorteile überwiegen? Werden CoCos im Falle einer weiteren Finanzkrise eine stabilisierende oder destabilisierende Rolle spielen?

Diese Doktorarbeit zielt darauf ab, die vom Bankensektor seit der Krise von 2008 ausgegebenen CoCos in einem flussgrößenkonsistenten agentenbasierten Modell (SFC-ABM) (genauer gesagt das von Caiani et al. (2016), entwickelte JMAB-Modell) einzubeziehen, das es ihnen ermöglicht, Kapitalpuffer aufzubauen, die im Rahmen von Bail-ins mobilisiert werden können, wenn sich ihre Bilanz zu stark verschlechtert. Da diese Anleihen noch nie in großem Umfang in Anspruch genommen wurden, führe ich eine kontrafaktische Analyse dessen ein, was im Falle einer Aktivierung auf der Grundlage eines SFC-AB-Modells geschehen würde. Meine Arbeit besteht in der Erweiterung des JMAB-Modells durch Hinzufügen von: 1. eine neue Klasse von Finanzaktiva, 2. Lernverhalten auf Seiten der Investoren, 3. eine variable Meinungskomponente (abwechselnd Optimismus und Pessimismus/Vorsicht auf Seiten der emittierenden Banken und Investoren), die es ermöglicht, potentielle finanzielle Ansteckungseffekte durch Informationsübertragungen zu berücksichtigen.

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RÉSUMÉ COURT

Au cours de la période précédant 2008, la taille des bilans bancaires a augmenté rapidement dans le cadre de prêts à des ménages qui ne pouvaient pas les rembourser. Cela a provoqué une crise financière qui s'est ensuite propagée au secteur réel via des effets de bilan (baisse de la valeur nette du secteur des ménages et donc de sa consommation, forte contraction du crédit, etc.) Pour éviter que cela ne se reproduise, les régulateurs exigent des banques qu'elles soient en mesure de faire face ex ante à ce type de problème en mettant en réserve des fonds propres plus importants et de meilleure qualité et en recourant davantage aux mécanismes de bail-in. En conséquence, le secteur bancaire a créé un nouveau type d'actif : les obligations convertibles contingentes (CoCos). Lorsque le rapport entre l'actif et le passif des banques dépasse un certain seuil, ces obligations sont soit converties en actions, ce qui renforce la capitalisation de la banque, soit annulées. Ces obligations convertibles contingentes ont pour but de renforcer la stabilité du système bancaire et de faire en sorte que le gouvernement ne soit pas obligé d'assumer entièrement le sauvetage des banques en cas de nouvelle crise financière.

Comme aucune CoCo n'a encore été activée, leur efficacité reste hypothétique. La question principale de cette thèse est de savoir s'ils pourraient ou non remplir leur mission de stabilisation du secteur bancaire. Quels autres effets peut-on attendre ? Étant donné que les détenteurs de CoCos pourraient subir une dépréciation totale ou partielle de ce qu'ils étaient censés gagner, quel type de comportements peut-on attendre en cas d'activation ? Comment ce transfert de risque se traduit-il pour l'ensemble de l'économie, par rapport à un système sans cocos ? Les coûts de ces bail-ins pourraient-ils l'emporter sur leurs avantages dans certaines situations ? Les CoCos joueront-ils un rôle stabilisateur ou déstabilisateur en cas de nouvelle crise financière ?

Cette thèse vise à incorporer dans un modèle stock-flux cohérent à base d'agents (plus précisément le modèle JMAB développé par Caiani et al. (2016)) les obligations convertibles contingentes émises par le secteur bancaire depuis la crise de 2008, leur permettant de constituer une réserve de fonds propres mobilisable dans le cadre de bail-ins lorsque leur bilan se détériore trop fortement. Comme ces obligations n'ont jamais été déclenchées à grande échelle, je propose une analyse contrefactuelle de ce qui se passerait en cas d'activation sur la base d'un modèle SFC-AB. Mon travail consiste à étendre le modèle JMAB en ajoutant : 1. une nouvelle classe d'actifs financiers, 2. des comportements d'apprentissage de la part des investisseurs, 3. une composante d'opinion variable (alternant entre optimisme et prudence de la part des banques émettrices et des investisseurs) permettant de prendre en compte d'éventuels effets de contagion financière par le biais de retombées d'informations.

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INTRODUCTION

In 2008, excessive risk-taking and securitization opacity led to large losses for banks when households couldn't repay their debt. It resulted in bank failures and ultimately in costly bailouts borne by the taxpayers. Some banking regulation has been implemented since then to prevent this situation from happening again. Among others, the Dodd Frank Act in the United States and the Basel III agreements worldwide have encouraged so-called "second generation mechanisms" based on ex-ante resolution procedures with a focus on two pillars: first, priority given to bail ins over bailouts, and second, stricter Tier 1 capital requirements for banks. The focus on these two pillars has led banks to issue a new type of asset since 2008: contingent convertible bonds (CoCos).

CoCos are a debt instruments with an option. As long as the issuing banks are doing well from a solvency point of view, CoCos work exactly like standard bonds. Banks can issue them when they need funds. Investors buy them and are entitled to interest payments and will get back the principal when the bond expires. But when banks' balance sheets deteriorate too much, CoCos are triggered and either convert into equities or are simply written off. In both cases, the principal retained by banks allows them to give a boost to their capitalization. CoCos are therefore used as a safety cushion that kicks in only in case of difficulties for the banking sector. They are intended to strengthen the stability of the banking system and to ensure that governments are not required to fully assume the bailout of banks in the event of a new financial crisis.

However, as no CoCo bond has yet been activated, their effectiveness remains hypothetical and subject of debates. Some authors argue that they should improve the solvency of the banking sector and reduce the likelihood of taxpayer-funded bailouts (Calomiris & Herring, 2013; Pennacchi, 2010). Other authors insist on the fact that CoCos reduce the need for fire-sells when banks' solvency worsen too much, which limits the risk of death spirals and financial contagion (Vallée, 2019). And finally, their advocates argue that they mitigate the hindering effects of regulation on banks' profitability, allowing them all things being equal to increase lending to the real economy (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009).

But CoCos also have detractors. On the disadvantage side, several research papers warn about a potential increase in risk-taking and moral hazard as banks know that they will be

bailed-in by investors if not bailed-out by governments (Berg & Kaserer, 2015; Flannery, 2016; Hilscher & Raviv, 2014; Martynova & Perotti, 2018). Some authors show how sudden risk reassessments by investors due to CoCos' complexity could have destabilizing effects on the financial sector (Admati et al., 2013; M. Allen et al., 2002; Goodhart, 2010; Sundaresan & Wang, 2015). Others focus on how the loss-absorption mechanism triggered by CoCo activations may occur too late, hence limiting their usefulness (Delivorias, 2016; Pazarbasioglu et al., 2011). There are also concerns that CoCos might not reduce the actual risk the banking sector is facing, but simply displace it to other sectors in the economy (Avdjiev et al., 2013). And finally, a recent empirical paper by Bologna et al. (2020) shows the existence of a CoCo-specific financial contagion channel.

The existing literature is therefore particularly divided on the subject of CoCos. On the one hand, one can expect positive effects from CoCos issuances: individual banks should be more resilient in times of crises and there should be less need for bailouts. But on the other hand, these theoretical benefits are to be contrasted with expected (and even observed) negative effects such as an increase in moral hazard, sudden and destabilizing market adjustments and potential financial contagion effects.

This leaves three sets of questions open. The first one is related to the effectiveness of CoCo bail-ins. Can CoCos fulfil their mission of stabilizing the banking sector in the event of a financial crisis. Can they prevent bankruptcies? How much capital would be necessary to bail-in banks after a crisis? To what extent do they reduce the need for bailouts?

The second one is related to potential hidden costs for the rest of the economy. Provided CoCos are effective for the banking sector, are they also for the economy as a whole? Could the costs of such bail-ins outweigh their benefits in some situations? Is the risk transfer from taxpayers to investors always a positive outcome? How does this risk shifting translate for the whole economy versus a system without CoCo bonds? How does CoCo bond issuances impact the systemic risk? Do they indeed reduce it, or simply shift it, or even worse, increase it? Will CoCos play a stabilizing or destabilizing role in the event of another financial crisis? In what situations could CoCos destabilize the economy?

And finally, given all these uncertainties, are regulators right to encourage such bail-in mechanisms?

This PhD thesis is based on a key assumption: the inability of the existing literature to settle these debates and answer these questions can be explained by the lack of research bridging the gap between microeconomics and macroeconomics. Indeed, as Charles Goodhart notes: "One of the weaknesses of some of the analysis of CoCos is that it concentrates on the effect on a particular troubled bank, rather than also exploring the effects on the market dynamics of the financial system as a whole, (one of the key inherent weaknesses of our prior regulatory system)." (Goodhart, 2010). Indeed, most of the existing theoretical literature focuses on the advantages and disadvantages of CoCos at a micro level. In doing so, these analyses do not allow to conclude whether CoCos are useful or dangerous for the economy as a whole. They only provide information on one particular aspect of CoCos at a time and only at the level of an individual bank.

However, what is valid for an isolated bank is not necessarily valid for the whole sector – as many aggregated repetitions of the same phenomenon. In a sector where the importance of its agents can be systemic and where each decision can have profound repercussions on a macroeconomic scale, as the 2008 crisis showed, banks are interdependent. They influence each other directly through their actions, but also indirectly by affecting their environment, which in turn affects the behaviour of other banks. As a result, well-documented simple and predictable local interactions may generate intricate and unexpected global patterns. For example, if two banks have invested in the same asset and one of them is in trouble due to a sudden drop in the value of its assets, it will react by triggering fire sales, accentuating the drop in price even more, which will affect the portfolio of the other bank that was until then solid.

Therefore, any comprehensive assessment of the effectiveness and potential hidden costs of contingent convertible bonds, should rely on a macroeconomic framework that takes into account the interactions between the agents that populate the economy. Since there have not yet been any regular CoCo activations, we cannot rely on empirical data so we need to simulate what would happen if CoCos were activated in an economy sufficiently close to what is actually observed in reality. This requires the use of a theoretical counterfactual model that is empirically anchored. The model must be able to draw macroeconomic conclusions based on microeconomic interactions.

This is precisely the purpose and main contribution of this PhD thesis: to propose a credible theoretical model, incorporating the contingent convertible bonds issued by the banking sector since the 2008 crisis, and seeking to answer the various questions posed above

and so far, unanswered in the existing literature. More precisely, this work consists in extending the stock-flow consistent agent-based JMAB model developed by Caiani et al. (2016) by adding: 1. a new class of financial asset, 2. learning behaviours on the part of investors, 3. a variable opinion component (alternating between optimism and pessimism/prudence on the part of issuing banks and investors) allowing to take into account regime shifts and possible financial contagion effects through information spillovers. This results in the very first agent-based macroeconomic assessment of contingent convertible bonds.

STRUCTURE OF THE THESIS

This thesis is divided into four chapters. Chapter 1 extends the introduction by exploring the links between the development of the CoCo market, the existing literature on this subject and the methodological choices made in the rest of the thesis to answer the questions left unanswered by this literature. The next three chapters consist of three blocks, which build on each other to arrive progressively at a final version of a model allowing to answer these questions. Chapter 2 features a stock-flow consistent model. This purely macroeconomic framework is a preliminary step and should be considered as such. Its purpose is to provide a few qualitative results, but above all to pave the way for the next two chapters which are the core of the thesis. Chapter 3 brings microfoundations and heterogeneity to this macro framework as part of an agent-based stock-flow consistent model. It focuses on the effectiveness of CoCo bail-ins, compares them to bailouts and analyses their macroeconomic impact. Finally, the agent-based stock-flow consistent model is extended by adding investor learning and dynamic opinion behaviours (Chapter 4). This last chapter focuses mainly on the systemic risk and financial contagion that could be associated with CoCos.

Chapter 1: Context, motivation and methodology

This chapter presents an in-depth introduction to this research. I review the genesis of CoCos. I describe their functioning and how they fit into the Basel III regulatory framework before examining the evolutions of the market, from its initial boom to more recent disruptions. I then conduct a literature review on contingent convertible bonds to highlight the research previously done and upon which my work builds, to illustrate the lack of certainty about the effects of CoCos activation and to identify a number of blind spots that this thesis seeks to fill. I then justify the methodological choices made in the following chapters, and in particular the types of models used.

Chapter 2: Contingent convertible bonds and macroeconomic stability in a stock-flow consistent model

This chapter builds a kaleckian economy into a stock-flow consistent model in order to assess the effect of contingent convertible bonds from a stability perspective through numerical simulations. The distinguishing features of the model are a dual household sector (workers and investors) and a dual banking system (retail banks and investment banks). Two sets of simulations are implemented. One focuses on an increase in defaults on workers' loans that triggers a write-down of CoCos issued by retail banks and the other on a decrease in corporate share prices which triggers a write-down of CoCos issued by investment banks. The overall effects are qualitatively similar. There is a risk and adjustment cost transfer from issuers to CoCo holders which reduces investing-households' consumption and firms' investment. The simulations show that the activation of CoCos has a positive effect on the balance sheet of CoCos issuers. It also lowers the cost of bailouts. The trade-off is an increase in real and financial instability. Two regulatory recommendations follow from this work: (1) Banks could be required to issue a fraction of their debt in CoCos in order to reduce bailout costs. (2) When CoCos are activated, their issuer could be compelled not to intervene on all or part of the financial markets, for a predefined period of time and/or value in order to limit the destabilization of asset prices.

Chapter 3: Contingent convertible bonds and macroeconomic stability in a stock-flow consistent agent-based model

This chapter focuses on providing microfoundations to the macroeconomic framework presented in Chapter 2. The analysis is based on an extension of the JMAB model developed by Caiani et al. (2016). Macroeconomic dynamics and variables are deduced from the adaptive behaviour and interactions of heterogeneous agents. The supply, demand, interest rate setting and market organization of CoCos are refined further. The model is empirically validated by verifying that the extension is able to reproduce microeconomic and macroeconomic stylized facts initially reproduced by the original JMAB model. A parameter sweep is carried out for different values of the CoCo activation threshold. Monte Carlo simulations show that bail-ins resulting from the activation of CoCos in a crisis not only partially replace costly bailouts for the taxpayer, but also effectively prevent bank failures and contribute to higher average capital adequacy ratios. This stabilization of the banking sector is positive for the economy as a whole as long as the volume of CoCos in circulation is not too high. We observe positive second-order effects on investment and GDP. Indeed, since there are less bank bankruptcies, banks can keep

up with their activities, especially lending to firms to finance their investment and production. Above a certain volume, their activation negatively affects macroeconomic aggregates. The more CoCos in circulation, the greater the net wealth transfer when bail-ins occur. Beyond a certain amount, the negative effects on consumption start to outweigh the positive second order effects and this eventually affects GDP as well. In some situations, CoCos may contribute to reinforcing the effects of a crisis rather than mitigating them. It is therefore in the regulator's interest to control the expansion of the CoCo market.

Chapter 4: Contingent convertible bonds and macroeconomic stability in a stock-flow consistent agent-based model, augmented by a dynamic opinion component and investor learning

This chapter focuses on extending the model presented in Chapter 3 with the addition of a dynamic opinion component (similar to Salle & Sepecher, 2015) and investor learning behaviours following a modified Roth-Erev algorithm (Nicolaisen et al., 2001). The model is empirically validated by verifying that this extension is able to reproduce microeconomic, macroeconomic and financial relevant stylized facts. A Poisson autoregressive model is used to show that CoCo activations are prone to domino effects and financial contagion through information spillovers following repayment delay announcements. A parameter sweep is carried out to show that these information spillovers happen for different learning behaviours. CoCos are likely to play a destabilising role for the financial sphere. When banks decide to delay repayment of principal because they are cautious about their solvency, investors may react to such announcements by turning away from the CoCo market. This creates a feedback loop: because of these information spillovers, it becomes harder for banks to set aside Additional Tier 1 capital, which leads to CoCo activations due to a specific contagion channel that seems to be weakening as buyers adapt their behaviour. Two recommendations for prudential regulation follow: (1) The Basel framework should consider more carefully the role of CoCos in the Tier 1 capital compartment. While the Additional Tier 1 capital cushion can, all other things being equal, absorb some shocks and limit the use of bailouts, it can also create opportunities for the difficulties of individual banks to spread to the rest of the sector. (2) Every effort should be made to ensure that the way in which CoCos operate is as clear as possible to investors who buy them. This may mitigate over-adjustments in the market in case of disruptions.

CHAPTER 1: CONTEXT, MOTIVATION AND METHODOLOGY

This chapter serves as an in-depth introduction to this research. First, the context surrounding the genesis CoCos is developed. I describe their functioning and how they fit into the Basel III regulatory framework before examining the evolutions of the market, from its initial boom to more recent disruptions. Secondly, I present the motivation for this research. I conduct a literature review on contingent convertible bonds to highlight the research previously done and upon which my work builds, to illustrate the lack of certainty about the effects of CoCos activation and to identify a number of blind spots that this thesis seeks to fill. Last, I justify the methodological choices made in the following chapters, and in particular the types of models used.

1.1 CONTEXT

1.1.1 The genesis of contingent convertible bonds

The financial crisis of 2008 brought to light the problem caused by an over-leveraged financial sector. First, it is likely to suffer significant losses that could ultimately be transferred to the taxpayer. Second, an over-indebted financial sector is encouraged to invest in risky assets to maximize returns. Finally, in order to avoid diluting their power, bank shareholders are opposed to the issuance of new shares likely to rebalance the balance sheets. Therefore, once a bubble is initiated, it is unlikely that a rollback will occur. Rising prices are pushing investors to get more debt to buy more assets, pushing up prices (Minsky, 1992b). This will likely have negative effects on business decisions, especially financial institutions such as banks, which may choose to invest more and more in these assets (Minsky, 1992a). Leverage is then pro-cyclical, generating instability in the financial sector and causing crises such as the 2008 Great Financial Crisis (GFC). In times of prosperity, the financial sector is left with excess capacity. To use it, it has to expand its balance sheet. On the liabilities side, it is moving towards short-term debt. On the asset side, it seeks to buy and lend more and more. In the period prior to 2008, balance sheets increased so rapidly that the banking sector lent to households that could obviously not repay their debts. This resulted in a financial crisis that then spread to the real sector via other balance sheet effects (a drop in the net worth of the household sector and therefore in its consumption, a sharp contraction in credit etc.). Such an accounting approach of financial

meltdowns has been advocated by the IMF for several decades (Adrian & Shin, 2010; M. Allen et al., 2002).

In addition, it is now acknowledged that when a financial crisis occurs, large financial corporations pose a systemic risk to the rest of the economy (Acemoglu, 2009). In order to avoid a major crisis, the government has no choice but to put in place a bailout at the ultimate expense of taxpayers. Faced with such a situation, states generally do not let big banks crash because this would cause significant damage to the rest of the economy and to market liquidity. As this implicit backing is common knowledge, it amounts to a form of non-priced insurance for large financial corporations. To reframe it in the words of modern finance, with bailout plans governments are providing call options for free to big financial institutions, but these potential losses are not reflected in the public budget (Bryan et al., 2020; Bryan & Rafferty, 2006; Martin, 2014). From a taxpayer's perspective, a potential bailout represents a rise in future taxes or a decline in the quality or the quantity of future public services. In this “too big to fail” paradigm, banks managers and share-holders can indefinitely take advantage of possibly inflicting large negative externalities to the rest of the economy to enjoy bigger risks and profits through overleveraged financial companies at the expense of governments and tax payers. This creates a moral hazard situation (Alessandri & Haldane, 2011; A. Haldane, 2013; Siegert & Willison, 2015).

To prevent this from happening again, national and international regulators are promoting “second generation mechanisms” by forcing banks to deal with this type of problem ex ante (Tropeano, 2011). Two solutions have been more particularly considered under Basel III since the 2008 crisis. The first solution is to ensure that banks can deal with it alone. Thus, they are encouraged to set aside larger, higher quality capital and reduce their debt (Blundell-Wignall & Atkinson, 2010; Howarth & Quaglia, 2016). In addition, the agreement allows contingent capital instruments to be included in a special compartment called additional Tier 1 (AT1) which can substitute for up to 1.5% of the common equity in Tier 1. The second solution is to transfer part of the risk to private investors. In the Euro Area, this has resulted in the implementation of the Recovery and Resolution Directive in May 2014: when a bank threatens to go bankrupt, the bondholders are called upon (Howarth & Quaglia, 2014; Thole, 2014).

As a result, the banking sector has created a new type of asset: contingent convertible bonds (“CoCo bonds” or “CoCos”). To understand how exactly the Basel III regulatory

framework has created the right conditions for the emergence of contingent convertible bonds, it is first necessary to explain what they are (section 1.1.2) and how they work (section 1.1.3).

1.1.2 What is a contingent convertible bond?

A CoCo is a hybrid financial instrument that has characteristics of both debt and equity. In normal times, it works exactly like a standard bond. A bank issues some when it needs funds. Investors buy them and are entitled to interest payments and will get back the principal when the bond expires. In a crisis, when banks' capital crosses a certain threshold, these bonds convert into equity shares or are written off (principal write-down, PWD), which then boosts the capitalization of the issuers. PWD can be either full or partial. These two possibilities (conversion vs. PWD) define the loss absorption mechanism and allow for the recapitalization of the banks.

CoCos are intended to provide large financial companies with more stability and to prevent them from shifting their own risks and imbalances to the rest of the economy. Instead of trying to reduce the size of the assets through fire sales when solvency goes down as often observed, CoCos create a mechanism which modifies the composition of the right-hand side of the issuers' balance-sheet by substituting equity for the debt once a solvency ratio goes beyond a certain threshold. Such a device puts an explicit limit to the leverage effect that banks can take advantage of. In other words, the growth of a financial company that issues CoCos can rely to a more limited extent on debt and leverage. The government is not required to fully assume the bailout of banks in the event of a new financial crisis as they theoretically allow banks to raise capital very quickly (Avdjiev et al., 2013).

How are CoCos different from convertible bonds, some of which have been around for more than a century (Lummer & Riepe, 1993)? Convertible bonds are mainly issued by companies. The holder of a convertible bond has a right to convert her bond into a specified number of shares of the issuing company at a strike price. This type of security can be interpreted as a combination of a regular bond and an option to buy the issuer's stocks at some predetermined price or ratio, and some convertible bonds are explicitly designed that way. Very often, the conversion price is higher than the price of the stock at the issuance moment. Since the conversion right increases the value of the convertible bond compared to a normal bond, the interest paid by the issuer might be lower. In addition to a reduction of cash interest payments, another advantage for the issuer is that debt disappears when bonds are converted into stocks. But the disadvantage is that a relative dilution is expected which reduces the value

of shares. From the point of view of investors, they can bet on a rise of the issuer's stock price while enjoying the usual advantages of a debt security. This type of hybrid investment vehicle is traditionally used by companies as a debt management device. For instance, contingent bonds can be used to restructure illiquid but solvent debt-laden companies. They are of some interest as well for start-ups at the very beginning of their development as a way to delay the valuation of the company. If the start-up is successful the stock price goes beyond the strike price. This induces debt holders to transform their convertible bonds into shares. It brings also potentially more money to the investors than the modest interest rate on the convertible bonds and, at the same time, the conversion cleans the company's balance sheet of its debts, which further stimulates its expansion. If the share price is below the conversion price, the bondholder has an interest in requesting the redemption of her bond at par (some bonds are automatically converted at maturity, which amounts to selling futures shares).

While convertible bonds are made to trigger conversion upwards, CoCos are designed to trigger conversion on the down side. Convertible bonds are an instrument for the development of new industries from which very high returns are likely to be expected while CoCos are an instrument for the bail-in of banks in distress situation. More precisely, Cocos are sending the signal that the issuer is credibly conforming to Basel III.

1.1.3 How do contingent convertible bonds work?

The main detailed technical features of CoCos have been outlined by Avdjiev et al. (2013). Contingent convertible bonds feature both a trigger mechanism and a loss absorption mechanism.

The trigger mechanism dictates when the activation takes place. Triggers can be classified into two separate categories: either discretionary or mechanical.¹ CoCos may be activated based on the regulator's assessment of the issuer's solvency. This is known as a discretionary or a point of non-viability (PONV) trigger. When it comes to mechanical triggers, the activation of CoCos occurs when the issuing bank's capital falls below a fraction of its risk-weighted assets. This fraction is specified in advance when the bonds are issued and remains fixed. Bank capital can be measured in two different ways: either according to book values or according to market values. Book-value triggers are breached when an accounting ratio that reflect the balance-sheet state of the issuer fall below a certain threshold. The most commonly

¹Two things should be noted. First, a CoCo can have multiple triggers. In this case, the activation occurs when at least one of them is crossed. Second, when a CoCo has multiple triggers, they can be both mechanical and discretionary.

used is the Common Equity Tier 1 risk-weighted ratio. But other kinds of capital adequacy ratios, as well as the leverage ratio or the liquidity ratios are sometimes used too. Market-value triggers are breached when the share price of the issuing bank falls below a certain threshold. More precisely, they are based on the stock market capitalization-to-assets ratio.

The loss absorption mechanism dictates what happens after the activation takes place. Loss absorption can happen in two ways: principal write-down or conversion into equity. In both cases, the loss absorption results in an increase in capital. With a principal write-down, the increase in capital occurs as CoCos become void and null. Their interest and principal repayments are cancelled and the issuer can keep them as capital. The write-down can be either partial or full, temporary or permanent. Most PWD CoCos have a full and permanent feature. With a conversion-into-equity, the increase in capital occurs as CoCos turn into equity shares. The conversion rate is pre-defined in the contract and depends either on the stock selling price at the time of issuance, the stock market price at the time of activation or a combination of both.

Now that we have seen what contingent convertible bonds are and how they work, let's have a look at their advantages, the way they have been integrated into the Basel III regulatory framework and how they promoted the growth of the market.

1.1.4 The integration of CoCos into the Basel III regulatory framework

After the GFC, national and international authorities have coordinated to both reduce the incentives of banks to take excessive risks and to reduce the impact of the failure of systemic financial companies (Bank for International Settlements, 2017). Regulators have implemented stricter prudential rules encouraging, among other things, higher capital ratios. The problem with such a single capital adequacy constraint is that when the solvency ratio of a financial company goes down its share-holders are induced to shrink assets instead of reducing the debt-to-equity ratio by issuing new shares. This contributes to further destabilize financial markets and other institutions in case of fire sales. How to make private claimants -shareholders and debt holders- bear losses in case of bankruptcy without destabilizing the whole economy? A side problem is that bankruptcy procedures take time. This might complicate a resolution as customers of insolvent institutions are also creditors and they could be encouraged by a potential failure of their bank to move their business away (Flannery, 2014).

This is where CoCos are important. Their feature is to set up a bail-in that is determined in advance, before the default. With CoCos, financial firms can rapidly deleverage without fire-selling their assets. Such hybrid security is a means of automatic recapitalization that decreases

the likelihood of a taxpayer-funded bailout since the risk is transferred from taxpayers to investors. CoCos are hence useful for society ex post as their trigger improves solvability of the banking sector (Calomiris & Herring, 2013; Pennacchi, 2010). They can also contribute to reduce ex-ante default probability when used as a device to shape compensation practices so that financial companies' leaders avoid taking excessive risks. Dudley (2013) proposes that in order to deter senior managers to take excessive risks a significant portion of their bonuses should be deferred each year so as to cover future capital losses by investing for instance in PWD CoCos.

It has been therefore in the regulator's interest to make room for them in the Basel III capital adequacy framework.

The Basel Framework is the set of standards established by the Basel Committee on Banking Supervision (BCBS). Its purpose is to ensure the prudential regulation of banks worldwide. This framework has evolved over time and has gone through three phases, corresponding to the three Basel agreements (Basel I, Basel II and Basel III). The first Basel agreement dates from 1988 and implemented capital requirements based on credit risks, namely losses due to defaults on debts incurred by banks' borrowers (Basel Committee on Banking Supervision, 1988). It was followed by the second Basel agreement in 2004. Its goal was to extend regulatory standards to more countries, as well as to expand those standards to cover more of the risks faced by banks (such as market and operational risks). It is this agreement that gave birth to the three regulatory pillars still in force today: minimum capital requirements (Pillar 1), supervisory review (Pillar 2) and market discipline (Pillar 3) (Basel Committee on Banking Supervision, 2004).

However, the Basel II regulatory framework failed to prevent the 2008 financial crisis. The Basel III agreement, dating from 2010, is an attempt strengthen the capital adequacy requirements with regard to quantity and quality of capital which banks need to set aside in order to absorb losses (Basel Committee on Banking Supervision, 2010).

The total capital of banks is subdivided into two compartments: Tier 1 capital and Tier 2 capital. Tier 1 concerns the so-called core capital and is mainly composed of shareholders' equity and disclosed reserves. If a bank experiences significant losses, Tier 1 capital provides a safety cushion that can allow it to maintain its operations. Tier 2 refers to the supplementary capital of banks and includes unsecured subordinated debt instruments as well as undisclosed reserves.

The Basel II agreement stipulated that the minimum total capital (Tier 1 + Tier 2) that a bank must set aside should cover 8% of its total risk-weighted assets, with a minimum Tier 1 capital ratio of 4%. The Basel III agreement retains this total ratio of 8% but revises its composition to give more importance to Tier 1 capital, which is considered more secure than Tier 2 capital. The minimum Tier 1 capital ratio has been increased from 4% to 6%.

Another change has been made and it is precisely this one that is of interest with regard to convertible contingent bonds. The Tier 1 compartment itself has been subdivided into two subcompartments. The first one is called Common Equity Tier 1 capital (CET1). It is the highest quality of regulatory capital as it is always available to banks. This includes common shares and disclosed reserves and covers at least 4.5% of risk-weighted assets. The second one is called Additional Tier 1 (AT1) and consists of hybrid capital featuring properties of both debt instruments and equity. This is regulatory capital that only materializes when banks incur a minimum level of losses. It is mainly made up of contingent convertible bonds issued by banks and covers at least 1.5% of risk-weighted assets. Figure 1 provides a summary overview of this regulatory framework.

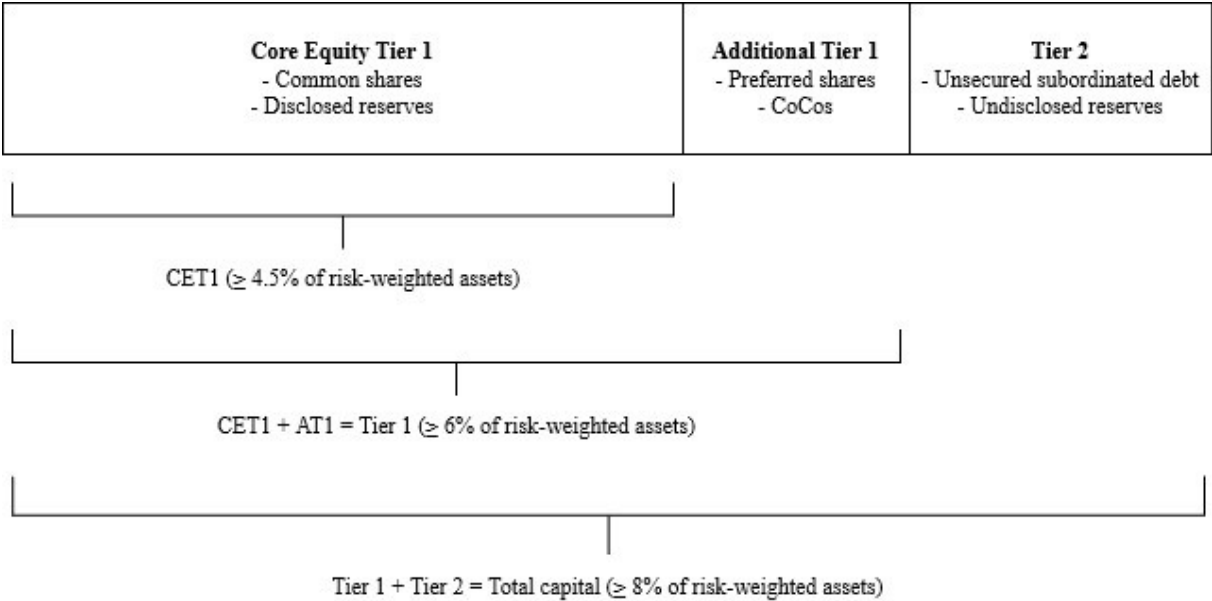


Figure 1: Basel III regulatory capital requirements

This means that the Basel III agreement has given convertible contingent bonds a privileged status on the banks' balance sheets. These allow them to meet part of the regulatory capital requirements.

1.1.5 Theoretical advantages and how they fostered the market growth

By being counted as Additional Tier 1 in the overall Tier 1 calculation (CET1 + AT1), CoCos help banks complying with regulatory requirements without sacrificing too much profitability. Indeed, since CoCos are considered as AT1 it means for banks that they can get closer to regulation requirements without having to set aside capital just by simply issuing these bonds which are less expensive for them than equities². Their advocates argue that this prevents negative effects on lending to the real economy (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009; Vallée, 2019). Since banks don't have to set aside costly extra capital, they can lend more to the real economy, supporting economic activity.

As far as investors are concerned, CoCos have two main advantages. First, they have seniority over common equity in terms of repayment priority, in accordance with the Recovery and Resolution Directive (BRRD), the Capital Requirements Regulation (CRR) and the Capital Requirements Directive IV (CRD VI). Second, CoCos are associated with high yields since there is a risk premium based on five components:

- An interest component: In the present environment, interest rates are rather small
- A liquidity component: CoCos are an asset class with only relative liquidity
- An extension risk component: Most CoCos are called upon and repaid by banks on a frequent basis, but they might decide not to in case of difficulties
- A coupon cancellation risk component: For some CoCos, coupons are cancellable at the discretion of the issuer and/or the regulator.
- A conversion component: This one compensates for the event that the CoCo bond might be converted into equities or written off

Thus, since 2008, all the conditions have been in place to promote the growth of the market: a favourable regulatory framework that encourages banks to issue CoCos, which investors are fond of given their high returns. CoCos then appeared where loss-absorbing capital requirements were implemented first, namely in the United Kingdom and Switzerland. A turning point occurred in July 2013 with the Capital Requirements Directive IV, which transposed Basel III into EU law. From then, more and more EU banks started to issue CoCos.

They have been primarily bought by three groups of investors (Avdjiev et al., 2013). The first and biggest one is made of retail investors and private banks from Asia and Europe

² Not all CoCos are considered as AT1. Some of them are considered as T2. They are considered as AT1 when they include a PONV clause and when their trigger level is high enough (5,125% in terms of CET1/RWA).

looking for high yields when interest rates were particularly low these last years. Then come US institutional investors looking to diversify their investment portfolios. And finally, there have been a few European non-bank financial institutions, held back by the lack of clarity about how CoCos as assets in their balance sheets are treated by national regulators. It is difficult though to say more about the demand side of CoCos. Boermans & van Wijnbergen (2018) note that the majority of European CoCos (which constitute the bulk of the CoCos market) are held by foreign investors whose exact status is difficult to know. Households have much more indirect exposure through European mutual funds or non-European entities than a first glance at the available data on primary holders would suggest (Götz & Tröger, 2016). All in all, there is a critical lack of information in this regard (Avdjiev et al., 2020).

Although there may be a multitude of combinations of trigger mechanisms, trigger levels and loss absorption mechanisms, there is a concentration of one specific type of CoCos: permanent PWD with a PONV clause and a trigger precisely set to 5.125% in terms of CET1/RWA. This is not a coincidence. The PONV clause is necessary for CoCos to qualify as AT1. But a PONV clause alone turns off investors because of the increased uncertainty. This is why it is associated with a mechanical loss absorption mechanism. This one tends to be more of a PWD type - 60% of issued CoCos (Vullings, 2016) - for two reasons. First, insider bank shareholders push toward more PWD issuances since they are under threat of a dilution of their power and dividends in the event of the triggering of convertible CoCos (Avdjiev et al., 2013). Second, there has been a growing demand for CoCos by fixed income investors contractually forbidden from holding CoCos converting into equities. Finally, regarding the trigger level of 5.125% CET/RWA, it is particularly interesting for banks because it is the qualifying threshold for AT1 capital. By keeping to the bare minimum, banks minimize the costs of their issuance compared to what higher trigger levels would entail.

1.1.6 Recent market disruptions

In a recent paper, Avdjiev et al., (2020) provide comprehensive empirical evidence about CoCos issuance by banks between January 2009 and December 2015. They find that banks around the world issued \$521 billion in CoCos through 731 different issues, to which can be added about \$220 billion between 2015 and early 2021. This is modest in view of the size of the bond market - estimated around \$100.130 billion in 2017 by the bank for international settlements - but represents nonetheless a segment large enough to produce interesting data and fuel a rapidly expanding academic literature (for an in-depth statistical discussion on the increase in contributions on this topic, see the systematic literature survey by Oster, (2020)).

Although in full expansion and a theoretical sign of the good health of the banks that issue them, the market for conditional convertible bonds has faced many challenges over the last four years.

In January 2016, Deutsche Bank announced expected negative results³. A few months later, in September 2016, the press announced that Deutsche Bank had received a large fine from the US Department of Justice⁴. After these two events, not only did Deutsche Bank's CoCos yield-to-maturity reach historical highs, but it also created tensions in the entire market, affecting all major European banks' CoCos. This incident highlighted that an isolated disruption could cause investors to suddenly fear systemic risks and flee from CoCos, inducing financial contagion, destabilizing the market and exacerbating the original problem.

In June 2017, the European authorities decided through the Single European Resolution Mechanism to approve Santander's acquisition of Banco Popular (the sixth largest bank in Spain at the time). The latter faced economic difficulties due to a high concentration of bad debts and was unable to raise capital after the stock market crash of its shares and the flight of its depositors. All existing Banco Popular shares and additional Tier 1 instruments were written down, resulting in the cancellation of 1.25 billion euros of CoCos⁵. It was the very first time that contingent convertible bonds were wiped out, although due to a discretionary decision made in the context of a merger between banks. In 2019, Banco Santander once again destabilized the market by temporarily postponing the call of 1.5 billion euros in 6.25% CoCos⁶.

But it is above all the economic crisis caused by the SARS-CoV-2 pandemic that has led to the most disruptions. Encouraged by governments, banks lent massively to companies to support the economy, resulting in a sharp increase of private debt.

Faced with the risk of increased defaults, some central banks asked domestic banks to suspend capital note repayments – including AT1 CoCos – in order to preserve their capital requirements given the overall economic uncertainty. This was the case for the Central Bank of New Zealand in April 2020. Similarly, at the end of December 2020, Piraeus Bank did not receive permission from the European central bank to redeem CoCos issued in 2015 and with

³ DB's own announcement of its poor results: https://www.db.com/newsroom_news/2016/medien/deutsche-bank-reports-preliminary-full-year-and-fourth-quarter-2015-results-en-11368.htm

⁴ News article reporting on the fine: <https://www.theguardian.com/business/2016/sep/16/deutsche-bank-14bn-dollar-fine-doj-q-and-a>

⁵ Full press release by the Single Resolution Mechanism: <https://srb.europa.eu/en/node/315>

⁶ News article reporting on Banco Santander's repayment delay: <https://www.ft.com/content/8539f7b4-2ad9-11e9-a5ab-ff8ef2b976c7>

a coupon due on December 2, 2020.⁷ This triggered the conversion into shares. However, this was a very specific case as the triggered contingent convertible bonds were owned by the Greek government. This activation made Piraeus Bank a public bank.

Some national banks chose to defer the CoCo coupon repayment themselves. Although CoCo contracts provide for this possibility, this caused further disruption in the market. Just one month after the success of its first CoCo issue in 6 years in February 2020, Deutsche Bank announced that it would delay the repayment of \$1.25 billion of the 6.25% CoCo debt⁸. The value of the recently sold CoCo bond fell to approximately 50% of its face value. At the same time, investors tried to protect themselves from risks by buying massively CDS on Deutsche Bank's debt as well as CDS on other banks' debt. As a result, at the end of March, the global investment management firm Pimco saw its \$8bn capital securities melt– which had CoCos as its top five holdings at the end of 2019 – down by nearly 13 per cent for the year through. On May 2020, Lloyds Banking Group, whose first quarter profits had heavily decreased because of provisioning for predictable bad loans due to the crisis, told investors it would not call back a 750-million-euro CoCo bond⁹.

The poor economic outlook, the risk of activation of CoCos and the intervention of central banks in decisions to redeem or not to redeem them led to a sharp contraction of the market at the beginning of 2020. But since then, banks have reported capital requirements sufficient enough to reassure investors. This led to an almost complete recovery of the market by the end of 2020 (see Figure 2 for the sharp contraction followed by the sharp increase of the ICE BofA Contingent Capital Index, the main index reflecting the state of the CoCo market).

The CoCo market is experiencing new turmoil since 2022.¹⁰ After years of very low interest rates, central banks are raising them to counter inflation. As long as rates were close to zero, CoCos provided investors with an opportunity for high returns and demand was strong. In order to continue to attract investors, banks have now to pay more and more interest on their CoCos. A record has been set when Credit Suisse issued EUR 1.6 billion in CoCos at an interest rate of 9.75%¹¹. By comparison, the last issue of CoCos by Credit Suisse was in 2020 for an

⁷ Announcement of the decision regarding Piraeus Bank: <https://www.fitchratings.com/research/banks/piraeus-conversion-of-contingent-convertibles-credit-positive-27-11-2020>

⁸ News article reporting on DB's announcement: <https://www.ft.com/content/29988546-67a6-11ea-800d-da70cff6e4d3>

⁹ News article reporting on Lloyds' decision: <https://www.reuters.com/article/lloyds-bonds/update-1-lloyds-wont-redeem-750m-euro-coco-bond-amid-covid-19-crisis-idUSL8N2D4308>

¹⁰ This time, not isolated to the CoCo market but due to the tightening of monetary policies.

¹¹ News article reporting on new Credit Suisse's issuance: <https://www.ft.com/content/7ff9ccba-1384-48d3-90f1-ee6b96288ade>

amount of 1.5 billion euros and an interest rate of 4.5%. This trend is confirmed by the evolution of the option-adjusted spread (OAS)¹² on the ICE BofA Contingent Capital Index (see Figure 3). The difference between the yield of CoCos after adjusting for their option and the current U.S Treasury rates has been increasing. The question is whether this rise in rates will be sustainable for banks as maintaining their AT1 levels will become increasingly costly.



Figure 2: Evolution over time of the ICE BofA Contingent Capital Index (source: elaboration on Intercontinental Exchange data)

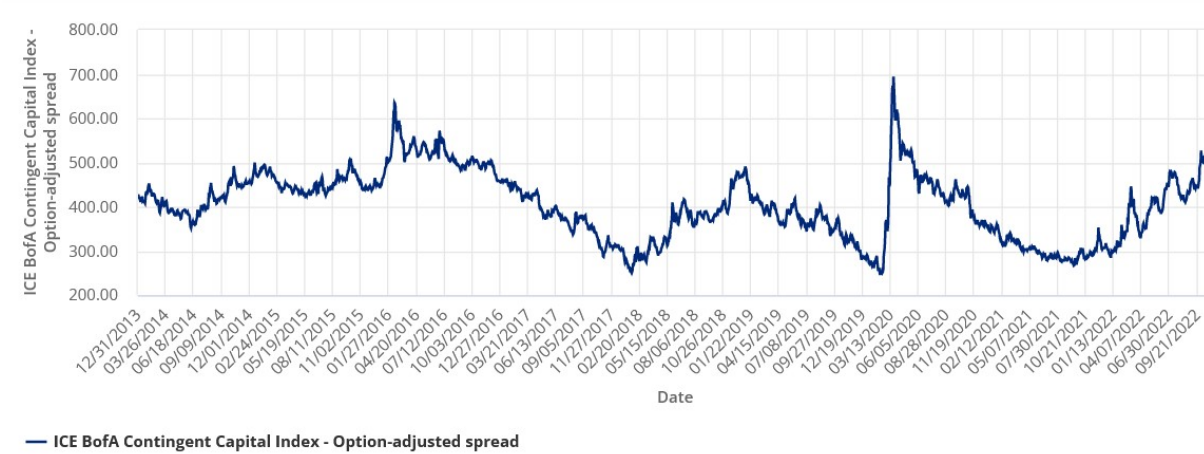


Figure 3: Evolution over time of the ICE BofA Contingent Capital Index Option-adjusted spread (source: elaboration on Intercontinental Exchange data)

¹² The option-adjusted spread is used for bonds with options, including CoCos.

1.2 MOTIVATION

1.2.1 Literature review

Contingent convertible bonds have been for years subject of theoretical debates that Oster (2020) summarizes with the following formula: “making everything and nothing possible”. Reviewing the major milestones of the existing literature serves a triple purpose: 1. It puts in context this PhD dissertation by highlighting the research previously done and upon which my work builds. 2. It emphasizes the lack of certainty about the actual effects of a generalized activation of CoCos in the event of a new financial crisis. 3. It points to a number of blind spots that this thesis seeks to fill and to justify the methodology employed.

The existing literature can be divided into two threads. The first one is mainly concerned with the optimal design of CoCos in order to make their use by the banking sector more efficient. The second one is concerned with the advantages and disadvantages of issuing and activating CoCos.

Optimal design literature

In the early years of the market, authors focused on trying to find the optimal design for CoCos and discussed the perverse effects that poorly designed trigger and loss absorption mechanisms could have. With mechanical book-value triggers, accounting ratios are not calculated often (Plosser, 2013) and are measured in a backward-looking fashion in addition to being subject to political pressure (McDonald, 2010). It can lead to a lack of information for investors and to an activation occurring too late as showed by Duffie (2009) in an analysis of what would have happened for the American investment bank CityGroup in 2008 if it had issued CoCos with a book-value trigger.

While mechanical market-value triggers can be calculated with a much higher frequency, hence bypassing the inconvenient of the book-value triggers, they come with their own disadvantages. First, they may prompt investors to short-sell the issuer stock in order to generate a self-fulfilling spiral, depressing the share price and triggering the CoCos (Hillion & Vermaelen, 2004). There is also a possible issue with multiple pricing equilibria, making them vulnerable to stock price manipulation and speculative attacks as show by Calomiris & Herring (2013), Pennacchi et al., (2014) and Sundaresan & Wang, (2015). Lastly, market-based triggers can also result in distortions of the information content of prices (Berg & Kaserer, 2015; Bond et al., 2010; Faure-Grimaud, 2002; Glasserman & Nouri, 2016). All these disadvantages explain

why market-value triggers have remained a theoretical option, only explored by academic literature. In practice, all CoCos that have been issued so far use a book-value trigger.

Pure discretionary triggers also have their share of issues related to the rule-vs-discretion debate. Admittedly, there is no problem of activation timing, as the regulator can decide it at any time. There are also no incentives to manipulate share prices or multiple-equilibria pricing. However, the arbitrary nature of this decision introduces a lot of uncertainty for investors who don't know when and how the activation will occur. Another important issue here is the credibility of the supervisor's intervention because of the "too-big-to-fail" problem (Aiyar et al., 2015). If the conversion depends only on supervisory discretion, evidences show that it occurs often too late and only when the solvency of the financial institution is already seriously degraded (Consiglio & Zenios, 2018). Bulow & Klemperer (2013) argue that the failure of the banking regulation is due to the fact that regulatory capital system is able to reflect the changes in financial health only very slowly. In addition, the authors point out a structural excess of regulatory forbearance. It is difficult for a third party to know what the exact condition of a bank is. Considering this uncertainty, it can be difficult to resist from waiting for more information and hence to repeat forbearance (Posner, 2010). As a result, a combination of discretionary and mechanical rather than a purely discretionary trigger is likely to produce a better credibility of the issuer's commitment for a prudential behaviour. In practice, this is why most actual CoCos triggers are hybrid (Avdjiev et al., 2013).

Regarding the loss-absorption mechanism, Bulow and Klemperer (2013) show that an equity conversion results in a sudden inflow of new shareholders and hence a dilution of shareholder power. Avdjiev et al. (2013) elaborate further: when the conversion is done according to the share price at the time of activation, it results in more new equity shares as the stock price is very low, and therefore more dilution. Shareholders are then encouraged to prevent the bank's balance sheet from deteriorating too much. Therefore, as Dudley (2013) suggests, CoCos converting into equities can be used to efficiently control the risk aversion of bank managers and to reduce the ex-ante likelihood of a failure. While Admati et al. (2013) show that PWD CoCos introduce a higher moral hazard risk than convertible CoCos in that bank shareholders have less incentive to avoid activation, other authors advocate their use. Li et al. (2018) argue that they help stabilize the financial sector by improving the value of banks, while Vallée (2019) shows that they are not associated with any "death spiral risk" as there is no need for fire sales from fixed-income investors following a trigger.

Advantages and disadvantages literature

It thus appears that 11 years after the first CoCos issuances, there is still no consensus on what an optimal design should be. But the academic debate on CoCos goes further. While some authors see it as a useful tool for stabilizing the banking sector in the event of a crisis, others question their use altogether and warn about certain situations where CoCos could prove destabilizing to the economy.

Some authors argue that they should improve the solvency of the banking sector and decrease the likelihood of taxpayer-funded bailouts (Calomiris & Herring, 2013; Pennacchi, 2010). Other authors insist on the fact that CoCos reduce the need for fire-sells when banks' solvency worsen too much, which limits the risk of death spirals and financial contagion (Vallée, 2019). And finally, their advocates argue that they mitigate the hindering effects of regulation on banks' profitability, allowing them all things being equal to increase lending to the real economy (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009).

But CoCos also have detractors. On the disadvantage side, several research papers warn about a potential increase in risk-taking and moral hazard as banks know that they will be bailed-in by investors if not bailed-out by governments (Berg & Kaserer, 2015; Flannery, 2016; Hilscher & Raviv, 2014; Martynova & Perotti, 2018). Some authors show how sudden risk reassessments by investors due to CoCos' complexity could have destabilizing effects on the financial sector (Admati et al., 2013; M. Allen et al., 2002; Goodhart, 2010; Sundaresan & Wang, 2015). Others focus on how the loss-absorption mechanism triggered by CoCo activations may occur too late, hence limiting their usefulness (Delivorias, 2016; Pazarbasioglu et al., 2011). There are also concerns that CoCos might not reduce the actual risk the banking sector is facing, but simply displace it to other sectors in the economy (Avdjiev et al., 2013). And finally, a recent empirical paper by Bologna et al. (2020) shows the existence of a CoCo-specific financial contagion channel.

The existing literature is therefore particularly divided on the subject of CoCos. On the one hand, one can expect positive effects from CoCos issuances: individual banks should be more resilient in times of crises and there should be less need for bailouts. But on the other hand, these theoretical benefits are to be contrasted with expected (and even observed) negative effects such as an increase in moral hazard, sudden and destabilizing market adjustments and potential financial contagion effects.

1.2.2 Research questions

The review of the existing literature in the previous section shows that while CoCos have various theoretical benefits, they also appear to cause uncertain and undesirable effects at the macro level. The ambiguity is further aggravated by the fact that, so far, “we don’t know the delta from theory and practice” (Oster, 2020). Indeed, since CoCos have never activated yet, we don’t have empirical data to carry out an overall econometric assessment that would settle at least part of these discussions.

This leaves three sets of questions open. The first one is related to the effectiveness of CoCo bail-ins. Could CoCos fulfil their mission of stabilizing the banking sector in the event of a financial crisis. Can they prevent bankruptcies? How much capital would be necessary to bail-in banks after a crisis? To what extent do they reduce the need for bailouts?

The second one is related to adverse and beneficial effects for the rest of the economy. Provided CoCos are effective for the banking sector, are they also for the economy as a whole? Could the costs of such bail-ins outweigh their benefits in some situations? Is the risk transfer from taxpayers to investors always a positive outcome? How does this risk shifting translate for the whole economy versus a system without coco bonds? How does CoCo bond issuances impact the systemic risk? Do they indeed reduce it, or simply shift it, or even worse, increase it? Will CoCos play a stabilizing or destabilizing role in the event of another financial crisis? In what situations could CoCos destabilize the economy?

And finally, given all these uncertainties, are regulators right to encourage such bail-in mechanisms?

1.3 METHODOLOGY

A key assumption of this PhD dissertation is that the inability of the existing literature to answer the questions raised in the previous section is due to the lack of research bridging the gap between microeconomics and macroeconomics. I argue that the most appropriate type of model to perform this task is a stock-flow consistent agent-based model (SFC-ABM).

To arrive at such a model, I start by building its macroeconomic framework. This results in the stock-flow consistent (SFC) model presented in Chapter 2. This purely aggregated model is a preliminary step and should be considered as such. Its purpose is to provide a few qualitative results, and to pave the way for the next two chapters which are the core of the thesis. In Chapter

3, I add agent-based (AB) microfoundations to the SFC framework. In Chapter 4, I make these microfoundations more complex by introducing learning behaviours.

This methodological choice in favour of an SFC-AB model is justified in four steps in the rest of this section. First, I show why there is a need to bridge the gap between microeconomics and macroeconomics when it comes to assessing the effects of CoCos activations. Second, I motivate the use of a SFC framework. To do so, I review the history of these models as well as their advantages and disadvantages. Third, I advocate the use of agent-based microfoundations. I explain what they are, their strengths and weaknesses. I show how the combination of the SFC framework and AB microfoundations generates complementarities between the two paradigms and addresses some limitations of each. Finally, I discuss another type of models that could have been used: dynamic stochastic general equilibrium (DSGE) models. I comment on an attempt to analyse CoCos that was done with a DSGE model and I show how the SFC-AB paradigm can overcome a number of obstacles it encountered.

1.3.1 The need to bridge the gap between micro and macroeconomics to provide a comprehensive assessment of CoCos

As Charles Goodhart notes: "One of the weaknesses of some of the analysis of CoCos is that it concentrates on the effect on a particular troubled bank, rather than also exploring the effects on the market dynamics of the financial system as a whole (one of the key inherent weaknesses of our prior regulatory system)." (Goodhart, 2010). Indeed, most of the existing theoretical literature focuses on the advantages and disadvantages of CoCos at a micro level. In doing so, these analyses do not allow to conclude whether CoCos are useful or dangerous for the economy as a whole. They only provide information on one particular aspect of CoCos at a time and only at the level of an individual bank.

However, what is valid for an isolated bank is not necessarily valid for the whole sector – as many aggregated repetitions of the same phenomenon. In a sector where the importance of its agents can be systemic and where each decision can have profound repercussions on a macroeconomic scale, as the 2008 crisis showed, banks are interdependent. They influence each other directly through their actions, but also indirectly by affecting their environment, which in turn affects the behaviour of other banks and prices. As a result, well-documented simple and predictable local interactions may generate intricate and unexpected global patterns. For example, if two banks have invested in the same asset and one of them is in trouble due to a

sudden drop in the value of its assets, it will react by triggering fire sales, accentuating the drop in price even more, which will affect the portfolio of the other bank that was until then solid.

Therefore, any comprehensive assessment of the effectiveness and potential hidden costs of contingent convertible bonds, should rely on a macroeconomic framework that takes into account the interactions between the agents that populate the economy. Since there have not yet been any regular CoCo activations, we cannot rely on empirical data so we need to simulate what would happen if CoCos were activated in an economy sufficiently close to what is actually observed in reality. This requires the use of a theoretical counterfactual model that is empirically anchored. The model must be able to draw macroeconomic conclusions based on microeconomic interactions.

1.3.2 The case for a stock-flow consistent framework

The development of stock-flow consistent models

The SFC approach stems from the financial flow analysis of Morris Copeland, who was one of the architects of American national accounting. Copeland wanted to build a theoretical framework to answer the following questions: “When total purchases of our national product increase, where does the money come from to finance them? When purchases of our national product decline, what becomes of the money that is not spent?” (Copeland, 1949).

The System of National Accounts (SNA), introduced in 1968 and supported by the 1993 revision, provides this theoretical framework by focusing on the integration of national income, financial transactions, capital stocks, and balance sheets. It is complemented by the four-part accounting approach (which is fundamental to SFC modelling). Indeed, most transactions involve two institutional sectors. Each transaction must then be reported twice on the liabilities and assets sides of each agent's balance sheet.

The Yale School and more specifically James Tobin extended Copeland's approach. In a paper he co-authored with David Backus, William C. Brainard and Gary Smith (Backus et al., 1980), he developed an empirical model of the American economy based on both the real and financial spheres. This is one of the first stock-flow consistent models. It incorporates key features found in the most recent SFC models: stock-flow matrices, discrete-time reasoning to exploit available quarterly data, accounting identities, portfolio arbitrage based on the rate of return on different assets (and not just one as in IS-LM models), and budget and accounting constraints. Tobin's contribution to SFC modelling is summarized in his acceptance speech

when he received the Nobel Prize. He then laid the foundations of what he believed a good macroeconomic model should be: *“It should: 1. Integrate stocks and flows into the analysis, and their accounting must be done in a fully coherent manner; 2. Include a multitude of sectors and of assets, each with its own rate of return; 3. Incorporate all monetary and financial operations, and thus integrate the central bank and commercial banks; 4. Have no ‘black holes’: all flows must inevitably have an origin and a destination; all budget and portfolio adding-up constraints must be respected, both for behavioural relations and for the actual values of the variables”* (Tobin, 1982).

The 1970s and 1980s marked a turning point in SFC modelling. For the first time, it was used for economic forecasting purposes. The Cambridge political economy group, organized around Wynne Godley, sought to identify the factors of instability that could weaken the UK economy. Wynne Godley was one of the first authors to formalize the "consistent" character of SFC models, which meant that there were no "black holes" in the sense of Tobin. In a pioneering work, Wynne Godley and Francis Cripps link the four-part accounting approach to the consistency of these models: *“The fact that money stocks and flows must satisfy accounting identities in individual budgets and in an economy as a whole provides a fundamental law of macroeconomics, analogous to the principle of conservation in physics”* (Godley & Cripps, 1983).

The main features and advantages of stock-flow consistent models

The structure of SFC models is based on a combination of different blocks: balance sheet matrix, transaction matrix, behavioural equations, and sectors studied. SFC modelling provides a relevant framework for modelling chains of adjacent short periods (e Silva & Santos, 2011). In particular, the balance sheets of each period are driven by the payment flows and capital gains (or losses) of each previous period. These models are "intrinsically dynamic and path dependent" (Turnovsky, 1977). The effects of modelling choices are all the more important as they accumulate over the long term. Repeatedly miscalculated balance sheets lead to wrong conclusions about financial market behaviour. In the end, all the accounting deployed in SFC models ensures that the balance sheet dynamics are correctly described in order to avoid this type of problem. Compared to other types of models, they offer a number of advantages:

- They are based on accounting identities. Thus, the assets of some are the liabilities of others. This makes it possible to completely close the models, without forgetting any components and without introducing any from scratch. As Caiani et al. (2016) say: “it provides a

fundamental check of the model logical consistency”. Any model that deviates from these accounting identities sees certain sectors or agents accumulate a stock of liabilities or assets without any counterpart. The transactions that are linked to these stocks can generate inconsistencies that bias the evolution of the agents' balance sheets and possibly the results of the model.

- They take into account the role that money, credit and the financial system can play. They thus allow to model explicitly the banking sector (not only indirectly as a friction on the real sphere) as well as endogenous and government money, and to better understand events such as financial crises.
- They capture interconnections between the real and the financial spheres (which we want to do since we want to explore how the stabilizing of the financial sector through bail-ins can be positive or negative for the rest of the economy).
- They can easily keep track of accounting ratios and imbalances between assets and liabilities for different sectors.
- They can easily feature multiple assets (as many as necessary), accounting ratios and imbalances between assets and liabilities for different sectors.
- They account for path dependency. Persistence effects are not artificially produced. They come from the SFC structure of the model and the fact that the model never returns to the ex-ante status. Accumulation occurs in a differentiated and irreversible way.

Given these advantages and since the aim of this thesis is to incorporate a financial asset into a macroeconomic model, to take into account the interactions between the financial and real spheres (in the context of bail-ins), to monitor accounting ratios for the triggering of CoCos and to observe the lasting consequences of their triggering throughout the economy, the choice of a SFC theoretical framework seems appropriate and results in the model presented in Chapter 2.

The limitations of stock-flow consistent models

The scope of purely aggregated stock-flow consistent models is limited by three sets of factors.

The first is the lack of empirical grounding. The parameters are not fully estimated or calibrated since the function of Chapter 2 is simply to lay macroeconomic foundations used in the next chapters. Although qualitative results are drawn from it, nothing can be said from a quantitative standpoint and no policy recommendations can be made based on the current state of the contingent convertible bond market.

Second, there is no heterogeneity *per se* because all the sectors are fully aggregated. It means for instance that the first model doesn't take into account the fact that not all CoCos activate simultaneously. Moreover, it cannot capture bank failures since the net worth of the aggregate banking sector never reaches zero. And yet, stability at the aggregate level does not necessarily mean that all agents are in equilibrium. There are no distributional effects (e.g., with some banks being stronger than others). The difficulties of some banks cannot be transmitted to others, and the effects of financial contagion are not captured.

Finally, there are no microfoundations for behavioural rules, which are only specified at the aggregate sector level. This is equivalent to thinking in terms of one representative agent per sector. However, the properties of an aggregate function do not reflect those of individual functions (Gallegati & Kirman, 2019) and the aggregate behaviour of a heterogeneous set of agents cannot be interpreted as the decision of a representative agent as stated by Arrow's Weak Axiom of Revealed Preferences (WARP) (Arrow, 1959). Rather than allowing endogenous macroeconomic phenomena to emerge as a result of microeconomic interactions, they are imposed.

The adoption of the bottom-up perspective of agent-based models (ABM) helps to overcome these limitations.

1.3.3 The case for agent-based microeconomic foundations

The development of economic agent-based models

The ABM approach in economics stems from Herbert Simon's call to rethink the theory of the decision-making process by relying on complex systems "putting together a model of adaptive man than would compare in completeness with the simple model of classical economic man" (Simon, 1959). He also states: "Roughly, by a complex system I mean one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of the parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole. In the face of complexity, an in-principle reductionist may be at the same time a pragmatic holist" (Simon, 1962). As mentioned by Dawid & Delli Gatti (2018), these quotes can be seen as the first formulations of a research agenda, now referred to as agent-based modelling, and initiated among others by Thomas Schelling with his models of segregation (Schelling, 1971) and the Santa Fe Institute, born in 1984.

The main features and advantages of agent-based models

Agent-based models are defined by Turrell (2016) as “any model in which the interactions of a large number of heterogenous agents are simulated”. Each agent follows its own behavioural rule and influences others while being influenced by them. There may be different types of agents (households, firms, banks, government, etc.) and agents may differ within each type (working households with different productivities, firms with different sizes, etc.).

ABMs are particularly appropriate when one is interested in global and emergent patterns that are more than the simple aggregation of individual behaviours, but that cannot be understood without starting from these individual behaviours in a microfounded bottom-up approach. They are used to describe how the combination of simple and predictable individual interactions can drive the behaviour of the overall systems and give rise to unexpected global patterns.

These models feature stochastic components (Tesfatsion, 2006) that bring randomness to their dynamics. This makes the aggregate behaviour of the system unpredictable and paves the way for emergent properties like economic cycles and endogenous fluctuations (Dosi et al., 2010; Raberto et al., 2008). This is why every agent-based simulation is run several times. The aim is to detect trends in the time series produced by each set of parameters and to verify how their modifications impact the trajectories of the model. This is the principle of Monte Carlo simulations.

Agent-based microfoundations rely on five key principles:

- Agents are autonomous. The overall system evolves as a result of local interactions rather than being organized by centralized authorities or institutions (even if they may exist in the model as environmental constraints). This principle is also known “self-organization” (Kauffman, 1995).
- Agents are interdependent. This means that each individual’s decisions depend at least in part on the decisions of others. This may be the case directly, as they influence each other by imitation or persuasion in response to the influence they receive. But it can also be the case indirectly when their actions change the environment, which in turn affects the behaviour of other agents.
- Agents follow simple rules. They do not necessarily optimize and are characterized by bounded rationality (Simon, 1955, 1959). They follow rules taking the form of habits, protocols, conventions, norms and heuristics that appear to be robust tools for inference

(Dosi et al., 2020; Gigerenzer & Brighton, 2009). This results in the update of a multitude of microeconomic variables for each agent.

- Agents are adaptive. They adapt to the information they receive based on feedback loops which can reinforce dynamics or create tipping points. This happens in two ways:
 - Through learning, which occurs during processes like reinforcement, the back-propagation of error in artificial neural networks or Bayesian updating. This affects the probability distribution of competing behaviours within the range available to each individual.
 - Through evolution, which occurs during processes like imitation, social influence and selection. This affects the frequency distribution of agent types and of behaviours across the population of agents.
- Agents are heterogeneous. They differ by income, preferences, productivity, size, etc. It allows to have a look at distributional effects.

Limitations of agent-based models

AB models are limited by several factors in terms of behavioural assumptions, parametrisation, and their interpretation, although work is being done to overcome these obstacles (Turrell, 2016):

- “The wilderness of bounded rationality” (Sims, 1980). Agent-based models are built by making a large number of choices and behavioural assumptions. Some of them are supported by research in behavioural economics. But there are not always criteria for choosing which behaviour is the most realistic. However, the results presented can vary greatly depending on these assumptions.
- Lucas Critique. Agents may not follow the same behaviours when policy interventions are made. Some of the heuristics used in ABM models do not take that into account. However, it is possible to model such changes in behaviour, in particular through the introduction of learning agents.
- Interpretation. Changes in model inputs can greatly affect model outputs and it can be difficult to understand how exactly. This is inherent to complex systems. More analytically tractable models do not have this issue. A change of parameter has clearer effects. One way to remedy this problem is to carry out extensive robustness tests on the behavioural assumptions made and the parameter spaces.

Complementarities between stock-flow consistent and agent-based approaches

The combination of a stock-flow consistent framework and agent-based microfoundations generates complementarities between the two paradigms and addresses some limitations of each.

Adding agent heterogeneity to the SFC framework presented in Chapter 2 allows to take into account that not all CoCos activate simultaneously as well as the possibility of isolated bankruptcies. We can then study more precisely whether CoCo bail-ins are able to prevent these failures, whether some banks are more resistant than others and whether there are possible contagion effects without being blind to what happen within sectors.

Adding agent-based microfoundations eliminates the need for ad hoc assumptions such as the exogenous shocks simulated in Chapter 2. The macroeconomic accounting identities and constraints typical of the SFC accounting emerge from the interactions of single agents' balance sheets rather than being imposed. Furthermore, it allows us to observe how interactions at the micro level such as the supply, demand and activation of individual CoCos can generate unexpected global dynamics such as information diffusion and decreasing waves of adjustments following market disruptions, or non-linearities in macroeconomic effects of activations.

Conversely, while several ABM models are stock-flow consistent¹³, not all are. This can lead to inconsistencies as pointed out by Caiani et al. (2016). For example, a situation may arise where banks can buy government bonds using a positive net worth but without the liquid assets needed to complete the transaction. This would happen if they have high loans but low reserves and if no attention is paid to accounting counterparts. Another problematic case comes from the entry-exit process of firms in some AB models which assume that a failed firm is replaced by another with a given stock of capital and liquid assets. If this stock appears ex-nihilo, it is similar to a positive exogenous shock. This is likely to skew consumption, savings, credit and investment upwards in the model.

Therefore, SFC models provide boundary macroconditions to AB models and AB models provide microfoundations to SFC models. Combining the two paradigms allow to model both the dynamic network of balance sheets which connect the real and the financial sphere, as well as agent interactions and heterogeneity (Godin, 2016). Given these advantages

¹³ See e.g. Caiani et al. (2016); Riccetti et al. (2015); Salle & Seppecher (2015)

the choice of an SFC-AB theoretical framework seems appropriate and results in the model presented in Chapter 3 and extended in Chapter 4.

1.3.4 A few notes on DSGE models

Dynamic stochastic general equilibrium (DSGE) models are a class of models in which markets are assumed to clear simultaneously. "In their most stripped down form, these DSGE models have a unique equilibrium with deviations that are small and smooth, no role for stock variables and micro behaviours of agents which can be simply and linearly aggregated into the behaviour of a representative agent with rational expectations."(A. G. Haldane & Turrell, 2018).

The 2008 crisis showed that the economy is complex and not always at a stable equilibrium. It also brought to light some issues with standard DSGE models, which at the time did not take into account essential characteristics of our economies, notably their financialization and the resulting instability. This led to them being challenged for not saying enough about the risks of financial crises (Ascari et al., 2015).

This questioning had two results. The first is the increased use of SFC-AB models (presented in the previous sub-sections). And the second is the improvement of existing DSGE models.¹⁴ It is not the purpose of this thesis to completely review these improvements and the criticisms that can be made of them¹⁵.

However, it is interesting to look at the only paper to date that look at the effects contingent convertible bond activations using a DSGE model (Hollander, 2017). It features a representative household buying CoCos. It is impossible for the author to explicitly model the CoCos, otherwise it is impossible to solve the model. To circumvent this problem, it is assumed that CoCos can be assimilated to deposits. In case of activation, the issuing bank takes a part of these deposits to mimic a trigger. Since they are not explicitly modelled, there is no supply rule for CoCos (banks issue shares in such a way as to maximise the dividends paid out and that's it), no demand rule (no portfolio arbitrage between multiple assets), and no pricing for the asset. The share of CoCos that is activated is exogenous so that it corresponds in an ad hoc way to a given percentage of the banks' capital. Activations are forced via exogenous technological shocks and are never the result of endogenous dynamics in the model.

¹⁴ For example, in DSGE models, Benes et al. (2014) account for the 2008 crisis, Gabaix (2014) introduces some type of bounded rationality and Fernández-Villaverde & Levintal (2018) explore exogenous time-varying rare disaster risk.

¹⁵ On this subject, see e.g. Dosi & Roventini (2019); Fagiolo & Roventini, (2017); A. G. Haldane & Turrell, (2018).

The author identifies only positive outcomes from the activation of CoCos: a gain in net worth for the banking sector, better solvency ratios and positive second order effects for the rest of the economy. These results expand the existing literature on contingent convertible bonds. The article is one of the few macroeconomic analyses on the subject and proposes results consistent with the microeconomic literature (notably a strengthening of issuing banks).

I argue, however, that the use of an SFC-AB model makes it very easy to solve all the problems encountered by Hollander. The stock-flow consistent framework makes it trivial to explicitly introduce additional assets without resorting to the artifice of amalgamating a safe asset (bank deposits) with a risky and complex hybrid instrument (CoCos). By separating the two, it is possible to model CoCos supply, demand, lifespan, pricing, interest rate determination, etc. There is no need to postulate an ad hoc share of activated CoCos. Only those of the (multiple and heterogeneous) banks involved are activated. And there is never a need to force activations. They occur through endogenous cycles in the model.

All of these things are not possible in the DSGE paper. The framework forces the author to make simplifying assumptions that limit the scope of his results. The purely aggregate model presented in Chapter 2 of this thesis arrives at the same results. While Chapters 3 and 4 take advantage of the agent-based microfoundations to find unexpected results (such as non-linearities in the macroeconomic effects of activations, or financial contagion effects following activations).

Different models are good for answering different questions. They are not necessarily competing. We need a large range of models. However, given Goodhart's observation reported at the beginning of this chapter about the need to analyse CoCos in a macroeconomic framework while keeping in mind the interactions between banks that issue them, given the strengths of the SFC and AB models and the synergies resulting from their combination, and given the difficulties that the DSGE framework seems to face when it comes to modelling CoCos, I therefore choose in this PhD dissertation to adopt an SFC-AB model.

More precisely, this work consists in extending the stock-flow consistent agent-based JMAB model developed by Caiani et al. (2016) by adding: 1. a new class of financial asset, 2. learning behaviours on the part of investors, 3. a variable opinion component (alternating between optimism and pessimism/prudence on the part of issuing banks and investors).

CHAPTER 2: CONTINGENT CONVERTIBLE BONDS AND MACROECONOMIC STABILITY IN A STOCK-FLOW CONSISTENT MODEL¹⁶

2.1 INTRODUCTION

As discussed in Chapter 1, a comprehensive assessment of CoCos needs to take into account the macroeconomic consequences of their activation, which is left out of most of the existing literature. Given the respective advantages of the SFC and ABM models and the synergies resulting from their combination, an SFC-AB model seems an appropriate candidate to perform this task.

Chapter 2 is a first step towards such an SFC-AB model. It features a purely macroeconomic SFC model whose aggregated nature limits its scope, but still serves several important functions. First, it builds the macroeconomic structure that then serves as the framework for the microfounded model used in Chapters 3 and 4. While some of the modelling implementations are then left out of the SFC-AB model to focus on the essentials, others are indeed reused. This is the case, for example, of the portfolio arbitrage governing the demand for CoCos, or the accounting transfer of net worth resulting from their activation.

Second, this aggregate model also makes it possible to draw qualitative results answering questions about the effectiveness of CoCo bail-ins: Can CoCos fulfil their mission of stabilizing the banking sector in the event of a financial crisis? To what extent do they reduce the need for bailouts? Provided CoCos are effective for the banking sector, are they also for the economy as a whole? How does this risk shifting translate for the whole economy versus a system without coco bonds?

These issues are addressed with simulations on a Kaleckian stock-flow consistent (SFC) model based on Godley & Lavoie (2006) with two types of households and two types of banks issuing PWD-type CoCos. This model is also inspired by Caverzasi & Godin (2015) updating and extending Minsky to the banking sector and highlighting the role of financial deregulation.

¹⁶ This chapter led to the publication of a paper in a peer-reviewed journal. See Kremer & Tinel (2022).

Such a macro approach to CoCos is useful and necessary as most publications on the subject are focused on a micro level.

The choice to focus only on PWD CoCos in this chapter is based on two reasons. The first one is empirical. As highlighted in section 1.1.5, PWD CoCos account for the majority of issuances (Vullings, 2016). This is due to the fact that insider bank shareholders push toward more PWD issuances since they are under threat of a dilution of their power and dividends in the event of the triggering of convertible CoCos (Avdjiev et al., 2013).

The second reason for focusing on PWD CoCos only is methodological. The existing literature shows that the difference between convertible CoCos and PWDs lies not so much in the ex-post effects of their activation as in the ex-ante effects of the threat of their activation on the risk-taking behaviour of issuing banks¹⁷. These ex-ante effects therefore pass through a channel of forward-looking expectations that are not easy to model in a purely aggregate model. This chapter therefore focuses only on the ex-post effects of CoCos activations.

Section 2.2 gives a presentation of the structure of the model with the main features of each institutional sector. Section 2.3 presents the two sets of simulations and their results. Section 2.4 provides a final discussion

2.2 PRESENTATION OF THE MODEL

The model involves seven institutional sectors: working-households, investing-households, firms, retail banks, investment banks, the government and the central bank. Separating both households and banks into two such opposite categories may be perceived as unrealistic. Indeed, households can earn revenues from both their work and possible financial investments in different proportions. With regard to banks, there were regulations in the past which required such a separation but these have since been repealed.¹⁸ However, while these separations are not as clear-cut, they still exist on a spectrum. Households have different propensities to save depending on their income. And banks are heterogeneous in their balance sheet structure.¹⁹ While it is possible to take this into account in a model with heterogeneous agents, this is not

¹⁷ Admati et al. (2013) show for instance that PWD CoCos introduce a higher moral hazard risk than convertible CoCos in that bank shareholders have less incentive to avoid activation. See section 1.1.5 for more details.

¹⁸ For example, the Glass-Steagall Act of 1933 in the United States imposed a strict separation between retail banks and investment banks and was repealed in 1999. In France, the law of 2 December 1945 on the organisation of credit was repealed by the Banking Law 84-46 of 24 January 1984. And in Belgium, the Royal Decree of 1935 was unravelled in two stages with the decision in 1970 to make the status of retail and private banks similar, and the authorisation in 2004 for banks to carry out insurance activities.

¹⁹ The separation sometimes takes other forms when banks create subsidiaries dedicated to investment activities. One example among many is the French group BPCE and its subsidiary Natixis.

the case in a purely aggregated model. I therefore introduce simplifying dichotomies to overcome this limitation. This imperfect heterogeneity allows to derive results according to broad typical profiles and to check for example what can be expected in case of CoCo activations for banks depending on whether they have an investment or retail profile, and for households depending on whether they have direct or indirect exposure to CoCos. These categories therefore provide general insights and pave the way for the introduction of heterogeneous agents in the following chapters, while enriching the insights provided by the SFC-AB model by framing them with

The model considers twelve types of financial and non-financial assets: inventories, fixed capital, treasury bills, loans granted to households, loans granted to firms, equities issued by firms, deposits with retail banks, time deposits with investment banks, advances from the central bank, banks' reserves at the central bank, coco bonds issued by retail banks and coco bonds issued by investment banks.

It is a closed economy model with an integrated growth component. The matrices of stocks, flows and revaluation are presented in Table 1, Table 2 and Table 3.

This model is designed for exploratory purposes rather than trying to reproduce stylized facts like the financialization of companies (van Treeck, 2009), or past events such as the subprime crisis (Caverzasi & Godin, 2015; Nikolaidi, 2015). The model presented in this paper aims to explore what would happen in the economy as a whole if CoCos were to be activated and therefore proposes a counterfactual analysis. This implies certain methodological particularities. Elements that are not directly related to the activation of CoCos such as household, corporate and public sector behaviours are deliberately kept at a low level of complexity. The present model only includes two types of households, workers and investors like in Botta et al. (2015).

The model focuses mainly on the financial sector and is similar to what is observed in Le Heron & Mouakil (2008) with "non-Wicksellian" banks imposing credit restrictions to part of the economy, or two types of banks (investment and retail) like in Botta et al. (2015) to differentiate the effect of the activation of CoCos according to the main activity of financial institutions. The portfolio rules of the different sectors are sufficiently detailed to account for how CoCos enter into their composition and the impact of their price changes and their activation. The originality of this analysis lies in the introduction of CoCos for the first time in

a SFC model. The structure of the model is inspired from Godley & Lavoie (2006) in particular the growth model presented in Chapter 11.

Regarding the notation, working households' variables have a subscript w , investing-households have a subscript r , retail banks have subscript $b1$, investment banks have a subscript $b2$ the government has a subscript g and the central bank has a subscript cb . We use the additional subscript s , d and h for supplied, demanded and held variables (we do this to consider the fact that sometimes what is supplied is not equal to what is demanded and held.). Agents form their anticipations (associated with an e subscript) in an adaptive backward-looking way. Capitalized variables are given in nominal terms. Lower case variables are given in real terms.

Having posed the main hypotheses, written the equations and attributed values to parameters²⁰ and variables²¹ (for the first period), simulations are computed without imposing constraints on the results with Python and the *pysolve* package which is very helpful for such a model with many nested variables²².

²⁰ The full list of parameters can be found in appendix A

²¹ The full list of variables can be found in appendix B

²² The code with full equations and calibration of the model can be found here: https://github.com/elskr/sfc_cocos/tree/master

Table 1: Stock matrix

	Worker households	Investor households	Firms	Retail banks	Investment banks	Central bank	Government	Σ
Inventories			+IN					+IN
Fixed capital			+K					+K
Reserves				+HPM _{bl}	+HPM _{ib2}	-HPM		0
Bills		+B _r	+B _f		+B _{ib2}		-B	0
Household loans	-L _w			+L _w				0
Firm loans			-L _f	+L _f				0
Firm shares		+pe.E _r	-pe.E _f		+pe.E _{ib2}			0
Checking deposits	+D _w	+D _r		-D				0
Time deposits		+TD _r			-TD _r			0
Advances				-A _{bl}	-A _{ib2}	+A		0
Coco bonds retail banks		+pbco1.BCO1 _r	+pbco1.BCO1 _f	-pbco1.BCO1				0
Coco bonds investment banks		+pbco2.BCO2 _r	+pbco2.BCO2 _f		-pbco2.BCO2			0
Net wealth	-V _w	-V _r	-V _f	-V _{bl}	-V _{ib2}	0	-V _g	-(IN+K)
Σ	0	0	0	0	0	0	0	0

Table 2: Flow matrix

	Worker households		Investor households		Firms		Retail banks		Investment banks		Central bank		Government		Σ
	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	Current	Capital	
Consumption	-C _w		-C _r		+C _w +C _r										0
Public expenditures					+G										0
Fixed capital investment					+I										0
Inventory accumulation					+ Δ IN	- Δ IN									0
Income taxes	-T _w		-T _r											+T	0
Wages	+WB				-WB										0
Inventory costs					- $\pi_{t-1} \cdot \text{IN}_{t-1}$	+ $\pi_{t-1} \cdot \text{IN}_{t-1}$									0
Firm profits			+FD _{rf}		-F _f	+FU _f			+FD _{b2f}						0
Central bank profits														+F _{CB}	0
Retail bank profits							-F _{b1}	+FU _{b1}							0
Investment bank profits									-F _{b2}	+FU _{b2}					0
Interest on household loans	- $\pi_{t-1} \cdot L_{w,t-1}$														0
Interest on Bills			+ $\pi_{b-1} \cdot B_{r,t-1}$		+ $\pi_{b-1} \cdot B_{f,t-1}$										0
Interest on coco bonds (1)			-BCO _{1,t-1}}		+BCO _{1,t-1}}										0
Interest on coco bonds (2)			+BCO _{2,t-1}}		+BCO _{2,t-1}}										0
Interest on checking deposits	+ $\pi_{d-1} \cdot D_{w,t-1}$		+ $\pi_{d-1} \cdot D_{r,t-1}$												0
Interest on time deposits			+ $\pi_{td-1} \cdot TD_{w,t-1}$												0

Table 2 (continued)

	Worker households	Investor households	Firms		Retail banks		Investment banks		Central bank		Government
			Current	Capital	Current	Capital	Current	Capital	Current	Capital	Σ
Interest on advances			$-\Gamma_{A-1} \cdot A_{b1,-1}$		$-\Gamma_{A-1} \cdot A_{b2,-1}$		$+\Gamma_{A-1} \cdot A_{-1}$				0
Δ checking deposits	$-\Delta D_w$	$-\Delta D_r$			$+\Delta D$						0
Δ time deposits		$-\Delta TD_r$					$+\Delta TD_r$				0
Δ reserves					$-\Delta HPM_{b1}$		$-\Delta HPM_{b2}$		$+\Delta HPM$		0
Δ firm shares		$-pe \cdot \Delta e_r$		$+pe \cdot \Delta e$			$-pe \cdot \Delta e_{b2}$				0
Δ advances					$+\Delta A_{b1}$		$+\Delta A_{b2}$		$-\Delta A$		0
Δ household loans	$+\Delta L_w$				$-\Delta L_w$						0
Δ firm loans				$+\Delta L_f$	$-\Delta L_f$						0
Δ treasury bills		$-\Delta B_r$		$-\Delta B_f$			$-\Delta B_{b2}$			$+\Delta B$	0
Δ coco bonds (1)		$-pbco1 \cdot \Delta BCO1_r$		$-pbco1 \cdot \Delta BCO1_f$		$+pbco1 \cdot \Delta BCO1$					0
Δ coco bonds (2)		$-pbco2 \cdot \Delta BCO2_r$		$-pbco2 \cdot \Delta BCO2_f$			$+pbco2 \cdot \Delta BCO2$				0
Defaulted household loans	$+\Delta NPLW$				$-\Delta NPLW$						0
Σ	0	0	0	0	0	0	0	0	0	0	0

Table 3: Revaluation matrix

	Worker households	Investor households	Firms	Retail banks	Investment banks	Central bank	Government	Σ
Coco bonds (1)		$+\Delta pbco1.BCO1_{h,t-1}$	$+\Delta pbco1.BCO1_{f,t}$	$-\Delta pbco1.BCO1_{t-1}$				0
Coco bonds (2)		$+\Delta pbco2.BCO2_{h,t-1}$	$+\Delta pbco2.BCO2_{f,t}$		$-\Delta pbco2.BCO2_{t-1}$			0
Firm shares		$+\Delta pe.E_{h,t-1}$	$-\Delta pe.E_{f,t}$		$+\Delta pe.E_{b2,t-1}$			0
Inventories			$+\Delta pIN.IN_{t-1}$					$+\Delta pIN.IN_{t-1}$
Fixed capital			$+\Delta p.K_{t-1}$					$+\Delta p.K_{t-1}$

2.2.1 Working-households sector

Income and consumption choices

The consumption function of workers (W1) depends on several factors. In a standard way, it is determined by expected disposable income yd_{we} and past net worth v_{w-1} . There is also a positive effect on consumption coming from expected new granted loans nl_{wse} . This variable is introduced in several other stock-flow consistent models (Fontana & Godin, 2013; Godley & Lavoie, 2006; Nikolaidi, 2015), based on the observation that households tend to use new granted loans to finance part of their consumption expenditures. This has been verified in empirical works such as in Lusardi & Mitchell (2011) who provide an analysis of households' consumption data for 13 countries extracted from the 2009 TNS Global Economic Crisis Survey for 13 countries.

In line with Godley & Lavoie (2006), the expected disposable income of working households (W2) is equal to a weighted average of their disposable income and the expectations of the previous period adjusted for the growth rate of labour productivity gr_{pr} (constant and exogenous)²³. The disposable income of working households (W3) is given by their income (wage bill and interests on deposits) minus their taxes (a fixed share of their income) and interest rates on loans. Expected new granted loans (W4) correspond to a weighted average of the granted credits and the expectations of the previous period. The amount of workers' net worth (W5) is equal to its past value plus savings, given by the difference between disposable income and consumption. Working-households' net wealth is kept as deposits.

(W1): Real consumption of working-households

$$c_w = \alpha_1 \cdot (yd_{we} + nl_{wse}) + \alpha_2 \cdot v_{w-1}$$

(W2): Real expected disposable income of working-households

$$yd_{we} = \varepsilon \cdot yd_w + (1 - \varepsilon) \cdot yd_{w-1} \cdot (1 + gr_{pr})$$

(W3): Real disposable income of working-households

$$yd_w = \frac{YD_w}{p} = \frac{WB + r_{d-1} \cdot D_{wh-1} - T_w - r_{l-1} \cdot L_{ws-}}{p}$$

(W4): Net real supply of loans to working-households

²³ Note that labour productivity grows here at a constant exogenous rate for simplicity. One could possibly make it endogenous and in particular link it with effective demand, in line with the work of Kaldor (1960) and Robinson (1956). If it were endogenous, the introduction of labour productivity into income expectations would represent a much stronger assumption.

$$nl_{wse} = \varepsilon_1 \cdot nl_{ws-1} + (1 - \varepsilon_1) \cdot nl_{wse-}$$

(W5): Real net worth of working-households

$$v_w = \frac{V_w}{p} = \frac{V_{w-1} + YD_w - C_w}{p}$$

Borrowing decisions

The net amount of new loans demanded by working- households (W6) corresponds to their gross amount GL_{wd} minus their loan-repayments REP_w . These repaid loans are a fixed fraction δ_{rep} of the total stock of loans in the previous period L_{ws-1} .

The gross amount of new loans demanded by working-households (W7) corresponds to a fraction η of their disposable income. This fraction depends negatively on the real interest rate on bank loans rr_1 .

In each period, there are some defaults NPLW on loans (W9). The fraction $nplw$ of defaulted loans to total loans is endogenous as it depends positively on the burden of households' debt BUR_w . When household defaults increase, banks react and reduce the availability of credit (see equation (BD3) in the section on retail banks for more information on this subject: an increase in defaulted loans will always cause a direct decrease in credit availability through the $klim_2$ parameter and an indirect one through $klim_1$ as the capital adequacy ratio of banks decreases, regardless of the value of these two parameters). Without such an endogenous booster effect, the model would simply collapse after the onset of a crisis.

The burden of household debt (W10) is the ratio of the sum of their interest payments and repayments to their disposable income (Dafermos, 2012; van Treeck, 2009).

(W6): Net nominal demand of loans to working-households

$$NL_{wd} = GL_{wd} - REP_w = GL_{wd} - [\delta_{rep} \cdot L_{ws-1}]$$

(W7): Gross amount of new loans demanded by working-households

$$GL_{wd} = \eta \cdot YD_w = (\eta_0 - \eta_1 \cdot rr_1) \cdot YD_w$$

(W8): Nominal demand in loans from working-households

$$L_{wd} = L_{wd-1} + NL_{wd} - NPLW$$

(W9): Defaulted working-households' loans

$$NPLW = nplw \cdot L_{ws-1} = (nplw_0 + nplw_1 \cdot BUR_{w-1}) \cdot L_{ws-1}$$

(W10): Burden of working-households' debt

$$BUR_w = \frac{(REP_w + r_{1-1} \cdot L_{wd-1})}{YP_w}$$

2.2.2 Investing-households sector*Income and consumption choices*

Incomes and consumption equations are similar for both types of households but investing-households don't borrow from the banking sector so there is no borrowing equation. They also do not work and therefore do not earn wages. We introduce this simplification because we want to distinguish the effects of a CoCos activation according to the main activity of the household (work or investment). Investing-households' real disposable income yd_r (R3) is given by the sum of:

- Perceived interests on checking and time deposits ($r_d \cdot D$ and $r_{td} \cdot TD$)
- Perceived interests on treasury bills ($r_b \cdot B$)
- Distributed profits from firms (FD_{rf}) (on account of the firm equities they hold)
- Repayments of CoCo principals issued by retail banks (BCO1) and investment banks (BCO2). For the sake of simplicity, which does not impact the results, these convertible contingent bonds are assumed to have a life of one period. II_{b1} and II_{b2} are indicator functions that capture the contingent nature of these assets. They are described in more detail in the sections on the financial sector.
- Taxes (T_r) as a fixed share of their income (the same share as working households).
- Capital gains (CG_r) (R5) resulting from changes in the price of the financial assets they hold (see revaluation matrix in annex, Table 3).

In case of an activation, the net worth of the sector (R5) is decreased by ($II_{b1} \cdot share_{b1} \cdot pbco1_{-1} \cdot BCO1_{rh-1}$) and ($II_{b2} \cdot share_{b2} \cdot pbco2_{-1} \cdot BCO2_{rh-1}$), the amount of CoCos which are triggered (see the section on retail and investment banks for more details on the amount activated).

(R1): Real consumption of investing-households

$$c_r = \alpha_1 \cdot yd_{re} + \alpha_2 \cdot v_{r-1}$$

(R2): Real expected disposable income of investing-households

$$yd_{re} = \varepsilon \cdot yd_r + (1 - \varepsilon) \cdot yd_{r-1}$$

(R3): Real disposable income of investing-households

$$y_{dr} = \frac{YD_r}{p}$$

$$= \frac{r_{d-1} \cdot D_{rh-1} + r_{td-1} \cdot TD_{rh-1} + r_{b-1} \cdot B_{rh-1} + r_{BCO1-1} \cdot BCO1_{rh-1} + r_{BCO2-1} \cdot BCO2_{rh-1} + FD_{rf} + CG_r - T_r}{p}$$

(R4): Capital gains of investing-households

$$CG_r = (pbco1 - pbco1_{-1}) \cdot BCO1_{rh-1} + (pbco2 - pbco2_{-1}) \cdot BCO2_{rh-1} + (pe - pe_{-1}) \cdot e_{rh-1}$$

(R5): Real net worth of investing-households

$$v_r = \frac{V_r}{p} = \frac{V_{r-1} + YD_r - C_r - (IIbis_{b1} \cdot share_{b1} \cdot pbco1_{-1} \cdot BCO1_{rh-1}) - (IIbis_{b2} \cdot share_{b2} \cdot pbco2_{-1} \cdot BCO2_{rh-1})}{p}$$

Asset choices

Investor households manage their portfolio according to a Tobin principle (Tobin, 1958). Their demand for an asset (R6) depends positively on its rate of return and negatively on the rate of return on other assets. These portfolio choices are subject to constraints *à la* Tobin (Tobin, 1958) that guarantee the accounting consistency of the model (R7). The very first constraint states that all things being equal, agents cannot allocate more of their wealth to a financial asset without allocating less to another one (in other words, the sum of the shares of all assets in the portfolio arbitrage is equal to 1). The others imply that if a change in a variable causes the relative share of an asset in a sector's portfolio to increase, the share of other assets must decrease.

If there are anticipations errors, households are left with more or less savings than expected and adjust by adding or subtracting to their checking deposits (R8). Checking deposits are an adjustment variable.

(R6): Portfolio arbitrage of investing-households

$$\begin{bmatrix} D_{rd} \\ TD_{rd} \\ B_{rd} \\ pe \cdot e_{rd} \\ pbco1 \cdot BCO1_{rd} \\ pbco2 \cdot BCO2_{rd} \end{bmatrix} = \begin{bmatrix} \lambda_{10} \\ \lambda_{20} \\ \lambda_{30} \\ \lambda_{40} \\ \lambda_{50} \\ \lambda_{60} \end{bmatrix} \cdot V_{r-1} + \begin{bmatrix} +\lambda_{11} & -\lambda_{12} & -\lambda_{13} & -\lambda_{14} & -\lambda_{15} & -\lambda_{16} \\ -\lambda_{21} & +\lambda_{22} & -\lambda_{23} & -\lambda_{24} & -\lambda_{25} & -\lambda_{26} \\ -\lambda_{31} & -\lambda_{32} & +\lambda_{33} & -\lambda_{34} & -\lambda_{35} & -\lambda_{36} \\ -\lambda_{41} & -\lambda_{42} & -\lambda_{43} & +\lambda_{44} & -\lambda_{45} & -\lambda_{46} \\ -\lambda_{51} & -\lambda_{52} & -\lambda_{53} & -\lambda_{54} & +\lambda_{55} & -\lambda_{56} \\ -\lambda_{61} & -\lambda_{62} & -\lambda_{63} & -\lambda_{64} & -\lambda_{65} & +\lambda_{66} \end{bmatrix} \cdot \begin{bmatrix} r_d \\ r_{td} \\ r_b \\ r_K \\ r_{BCO1} \\ r_{BCO2} \end{bmatrix} \cdot V_{r-1}$$

(R7): Constraints on parameters

$$\lambda_{10} + \lambda_{20} + \lambda_{30} + \lambda_{40} + \lambda_{50} + \lambda_{60} = 1$$

$$\lambda_{11} - (\lambda_{21} + \lambda_{31} + \lambda_{41} + \lambda_{51} + \lambda_{61}) = 0$$

$$\lambda_{22} - (\lambda_{12} + \lambda_{32} + \lambda_{42} + \lambda_{52} + \lambda_{62}) = 0$$

$$\lambda_{33} - (\lambda_{13} + \lambda_{23} + \lambda_{43} + \lambda_{53} + \lambda_{63}) = 0$$

$$\lambda_{44} - (\lambda_{14} + \lambda_{24} + \lambda_{34} + \lambda_{54} + \lambda_{64}) = 0$$

$$\lambda_{55} - (\lambda_{15} + \lambda_{25} + \lambda_{35} + \lambda_{45} + \lambda_{65}) = 0$$

$$\lambda_{66} - (\lambda_{16} + \lambda_{26} + \lambda_{36} + \lambda_{46} + \lambda_{56}) = 0$$

(R8): Redundant equation in the portfolio arbitrage of investing-households

$$D_{rd} = V_r - TD_{rs} - B_{rs} - pe \cdot e_{rs} - pbco1 \cdot II_{b1} \cdot BCO1_{rs} - pbco2 \cdot II_{b2} \cdot BCO2_{rs}$$

2.2.3 Firm sector

Investment decisions

Firms' investment in period t (F1) corresponds to the accumulation of fixed capital between period t and period t-1 and the renewal of depreciated fixed capital (a constant exogenous share δ of capital). Fixed capital accumulation (F2) occurs at a growth rate gr_k . This growth rate is endogenous and depends on (F3)²⁴:

- The rate of capacity utilization of firms (F4) (positively)
- The real²⁵ interest rate firm pay on their loans (F5) and their leverage ratio (F6) (negatively)
- The real cash flow rate of firms (F9) (positively)
- The real Tobin's Q of firms (F10) (positively)

(F1): Real investment of firms

$$inv = (k - k_{-1}) + \delta \cdot k_{-1}$$

(F2): Real stock of capital of firms

$$k = k_{-1} \cdot (1 + gr_k)$$

(F3): Growth rate of the real stock of capital of firms

$$gr_k = \gamma_0 + \gamma_1 \cdot u_{-1} - \gamma_2 \cdot rr_1 \cdot l_{-1} + \gamma_3 \cdot rr_{cf-1} + \gamma_4 \cdot rr_{q-1}$$

²⁴ The resulting specification of the investment function is used by (Lavoie & Godley, 2001) and has been tested empirically by Ndikumana (1999).

²⁵ These three real rates rr_1 , rr_{cf} and rr_q correspond to their respective nominal rate r_l (fixed exogenously), r_{cf} (F7) and r_q (F8) adjusted for the inflation rate $\pi = \frac{p-p_{-1}}{p_{-1}}$

(F4): Rate of capacity utilization of firms

$$u = \frac{y}{k_{-1}}$$

(F5): Real interest rate on loans

$$rr_l = \frac{(1 + r_l)}{1 + \pi} - 1$$

(F6): Leverage ratio of firms

$$l = \frac{L_{fs}}{K}$$

(F7): Cash flow rate of firms

$$r_{cf} = \frac{FU_f}{K_{-1}}$$

(F8): Tobin's Q of firms

$$r_q = \frac{L_{fd} + pe \cdot e_s}{K + IN}$$

(F9): Real cash flow rate of firms

$$rr_{cf} = \frac{(1 + r_{cf})}{1 + \pi} - 1$$

(F10): Real Tobin's Q of firms

$$rr_q = \frac{(1 + r_q)}{1 + \pi} - 1$$

Production decisions

The accumulation of inventories $in - in_{-1}$ (F12) is equal to the difference between production y and sales s for the given period. Inventories exist because production takes time and also because firms make mistakes as regard to the number of sales they anticipate.

Firms decide to produce what they expect to sell s_e plus a possible planned inventory change $in_e - in_{-1}$ (F13). In line with Godley & Lavoie (2006), expected inventories (F14) are a weighted average of past inventories and the gap between past inventories and target inventories. It is indeed assumed that there is a target of long-term inventories that corresponds to a fraction of anticipated sales. However, firms know that their expectations can be mistaken. Consequently, they only partially seek to reach this long-term target.

Expected sales (F15) are a weighted average of current sales and past sales (adjusted for the growth rate of productivity gr_{pr} which represents long-term trends in sales).

Finally, sales (F16) are equal to what is consumed by worker households, investor households and the government, plus investments.

(F12): Real inventories of firms

$$in = in_{-1} + (y - s)$$

(F13): Real production of firms

$$y = s_e + in_e - in_{-1}$$

(F14): Expected real inventories of firms

$$in_e = in_{-1} + \gamma \cdot (in_T - in_{-1}) = in_{-1} + \gamma \cdot (\sigma_T \cdot s_e - in_{-1})$$

(F15): Real expected sales of firms

$$s_e = \beta \cdot s_{-1} + (1 - \beta) \cdot s_{e-1} \cdot (1 + gr_{pr})$$

(F16): Real sales of firms

$$s = c_w + c_r + g + inv$$

From cost to price decisions

Inflation in the model depends mainly on the demands of workers on the goods market. Workers arrive at the bargaining table and demand at discrete intervals of time a nominal wage (F17) which depends on the exogenous trend of labour productivity pr , the employment rate ER and the previous evolution of prices. It is assumed that workers try to recover past increases in their costs of living. They only catch up. They do not attempt to forecast future inflation rates. Expectations in the model are purely backward-looking.

The nominal wage (F18) then changes according to the difference between the wage Ω_T targeted by workers and the actual wage W at the beginning of the period. The extent to which this gap is closed depends on a parameter Ω_3 (such as $0 < \Omega_3 < 1$) that represents the bargaining power of workers. This makes inflation endogenous into the model (wage inflation) through a form of "fair pay" theorized by Wood (1978). According to him, the real wage is determined by two types of factors:

- "Normative pressures": if there is a rise in productivity, workers then increase their demands when negotiating wages (considering that the increase in production is the result of their work)
- "Anomic pressures": in relation to external supply-demand conditions there is a standard Phillips relation effect. Workers' bargaining power depends inversely on the pressure of unemployment.

Once the wage has been decided, firms set their prices according to a mark-up φ based on normal historic unit costs NHUC (F19). These normal historic unit costs (F20) depend on past and present normal unit costs NUC (F21) and the interest rate to be paid back to banks. The same process of wage and price determination can be found in other works²⁶.

(F17): Nominal wage bargained by workers at the moment of negotiations

$$\Omega_T = [\Omega_0 + \Omega_1 \cdot pr + \Omega_2 \cdot ER] \cdot p_{-1} = [\Omega_0 + \Omega_1 \cdot pr_{-1} \cdot (1 + gr_{pr}) + \Omega_2 \cdot ER] \cdot p_{-1}$$

(F18): Nominal effective wage paid by firms

$$W = W_{-1} + \Omega_3 \cdot (\Omega_T - W_{-1})$$

(F19): Price charged by firms

$$p = (1 + \varphi) \cdot NHUC$$

(F20): Normal historic unit costs paid by firms

$$NHUC = (1 - \sigma_N) \cdot NUC + \sigma_N \cdot (1 + r_{1-1}) \cdot NUC_{-1}$$

(F21): Normal unit costs paid by firms

$$NUC = \frac{W}{pr}$$

Financial consequences for firms

Firms finance their investment expenditures with some part ζ of their retained profits FU_f , with new equities issuance e_s and with loans supplied by commercial banks (F22). Loans demanded by firms L_{fd} play a buffer role and help to absorb variations in their financing needs. Any additional profits (relative to expected profits) will lead to a decline in the demand for credit.

²⁶ For general considerations, see e.g. Layard et al., 1991; Rowthorn, 1977; Sawyer, 1982. For direct applications to SFC models, see e.g. Godley & Lavoie, 2006.

Since the number of corporate equities in the market is determined by the investment financing needs of firms, it is the total number of shares demanded by investing households and investment banks ($e_d = e_{rd} + e_{b2d}$) that adjusts to the supply of shares e_s . The price pe clears the market by equalising supply and demand. As a result, pe is endogenous in equations R6 and BI1 and is given by equation F27.

In case of an activation, the net worth of the sector (F23) is decreased by $(IIbis_{b1} \cdot share_{b1} \cdot pbco1_{-1} \cdot BCO1_{fh-1})$ and $(IIbis_{b1} \cdot share_{b1} \cdot pbco1_{-1} \cdot BCO1_{fh-1})$, the amount of triggered CoCos.

The part $1 - \zeta$ of the retained profits that is not used to finance productive investments is used for financial investments. Firms perform a Tobin-like portfolio arbitrage between treasury bills and contingent convertible bonds issued by retail banks and investment banks (F24 and F25).

(F22): Loans demanded by firms

$$L_{fd} = L_{fd-1} + INV + (IN - IN_{-1}) - \zeta \cdot FU_f - (e_s - e_{s-1}) \cdot pe$$

(F23): Nominal net worth of firms

$$V_f = V_{f-1} + (1 - \zeta) \cdot FU_f - (IIbis_{b1} \cdot share_{b1} \cdot pbco1_{-1} \cdot BCO1_{fh-1}) - (IIbis_{b2} \cdot share_{b2} \cdot pbco2_{-1} \cdot BCO2_{fh-1})$$

(F24): Portfolio arbitrage of firms

$$\begin{bmatrix} B_{fd} \\ pbco1 \cdot BCO1_{fd} \\ pbco2 \cdot BCO2_{fd} \end{bmatrix} = \begin{bmatrix} \tau_{10} \\ \tau_{20} \\ \tau_{30} \end{bmatrix} \cdot V_{f-1} + \begin{bmatrix} +\tau_{11} & -\tau_{12} & -\tau_{13} \\ -\tau_{21} & +\tau_{22} & -\tau_{23} \\ -\tau_{31} & -\tau_{32} & +\tau_{33} \end{bmatrix} \begin{bmatrix} r_b \\ r_{BCO1} \\ r_{BCO2} \end{bmatrix} \cdot V_{f-1}$$

(F25): Constraints on parameters

$$\begin{aligned} \tau_{10} + \tau_{20} + \tau_{30} + \tau_{40} &= 1 \\ \tau_{11} - (\tau_{21} + \tau_{31} + \tau_{41}) &= 0 \\ \tau_{22} - (\tau_{12} + \tau_{32} + \tau_{42}) &= 0 \\ \tau_{33} - (\tau_{13} + \tau_{23} + \tau_{43}) &= 0 \end{aligned}$$

(F26): Redundant equation in the portfolio arbitrage of firms

$$B_{fd} = V_f - pbco1 \cdot II_{b1} \cdot BCO1_{fs} - pbco2 \cdot II_{b2} \cdot BCO2_{fs}$$

(F27): Price of firm equities

$$pe = \frac{V_{f-1}(\lambda_{40} - \lambda_{41}r_d - \lambda_{42}r_{td} - \lambda_{43}r_b + \lambda_{44}r_K - \lambda_{45}r_{BCO1} - \lambda_{46}r_{BCO2}) + V_{b2-}(\epsilon_{20} - \epsilon_{21}r_b + \epsilon_{22}r_K)}{e_s}$$

2.2.4 Public sector

Government

The evolution of public expenditures G (G1) is driven by an exogenous growth rate gr_g . Treasury Bills are supplied on demand to investing-households, firms and investment banks (G2). The fact that public assets issued by the government are provided on demand makes possible to consider rates on treasury bills as exogenous.

In this model, the government can bail out retail banks under certain conditions. Bailouts are more difficult to trigger than bail-ins (see section on the financial sector on this issue). They are implemented if the capital adequacy ratio of retail banks CAR_{b1} falls below a threshold value CAR_{Gb1}^T deemed critical by the regulator, which is itself lower than the threshold value CAR_{b1}^T below which the CoCos are activated. In addition, the trigger lag is higher than for bail-ins. Bailouts are assumed to take two periods to implement (compared to one for bail-ins). Since bailouts are more difficult and later to trigger than bail-ins, it will be possible in the simulations to check whether the issuance of CoCos reduces the need for bailouts. Formally, we model the triggering of bailouts using an indicator function Π_{BO} (equation G7).

When a bailout is implemented, the government increases taxes on the income of working households T_w (G4) and investing-households T_r (G5). Their tax rate θ_0 temporarily increases by θ_1 . This tax increase does not necessarily cover the amount of the bailout, in which case the government goes into debt. The bailout amount by the government BO_s (G6) is equal to the amount demanded by retail banks to cover the loan defaults they face.

(G1): Nominal public expenditures

$$G = G_{-1} \cdot (1 + gr_g)$$

(G2): Total supply of Treasury Bills issued by the government

$$B_s = B_{rd} + B_{fd} + B_{b2d}$$

(G3): Interest rate on Treasury Bills

$$r_b = r_a$$

(G4): Taxes on working households

$$T_w = (\theta_0 + \Pi_{BO} \cdot \theta_1) \cdot YP_w$$

(G5): Taxes on investing-households

$$T_r = (\theta_0 + \Pi_{BO} \cdot \theta_1) \cdot YP_r$$

(G6): Bailout money supplied to retail banks

$$BO_s = BO_d = \Pi_{BO} \cdot NPLW$$

(G7): Indicator function for bailouts

$$\Pi_{BO} = 1 \text{ if } CAR_{b1-3} < CAR_{Gb1}^T ; 0 \text{ else}$$

Central Bank

Profits made by the central bank are equal to the interest earned on advances granted to retail and investment banks. They are distributed to the government. The interest rate on advances is equal to the interest rate on Treasury Bills.

2.2.5 Financial sector

Retail banks

In line with the survey of empirical literature conducted by Jakab & Kumhof (2014), we consider that banks discriminate borrowers through credit rationing rather than interest rates. We assume that credits to firms are supplied on demand (BD1) while credits to working households are restricted (only a share κ_{lim} of their credit demand is satisfied) (BD2). This κ_{lim} share acts as a proxy for credit availability. Again, following Jakab and Kumhof, we assume that this credit rationing depends on several factors (BD3)²⁷:

- Minimum capital adequacy regulations. Banks consider the gap between the effective capital adequacy ratio of retail banks CAR_{b1} and their targeted capital adequacy ratio CAR_{b1}^T decided by the regulator. If their effective capital adequacy ratio is higher than the target, they can afford to take more risk and therefore increase credit availability (and vice versa).
- The risk of loan defaults in the household sector. The higher it is, the less the banking sector is willing to supply loans to households. Here, banks observe the share of defaulted loans $nplw$ in the previous period (W9)

Retail banks use Central Bank advances A_{b1} supplied on demand as an adjustment variable. In a standard fashion, their profits (BD6) correspond to what they earn (interests on

²⁷ A similar formulation can also be found on other SFC models such as in Le Heron & Mouakil (2008) and Dafermos (2012).

loans) minus what they must repay (interests on deposits, interests on advances and contingent convertible bonds' principal) as well as loss due to defaulted loans. In cases where banks are in difficulty, bailouts have a positive impact on their profits. Interest rates on loans, deposits and contingent convertible bonds r_d , r_l and r_{BCO1} (BD7) depend on the rate on advances r_a set by the central bank as well as spreads which are considered here as constant in order to simplify the model. The model is designed such as it would be possible to make them endogenous, like Godley & Lavoie (2006) who make the spreads dependent on profit targets set by the banks themselves. However, since we wish to focus on the effects of an activation of the contingent convertible bonds, we consider these interest rates to be exogenous and fixed.

Contingent convertible bonds (CoCos) are issued to cover variations in household deposits (BD8) and are demanded by investing-households (R6) and firms (F24). They are triggered (BD9) when the capital adequacy ratio of banks goes below an exogenous threshold fixed by the banking regulation framework or by the contract signed when the CoCo bonds have been issued. This contingent condition is modelled thanks to indicator functions that appear in several other equations (CoCo supply, CoCo demand, net worth of banks, households and firms). When the triggering threshold is reached, only part of the outstanding CoCos is written off, i.e., its value is set to zero in the model. The proportion of this partial cancellation $share_{b1}$ depends on the intensity of the shock encountered by retail banks (see equation BD10). It is equal to the share of defaults in total lending by retail banks.

Since the number of retail bank CoCos on the market is determined by the needs for retail banks to cover variations in checking deposits, it is the total number of demanded retail bank CoCos ($BCO1_d = BCO1_{rd} + BCO1_{fd}$) that adjusts to the total supply of retail bank CoCos $BCO1_s$. The price $pbco1$ clears the market by equalizing demand and supply. As a result, $pbco1$ is endogenous in equations R6 and F24 and is given by equation BD11.

To formally model the evolution of retail banks' CoCos stocks (see equation BD8), we use a linear combination of indicator functions: $I_{b1} + (1 - share_{b1}) \cdot I_{bis_{b1}}$. When CoCos are not activated, this endogenous parameter simply takes the value 1 and the stock of CoCos in circulation remains unchanged. When CoCos are activated, the stock in circulation is reduced in proportion to the intensity of the shock. There can therefore be chain activations over several periods and the stock of CoCos then gradually melts.

To formally model the evolution of the net worth of retail banks in the case of partial activation (see BD5), the indicator function $I_{bis_{b1}}$ is used. In case of partial activation, the

sector net value is increased by the portion of CoCos that has been activated, valued at the price of the previous period $\text{Ibis}_{b1} \cdot \text{share}_{b1} \cdot \text{pbco1}_{-1} \cdot \text{BCO1}_{s-1}$. The net worth of firms and investing-households is reduced by the same amount (see equations R5 and F23).

(BD1): Loans supplied by retail banks to firms

$$L_{fs} = L_{fd}$$

(BD2): Loans supplied by retail banks to working-households

$$L_{ws} = L_{ws-1} + \text{ klim} \cdot \text{NL}_{wd} - \text{REP}_w$$

(BD3): Share of new loans granted to working-households relative to their demand for new loans

$$\text{ klim} = \text{ klim}_0 + \text{ klim}_1 \cdot (\text{CAR}_{b1} - \text{CAR}_{b1}^T) - \text{ klim}_2 \cdot \text{ nplw}$$

(BD4): Capital adequacy ratio of retail banks

$$\text{CAR}_{b1} = \frac{V_{b1}}{L_{ws} + L_{fs}}$$

(BD5): Nominal net worth of retail banks

$$V_{b1} = V_{b1-1} + F_{b1} - \text{NPLW} + \text{Ibis}_{b1} \cdot \text{share}_{b1} \cdot \text{pbco1}_{-1} \cdot \text{BCO1}_{s-1}$$

(BD6): Profits realized by retail banks

$$F_{b1} = r_{l-1} \cdot (L_{fs-1} + L_{ws-1} - \text{NPLW}) - r_{d-1} \cdot D_{s-1} - r_{a-1} \cdot A_{b1s-1} - r_{\text{BCO1}-1} \cdot \text{BCO1}_{s-1} + \text{II}_{\text{BO}} \cdot \text{BO}_d$$

(BD7): Interest rate on loans, deposits and contingent convertible bonds

$$r_l = r_a + \chi_1$$

$$r_d = r_a - \chi_2$$

$$r_{\text{BCO1}} = r_a + \chi_3$$

(BD8): Total supply of coco bonds issued by retail banks

$$\text{BCO1}_s = \text{II}_{b1} + (1 - \text{share}_{b1}) \cdot \text{Ibis}_{b1} \cdot \text{BCO1}_{s-1} + z_1 \cdot \text{II}_{b1} \cdot \frac{(\text{D}_{s-1} - \text{D}_{s-2})}{\text{pbco1}}$$

(BD9): Indicator functions for coco bonds issued by retail banks

$$\text{II}_{b1} = 1 \text{ if } \text{CAR}_{b1-1} > \text{CAR}_{b1}^T ; 0 \text{ else}$$

$$\text{Ibis}_{b1} = 0 \text{ if } \text{CAR}_{b1-1} > \text{CAR}_{b1}^T ; 1 \text{ else}$$

(BD10): Share of activated CoCos

$$\text{share}_{b1} = \frac{\text{NPLW}}{L_{fs} + L_{ws}}$$

(BD11): Price of retail bank CoCos

pbc01

$$= \frac{V_{r-1}(\lambda_{50} - \lambda_{51}r_d - \lambda_{52}r_{td} - \lambda_{53}r_b - \lambda_{54}r_K + \lambda_{55}\Gamma_{BCO1} - \lambda_{56}\Gamma_{BCO2}) + V_{f-1}(\tau_{20} - \tau_{21}\Gamma_b + \tau_{22}\Gamma_{BCO1} - \tau_{23}\Gamma_{BCO2})}{BCO1_s}$$

Investment banks

We introduce a distinction between retail banks (whose activity consists of collecting checking deposits and granting loans) and investment banks (whose activity consists of collecting term deposits and investing in financial assets) to compare the effects of a CoCos activation according to the bank's profile.

Investment banks gather part of the savings of investing-households in the form of term deposits (TD_r) and make a portfolio choice according to Tobin principles (BI1 and BI2) between a safe asset (treasury bills, B_{b2}) and a risky asset (firms' equities, e_{b2}).

Investment banks use Central Bank advances A_{b2} supplied on demand as an adjustment variable. Their profits (BI4) correspond to what they earn (profits distributed by firms on account of the firm equities they hold, capital gains due to the changes in equities' price and interests on treasury bills) minus what they must repay (interests on deposits, interests on advances and contingent convertible bonds' principal). Interest rates on time deposits r_{td} and on contingent convertible bonds r_{BCO2} (BI5) depend on the rate on advances r_a set by the central bank as well as a spread which is considered here as constant in order to simplify the model.

Just like retail banks, investment banks issue contingent convertible bonds to cover variations in investing-households' time deposits (BI7). These CoCos are demanded by investing-households (R6) and firms (F24) as well. But while the CoCos of retail banks are activated according to a book-value trigger (depending on their capital adequacy ratio, those of investment banks are activated according to a market-value trigger). More precisely, their CoCos are activated when investment banks are exposed to too much market risks. If the market for firms' equities becomes too volatile (following a crash or a boom) and if standard deviation of the price of firms' equities σ_{pe} exceeds below a given threshold σ_{peT} (F9), then investment banks are in a risky situation that partly triggers their contingent convertible bonds. The activated share of CoCos corresponds to $share_{b2}$ (see equation BI9). It is proportional to the volatility of the share price at the time of activation. Again, chain activations can occur over different time periods.

Since the number of investment bank CoCos on the market is determined by the needs for investment banks to cover variations in time deposits, it is the total number of demanded investment bank CoCos ($BCO2_d = BCO2_{rd} + BCO2_{fd}$) that adjusts to the total supply of investment bank CoCos $BCO2_s$. The price $pbco2$ clears the market by equalizing demand and supply. As a result, $pbco2$ is endogenous in equations R6 and F24 and given by equation BI10.

Similar to retail banks, to formally model the evolution of the CoCos stock of investment banks under partial activation (see equation BI7), we use a linear combination of indicator functions $II_{b2} + (1 - share_{b2}) \cdot IIbis_{b2}$. When CoCos are activated, the stock in circulation is reduced in proportion to the intensity of the shock.

To formally model the evolution of the net worth of investment banks in the case of partial activation (see BI3), the indicator function $IIbis_{b2}$ is used. In case of partial activation, the sector net value is increased by the portion of CoCos that has been activated, valued at the price of the previous period $IIbis_{b2} \cdot share_{b2} \cdot pbco2_{-1} \cdot BCO2_{s-1}$. The net worth of firms and investing-households is reduced by the same amount (see equations R5 and F23).

(BI1): Portfolio arbitrage of investment banks

$$\begin{bmatrix} B_{b2d} \\ pe \cdot e_{b2d} \end{bmatrix} = \begin{bmatrix} \epsilon_{10} \\ \epsilon_{20} \end{bmatrix} \cdot V_{b2-1} + \begin{bmatrix} +\epsilon_{11} & -\epsilon_{12} \\ -\epsilon_{21} & +\epsilon_{22} \end{bmatrix} \begin{bmatrix} r_b \\ r_K \end{bmatrix} \cdot V_{b2-1}$$

(BI2): Constraints on parameters

$$\epsilon_{10} + \epsilon_{20} = 1$$

$$\epsilon_{11} - \epsilon_{21} = 0$$

$$\epsilon_{22} - \epsilon_{12} = 0$$

(BI3): Nominal net worth of investment banks

$$V_{b2} = V_{b2-1} - F_{b2} + IIbis_{b2} \cdot share_{b2} \cdot pbco2_{-1} \cdot BCO2_{s-1}$$

(BI4): Profits realized by investment banks

$$F_{b2} = FD_{b2f} + CG_{b2} + r_{b-1} \cdot B_{b2s-1} - r_{td-1} \cdot TD_{rs-1} - r_{bco2-1} \cdot BCO2_{s-1} - r_{a-1} \cdot A_{b2s-1}$$

(BI5): Interest rate on time deposits and contingent convertible bonds

$$r_{td} = r_a - \chi_4$$

$$r_{BCO2} = r_a + \chi_5$$

(BI6): Capital gains of investment banks

$$CG_{b2} = e_{b2h-1} \cdot (pe - pe_{-1})$$

(BI7): Total supply of coco bonds issued by investment banks

$$BCO2_s = \Pi_{b2} + (1 - \text{share}_{b2}) \cdot \Pi_{bis_{b2}} \cdot BCO2_{s-1} + z_2 \cdot \Pi_{b2} \cdot \frac{(TD_{rs-1} - TD_{rs-2})}{pbco2}$$

(BI8): Indicator functions for coco bonds issued by investment banks

$$\Pi_{b2} = 1 \text{ if } \sigma_{pe-1} < \sigma_{pe} ; 0 \text{ else}$$

$$\Pi_{bis_{b2}} = 0 \text{ if } \sigma_{pe-1} < \sigma_{peT} ; 1 \text{ else}$$

(BI9): Share of activated CoCos

$$\text{share}_{b2} = \kappa \cdot \sigma_{pe-1}$$

(BI10): Price of investment bank CoCos

$$pbco2$$

$$= \frac{V_{r-1}(\lambda_{60} - \lambda_{61}r_d - \lambda_{62}r_{td} - \lambda_{63}r_b - \lambda_{64}r_K - \lambda_{65}\Gamma_{BCO1} + \lambda_{66}\Gamma_{BCO2}) + V_{f-1}(\tau_{30} - \tau_{31}\Gamma_b + \tau_{32}\Gamma_{BCO1} - \tau_{33}\Gamma_{BCO2})}{BCO2_s}$$

2.3 NUMERICAL SIMULATIONS

The model is used to compare the effects on an economy with and without CoCos of a series of shocks that destabilize the financial sector. The dynamics of key variables like net worth, GDP, investment, consumption and income are compared in both conditions. It is important to note that we are not interested in the effects of a crisis compared to a non-crisis scenario. We want to isolate the effects of an activation of CoCos. To do so, we take the ratio of these key variables with and without activation. Before the shock, the variables follow exactly the same path and their ratio is equal to 1. After the shock, their paths diverge and we observe the effect of the activation. When the ratio is less than 1, it means that the activation has a negative effect on this variable. When the ratio is greater than 1, it means that activation has a positive effect on that variable.

The simulations consist in checking the accounting effects of two different shocks: one linked to retail banks (a sudden increase in defaulted loans) and one linked to investment banks (a sudden decrease in the price of equities). Both shocks are supposed to cause a deterioration in net worth and solvency ratios of the two types of banks. What is at stake here is whether triggering CoCos would mitigate or even fully offset these shocks, and how this activation would alter the balance sheets and transactions of the sectors.

As a pure simulated macroeconomic model, there is neither micro-foundation nor estimated parameters. There is no randomness in the equations. The model is totally

deterministic. Each simulation therefore only needs to be run once. As it stands, the model is not designed to give overall quantified effects or to make accurate economic policy assessment. Nevertheless, it is able to provide insights on how the activation of contingent convertible bonds could affect the different sectors in the economy by identifying direct and indirect effects.

An initial deterioration of the situation of the banking sector should trigger CoCos to be written off. As for the banks, one must then expect an improvement in their net worth. The effects on holders of CoCos (investing-households and firms) should be multiple. A direct expected effect is that they should experience a decrease in their net worth, which should affect their decisions. Regarding investing-households, one may expect a decline in their consumption. Regarding firms, one may expect a decline in their profits and investment. These direct effects should in turn induce indirect effects. The decline in the consumption of the investing-households should lead to a fall in firms' profit, which should imply a fall of the wages paid to working households.

2.3.1 First scenario: increase in defaults on workers' loans

Without bailout

This scenario explores a permanent increase in the share of defaulted loans granted to working-households. It compares an economy where CoCos are activated with an economy without CoCos (formally, CoCos are still in the model but their level of activation is made unattainable so they always behave like normal bonds).²⁸ The idea is to check whether the activation reduces or even compensates the negative impact on retail banks of more defaults.

The share of defaulted loans depends on the debt burden of households and an exogenous constant (see equation W9). The first shock is implemented onto the exogenous constant $nplw_0$, which is being increased. This change simulates a sudden augmentation in defaults on workers' loans. Depending on the capital adequacy ratio threshold (discussed below), the rise in percentage of $nplw_0$ has always the same type of effects on the rest of the economy, the change is only in terms of magnitude as the sign of the variables are not affected.

Several shock values in terms of increases in credit defaults are used to perform the simulations: +5%, +15%, and +25% in credit defaults. The intensity of the shock has an effect on whether or not the CoCos are triggered. One of the main results of the implementation of

²⁸ The simulation implies a scrapping of the first 100 periods of the model characterised by a burn-in period with unstable dynamics biased by the initial values of the variables. This allows to focus on the stable growth path and the deviations from this path when the shock occurs and the CoCos are activated.

partial activations is that, depending on the intensity of the shock, more or less CoCos are subsequently activated. Figure 5 presents a close-up on what happens with the trigger mechanism around the implementation of the shock: for the +5% shock, there is no activation; for the +15% shock, chain activations occur with a lag of 8 periods after the shock is triggered; for the +25% shock, chain activations occur with a lag of 5 periods after the shock is triggered.²⁹) None of these shocks is sufficient to trigger bailouts, according to the G7 equation.

As a first step, the crisis scenario is compared with the baseline scenario without crisis. The increase in loan defaults deteriorates the net worth of the retail banking sector. This reduces the capital adequacy ratio (CAR) of retail banks measured by a ratio of their net worth to the stock of supplied loans (see Figure 4), leading to an activation of contingent convertible bonds issued by retail banks (see Figure 5), except for the scenario with +5% on credit default which is not enough to trigger CoCos. The threshold value of the CAR defining the activation and the shock value triggering this activation are strongly related. The higher this threshold value, the greater the risk of activation for lower shock values. Only a part of the CoCos is activated, in proportion to the intensity of the shock. Later, once their net worth increases, banks are then issuing new CoCos again. It is therefore assumed here that activations have no effect on the subsequent demand for future CoCos emissions. This simplifying assumption aims to focus the analysis on the immediate effects after an activation. This has no impact on the results because the activations only occur at a single point in the simulations as they are triggered by a single exogenous shock. The SFC model does not generate cycles that can produce repeated financial crises with adaptation and learning effects on the part of investors.

After this first step, the baseline non-crisis scenario is no longer a benchmark in the following analysis. From now on, the crisis assessment focuses on the deviation occurring with CoCos activation compared with an economy without CoCos (we observe the ratios of several variables during the crisis with CoCo activation to the same variables during the crisis without CoCo activation). The effects on the five sectors composing the economy are now subject to scrutiny.

For investing-households, the activation of coco bonds leads to two immediate direct effects. The first one is a further decrease in their net worth since they lose a part of their assets (see Figure 6). The second one is a further decrease in their disposable income since they earn

²⁹ This is the only time when CoCos are activated in the model. To make Figure 4 more readable, the graph shows only a small number of periods around the activation. For the other graphs, we extend up to 1600 periods.

fewer financial interests (see Figure 7). These two effects cause a decrease in their consumption (see Figure 8).

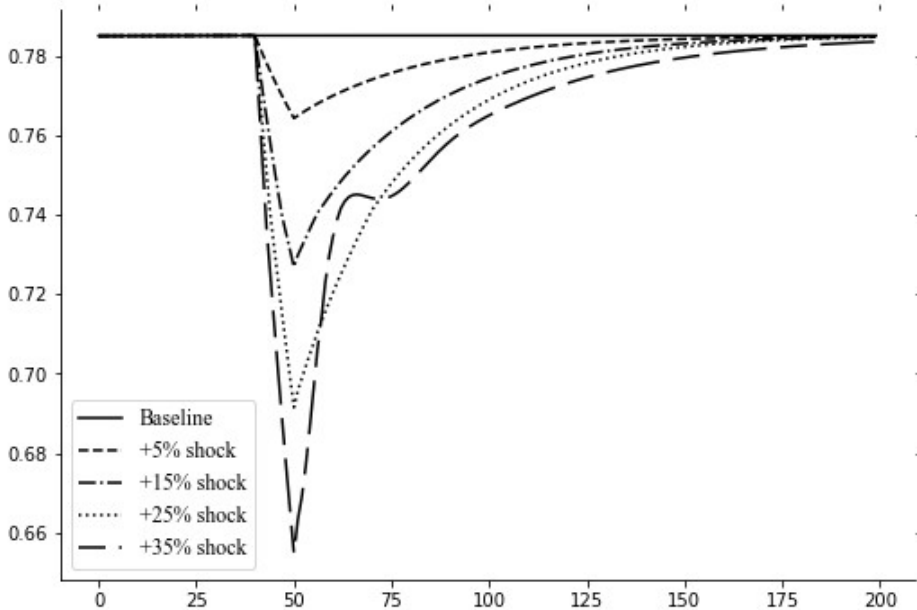


Figure 4: Evolution of the capital adequacy ratio of banks, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

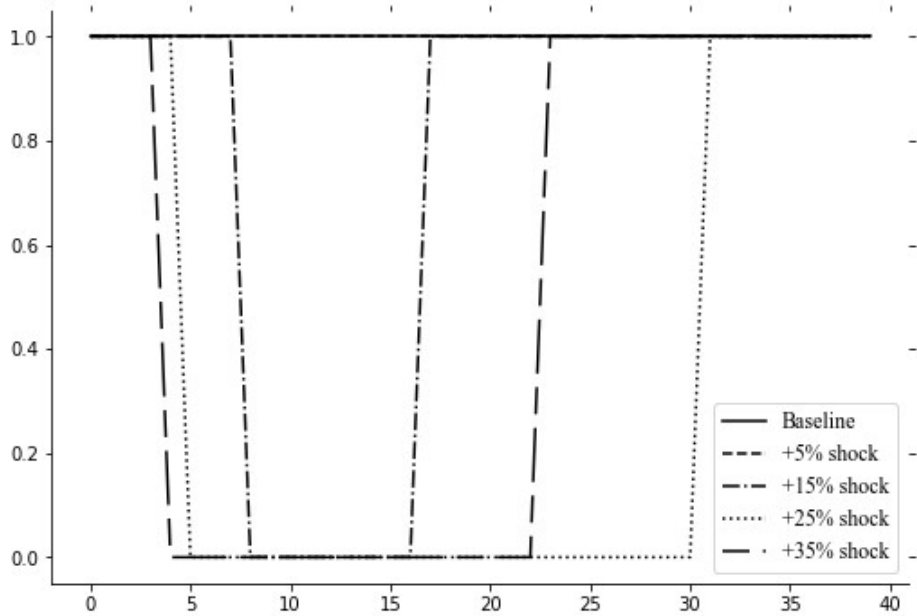


Figure 5: State of the contingent convertible trigger following an increase in defaulted loans (1 = not activated; 0 = activated)

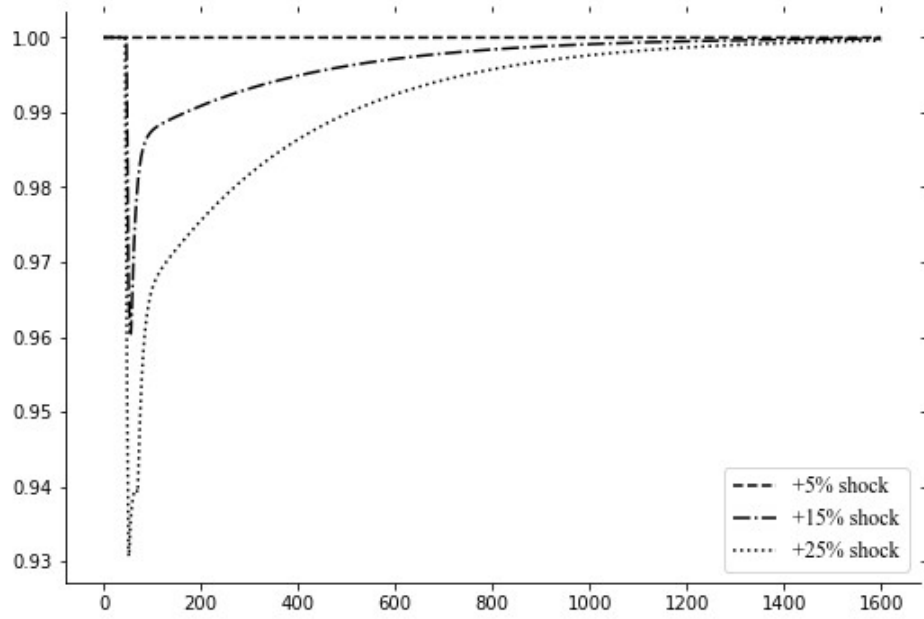


Figure 6: Evolution of the net value of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

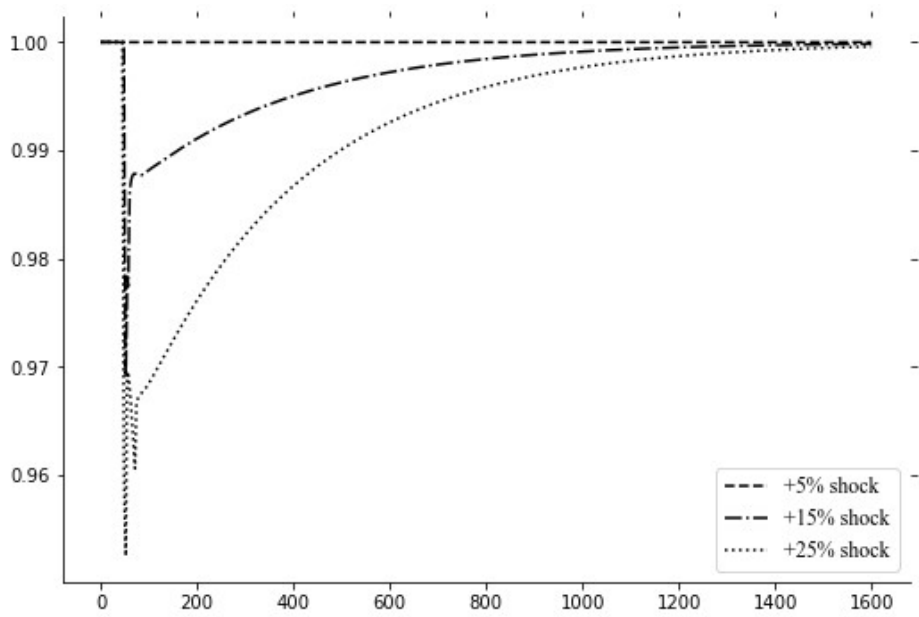


Figure 7: Evolution of the disposable income of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

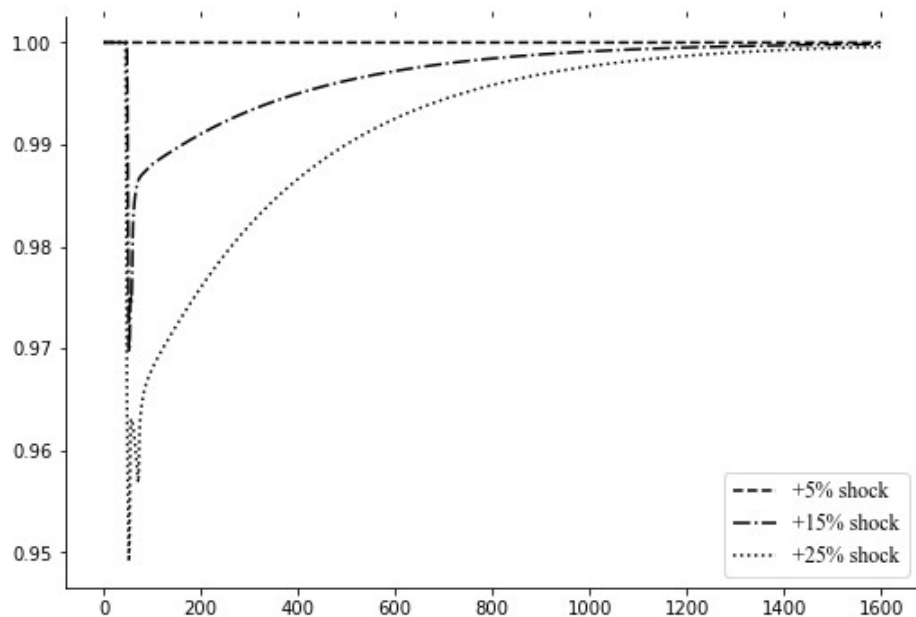


Figure 8: Evolution of the consumption of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

For firms, the activation of CoCos leads to similar direct effects, with a decrease in their net worth (see Figure 9) leading to a decrease in their investment (see Figure 10).

Effects concerning working-households are of smaller magnitude³⁰. They don't hold any contingent convertible bonds. Thus, their activation doesn't have any direct effects on their stock and flow variables. There are some indirect effects, such as a slight decrease in wages earned by working households (see Figure 11) because of a decline in aggregate demand leading to a decrease in economic activity. This results in a decrease in working households' consumption (see Figure 12) but it is a less important effect compared to the others described just above.³¹

Concerning retail banks, the activation of contingent convertible bonds has positive effects. They don't fully prevent the decrease in net worth following an increase in defaulted loans but they help mitigate their impact as banks' balance sheet improve when CoCos are written off (see Figure 13). This transfer of net worth from investors to the banking sector affects the ratio of bank debt to private (household and corporate) debt (see Figure 14) and the

³⁰ Since the model is not empirically calibrated, only the trajectories and the relative levels of the variables are of interest, while the absolute levels do not deserve to be interpreted.

³¹ The deleterious effects on working households are underestimated here, mainly because the SFC model does not allow for the modelling of individual firm and bank failures. For instance, firms decrease their production because of the decrease in consumption by investing households and the decrease in investments, so wages decrease. But that is all. The whole sector cannot go bankrupt as its net worth never goes below zero. We cannot take into account situations where a household's employing company would go bankrupt because of too much exposure to CoCos, resulting in a loss of employment and wages for the household.

ratio of bank debt to public debt (see Figure 15). The relative weight of banks' debt decreases with the activation of CoCos.

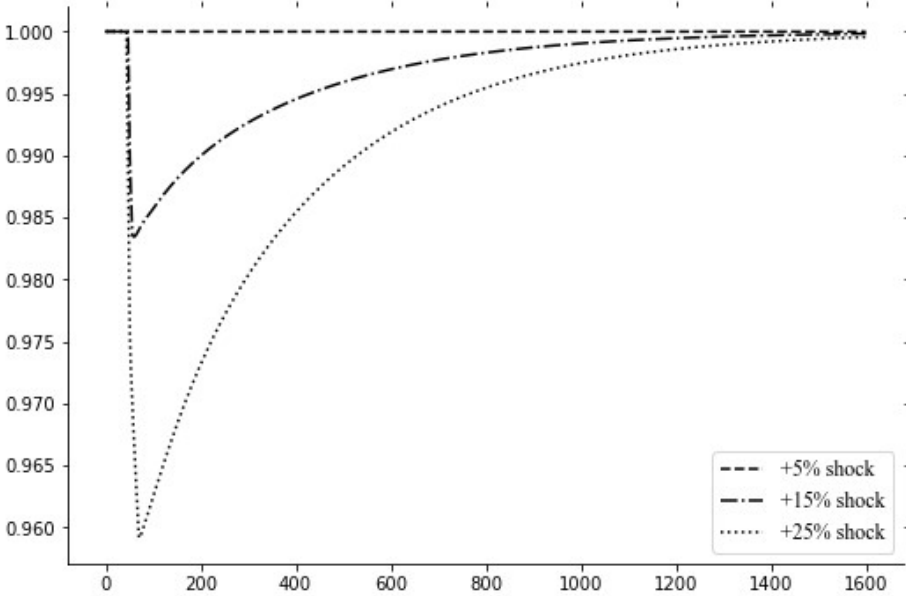


Figure 9: Evolution of the net value of firms, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

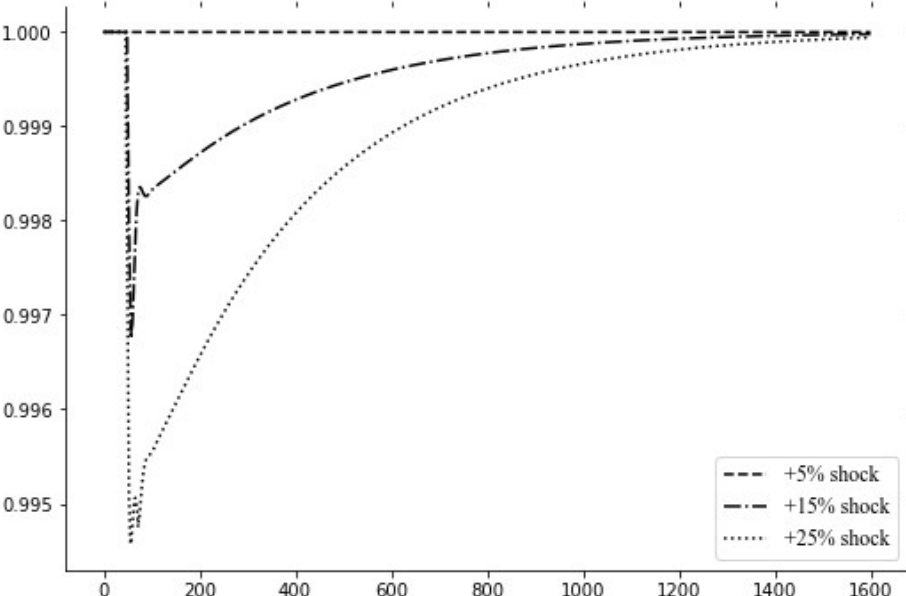


Figure 10: Evolution of firms' investment, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

Two additional results should be noted. First, the variables end up converging to the same result as a crisis scenario without CoCos (their ratio converges to 1 on the graphs). Second, this process occurs in some cases via oscillations. For investing-households and firms, the

greater the intensity of the shock, the greater the transitory oscillations, and thus the greater the amount of chain-activated CoCos. These chain activations lead to a change in the price of the assets that make up the asset portfolio of investing-households and firms. These changes in turn lead to changes in capital gains which mainly affect household disposable income (see equation R3) and business investment via the cash flow ratio (see equation F3). Regarding retail banks, after an initial improvement in their net worth, we observe the opposite. This is due to portfolio reallocations in the investing-household and firm sectors, temporarily affecting the price of contingent convertible bonds. These oscillations, although significant, depend on the calibration of the model. The main results here are the very short-run effects and the long-run convergence.

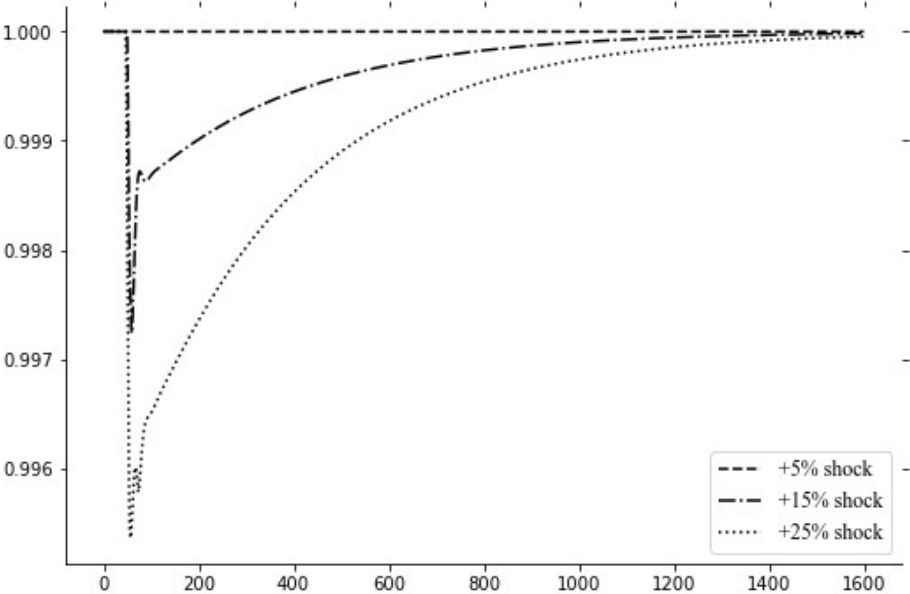


Figure 11: Evolution of the wage bill of working households following an increase in defaulted loans in both crisis scenario (with and without activation of coco bonds)

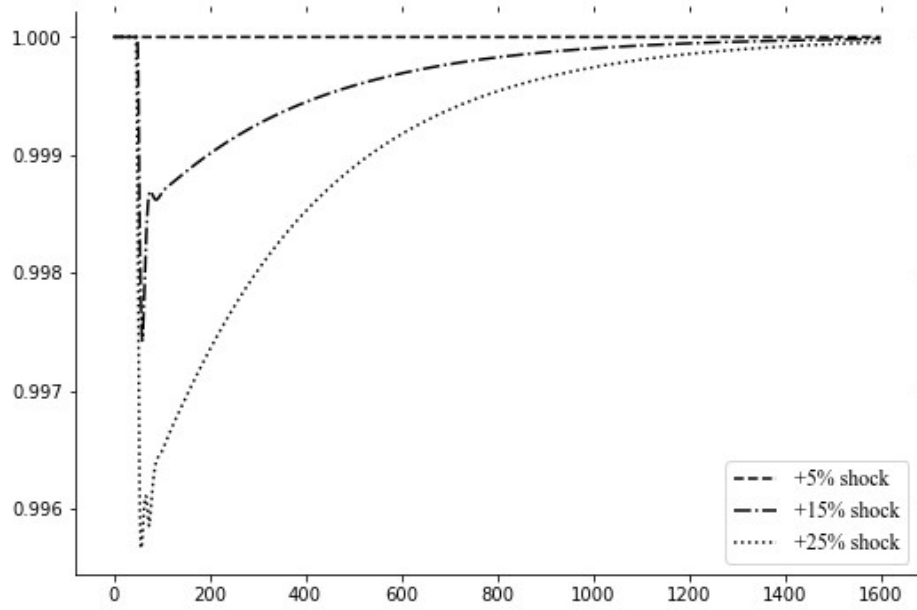


Figure 12: Evolution of the consumption of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

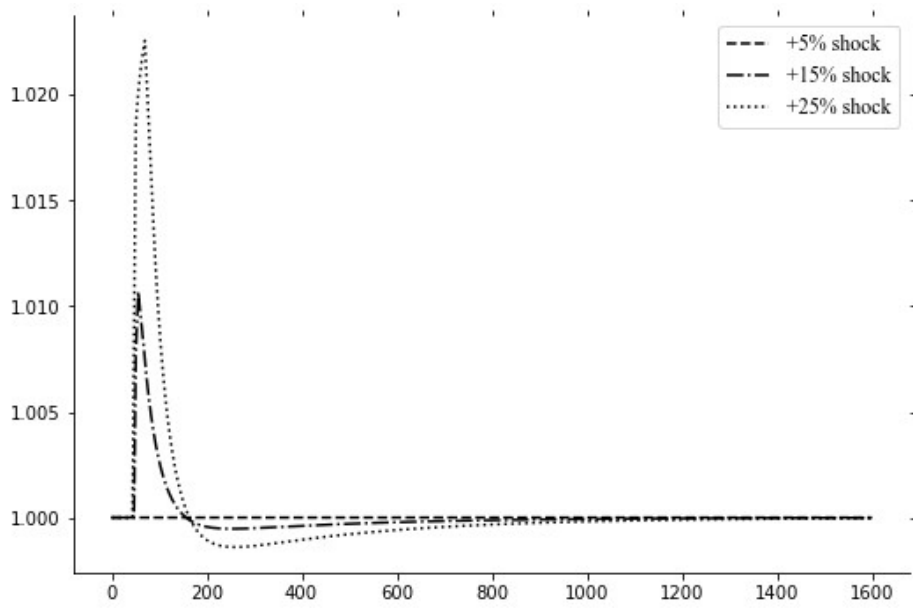


Figure 13: Evolution of the net value of retail banks following an increase in defaulted loans in both crisis scenario (with and without activation of coco bonds)

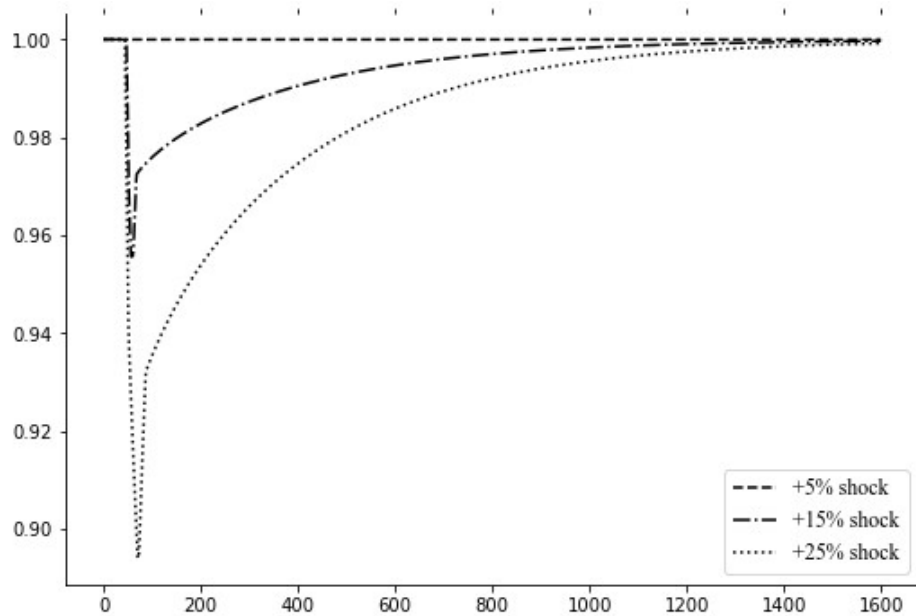


Figure 14: Evolution of the bank debt to private debt ratio relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

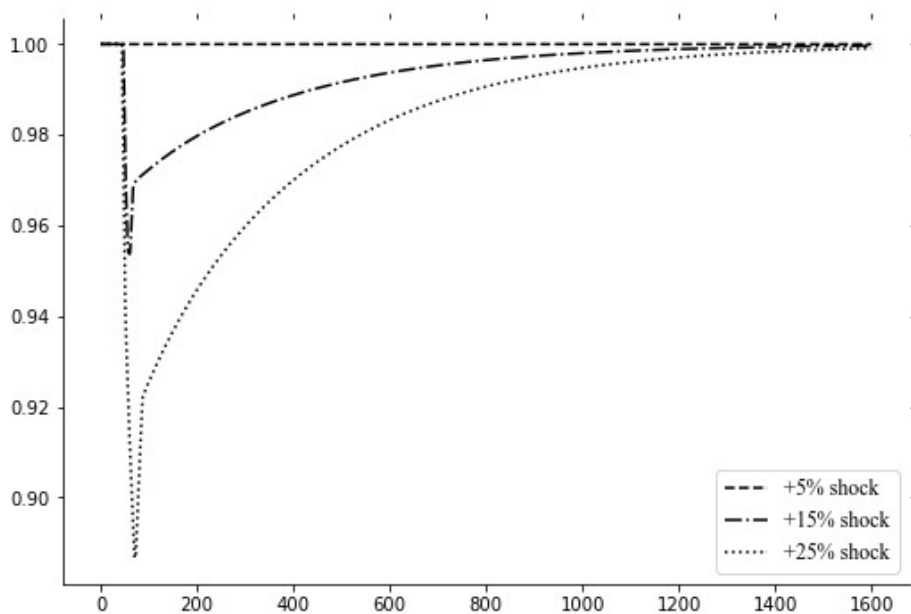


Figure 15: Evolution of the bank debt to public debt ratio relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans

Up to this point, the direct effects of a CoCos activation on the different sectors of the economy have been highlighted but nothing has been said about the stability of the overall economy. Table 4 provides an indicator of potential gains or losses of stability. Standard deviations are derived from the series of growth rates of relevant variables with and without CoCos. The indicator is a ratio of the standard deviation of the variable with CoCos to that without CoCos. If this ratio is greater than 1, then it can be said that the activation of CoCos

has a destabilizing effect on the growth rate of the variable under consideration compared to a crisis scenario without CoCos, and a stabilizing effect if the ratio is smaller than 1. Since the model follows a stable growth path, the growth rate of these variables is constant when there is no shock. Any deviation from the ratio relative to 1 is therefore attributable to the activation of CoCos and makes it possible to comment on the effects on the stability of the economy.

Table 4: Standard deviations in case of a crisis with a CoCo activation relative to standard deviations in case of a crisis without CoCos; base on the 25% shock simulation

	Relative standard deviations
Production	1.654
Total consumption of households	1.518
Net worth of investing-households	4.942
Net worth of working households	1.222
Net worth of firms	1.110
Net worth of retail banks	0.940

There is an increase in volatility for all variables relating to the real sphere. It is very strong for the investing-household sector whose net worth depends heavily on changes in their asset portfolio, as their only activity is to make financial investments. The firm sector is also affected by this increase in volatility but to a lesser extent since financial investments are not its main activity. This has an indirect effect on the volatility of variables associated with working households since they receive wages from firms. Conversely and as expected, volatility in the net worth of the retail banking sector declines. However, as we have an aggregate model here, bankruptcies are not considered, which seriously underestimates real variables instability of a crash without CoCos, as a result Table 4 must be interpreted very carefully. This aspect could be improved in future research by an agent-based model. This sub-section has shown that CoCos are fulfilling their expected role of transferring risk from the banking sector to its creditors, thereby destabilising somewhat the rest of the economy.³²

³² To determine the extent of such a destabilisation, new hypotheses need to be formulated in order to characterise more precisely the effects of a banking crisis without CoCo on the rest of the economy, which would require further specific research and is beyond the scope of this article.

With bailout

The model is designed so that retail banks can be bailed out by the government if their capital adequacy ratio deteriorates too much. We therefore compare now a bailout scenario with CoCos with a bailout without CoCos, in order to determine whether the activation of CoCos limits the size of bailouts. A shock value of +35% on loan defaults is introduced into the model, which is sufficient to trigger a bailout.³³ A baseline scenario is considered in which the bailout is financed by a sudden 4% increase in taxes on household income.

Three elements emerge from this simulation: 1/ the prior CoCos activation makes it possible to postpone the moment when a bailout becomes necessary; 2/ the period over which the bailout is extended is shorter (see Figure 16); 3/ the CoCos activation reduces the cost of bailouts (Figure 17).

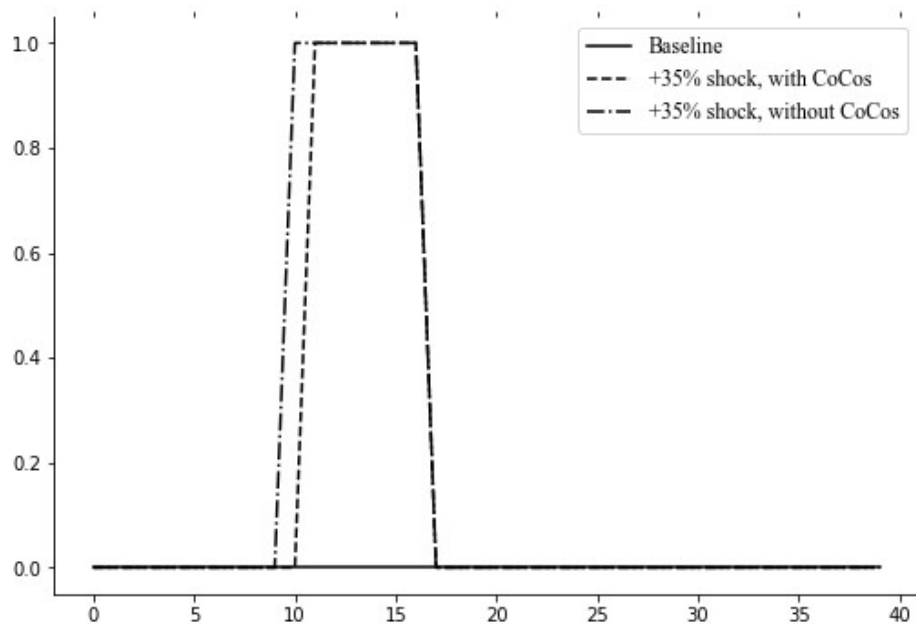


Figure 16: State of the bailout trigger following an increase in defaulted loans (1 = bailout; 0 = no bailout)

³³ The triggering of a bailout introduces significant distortions into the model that flatten the scales used in figures 3 to 12, making them unreadable, but without undermining the results of this section. To improve readability, this +35% shock is therefore not displayed in these graphs.

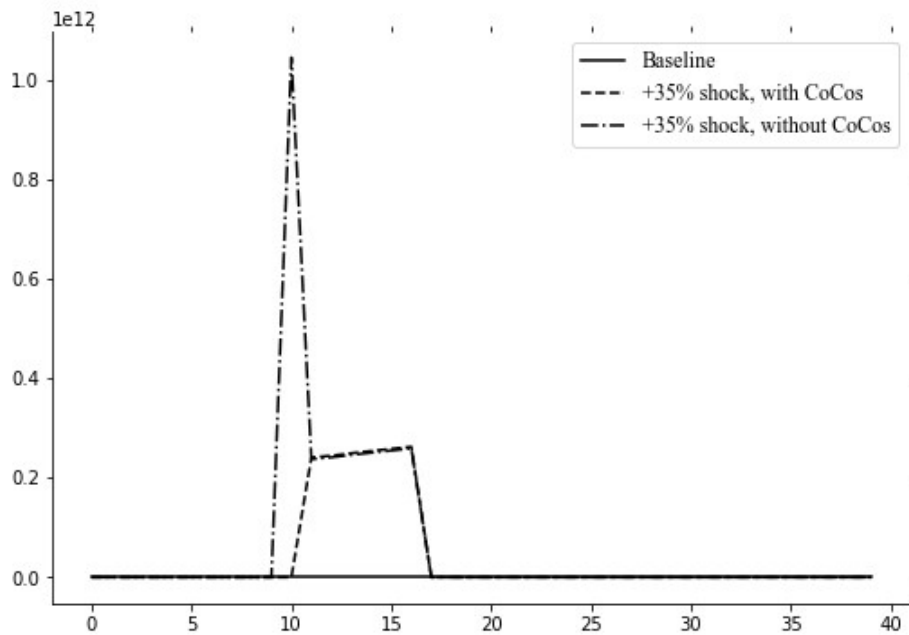


Figure 17: Evolution of retail bank bailout costs with and without bail-ins, following an increase in the share of defaulted loans

Two particular cases can be explored to identify boundary situations: bailouts financed by a sudden, one-off tax increase, and bailouts financed by an increase in public debt. Indeed, the way in which bailouts are financed can be expected to affect the results of the model.

A tax increase may have pro-cyclical effects and aggravate the current shock by weighing on the incomes of taxpaying households and thus on their consumption. Conversely, an increase in public debt may limit these deleterious pro-cyclical effects in the short term and the resulting burden may cause problems in the medium to long term.

In order to investigate these two different possibilities and their macroeconomic consequences, a sensitivity analysis on the method of financing the bailouts is carried out. I look at how different variables are affected for bailouts financed by a tax increase of 0% (i.e., financing them via debt only), 4% (the baseline case), 8% and 12%.

For the sake of readability of the graphs, a zoom is made on the period following the activation. This makes it possible to see the very short-term consequences of CoCo activations. In the long term, the variables presented all converge towards the level they would have reached without any shock³⁴. This suggests that it does not matter in the long run how bailouts are financed. This is obviously a limitation of the model due to its specification. It is not intended to be an accurate representation of all the mechanisms and effects surrounding public debt

³⁴ The reader can see this by looking at the entire graphs, in Appendix C

issues across time. The focus is on bail-ins and how they can substitute for bailouts in the short term.

Figure 18 shows the relative evolution of investing-household income for different tax increases. Several results should be noted. The first result is derived from the observation of the relative positions of each curve with respect to the others. The higher the tax increase to fund bailouts, the more beneficial CoCos activations are. Indeed, we know from Figure 16 that the issuance and activation of CoCos partially replace bailouts and reduce the time during which bailouts are needed to stabilise the banking sector. Therefore, the higher the tax increase, the more costly these bailouts are to the taxpayer, the more households gain from avoiding them. If bailouts are financed without tax increases and only by public debt, this positive transitional gain completely disappears. The second result is derived from the observation of the evolution of each curve and its position in relation to 1 on the y-axis.³⁵ One can see that the positive income effect of partly avoiding costly bailouts is only transitory. Shortly after activation, investor households are still harmed by the activation of CoCos. The resulting loss of CoCo interest payments then prevails and the income of investor households takes a long time to recover to the value it would have had without any shock.

Since income flows add to the net worth of the sector over time, this positive transitory effect is passed on to their savings as shown by Figure 19. We know that the net worth of the sector is profoundly affected - all other things being equal - by the bail-in resulting from the activation of CoCos (see Figure 6). However, when the possibility of bailouts is introduced, we find that this negative effect is mitigated depending on how they are financed. The larger the tax increase to finance bailouts, the more partially avoiding them through CoCos activations is beneficial to the sector's net worth. If bailouts are financed without tax increases and only by public debt, this positive transitional effect on net worth completely disappears once again as it does for income.

Not surprisingly, these effects on income and savings are transmitted to the consumption of investing households (see Figure 20).

³⁵ As a reminder, the variables follow exactly the same path and their ratio is equal to 1 before the shock. After the shock, their paths diverge and we observe the effect of the activation. When the ratio is less than 1, it means that the activation has a negative effect on this variable. When the ratio is greater than 1, it means that activation has a positive effect on that variable.

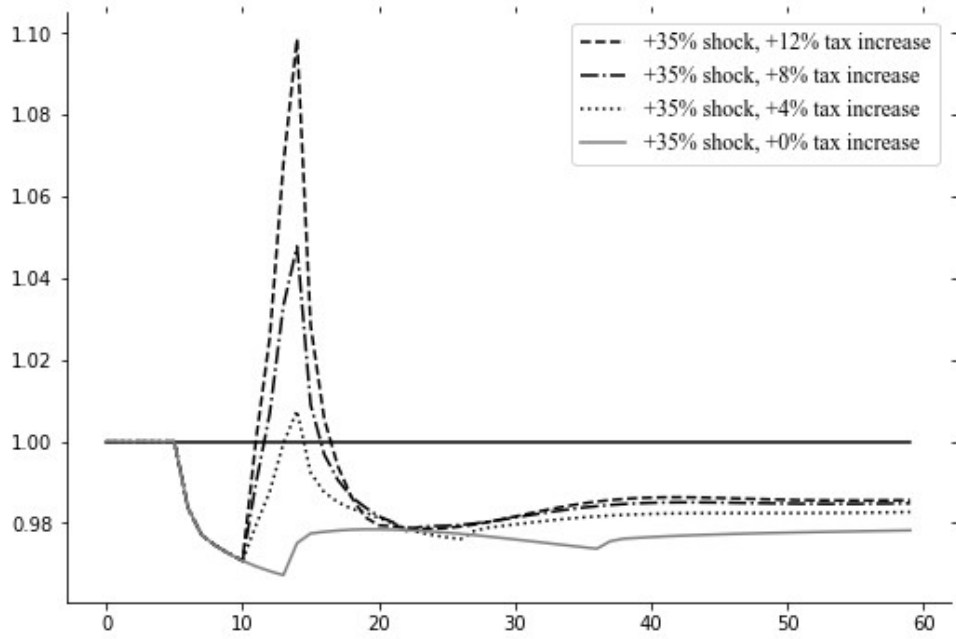


Figure 18: Evolution of the income of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

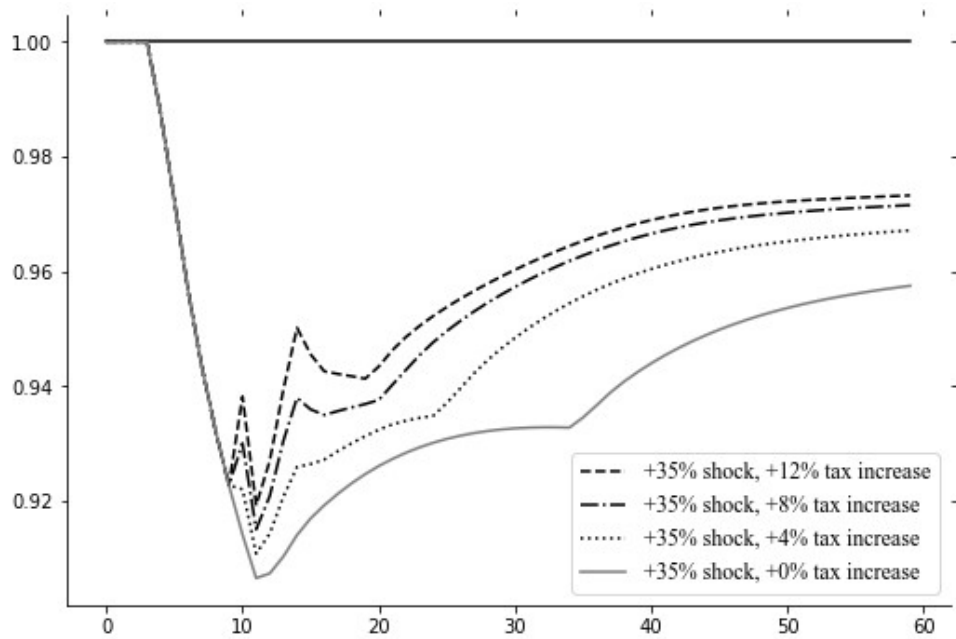


Figure 19: Evolution of the net value of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

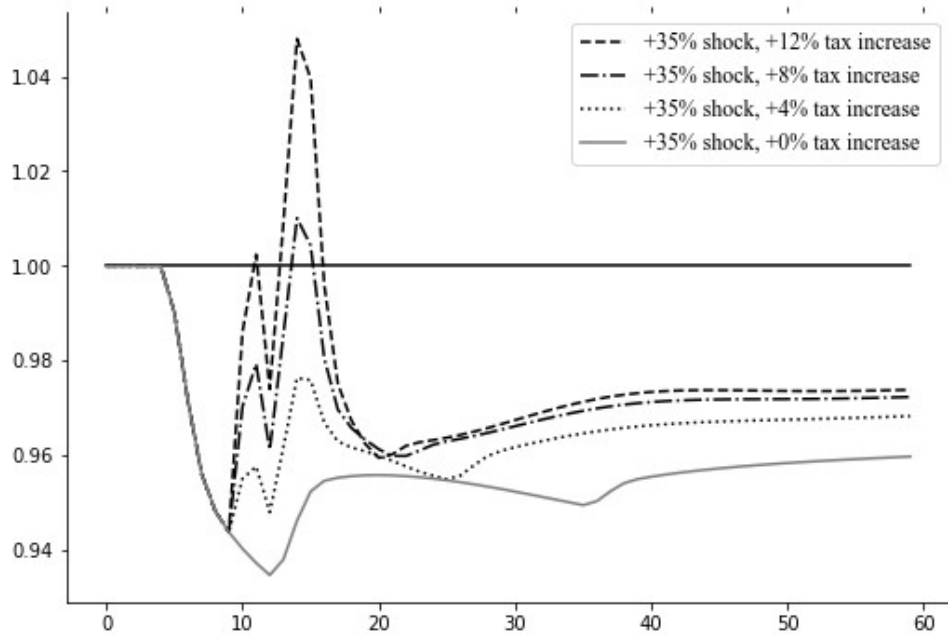


Figure 20: Evolution of the consumption of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

The other sector directly affected by potential tax increases is the working-household sector. Figures 21, 22 and 23 show the relative evolution of their income, net worth and consumption. The results are similar to those observed for investing-households. Scenarios in which bailouts are financed by increases in government debt tend to paint a more favourable picture of CoCos. The larger the expected tax increase, the more partially avoiding these bailouts through CoCo activations is beneficial for the incomes, savings and consumption of working households. CoCo activations are relatively less painful for working households but still are, as shown by the ratios falling below 1. Indeed, what is not paid as additional taxes is paid as lower wages induced by the bail-in.

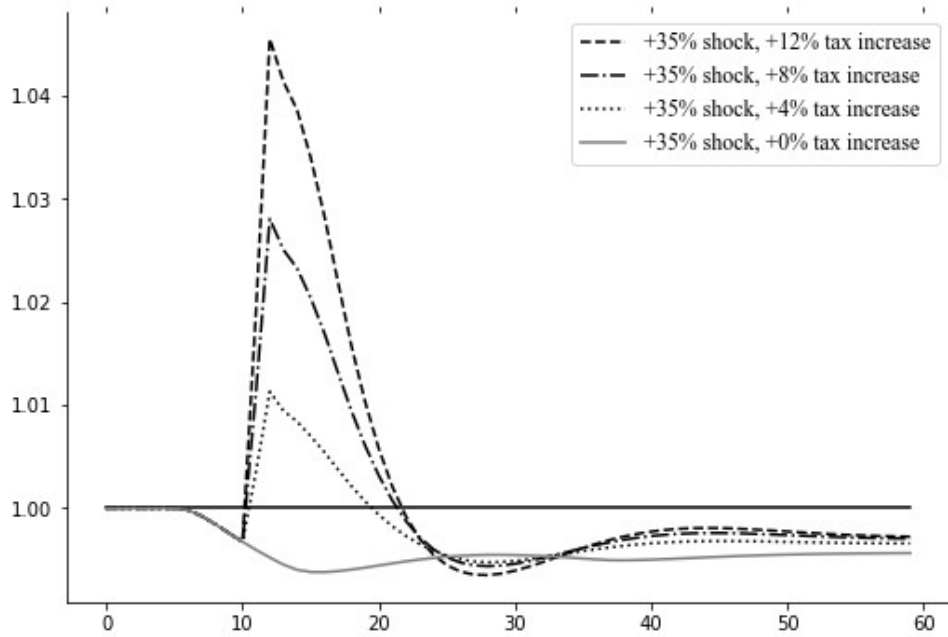


Figure 21: Evolution of the income of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

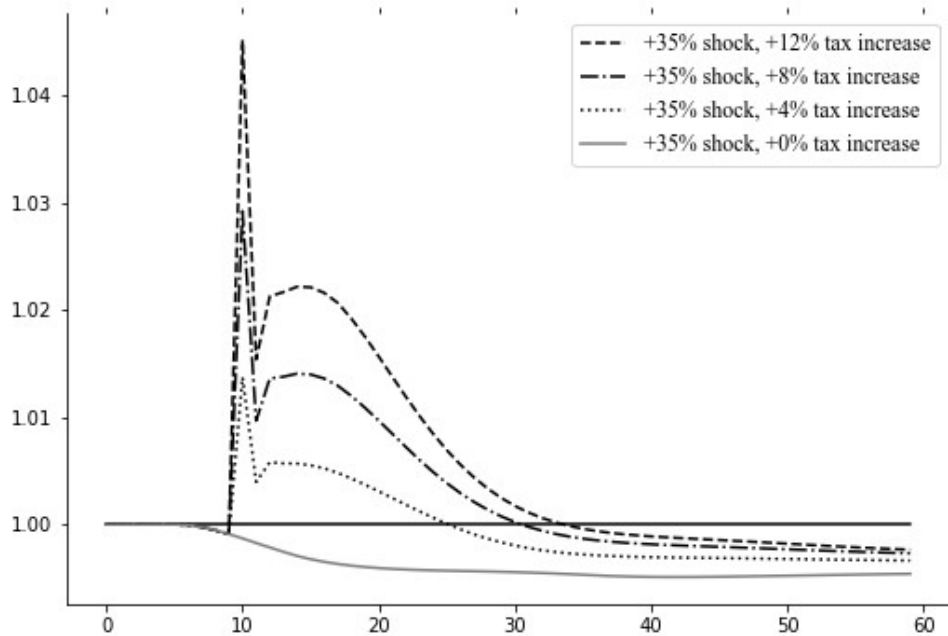


Figure 22: Evolution of the net value of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

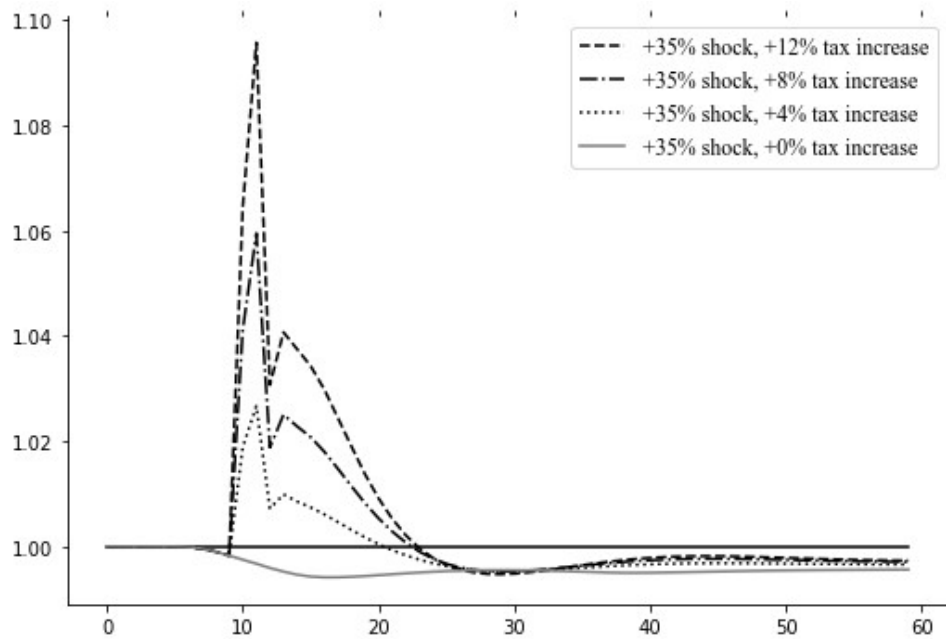


Figure 23: Evolution of the consumption of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

Finally, we can extend the sensitivity analysis to firms, even if they are not directly affected by bailouts (they do not pay taxes in this version of the model). One can expect that the effects on both types of households, and in particular those on their consumption, spill over to firms. This is verified in Figure 24 which shows the relative evolution of firms' sales. Once again, we see that the greater the tax increase planned to finance bailouts, the more partially avoiding these bailouts through CoCos activations is beneficial for sales and therefore for firms' profits (because the fall in consumption due to pro-cyclical taxes is mitigated). This positive effect, although transitory, passes to investment (see Figure 25) and to the sector's net worth (see Figure 26).

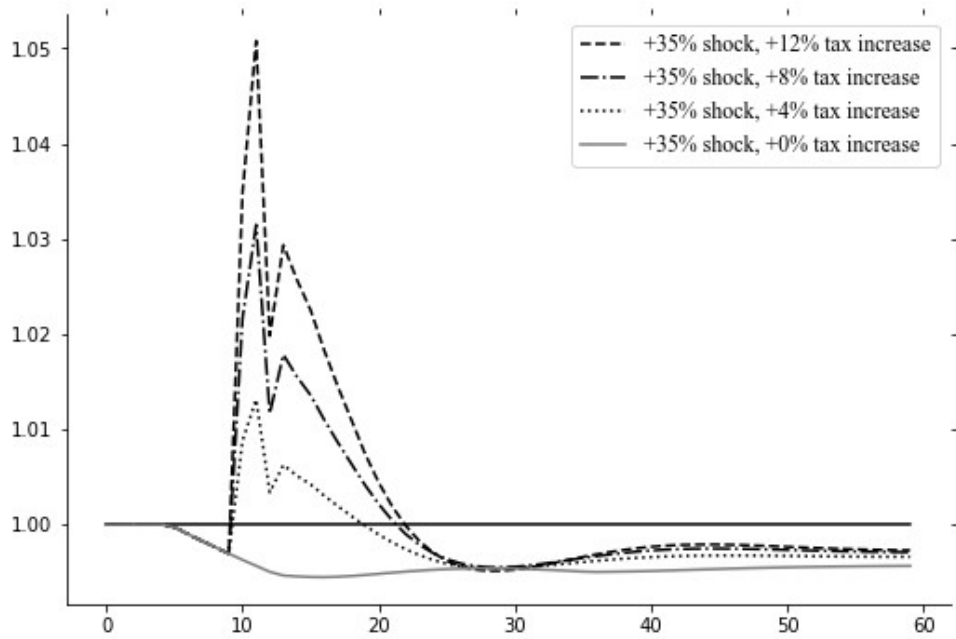


Figure 24: Evolution of firms' sales, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

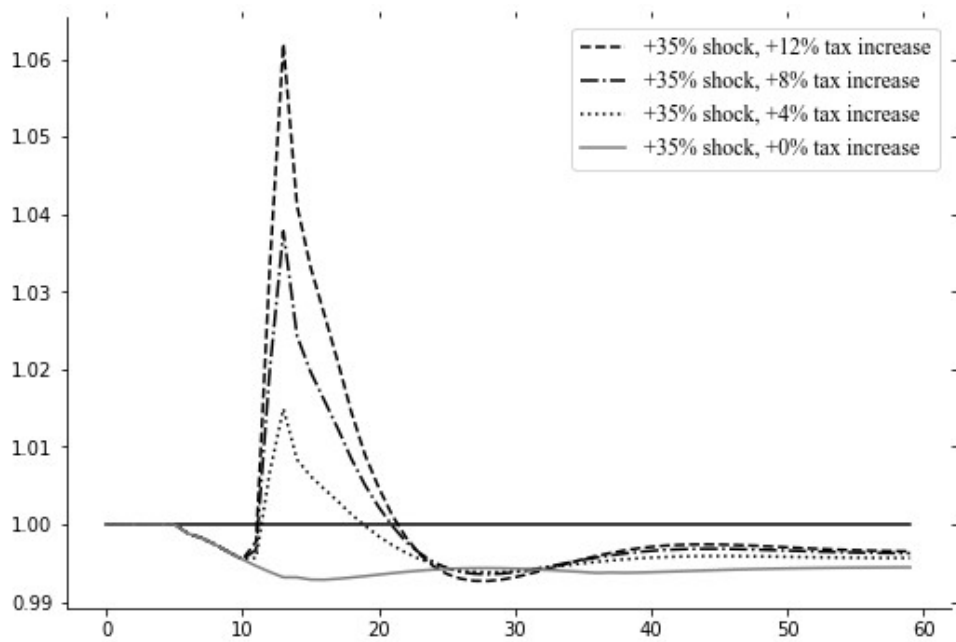


Figure 25: Evolution of firms' investment, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

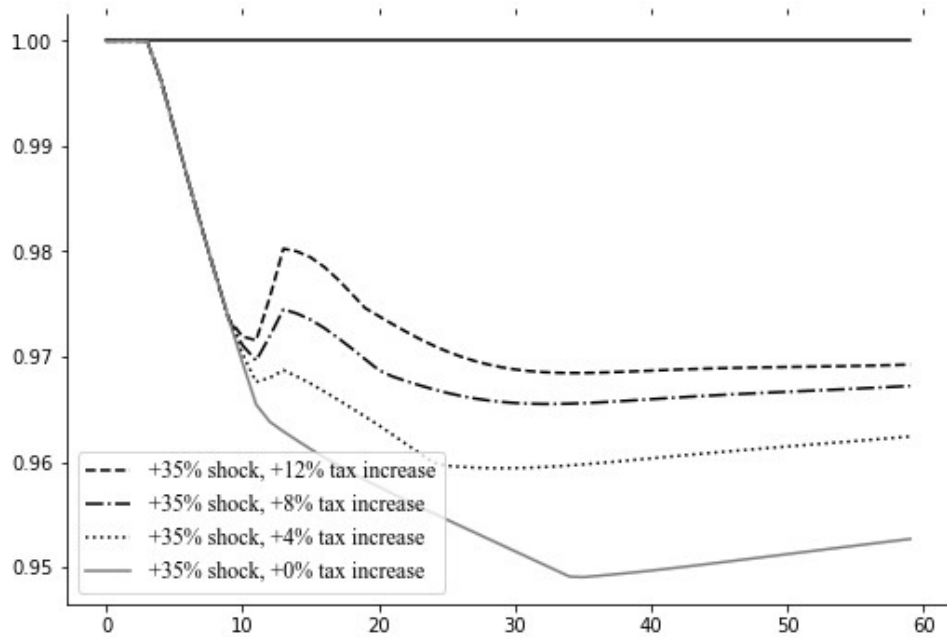


Figure 26: Evolution of firms' net value, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

The results of this section confirm our previous hypotheses. In case of a crisis, an activation of contingent convertible bonds has an immediate positive effect on the stock and flow variables of retail banks compared to a scenario without any activation of CoCos. This recovery in the banking sector is paid by investors who experience as holders of CoCos a decrease in their net worth and earned interests. The increase in the stability of the financial sector comes at the cost of an increase in the instability of the real sphere (including for agents who do not hold any CoCos like working households). With CoCos, risk is automatically shifted from banks to bank creditors. The real sector is affected indirectly by the change in behaviour of bank creditors. Last but not least, the effective cost of bailouts is reduced.

2.3.2 Second scenario: decrease in company' share prices

This scenario examines the effects of an increase in market risk. The starting point is a sudden and temporary decline in investors' preferences for corporate stocks. As in the previous section, this outline compares a crisis situation with and without CoCos activation. The idea is to check whether the activation of CoCos reduces or even offsets the negative effects of a crash on investment banks/institutional investors.

Three shock values are examined in the following simulation: a 15%, a 35% and a 55% decrease in preferences for firms' shares (the first one is not enough to trigger CoCos).

The demand of investors for companies' shares depends on their yield and on the yield of other possible assets plus a constant that represent their preference (all things equal) for such kind of financial asset (see equations R6 and BI1). The second shock is implemented through the constant λ_{40} which is reduced. This change simulates a sudden panic regarding companies' shares, comparable to a crash, resulting in a sudden increase in market volatility (see Figure 27). This market volatility σ_{pe} persists over several periods. The bigger the shock, the longer it lasts. We then observe jerky activations of CoCos by investment banks implied by equation BI8 (see Figure 28). As before, the volatility threshold of the share price that triggers the activation and the value of the shock inducing the activation are linked. The lower the threshold, the higher the risk of activation for low shock values. CoCos issued by the investment banks are partially activated as a result of the shock. Equation BI9 gives the share of activated CoCos. Once the preferences and therefore the share prices are stable again, the banks issue CoCos again.

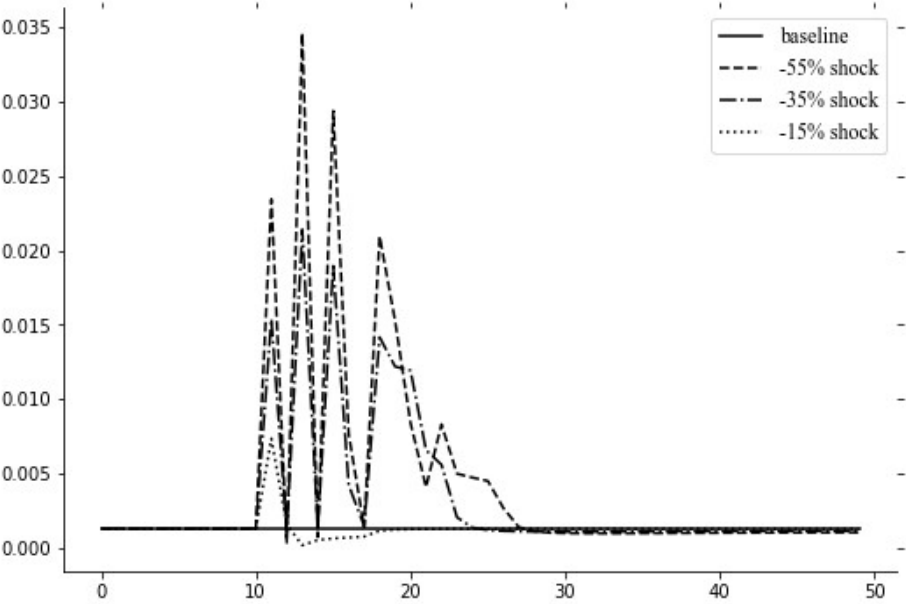


Figure 27: Standard deviation of firm equity prices following a decrease in preferences for them

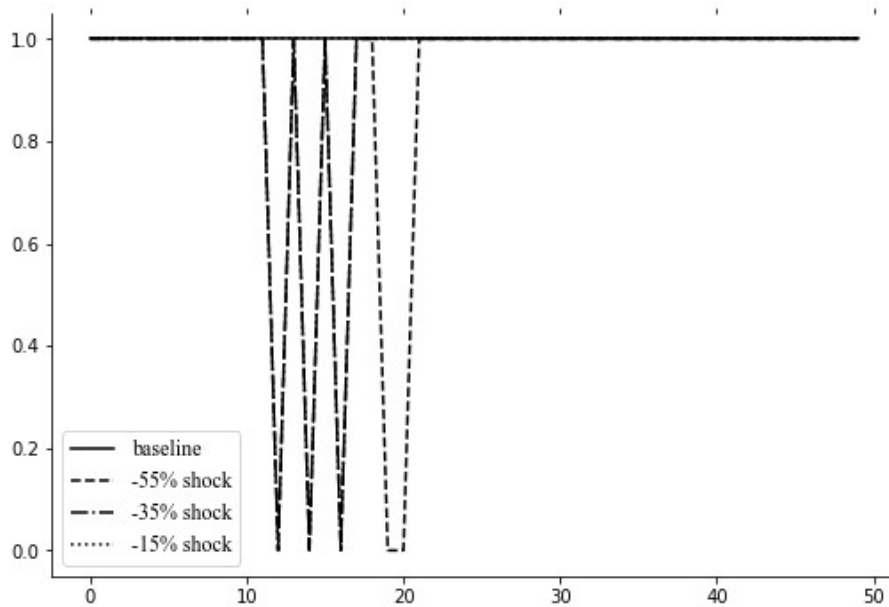


Figure 28: State of the contingent convertible trigger following a decrease in preferences for firm equities (1 = not activated; 0 = activated)

The shift in investor preferences for corporate shares has the same effect on the rest of the economy whatever the activation threshold. The signs of the variables do not change, only the magnitude of the effects differs.

After this first step, the baseline “no crisis” scenario no longer serves as a reference in the discussion. From this point on, the shock assessment is based on a comparison between a crisis economy with CoCos and a crisis economy without CoCos. The effects are examined on each sector one after another. The results are quite similar albeit not identical to those in the previous section.

As regard to investment banks net worth, the activation of contingent convertible bonds leads to an evolution in three phases. First, a sudden relative increase, activation of CoCos leading to a transfer of net worth from investors to banks. This corresponds to the first part of Figure 29 where we see a rise in the curve. As investment banks play a role in the various financial asset markets, unlike retail banks, this sudden increase in their net worth leads them to invest more in corporate shares and treasury bills (the two options available to them). This implies an increase in the capital gains associated with holding these assets. This second order effect plays a role in the results observed below for other sectors.

Secondly, there is a relative decline. The shock is over, net worth continues to rise because the economy is growing and there are no cycles in this model, but net worth rises less rapidly than if there had been no activation of the CoCos. This corresponds to the second part

of the graph where we see a fall in the curve. It should be remembered that this does not mean that there is an absolute decrease in the net worth of the sector in case of activation of the CoCos. It simply means that after the positive effect, there is a slowdown in the increase in net worth. And when the curve crosses the horizontal 1, this slowdown is such that the net worth of the sector is lower than if there had been no activation. This relative decrease (compared to a situation without CoCos) in the net worth of investment banks is related to a relative decrease in their profit after the activation of CoCos. This fall in profits is itself linked to a relative fall in the capital gains of investment banks (lower rise in asset prices) and incidentally in the capital gains of firms (hence a relative fall in the dividends paid to investment banks) and investing-households. Thirdly, there is a return to a stable growth path with the same growth rate but a lower net worth than without activation.

There is no absolute convergence between the crisis scenario with activation and the crisis scenario without activation, both of them follow a parallel path on the long run. In such a model, it is more relevant to focus on the directions taken by the different variables after the shock rather than their final levels but the parallel stationary path in this second simulation requires some explanation. Why is the growth path in this second simulation with CoCos lower than the path with CoCos, while the first simulation resulted in a convergent path? The explanation concerns the level of net wealth destroyed at the time of the shock. In the first simulation, the wealth destroyed due to credit defaults is identical in both scenarios with and without CoCos. That simulation examines the implications of such a loss transfer (risk transfer), i.e., the effects of changing the ultimate bearer of this wealth decrease. The second simulation is a little trickier because the shock to preferences increases volatility but does not in itself produce a fall in wealth. Thus, in the scenario without CoCos, there is no destruction of wealth because bankruptcies are not considered by the model, whereas the scenario with CoCos implies a loss of wealth resulting from activation. The gap between the two parallel paths corresponds to this destruction of wealth by the CoCos activation.

For investing-households, the activation of coco bonds leads to a further decrease in their net worth since they lose a part of their asset stock (see Figure 29). Activation leads initially to a decline in their income minus taxes and capital gains (Figure 30) because they no longer receive any interest from CoCos. However, the activation of CoCos leads to an increase in capital gains for sectors holding equities and Treasury bills, which is the case for investing-households (Figure 31). All of this has an impact on their consumption (Figure 32), which initially experience a sudden rise fuelled by their capital gains, before reverting to a stationary

path below the path without CoCos due to the loss of net worth and income resulting from the shock.

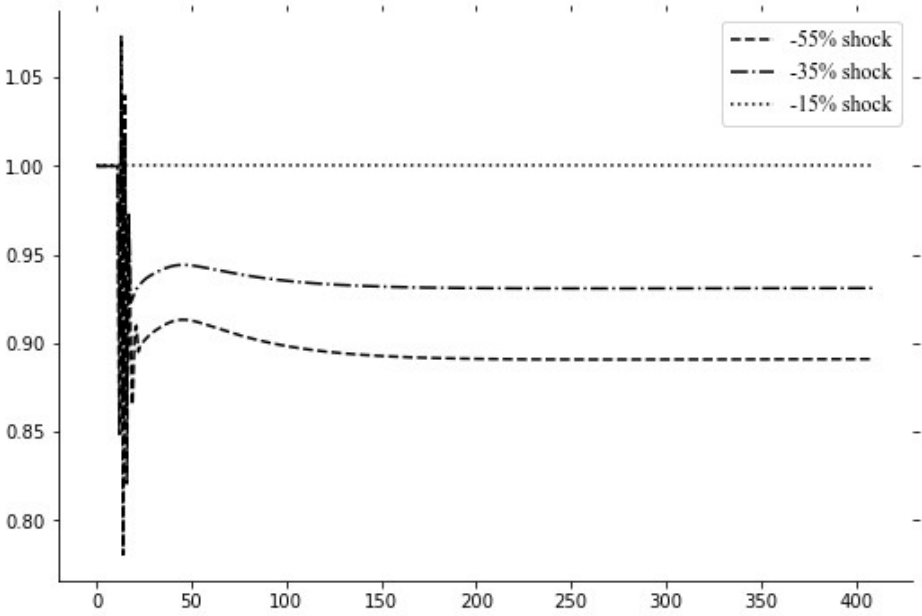


Figure 29: Evolution of the net value of investing households, relative to the scenario without any activation of CoCo bonds, following a decrease in preference for firm equities

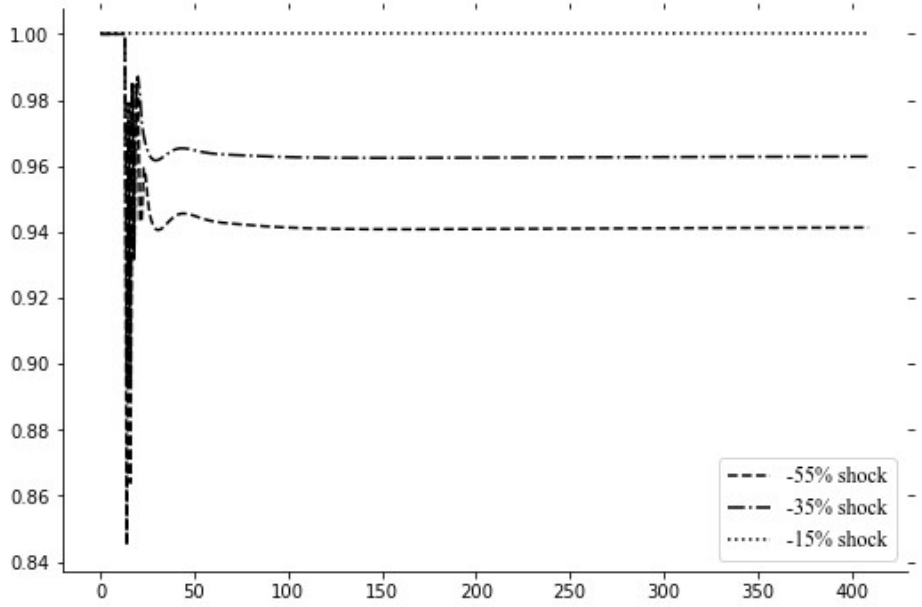


Figure 30: Evolution of the income of investing households before capital gains, relative to the scenario without any activation of CoCo bonds, following a decrease in preference for firm equities

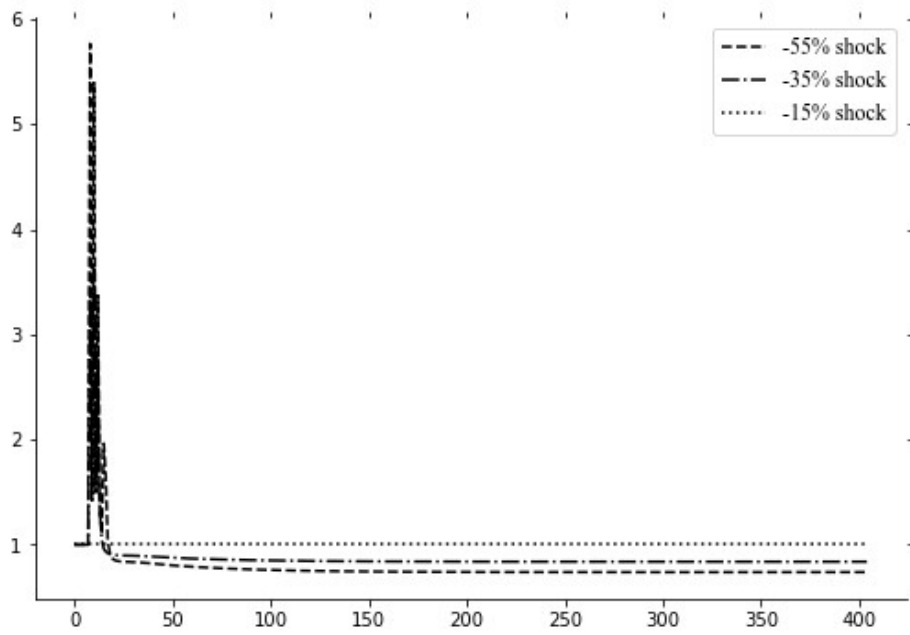


Figure 31: Evolution of the capital gains of investing households, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

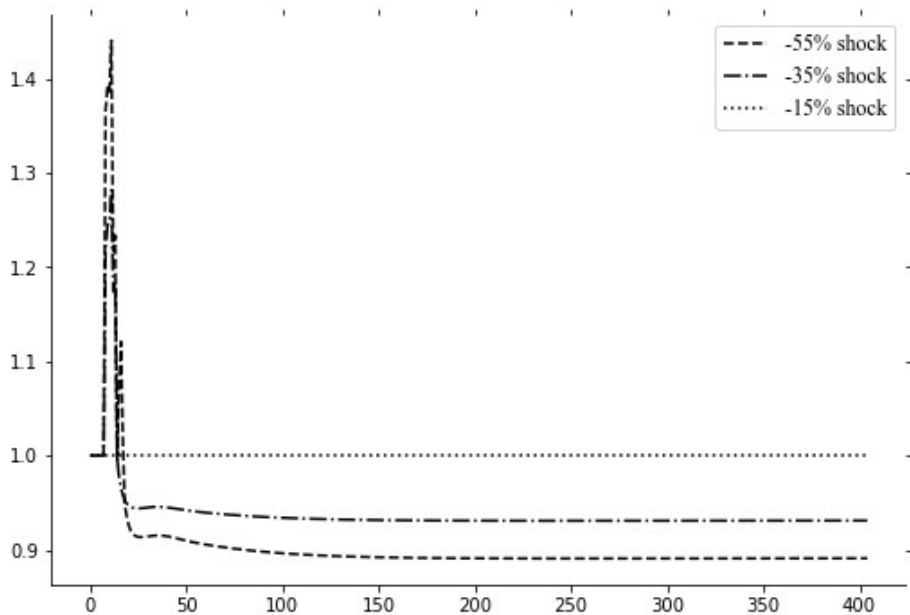


Figure 32: Evolution of the consumption of investing households, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

Regarding firms, the activation of CoCo bonds leads to a decrease in their net worth since they suddenly lose part of their assets (see Figure 33). Firm investment, on the other hand, is subject to oscillations: an initial decline linked to the decrease in interest received on CoCos, an increase linked to capital gains, and then a relative decline before reaching the stationary trajectory one notch below the no CoCos scenario (see Figure 34).

As working-households don't hold any CoCos, the activation has no direct effect on their stock and flow variables but indirect effects occur. Initially, we observe a relative increase in their wages (see Figure 35) and consumption (see Figure 36) linked to the temporary positive effects of capital gains following the activation of the CoCos. Then, there is a sustained relative decline in wages and consumption. The size of these effects is marginal compared to those affecting other sectors.

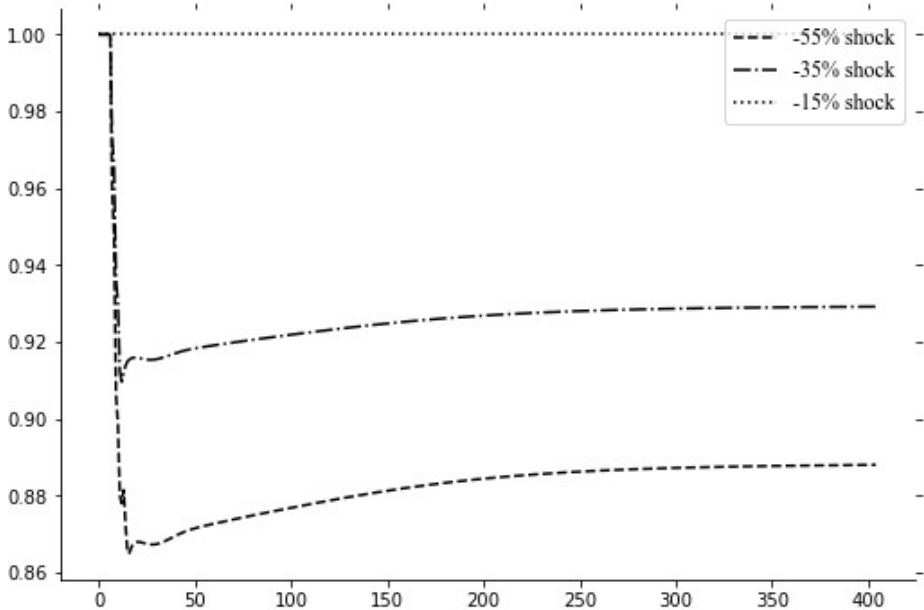


Figure 33: Evolution of the net value of firms, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

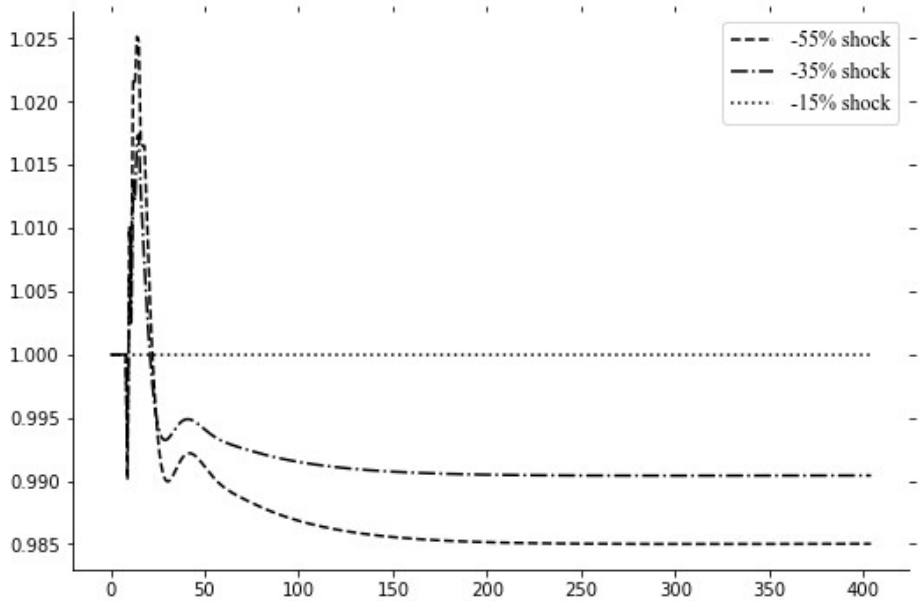


Figure 34: Evolution of the investment of firms, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

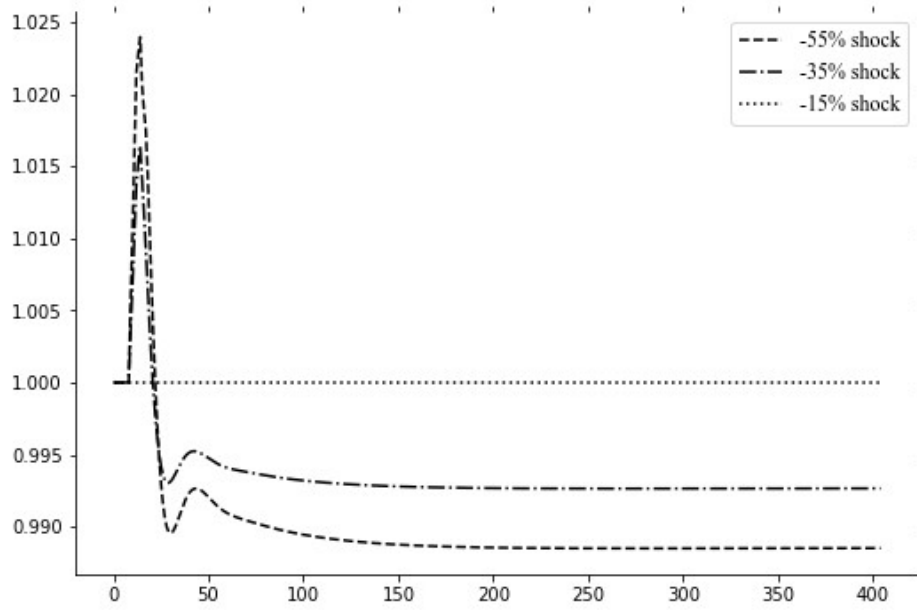


Figure 35: Evolution of the wage bill of working households, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

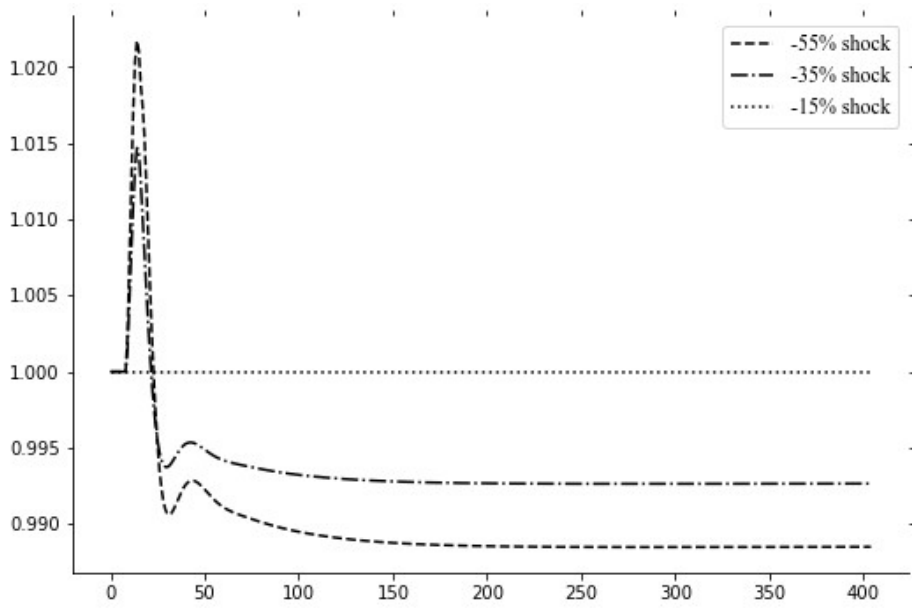


Figure 36: Evolution of the consumption of working households, relative to the scenario without any activation of coco bonds, following a decrease in preferences for firm equities

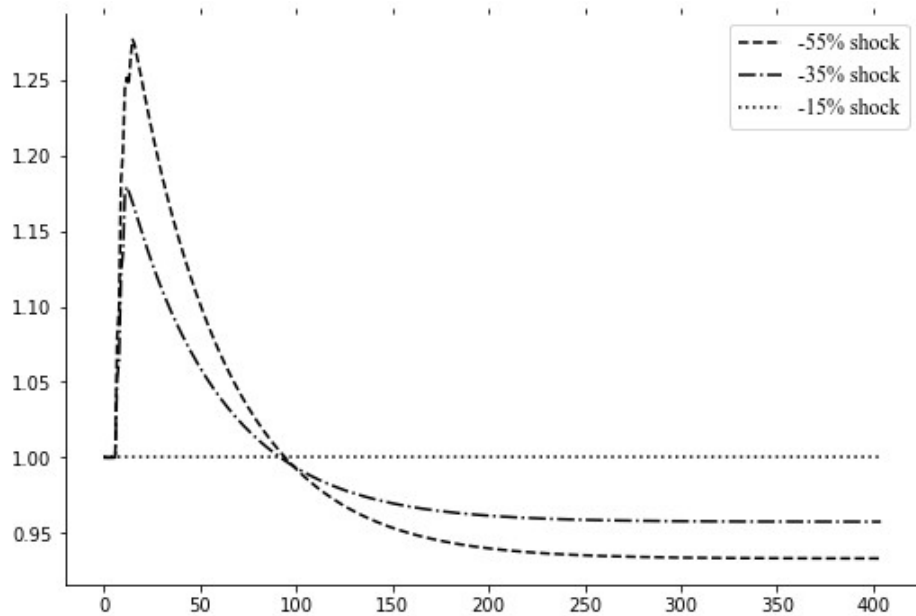


Figure 37: Evolution of the net value of investment banks, relative to the scenario without any activation of CoCo bonds, following a decrease in preferences for firm equities

At this point, the stability of the overall economy needs to be assessed. Table 5 shows the same indicator as in Table 4, applied to this new shock.

Table 5: Standard deviations in case of a crisis with a CoCos activation scenario relative to standard deviations in case of a crisis without CoCos scenario; based on the 55% shock simulation.

	Relative standard deviations
Production	1.752
Total consumption of households	1.800
Net worth of investing-households	3.213
Net worth of working households	1.633
Net worth of firms	2.425
Net worth of investment banks	6.726

There is an increase in the volatility for all variables. In contrast to the result for retail banks, there is an increase in the volatility of the net worth of investment banks. This can be explained in two ways. Firstly, investment on financial markets being their core business, investment banks are more sensitive to price changes in the financial markets than retail banks.

Any change in price affects their net worth much more than retail banks. Second, CoCos are activated here not to counter a decline in net worth (as in the first scenario) but because the asset portfolio of investment banks is too volatile. In terms of instability, the model says that CoCos do not seem to counteract the shock, but rather accentuate it, as their triggering leads to significant movements in asset prices. Nevertheless, it should be recalled here again that since bankruptcies are ignored by the model, instability is fairly underestimated in case of a shock without CoCos. As a result, Table 5 needs to be interpreted very carefully. At the very least, it can be said that CoCos are likely to trigger significant price movements and portfolio reallocations when activated by an investment bank.

This is an interesting result that needs to be confirmed by further research. It implies that instability is propagated here through changes in asset prices. In terms of regulatory recommendation, this could mean linking the triggering of CoCos to a temporary constraint on the issuer after activation. For example, a bank that has benefited from an activation would not be allowed to purchase securities (or certain categories of securities) for a certain period of time or for a certain share of its assets, in order to limit the impact on the prices of other assets.

To make a long story short, in case of a market crisis, an activation of contingent convertible bonds has an immediate positive effect on the stock variables of investment banks compared to a scenario without any activation of coco bonds. This improvement of the investment banking sector is paid by CoCos holders who experience a decrease in their net worth and earned interests, and to a lesser extent by working households. There is also a transitory effect linked to the capital gains received by households and corporate investors as a result of the excess financial investments made by investment banks resulting of their CoCos activation. In this second simulation, the activation of CoCos leads to an increase in instability not only in the rest of the economy but also in the sector that benefited from their activation, due to the resulting financial instability. Further research could indicate whether activation should be offset by a temporary constraint on portfolio reallocations to avoid spill-over effects on other financial prices, which would significantly reduce volatility.

2.4 CONCLUSION

This chapter has shown that CoCos do the job: their activation improves the situation of the issuer and transfers the risk to the rest of the economy. It also reduces the cost of bailouts. In return, there is an increase in real and financial instability. Further research is needed to

characterise this instability more precisely compared to the situation without CoCos. Two regulatory recommendations follow from this research. 1/ Banks could be required to issue a fraction of their debt in CoCos in order to reduce bailout costs. 2/ When CoCos are activated, their issuer could be forced not to intervene on all or part of the financial markets, for a predefined period of time and/or value, in order to limit the destabilisation of price assets.

These results have been obtained through an analysis of the behaviour of a Kaleckian economy that grows at a constant rate, inspired by the model of Godley & Lavoie (2006). This model is designed to study the macroeconomic effects of a CoCo bonds write-off (principal write-down type). It specifies some important channels of transmission through which destabilization can take place: the elasticity of business investment and of wealthy household consumption to fluctuations in the value of their financial portfolio. The household sector and the banking sector are both divided into two subsectors. Working-households receive a salary from their work in companies and have no financial wealth. Investing-households own and manage a financial wealth composed of six different types of assets issued by the other institutional sectors (Treasury bills, companies' shares, deposits with retail banks, term deposits with investment banks, CoCos issued by retail banks and investment banks). The banking sector is made up of commercial banks, specializing in loans to households and businesses, and of investment banks, which manage the same types of assets as investing-household. Both types of banks issue CoCos that can be automatically written off in the event of the issuer's insolvency.

Since the model is neither micro-founded nor econometrically estimated, the two banking sectors are deliberately modelled independently of one another. It would be possible to create more interactions between these two subsectors, for example by assuming that they can reciprocally buy and sell their debt securities. Such a sophistication would be welcome in future work and could capture potential minkian effects stemming from systemic risk. However, this would scramble the message presented in this model because the effects of the simulations would then crucially depend on the combinations of parameters, which makes no sense in the approach adopted here.

CoCos are held by investing-households and companies. The government and the Central bank play a passive role. They issue securities (overnight loans to banks and treasury bonds) that serve to balance the portfolios of other agents. The Central bank collects reserves

from the banking sector. The government collects taxes and buys goods from companies, and public expenditure rises at a steady rate.

Two simulations were conducted. The first simulation focuses on real instability. The shock implemented consists in increasing the share of defaults on workers' loans, by acting on an exogenous variable. This sharply degrades the net worth of retail banks, which reduces their CAR whose level sets the CoCos trigger. Their partial activation amounts to a cancellation of part of the banks' debts. Later, once the banks' net worth improves, they start issuing CoCos again. The good side of CoCos' write-down is their disappearance of bank liabilities. The bad side of this story is that companies and investing-households are enduring the cancellation of some of their assets. For both types of actors, this amounts to a decrease in their net worth. Companies respond to this decline in their financial income by lowering their level of investment. Meanwhile, investing-households' disposable income shrinks, inducing them to reduce their consumption.

At the macroeconomic level, there is an impact on the trajectory of the entire economy. Aggregate demand declines, which translates into a slight drop-off in wages and consumption for working households. With regard to the retail banks issuing these CoCos, their activation has a beneficial effect against this type of shock because the decrease in their net worth and their profits is less than in the absence of CoCos. In terms of volatility of the key variables at the level of the whole economy, the existence and the triggering of the CoCos resulting from an increase in the households' defaults on their loans produces an intuitive result. There is a shift in risk from CoCos issuers (retail banks) to CoCos holders (companies and investing-households). They react by restructuring their portfolios and changing their actual behaviour, which seems to have an existing but limited impact on the rest of the economy, especially on working households. Finally, the activation of CoCos has three notable effects on bank bailouts. First, it makes it possible to postpone the moment when they become necessary because of the safety cushion provided by Additional Tier 1 capital. Second, the period over which bailouts are extended is shorter. And finally, CoCos activation reduce the cost of bailouts.

This reduced need for bailouts is likely to have macroeconomic consequences on the real sphere depending on how they are financed. If we assume that they are financed by one-off increases in debt with pro-cyclical effects that aggravate the current shock, then avoiding them is all the more beneficial. The larger the planned tax increase, the more beneficial it is. However, this effect is only transitory and only mitigates investors' losses without turning them

into net gains. The transfer of net worth from the real to the financial sphere always puts a strain on investors' savings and financial income.

This beneficial transitional effect is absent if we assume that bailouts are financed without a tax increase but by public debt. Therefore, any comparison between CoCo bail-ins and public bailouts must take into account that the way in which bailouts are modelled can give a more or less flattering picture of CoCos. It should be noted, however, that the model presented here is limited in this respect. No adverse consequences are foreseen in the event of too much accumulation of public debt since the rate at which the government borrows is fixed. This does not detract from the results presented. This thesis focuses on the consequences of a bailout as such. But future work is needed to model more exactly the potential macroeconomic consequences of an accumulation of public debt in the context of bailouts.

The second simulation focuses on financial instability through the effects of a stock market crisis. It goes beyond the initial issue of banking regulation and supervision as it focuses more particularly on what we call here “investment-banks” which correspond in fact to a generic form of institutional investor. Such a simulation paves the way for research to determine the worst between a private financial bankruptcy, which would have possible domino effects throughout the financial sector, and a bail-in paid by the private creditors holding CoCos but which would destabilize the rest of the economy by transferring risk to the other sectors via wealth and prices variations. To induce this simulation, an exogenous variable in the corporate share demand function is drastically and permanently reduced. This leads to a fall in share prices and a deterioration in the balance sheet of investment banks that triggers the activation of CoCos they have issued in the previous periods. This degrades companies' balance sheets, which react by changing their portfolio allocation and reducing their investment, and the balance sheet of investing-households that modify their portfolio allocation and reduce their consumption due to a decline in their disposable income. This decline in aggregate demand has an existing but limited impact on the wages and consumption of working-households. The transmission mechanisms are a little more complex than in the first simulation because asset price changes play an important role here. As in the first scenario, there is an improvement in the net wealth of banks after activation, at the expense of the net wealth of CoCos holders. Here too, such a transfer of risk increases the instability of the rest of the economy. However, there are also portfolio reallocations as a result of changes in asset prices, leading to significant volatility which also affects the sector that benefited from the activation of the CoCos.

This method shows that an automatic bank bail-in resorting to CoCos would effectively improve the bank balance sheet in an efficient and therefore credible manner reducing the need for a large-scale government intervention. With CoCos activation, the burden of bank rescue is shifted from all taxpayers to bank creditors. In this sense, CoCos fulfil their objectives: they are able to help stabilize bank balance sheets and they are able to affect the cost of rescue in a more targeted way. Since bailouts operated by governments and control institutions are always late in nature, it can also be considered that the automatic nature of CoCos means that the bail-in takes place earlier and faster than a bailout, which limits all losses. However, this research shows that by shifting the risks and costs of rescue to other actors, CoCos may destabilize the rest of the economy on both real and financial spheres.

These results are only representative of what happens in the short term after a single activation. The SFC model assumes that CoCos issuance resumes as usual after a crisis and that investors do not adjust their subsequent demand. The results are not biased because the exogenous shock that triggers CoCos in the simulations occurs only once. The SFC model does not generate endogenous cycles that could produce repeated financial crises with adaptation and learning effects on the part of investors. This type of results and the medium-term horizon are explored in the following chapters when adding agent-based microfoundations. The generation of cycles in the SFC-AB model will give rise to endogenous crises and repeated activations, and the assumption that investors do not adapt to them will then be relaxed.

It seems that the destabilization of the real sphere appears as relatively limited but such a model does not allow more to say until a specific work has been done to estimate the parameters. Further research is required to measure whether the stabilizing effects of CoCos on bank balance sheets can offset the destabilizing effects on the rest of the economy. It would also allow for an accurate calculation of the distribution of losses and gains between investors, banks, households who may not invest and the government. Such an arbitration depends in particular on the effects on public finance and the distribution of the tax burden. For ordinary households, what is not paid as additional taxes (bailout) is paid as lower wages induced by the bail-in. The deleterious effects on working households are underestimated here, mainly because the SFC model does not allow for the modelling of individual firm and bank failures. Firms are only relatively distressed by CoCos activations. They decrease their production because of the decrease in consumption by investing households and the decrease in investments, so wages decrease. But that is all. The whole sector cannot go bankrupt as its net worth never goes below zero. We cannot take into account situations where a household's employing company would

go bankrupt because of too much exposure to CoCos, resulting in a loss of employment and wages for the household. Similarly, the SFC model does not feature actual bank failures that would lead for instance to a potential non-repayment of working households' checking deposits. As a result, the perverse effects of CoCos activations, if any, cannot be captured by a purely aggregate model that focuses only on general disequilibrium effects with net worth transfers and relative losses and gains of financial income resulting from activations. A better assessment of the stabilising or non-stabilising effect of CoCos therefore requires adequate modelling of bankruptcies, especially in the absence of CoCos. These elements are developed in the next chapters.

It remains to be developed as part of a SFC model a comparative analysis between CoCos that lead to principal write-down and CoCos that convert into equity (although these represent only a minority of CoCos issued as highlighted in section 1.1.5). However, the scope of this comparison can be expected to be limited. The ex-ante effects of an activation threat on banks' risk-taking behaviour is the main difference between convertible CoCos and PWD CoCos (as shown by Admati et al., (2013))³⁶. However, these ex-ante effects pass through a channel of expectations that cannot be easily modelled in an aggregate model. Any assessment without microfoundations can therefore only focus on the ex-post effects of the activations. In this respect, similar but attenuated results should be expected. Indeed, convertible CoCos are similar to PWD CoCos in that their activation results in a loss of net value and financial income for their buyers and a capital gain for their issuers. However, the loss of net value and financial income is relatively smaller for the buyers with convertible CoCos, because instead of being completely written off, they are converted partly into shares that pay dividends (although these dividends can be expected to be small if the bank is in such difficulty that it had to activate its CoCos). Conversely, the gains for banks are limited because they will have to pay excess dividends that they would not have had to pay if these CoCos had been completely written off.

³⁶ See the literature review section 1.2.1 for more details.

CHAPTER 3: CONTINGENT CONVERTIBLE BONDS AND MACROECONOMIC STABILITY IN A STOCK-FLOW CONSISTENT AGENT-BASED MODEL

3.1 INTRODUCTION

3.1.1 The limitations of the SFC model presented in Chapter 2

Chapter 2 provides qualitative results on the effects of a generalized activation of CoCos. Automatic bank bail-in resorting to CoCos seem to improve banks' balance sheets in an efficient manner without any government intervention. Thus, the direct burden of debt rescue is more focused. It is shifted from all taxpayers to bank creditors. In this sense, CoCos appear to fulfil their primary objectives: they affect the cost of rescue in a more targeted way than bailouts. Since bail-outs operated by governments and control institutions are always late in nature, it can also be considered that the automatic nature of CoCos means that the bail-in takes place earlier and faster than a bail-out, which limits losses. However, this research shows that by shifting the risks and costs of rescue to other actors, CoCos might destabilize the rest of the economy. It seems that the destabilization of the real sphere induced by CoCos is relatively limited, but such a model does not allow to say more. Indeed, the scope of the purely macroeconomic model presented in Chapter 2 is limited by three sets of factors.

First, there is a lack of empirical grounding. The parameters are not fully estimated or calibrated since the function of Chapter 2 is simply to lay macroeconomic foundations used in the next chapters. Although qualitative results are drawn from it, nothing can be said from a quantitative standpoint and no policy recommendations can be made based on the current state of the contingent convertible bond market.

Second, there is no heterogeneity *per se* because all the sectors are fully aggregated. It means for instance that the first model doesn't take into account the fact that not all CoCos activate simultaneously. To overcome this problem, it is considered that a share of CoCos proportional to the shock intensity is activated. But there may be isolated activations if only one or a few banks are in difficulty at a given time. Moreover, it cannot capture bank failures since the net worth of the aggregate banking sector never reaches zero. And yet, stability at the aggregate level does not necessarily mean that all agents are in equilibrium. There are no

distributional effects (e.g., with some banks being stronger than others). The difficulties of some banks cannot be transmitted to others, and the effects of financial contagion are not captured.

Finally, there are no microfoundations for behavioural rules, which are only specified at the aggregate sector level. This is equivalent to thinking in terms of one representative agent per sector. However, the properties of an aggregate function do not reflect those of individual functions (Gallegati & Kirman, 2019) and the aggregate behaviour of a heterogeneous set of agents cannot be interpreted as the decision of a representative agent as stated by Arrow's Weak Axiom of Revealed Preferences (WARP) (Arrow, 1959). Rather than allowing endogenous macroeconomic phenomena to emerge as a result of microeconomic interactions, they are imposed. For instance, exogenous shocks are needed to trigger contingent convertible bonds in the SFC model. The activation only happens just once then, and the results are only representative of what happens in the short term after a single activation. The SFC model assumes that CoCo issuances resume as usual after a crisis and that investors do not adjust their demand. This was an acceptable simplifying assumption as long as there were no endogenous cycles that could produce repeated financial crises. But what can we expect in case of repeated activations? Under these circumstances, it would be unrealistic for investors to behave the same way over and over again with each activation. In general, based on a purely aggregate model, no complex emergent properties can be observed.

3.1.2 The addition of agent-based microfoundations as part of an SFC-AB model

The adoption of the bottom-up perspective of agent-based models (ABM) creates synergies with the SFC framework (see section 1.3 for more details). It also helps to overcome the limitations of the purely aggregated model.

While the SFC model lacks empirical grounding, the SFC-AB model is empirically validated by showing that it can reproduce stylized micro and macro facts. Its results are therefore more robust and allow conclusions to be drawn for policy recommendations.

Adding agent heterogeneity to the SFC framework presented in Chapter 2 allows to take into account that not all CoCos activate simultaneously as well as the possibility of isolated bankruptcies. We can then study more precisely whether CoCo bail-ins are able to prevent these failures, whether some banks are more resistant than others and whether there are possible contagion effects without being blind to what happens within sectors.

Agent-based microfoundations and the resulting emergent properties are enough to capture endogenous business cycles and financial crises (Dosi et al., 2008; Riccetti et al., 2015) that are able to trigger CoCos without any ad hoc assumptions. AB microfoundations allow for repeated activations, which investors can adapt to and learn from. Furthermore, it allows us to observe how interactions at the micro level such as the supply, demand and activation of individual CoCos can generate unexpected global dynamics such as information diffusion and decreasing waves of adjustments following market disruptions, or non-linearities in macroeconomic effects of activations.

Adding heterogeneity and microfoundations to the model provides further insights into some of the questions discussed in the previous chapter, in particular when it comes to CoCos' ability to stabilize the banking sector in the event of a financial crisis and to reduce the need for bailouts. It also allows to answer other questions left unanswered by the purely macroeconomic model. Can CoCo activations prevent bankruptcies? How much capital would be necessary to bail-in banks? Could the costs of such bail-ins outweigh their benefits in some situations? Is the risk transfer from taxpayers to investors always a positive outcome?

These issues are addressed with Monte Carlo simulations on a stock-flow consistent agent-based model (SFC-ABM) based on the JMAB benchmark framework proposed by Caiani et al (2016), resulting in the very first microfounded macroeconomic assessment of the risks and benefits of CoCo issuances and activations. The overall effects of introducing CoCos into the economy – compared to a situation without CoCos – are examined, as well as the extent to which banks can issue them and beyond which they become destabilizing for the rest of the economy.

Section 3.2 gives a presentation of the structure of the model. Section 3.3 reviews two policy experiments and their results. Section 3.4 provides a final discussion

3.2 PRESENTATION OF THE MODEL³⁷

I do not create my own SFC-AB model from scratch. I extend an existing SFC-AB model called “JMAB”, proposed by Caiani et al (2016). I add the contingent convertible bonds with the help of the macro framework developed in Chapter 2.

³⁷ A list of the mentioned parameters can be found in Appendix D

Some of the modelling choices made in Chapter 2 are reinstated. This is the case, for example, of the Tobin portfolio arbitrage governing the demand for CoCos. Although it is improved to take into account past activations, it is still based on the comparison between rates of returns for different assets. The activation of CoCos the accounting transfer of net worth resulting from their activations. Moreover, the focus is still on PWD CoCos due to the fact that they account for the majority of issuances (Vullings, 2016).³⁸

On the contrary, some implementation choices are left aside. Some of them become obsolete in the SFC-AB model. For instance, there is no longer a need to make an arbitrary distinction between investing and working households, and between retail and investment banks. Initially, the agents that make up each sector are all identical. In the SFC-AB model, the decentralized interactions and the adaptive revision of agents' strategies over time gradually bring out heterogeneity in the model. After a few periods, the balance sheets of each agent differ. They face different prices and interest rates. Some households are fired and others hired, and they make financial investments in proportion to the savings at their disposal. Some firms and banks go bankrupt while others continue to operate. This puts some banks in difficulty and they have to strengthen their capital rather than invest in the financial markets.

I also want to avoid burdening an already complex model. Therefore, CoCos are no longer purchased by firms. While this was a scenario considered in the exploratory SFC model, this assumption is relaxed in the SFC-AB model. All in all, there is a critical lack of information in this regard (Avdjiev et al., 2020). This is due to the fact that the majority of European CoCos (which constitute the bulk of the CoCos market) are held by foreign investors whose exact status is difficult to know (Boermans & van Wijnbergen, 2018). What is certain is that retail investors are among the main buyers (Avdjiev et al., 2013) and that households are exposed to them indirectly in a way that is largely underestimated (Götz & Tröger, 2016). This is why I consider in the SFC-AB model presented in Chapter 3 and Chapter 4 that only households invest in CoCos.

Finally, I discard some modelling choices because of the limitations of JMAB. Its founders thought of it as a benchmark model made up of different modules. Each module can be made more complex. The basic model allows to reproduce a large number of stylised facts (more on this in section 3.3) but some modules are still rudimentary. This is particularly the case for the public sector. Monetary policy and fiscal policy are not fully fleshed out. I therefore

³⁸ See section 1.1.5 for more details.

consider, when CoCo bail-ins are again compared to public bail-outs, that bail-outs are financed via taxes and not via debt. This is also why the SFC-AB model features automatic stabilizers while the SFC model relies on public expenditures growing at a constant rate. Chapter 2 shows that these assumptions lead to a relatively more flattering picture of CoCos when compared to bailouts. Although this is something that should be kept in mind when studying the results of the SFC-AB model, this doesn't affect results unrelated to this comparison, which form the core of the findings presented in Chapters 3 and 4.

3.2.1 Overall structure

The overall structure of the model is described by the flow chart in Figure 38. The modelled economy consists of:

- A set of households who work for capital and consumption firms and receive wages in return. They consume and make portfolio arbitrage between bank deposits and banks' contingent convertible bonds. Households pay taxes on their gross income and own shares in banks, consumption firms and capital firms from which they receive dividends. Finally, unemployed households receive unemployment benefits from the government.
- Two sets of firms: consumption firms and capital firms. Consumption firms produce consumption goods sold to households, using labour and capital goods produced by capital firms. Firms borrow from banks to finance their investment and production. Retained earnings are held as deposits.
- A set of banks that collect deposits from capital firms, consumption firms and households, purchase government-issued bonds, provide credit to both types of firms and issue contingent convertible bonds sold to households³⁹. They are subject to liquidity and capital adequacy constraints. Banks can request cash advances from the Central Bank when they lack the liquidity to meet these requirements. Issuing credit results in a contingent increase in the size of their balance sheets. As loans create deposits, the quantity of money in the model is determined endogenously.
- A public sector consisting of a central bank and a government. The central bank holds both banks' reserve accounts and the government's account. It supplies advances to banks

³⁹ As highlighted in section 1.1.4, the demand for CoCos is not limited to retail investors. It also concerns private banks, mutual funds, investment funds, pension funds, etc. Excluding these other sectors is therefore a simplifying assumption. However, two things should be noted. First, it is not unrealistic in the light of existing empirical research. Retail investors are among the first group to purchase them, and households in general are exposed indirectly through the other sectors that purchase them. The demand-side results discussed below therefore remain relevant. Second, modelling these additional sectors, the agents that populate them, and their microeconomic behavioural rules is an indispensable research project for a better understanding of the CoCos market, but is outside the scope of this thesis, which focuses more on what happens on the supply side than on the demand side. Extending the demand side, however, is part of future personal research projects.

at a fixed exogenous rate and buys residual government bonds that have not been purchased by banks. Its profits are transferred to the government. The government issues bonds to cover its deficit and collects taxes from banks, capital firms, consumption firms and households. It also pays unemployment benefits to unemployed households.

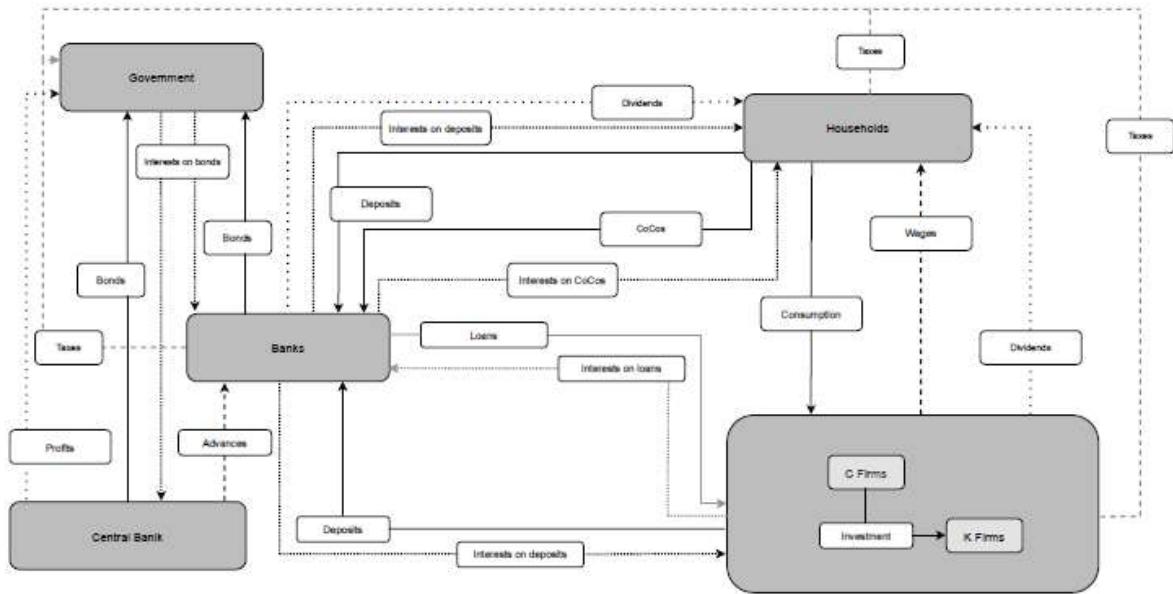


Figure 38: Flow diagram of the model. Arrows point from paying sector to receiving sector

In consistency with Caiani et al. (2016) who themselves followed Riccetti et al. (2015), we model these interactions between agents through a matching process. In each period, demanders compare the interest rates or prices charged by a random subset of suppliers. The size of this subset depends on a parameter reflecting the degree of information imperfection in the economy. Demanders switch from their old supplier to a new one with a probability defined by Delli Gatti et al. (2010) as a non-linear function (decreasing when the paid interest/price is a cash outflow for the demander or increasing when it is a cash inflow) of the difference between their old and their new interest/price. In some cases, suppliers may exhaust their selling stock, leaving demanders with an unsatisfied residual demand. Demanders then search for alternative suppliers among the initial random subset that was presented to them to satisfy this residual demand. Market interactions are closed when demand is completely satisfied, when demanders no longer have deposits to pay for the demanded stock, or when there are no suppliers able or willing to meet their demand.

I use the same calibration as Caiani et al. (2016) for the parameters and initial values of the variables not related to the introduction of contingent convertible bonds in the model. The

variables and parameters related to CoCos cannot be empirically calibrated due to the lack of sufficient data. To overcome this limitation, I perform robustness tests to check the validity of the results regardless of the associated values.

3.2.2 Agents' behaviour

In this section, we detail the behaviour of each type of agent. In terms of notation, the variables relating to capital firms have a k -subscript, the ones relating to consumption firms have a c -subscript, the ones relating to households have an h -subscript and the one relating to banks have a b -subscript. As for expectations (associated with an e -superscript), all agents share the same adaptive way of forming them:

$$z_t^e = z_{t-1} + \lambda(z_{t-1} - z_{t-1}^e)^{40} \quad (1)$$

With $0 \leq \lambda \leq 1$

Because of space constraints, we do not provide an exhaustive description of the entire model. We only review the main elements associated with each sector and focus in particular on how CoCos are modelled. For an exhaustive description of the sections of the model that are not related to CoCos, we refer the reader to Caiani et al. (2016), as well as to the online appendix⁴¹ which contains the full model code.

3.2.2.1 Firm behaviour

Production planning and labour demand

The desired output of capital and consumption firm in period t (y_t^D) depends on their expected sales for the same period. It is assumed that firms want to accumulate a certain amount of real inventories inv_t , expressed as a fixed share v of expected sales s_t^e , as a hedge against unexpected changes in demand (Steindl, 1976) and to avoid frustrating customers with an insufficient supply (Lavoie, 1992).

$$y_{kt}^D = s_{kt}^e(1 + v) - inv_{kt-1} \quad (2)$$

$$y_{ct}^D = s_{ct}^e(1 + v) - inv_{ct-1} \quad (3)$$

Capital firms produce their output solely out of labour. Their demand for labour N_{kt}^D depends on their desired output y_t^D and labor productivity μ^N which is assumed to be exogenous and fixed.

⁴⁰ In a similar way to what can be found in other ABM models (Assenza et al., 2015; Dosi et al., 2010)

⁴¹ https://github.com/elskr/sfc-abm_cocos

$$N_{kt}^D = y_{kt}^D / \mu^N \quad (4)$$

Consumption firms produce their output out of labour and capital goods. Their demand for labour N_{ct}^D depends on their real capital stock k_{ct} , the constant capital-labor ratio l^K and the rate of capacity utilization u_{ct}^D required to produce the desired level of output.

$$N_{ct}^D = u_{ct}^D \frac{k_{ct}}{l^K} \quad (5)$$

With u_{ct}^D such as:

$$u_{ct}^D = \text{Min} \left(\frac{y_{ct}^D}{k_{ct} \mu_c^K}, 1 \right) \quad (6)$$

Where μ_c^K indicates the capital productivity.

Excess workers are randomly selected from the pool of employees and are laid off. A positive turnover rate is assumed, expressed as a fixed share ϑ of firms' employees.

Pricing

Prices of consumption and capital firms, p_{ct} and p_{kt} , are set as a mark-up ($\varphi_{ct} > 0$ and $\varphi_{kt} > 0$) over their expected unit labor costs.

$$p_{ct} = (1 + \varphi_{ct}) \frac{W_{ct}^e N_{ct}^D}{y_{ct}^D} \quad (7)$$

$$p_{kt} = (1 + \varphi_{kt}) \frac{W_{kt}^e N_{kt}^D}{y_{kt}^D} \quad (8)$$

With W_{ct}^e and W_{kt}^e the expected average wage in both sectors.

The mark-up rate is endogenously readjusted every period according to a heuristic adaptive rule. When firms had more inventories than desired in the previous period, they lower their mark-up rate in order to make themselves more attractive to customers (and conversely increase their mark-up rate when they had fewer inventories than desired).

Firms' profits

Pre-tax profits of consumption firms are the sum of their sales revenues, their interest earnings and their nominal change in inventories valued at current unit production cost, minus wages, interest paid on loans and amortization of capital. Profits of capital firms differ only in that they do not include capital amortization.

This definition of profits is then used to calculate the amount of taxes that firms must pay (a fixed fraction of these profits). Dividends are then calculated as a constant share of after-tax corporate profits.

Investment

Firms invest in order to achieve a desired production capacity growth rate g_{ct}^D based on the difference between, on the one hand, the past period's rate of return r_{ct-1} and a fixed target \bar{r} ⁴² and, on the other hand, the desired capacity utilization rate u_{ct}^D and a fixed target \bar{u} corresponding to the “normal” utilization rate.⁴³

$$g_{ct}^D = \gamma_1 \frac{r_{ct-1} - \bar{r}}{\bar{r}} + \gamma_2 \frac{u_{ct}^D - \bar{u}}{\bar{u}} \quad (9)$$

$$r_{ct} = \frac{OCF_{ct}}{K_{ct-1}} \quad (10)$$

With:

- OCF_{ct} : the operating cash flow of consumption firm c in period t⁴⁴
- K_{ct-1} : the previous period value of consumption firm c's stock of capital discounted by the age of capital goods of which this stock is made up

The real demand for capital goods is equal to the number of units of capital needed to replace obsolete capital and close the gap between the current and the desired level of production capacity. Once consumption firms have chosen their supplier of capital goods, the desired nominal investment is calculated by multiplying the real demand for capital goods by the price charged by the selected supplier.

Demand for credit

Consumption firms' demand for credit corresponds to what they need to pay for their expenses (investment, wage payments, dividend payments) after using the surplus cash flow of the period (which corresponds to what is left after firms set aside a fixed part of their profits as a security deposit). The credit demand of capital firms is the same minus investment expenditure since they are considered in the model as not investing.

⁴² We assume here that firms do not necessarily seek to maximize their profit but rather to achieve at least some target. See, e.g., Rothschild (1947); Gordon (1948); Simon (1955) on the subject of profit satisficing.

⁴³ See Eichner (1976), for empirical evidence on firms aiming for normal rates of utilization ranging in the 80-90%

⁴⁴ See Gilchrist and Himmelberg (1995) for empirical evidence on the role of cash flow for firm investment

Labour, goods and deposit markets

After banks and firms have interacted on the credit market, firms interact on the labour market with unemployed households and production begins. If there are not enough workers available, the production of firms may be constrained. Households and consumer firms then interact on the consumption goods market and households consume what they buy. Consumption firms purchase capital goods that will be used in subsequent periods. Finally, taxes are paid on gross profits and dividends are distributed to households.

Firm bankruptcies

Firms default when their net wealth becomes negative or when they run out of liquidity. We assume that they are rescued through bail-ins supported by households (who own the firms and receive dividends). Their deposits are sufficiently depleted so that the net wealth of bankrupted firms becomes positive again. Thus, the number of firms in the model remains constant.⁴⁵

3.2.2.2 Household behaviour

Employed households set their reservation wage according to an adaptive heuristic rule: if over four periods (here, four quarters or one year) they have been unemployed for more than two, they reduce their reservation wage of the previous period by a stochastic amount. Otherwise, they increase their reservation wage only if the unemployment rate in the previous period is sufficiently low compared to a fixed threshold ν .

Households consume with fixed propensities out of expected real disposable income and expected real net wealth (following Godley and Lavoie, 2006) (see equation 11). They set their real demand based on expected prices of consumption goods before interacting with consumption firms.

$$c_{h,t} = \alpha_1 \frac{YD_{h,t}}{p_{h,t}^e} + \alpha_2 \frac{NW_{h,t}}{p_{h,t}^e} \quad (11)$$

With:

- $c_{h,t}$: the real consumption of household h in period t
- α_1 : propensity to consume out of expected real disposable income
- α_2 : propensity to consume out of real net wealth
- $YD_{h,t}$: nominal disposable income of household h in period t

⁴⁵ For more details on the firm bail-in mechanism, see Caiani et al. (2016)

- $NW_{h,t}$: nominal net wealth of household h in period t
- $p_{h,t}^e$: expectations on consumption good prices formulated in period t by household h

They hold deposit accounts at commercial banks $D_{h,t}$, earning a positive interest rate $i_{b,t}^d$ as well as contingent convertible bonds issued by commercial banks $COCO_{h,t}$, earning a positive interest rate $i_{b,t}^{COCO}$. At each period, households have to decide how to allocate their savings between these two types of financial assets. Following and extending Caiani et al. (2019), we implement a portfolio function inspired by Tobin's approach to household portfolio allocation (Brainard & Tobin, 1968). Households determine their desired allocation of financial wealth by comparing the expected rates of return on the assets they can purchase. While deposits are considered here as a safe asset, contingent convertible bonds are weighted according to their perceived degree of risk, represented by their past activation rate indicated by $Pr_t^{activation}$. We define this past activation rate as the average number of banks involved in a CoCo activation over the last four periods (four quarters or one year) divided by the total number of banks. In this way, investors are able to react to past activations. If the market was disrupted in previous periods, this is factored into their calculation of the profitability of CoCos and all else being equal they reduce their demand for them. However, one may suspect the existence of non-linearities. An isolated activation is likely to cause some turmoil that is quickly forgotten by investors. But what could be expected in the case of a generalised activation? What would happen to the demand for CoCos if banks reissued them afterwards? It is unlikely that investors would move past the event as quickly as they would after an isolated activation. Would investors avoid CoCos altogether? If so, it would be much harder for banks to raise AT1 capital. This version of the model only partially explores this possibility. There are periods in the model where there are more or less activations at the same time. If there are many, $Pr_t^{activation}$ will be higher and the demand for CoCos lower. However, further work may seek to complicate the specification of $Pr_t^{activation}$ in the demand equation with more sophisticated learning behaviours. The introduction of such behaviours is partially addressed in Chapter 4.

With lp_t the share of wealth households wish to hold as deposits, we obtain equation 12 which summarizes the portfolio arbitrage:

$$lp_t = \begin{cases} \sigma_1 \exp(-\sigma_2 [\overline{l_t^{BCO}} (1 - Pr_t^{activation}) - \overline{l_t^d}]) & \text{if } \overline{l_t^{BCO}} \geq \overline{l_t^d} \\ \sigma_1 & \text{if } \overline{l_t^{BCO}} < \overline{l_t^d} \end{cases} \quad (12)$$

With:

- σ_1 such as $0 < \sigma_1 < 1$, an exogenous upper bound to the share of wealth that households want to hold in the form of deposits.
- σ_2 such as $0 < \sigma_2 < 1$, a fixed parameter acting as a proxy for how sensitive households' portfolio arbitrage is to changes in expected rate of return and perceived risk of CoCos.
- $\overline{l_t^{BCO}}$: the average interest rate on CoCos in period t
- $\overline{l_t^d}$: the average interest rate on deposits in period t
- $(1 - Pr_t^{activation})$: the probability CoCos won't activate in period t

The share of deposits in household portfolio arbitrage (conversely the share of CoCos) depends negatively (positively) on the spread between the activation risk-weighted rate of return on CoCos and the interest rate on deposits. The higher the rate of return on CoCos, the higher the share of CoCos in household net wealth. The higher the probability of activation of CoCos, the riskier they will be perceived to be and the lower the share of CoCos in household net worth.

There are no individual reputations effect following an isolated activation. There is a general effect on the whole market in the sense that the overall demand for CoCos decreases afterwards. But investors do not treat the troubled bank differently when it is able to issue CoCos again. However, in the absence of activations that would provide more information but based on recent market disruptions, it can be concluded that such a reputation effect is not necessarily evident. When Deutsche Bank reissued CoCos in 2020, 6 years after a wave of uncertainty about its ability to repay the previous issue, investors welcomed the news as a sign that DB was strong enough to afford to issue CoCos again. The reissue in this case sent a positive information signal.

We derive equation (13) for the aggregate nominal demand for CoCos, as well as equations (14) and (15) which correspond respectively to the nominal demand for CoCos and the demand for deposits, expressed as a share of the net wealth of the household concerned.

$$COCO_t = (1 - lp_t) NWH_t \quad (13)$$

$$COCO_{h,t} = (1 - lp_t) NW_{h,t} \quad (14)$$

$$D_{h,t} = lp_t NW_{h,t} \quad (15)$$

With:

- $COCO_t$: the nominal aggregate demand for CoCos in period t
- $COCO_{h,t}$: the nominal demand for CoCos of household h in period t
- NWH_t : the net wealth of the household sector in period t

- $NW_{h,t}$: the net wealth of household h in period t
- $D_{h,t}$: the demand for deposits of household h in period t

The gross nominal income of employed households (see equation 16) is equal to the sum of their wages, interest earned on deposits, interest earned on CoCos and dividends received. They pay a tax on this gross income (a fixed lump sum). Unemployed households receive tax-free unemployment benefits from the government, defined as a fixed share of the average wage.

$$YP_{h,t} = W_{h,t} + i_{b,t-1}^d D_{h,t-1} + i_{b,t-1}^{COCO} COCO_{h,t-1} + Div_{h,t} \quad (16)$$

With:

- $YP_{h,t}$: the gross nominal income of household h in period t
- $W_{h,t}$: the wage earned by household h in period t
- $i_{b,t-1}^d$: the interest rate on deposits of bank b in period t-1
- $D_{h,t-1}$: deposits held by household h in period t-1
- $i_{b,t-1}^{COCO}$: the interest rate on CoCos of bank b in period t-1
- $COCO_{h,t-1}$: CoCos held by household h in period t-1
- $Div_{h,t}$: dividends received by household h in period t

3.2.2.3 *Bank behaviour*

Credit supply

Firms interact with several banks on the credit market during each simulation period, selecting the best partner charging the lower interest rate (see the corresponding section below for the determination of the interest rate on loans) and eventually obtaining loans over several periods. The likelihood that firms obtain a loan depends on the credit rationing mechanism used by banks to assess loan demand (rather than a credit price rationing mechanism, following empirical evidence surveyed by Jakab and Kumhof (2014)).

Consistent with Caiani et al. (2016), the model is based on a quantity rationing mechanism that takes into account both the risk and the bank's expected rate of return associated with each credit request. Therefore, the supply of credit for a given bank depends on its capital ratio targets, the probability of default and the creditworthiness of applicants based on collateral value and operating cash flows, as well as the expected rate of return of the loan for the bank.

The probability of firm default is computed in each of the next 20 periods ahead using a logistic function, based on the percentage difference between the borrowers' cash flows and the debt service on the given payment tranche associated with the hypothetical loans granted.

The expected return on loans depends on the associated repayment amount as well as the probability of default of the borrower and the bank's risk aversion. It also takes into account the collateral of the firms (in case of a default by a consumption firm, a bank can temporarily seize control of it and expect to recover a share of outstanding loans through the sale of capital goods).

Banks are willing to satisfy agents' demand for credit when the expected return is greater than or equal to zero. Otherwise, banks may still be willing to grant some credits, if there is an amount for which the expected return is non-negative.

Credit interest rate

Banks' interest rates on loans (see equation 17) depend on the difference between the banks' current capital ratio (equal to their net wealth divided by their total credit supply) and the target capital ratio (determined as the sector average for the past period). When banks are more capitalized than desired, they can afford to further expand their balance sheet by offering a lower interest rate than the average of their competitors, which has the effect of attracting more customers. When banks are less capitalized than desired, they reduce their exposure by offering a higher interest rate, which has the dual effect of making their loans less attractive while increasing their margin.

$$i_{b,t}^l = \begin{cases} \overline{i_{t-1}^l} (1 - FN) & \text{if } KR_{b,t} \geq KR_t^T \\ \overline{i_{t-1}^l} (1 + FN) & \text{if } KR_{b,t} < KR_t^T \end{cases} \quad (17)$$

With:

- $i_{b,t}^l$: the interest rate on loans of bank b in period t
- $\overline{i_{t-1}^l}$: the average interest rate on loans in period t-1
- FN : draw from a folded normal distribution $(\mu_{FN}, \sigma_{FN}^2)$
- $KR_{b,t}$: the capital ratio of bank b in period t
- KR_t^T : the target capital ratio

Deposits and bonds market

Banks hold the deposits of households, consumption firms and capital firms. They set their own deposit interest rate based on the difference between their actual liquidity ratio $LR_{b,t}$ and a

target liquidity ratio LR_t^T defined as the sector average over the last period (see equation 18). When their liquidity ratio is above the target, banks set their interest rate on deposits with a positive mark-up over the average interest rate in order to attract customers. When their liquidity ratio is below the target, they set their deposit interest rate with a negative mark-up over the average interest rate to pay less deposit interests and restore this ratio. When the liquidity ratio falls below a mandatory lower bound decided by the regulator, banks request cash advances from the Central Bank. Finally, banks use their excess reserves to buy government bonds. The remaining bonds are purchased by the Central Bank.

$$i_{b,t}^d = \begin{cases} \overline{i_{t-1}^d} \cdot (1 + FN) & \text{if } LR_{b,t} \geq LR_t^T \\ \overline{i_{t-1}^d} \cdot (1 - FN) & \text{if } LR_{b,t} < LR_t^T \end{cases} \quad (18)$$

With:

- $i_{b,t}^d$: the interest rate on deposits of bank b in period t
- $\overline{i_{t-1}^d}$: the average interest rate on deposits in period t-1
- FN : draw from a folded normal distribution $(\mu_{FN}, \sigma_{FN}^2)$
- $LR_{b,t}$: the liquidity ratio of bank b in period t
- LR_t^T : the target liquidity ratio

Bank bankruptcies

Banks default when their net wealth turns negative. We assume that they are rescued by the government through bailouts financed entirely by depositors (households and firms). The number of banks in the model remains constant.

In order to restore positive net wealth, deposits from households and firms are reduced until the bank's net wealth becomes positive and its capital ratio equals the minimum required capital ratio. The loss borne by depositors is distributed in proportion to the size of their deposits.

Contingent convertible bond issuance

Econometric estimates would be needed to verify the exact determinants of the issuance of CoCos by banks, but the available data do not yet allow for such work. We therefore propose a rule of thumb instead: banks issue no more and no less than the level of substitutability between Additional Tier 1 and Tier 1 allowed by the macroprudential rules laid down by the regulator. Basel III provides that Additional Tier 1 capital can substitute for Tier 1 capital up to 1.5% of the issuing bank's net wealth. We therefore assume that banks have no interest in issuing less

than 1.5% of their net wealth in the form of CoCos, since this helps them complying with the Basel III solvency ratio requirements. We also consider that it is not in the interest of banks to issue more than 1.5% of their net assets as CoCos. Beyond that, the benefit of issuing CoCos becomes limited. They are no longer counted as Additional Tier 1 capital. Banks can issue more of them but this does not contribute to improving their solvency ratio. They just pay more interest to investors and take the risk of dissatisfying their current shareholders who might fear too much dilution of their shareholder power in case of an activation (Bulow & Klemperer, 2013). The individual real supply and aggregate real supply of CoCos are therefore given by equation (19) and (20).

$$coco_{b,t} = \frac{Add^T NW_{b,t-1}}{pbco^T} \quad (19)$$

$$coco_t = \frac{AddT^T NWB_{t-1}}{pbco^T} \quad (20)$$

With:

- $coco_{b,t}$: the real supply of CoCos of bank b in period t
- $coco_t$: the aggregate real supply of CoCos in period t
- $AddT^T$: the substitutability between Additional Tier 1 capital and Tier 1 capital decided by the regulator (1.5% here)
- $NW_{b,t-1}$: the net wealth of bank b in period t-1
- NWB_{t-1} : the net wealth of the banking sector in period t-1
- $pbco^T$: the announcement price of CoCos (exogenous and fixed)

Contingent convertible bond interest rate

Banks compete in the contingent convertible bond market by setting their own interest rate on CoCos (see equation 21). It depends on the difference between banks' current liquidity ratio and the target liquidity ratio (determined as the sector average for the past period). When their liquidity ratio is above the target, banks set their interest rate on contingent convertible bonds with a positive mark-up over the average CoCo interest rate to attract investors. When their liquidity ratio is below target, banks lower their interest rate on contingent convertible bonds to limit interest payments and thus restore their liquidity ratio.

Thus, it is the CoCos of the most stable banks that tend to attract the most investors (consistently with observations made by Avdjiev et al., 2020). A bank in an already fragile situation may

issue CoCos but it will not be able to afford to pay high interest on them. Its CoCos will then be relatively less attractive to investors.

$$i_{b,t}^{BCO} = \begin{cases} \overline{i_{t-1}^{BCO}} (1 + FN) & \text{if } LR_{b,t} \geq LR_t^T \\ \overline{i_{t-1}^{BCO}} (1 - FN) & \text{if } LR_{b,t} < LR_t^T \end{cases} \quad (21)$$

With:

- $i_{b,t}^{BCO}$: the interest rate on CoCos of bank b in period t
- $\overline{i_{t-1}^{BCO}}$: the average interest rate on CoCos in period t-1
- FN : draw from a folded normal distribution $(\mu_{FN}, \sigma_{FN}^2)$
- $LR_{b,t}$: the liquidity ratio of bank b in period t
- LR_t^T : the target liquidity ratio

Contingent convertible bond pricing

The final price at which CoCos are traded is different from the announcement price $pbco^T$ set by the banks and shown in equations 19 and 20. This is a market clearing price which balances aggregate supply and demand. Households perform their portfolio arbitrage solely on the basis of the relative profitability of CoCos vs. deposits. Multiple prices based on the characteristics of the issuing banks could be implemented in a more sophisticated version of the model. However, the pricing of CoCos is not a central element of the analysis proposed here and we therefore opt for this simplifying choice. There is also no secondary market on which assets could be traded at different market prices. We have:

$$pbco_t = COCO_t / coco_t \quad (22)$$

With:

- $pbco_t$: the market clearing price for CoCos in period t
- $COCO_t$: the aggregate nominal demand for CoCos in period t
- $coco_t$: the aggregate real supply for CoCos in period t

Contingent convertible bond market matching mechanism

Following Riccetti et al. (2015), households are allowed to observe the interest rates charged by a random subset of banks (whose size depends on the degree of imperfect information investors face: they compare all interest rates if they have access to perfect information, or only a few otherwise). Following Delli Gatti et al. (2010), households switch from their previous partner to the best potential partner with a certain probability given by a non-linear function of

the distance between the two compared interest rates. This means that households do not necessarily switch banks to buy their CoCos, even if they find a higher interest rate elsewhere. This inertia reflects their habits.

Households may exhaust the stock of CoCos available at a given bank. In this case, they look for other suppliers in the randomly selected subset.

Contingent convertible bond activation mechanism

CoCos are activated when the banks' capital adequacy ratio falls below a given threshold value CAR^T . When this happens, all CoCos issued by the bank concerned are cancelled, regardless of their maturity. If the principal of some were to be repaid during this period, it is not and never will be. If CoCo interests were to be paid, they are not. The bank also does not issue new CoCos as long as its capital adequacy ratio is below this threshold.

If the capital adequacy ratio continues to deteriorate and the bank's net worth reaches zero, then the bank goes bankrupt, triggering its bailout. This implementation therefore allows the bank to potentially recover between the time its CoCos are activated and the time it declares bankruptcy.

3.2.2.4 Public sector behaviour

The central bank makes a profit equal to the interest it earns on the residual bonds it purchases and on the cash advances it makes to banks. These cash advances are repaid after a period with a fixed interest rate that acts as an upper bound to the interest rate set by banks on deposits.⁴⁶

The government pays benefits to unemployed households. It also collects taxes on income and profits from households, firms, and banks (a lump sum). It issues bonds that last one period (for simplicity's sake). Their interest rate and price are set exogenously. The amount of bonds issued is such that it covers what is needed to pay for public expenditures (unemployment benefits and interest payments on bonds) minus taxes and the profit redistributed by the central bank.

3.3 NUMERICAL SIMULATIONS

We follow the procedure used in the JMAB framework. We start by deriving an aggregate version of the model associated with a real stationary state and a balanced nominal growth path. The aggregate model is solved numerically by setting reasonable exogenous values for the

⁴⁶ In the original JMAB model, the public sector is not very developed. In particular, there is no monetary policy as such. The central bank rate is fixed. This part of the model could be improved in future work.

parameters for which empirical data are available. We then distribute the initial aggregate stock and flows values of each sector uniformly among its constituent agents. Only then do the microeconomic interactions begin. Initially, the agents that make up each sector are all identical. Their decentralized interactions and the adaptive revision of their strategies over time gradually bring out heterogeneity in the model. After a few periods, the balance sheets of each agent differ. They face different prices and interest rates. Some households are fired and others hired, some firms and banks go bankrupt while others continue to operate.

A Hodrick-Prescott filter is applied on each time series to separate their cyclical component from their trend component. As a result, the statistical tests and econometric analyses conducted in the following sub-sections are performed on stationary time series. Otherwise, the tests would be invalid and the estimates spurious.

3.3.1 Empirical validation

We first conduct an empirical validation of the model by verifying that our extension is able to reproduce the stylized facts initially reproduced by the original JMAB model of Caiani et al. (2016). The introduction of CoCos into the JMAB framework should not unduly disrupt its ability to capture mechanisms relevant to real-world economic dynamics. The parameters used to reproduce these stylized facts correspond to the calibration used for the baseline scenario.

The baseline scenario consists in 100 Monte Carlo Simulations of 400 periods each. We use the results of these simulations to check whether the model is able to reproduce the same stylized facts as the original JMAB model. This is done by comparing the properties of our artificially produced time series with those of real time series, following the same method as Caiani et al. (2016).

Indeed, our simulations yield similar results suggesting that our extension fits several key macro and microeconomic stylized facts. At the macro level, the model reproduces important properties of business cycles such as the pro-cyclicality of employment, consumption and investment (Stock & Watson, 1999). Inflation is pro-cyclical and lagging and mark-ups are counter-cyclical and lagging (Rotemberg & Woodford, 1999) (see Figure 39). Firms' total debt and leverage are pro-cyclical (Lown & Morgan, 2006; Leary, 2009) (see Figure 40, top and bottom left, and bottom right). Banks' leverage is pro-cyclical (Nuño & Thomas, 2017) (see Figure 40, top right).

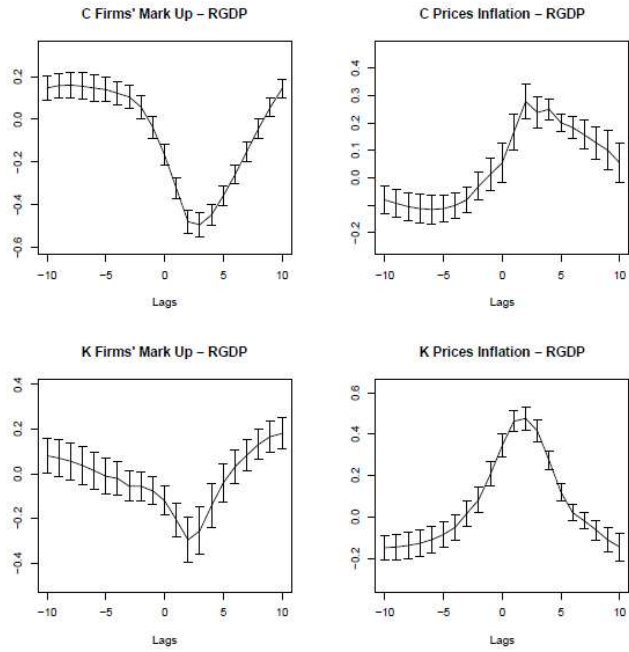


Figure 39: Average artificial cross-correlations of the markup and price de-trended series up to the 10th lag. Segments show the standard deviations of Monte Carlo average cross-correlations.

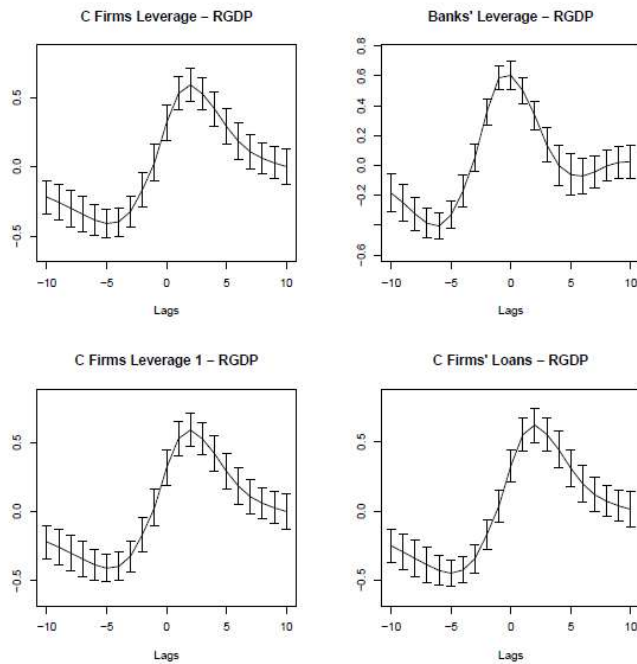


Figure 40: Average artificial cross-correlations of the markup and price-detrended series up to the 10th lag. Segments show the standard deviations of the Monte Carlo average cross-correlations.

At the micro level, the model generates hump-shaped investment, in accordance with the observations reported by Doms & Dunne (1998) who show thanks to US longitudinal data that investment is not smoothed over time, but alternates between high-intensity spikes and periods of lower intensity or even high intensity and periods of low intensity (with sometimes no investment at all). This lumpiness is illustrated by Figure 41.

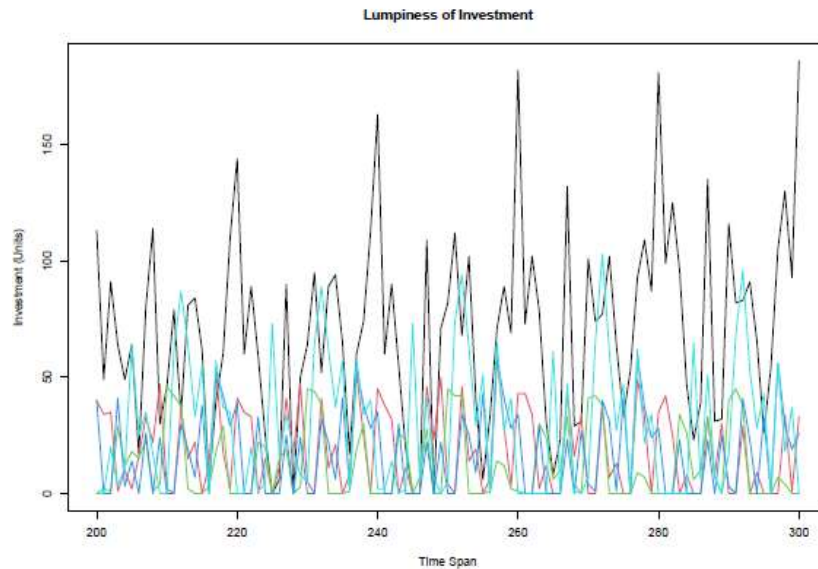


Figure 41: Hump-shaped investment. Lines show 5 consumption firms between periods 200 and 300 of a single simulation run.

The model is also able to reproduce both high path dependency and strong heterogeneity for firms, consistent with empirical observations reported by Dosi et al. (1997). The high path dependency is illustrated by Figures 42 and 43, which show the market shares of 20 capital and consumption firms, between periods 200 and 400 of one typical simulation run. One can observe that firms that succeed in establishing a dominant position on the market tend to maintain this dominant position over time (and vice versa), even if disruptions are occasionally possible.

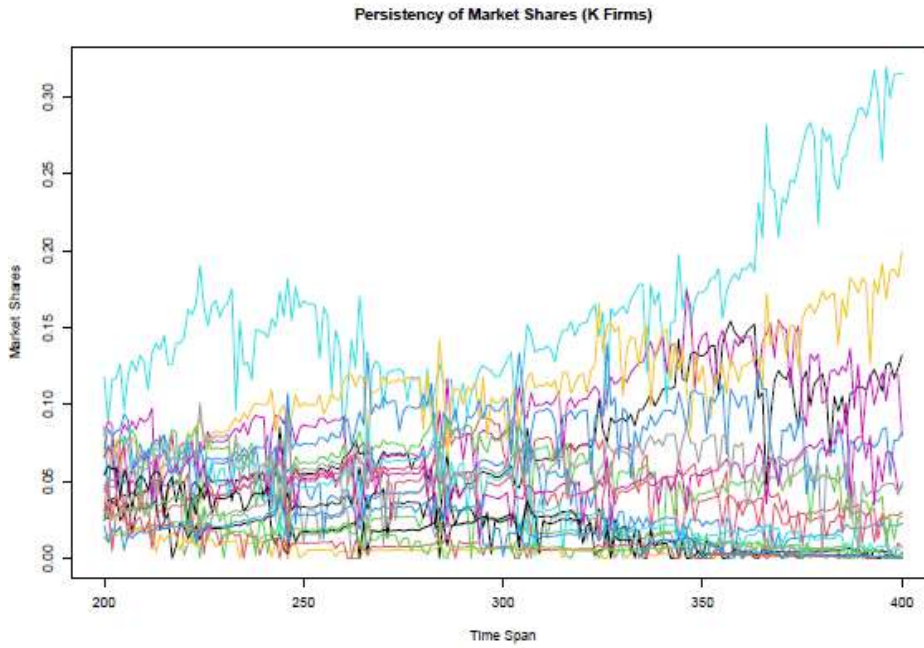


Figure 42: Market shares persistency for capital firms. Lines show 20 capital firms between periods 200 and 400 of a single simulation run.

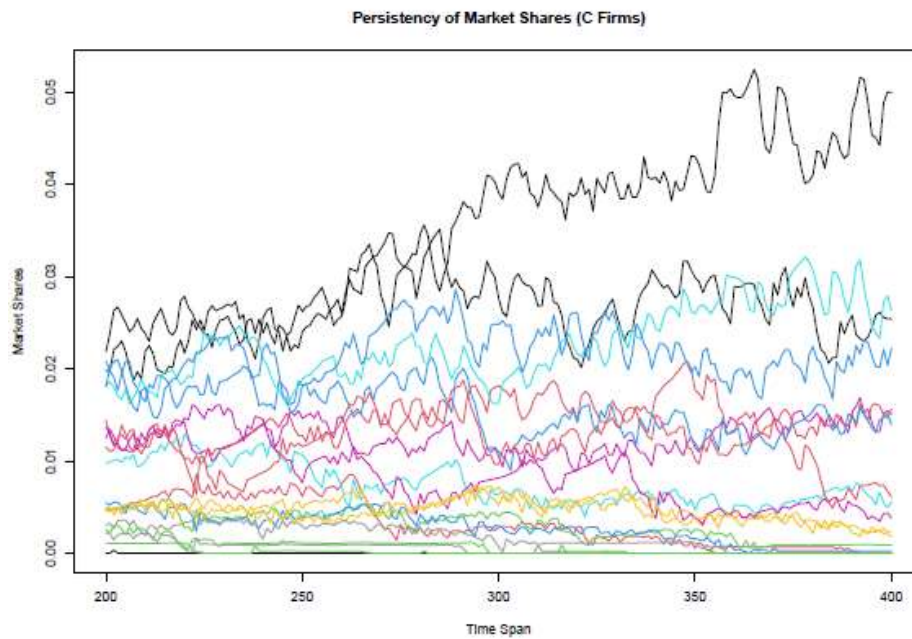


Figure 43: Market shares persistency for consumption firm. Lines show 20 consumption firms between periods 200 and 400 of a single simulation run.

Firm heterogeneity is analysed by different means: shape parameters, Jarque-Bera tests, graphic analysis, and comparisons with log-normal and power-law fits through Vuong's likelihood tests. When it comes to shape parameters. Capital firm size measured by their sales

has a skewness equal to 2.79 and an excess kurtosis equal to 10.22, suggesting a strongly right-skewed distribution (Bulmer, 1979). The same applies to consumption firms with a skewness equal to 1.02 and an excess kurtosis equal to 1.13.

Jarque-Bera statistical tests (which are used to test the null hypothesis that these skewnesses and kurtoses match a normal distribution⁴⁷) yield p-values equal to 0 for both capital and consumption firms, and χ^2 respectively equal to 9629.7 and 1697.2. Thus, the normal distribution hypothesis is unquestionably rejected for both types of firms.

This is illustrated by figures 44 and 45, which show a photography of the degree distribution of capital and consumption firms in period 400 of the 100 baseline Monte Carlo simulations. These log-log plots display the actual distribution of firm sizes (dots), the theoretical power law fit (in red) and the theoretical log-normal fit (in green). Even if the model is initialized with identical firms, they eventually vary in size with, with a concentration of small ones (displayed at the top left of both graphs) and some very large ones (displayed at the bottom right of both graphs).

To describe more precisely these fat-tailed distributions, we compare them first with a power law fit, and then with a log-normal fit. If the degree of distribution follows a power law, it means that there is a pattern of linear preferential attachment (agents who are already wealthy receive more than those who are not in a linear way). If the degree of distribution follows a log-normal fit, it means that there is a sublinear preferential attachment (agents who are already wealthy receive more than those who are not in a less than proportional way).⁴⁸ An inspection of the Figures 44 and 45 does not provide much information on this subject. The actual distribution is close to the two fits. Therefore, statistical tests must be performed. Similarly to Caiani et al. (2016), themselves following Clauset et al. (2009), a power law fit and a log-normal fit are estimated. A bootstrap check is conducted to verify how likely the data fits a power law (which is accepted for p-values greater than 0.1). The p-values are respectively equal to 0.57 and 0.45 for capital firms and consumption firms, meaning that a power law fit is plausible in both cases. But a log-normal fit may be just as plausible. To rule out the null hypothesis that both fits could be suitable (in which case it is impossible to describe the distribution more precisely than in the paragraphs above), Vuong's likelihood ratio tests (Vuong, 1989) are used. If the p-value is close to zero, then only one fit is suitable. An

⁴⁷ See Verbeek (2017) for more details on Jarque-Bera statistical tests

⁴⁸ See Newman (2004) for more details on distribution analysis and especially power-law fits

inspection of the likelihood ratio determines which one: if significantly different from zero and negative, then the log-normal fit is favoured. If significantly different from zero and positive, then the power-law fit is favoured. For both types of firms, the p-value is different from zero. As a result, the null hypothesis can't be rejected.

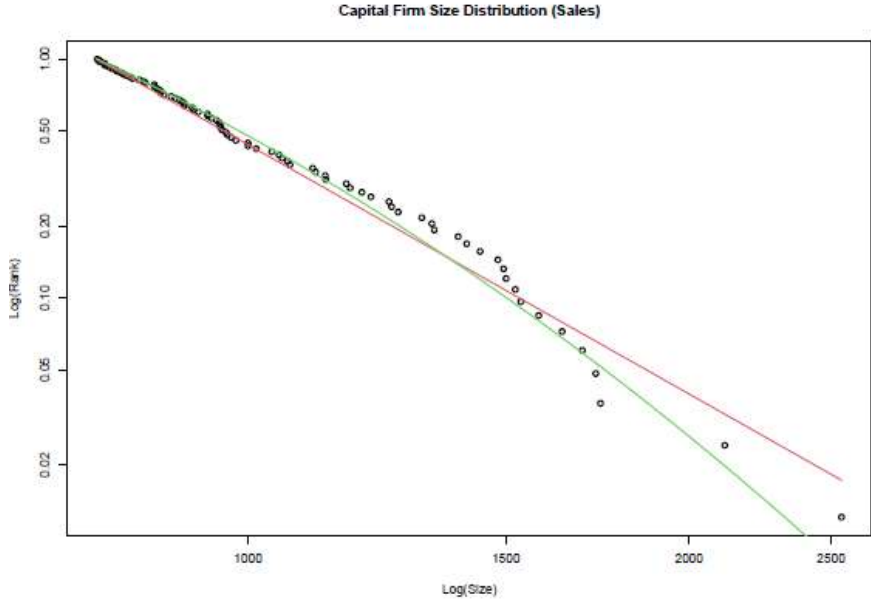


Figure 44: Capital firms upper tail size distribution (dots), log-normal fit (green line) and power-law fit (red)

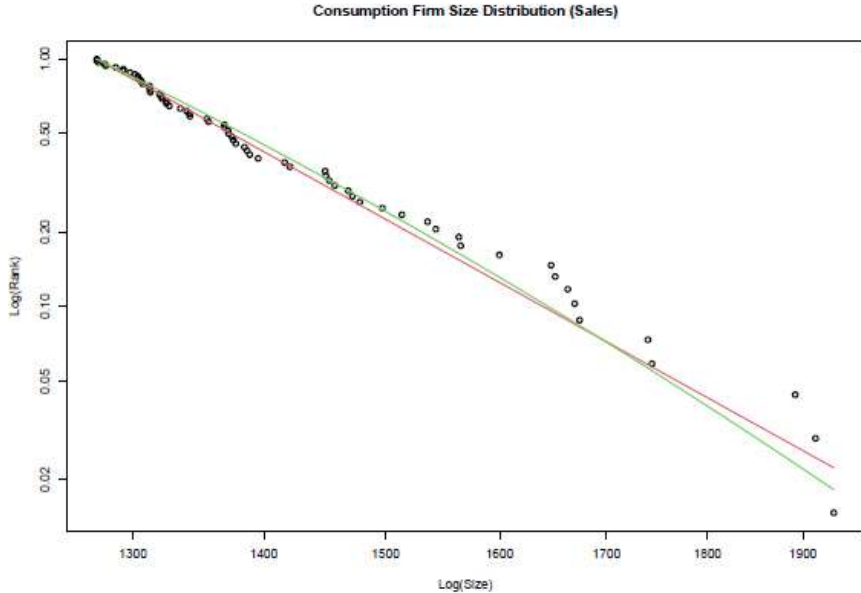


Figure 45: Consumption firms upper tail size distribution (dots), log-normal fit (green line) and power-law fit (red)

3.3.2 Policy experiment 1: testing the effects of introducing CoCos for different values of the activation threshold

The empirical validation of the model discussed in the previous section shows that the model generates cycles. These cycles are sufficient to lead to bank failures, requiring costly bailouts borne by the taxpayer. The introduction of automatic bail-in mechanisms through the issuance and activation of CoCos should improve bank balance sheets in time of crisis without government intervention. Thus, we should observe a decrease in the total cost of bailouts with the introduction of CoCos in the model.

To verify this, we run two sets of 25 simulations⁴⁹: one without CoCos (this is simply the original JMAB model), the other with CoCos activated when the bank's capital ratio falls below 60 percent (this threshold corresponds to our baseline scenario, other threshold values are tested later).

We first provide some descriptive statistics which give an initial idea of the orders of magnitude involved (see Table 6 and Table 7).

Table 6: Mean, standard deviation, and interquartile range for the number of bank bankruptcies, total cost of bailouts, and the average capital ratio in the banking sector over 25 Monte Carlo simulations of 400 periods without CoCos.

	Mean	Standard deviation	Interquartile range
Bank bankruptcies	22	2,99	4
Total cost of bailouts⁵⁰	385673	50155	51883
Banks' average capital ratio	1,55	0,0479	0,0544

Table 7: Mean, standard deviation, and interquartile range for the number of bank bankruptcies, total cost of bailouts, and the average capital ratio in the banking sector over 25 Monte Carlo simulations of 400 periods with CoCo activations when banks' capital ratio falls below 60 percent

	Mean	Standard deviation	Interquartile range
Bank bankruptcies	7	2,27	3
Total cost of bailouts	213410	53292	68062
Banks' average capital ratio	1,59	0,0515	0,0486

⁴⁹ Following the method used by Caiani et al. (2016) for their own sensitivity analyses.

⁵⁰ We create an indicator that measures the total cost of bailouts over the 400 simulated periods.

We then perform Mann-Whitney tests⁵¹ to check for statistical differences for several variables of interest: the number of bank bankruptcies and the bailout costs, but also their liquidity and capital adequacy ratios, consumption, investment and GDP. The results from these tests are presented in Table 8 below.

*Table 8: Mann-Whitney nonparametric tests (25 Monte Carlo runs of 400 periods) with and without CoCos - (***) : p-value < 0.001; (**): p-value < 0.01; (*): p-value < 0.05*

<i>Effects of the introduction of CoCos on ...</i>	
<i>... bank bankruptcies</i>	< (***)
<i>... bank bailout costs</i>	< (***)
<i>... bank average capital ratio</i>	> (***)
<i>... average consumption</i>	-
<i>... average investment</i>	> (***)
<i>... average GDP</i>	> (***)

The introduction of CoCos into the economy has significant effects. For the banking sector, we observe fewer bankruptcies, lower bailouts costs⁵² and higher capital ratios. These positive effects are due to the fact that the crises that banks face over the cycles generated by the model are relatively less fatal for them when they issue CoCos. Not only do CoCos help with shifting the direct burden of bank rescues from all taxpayers to banks' creditors, but they also limit losses as their automatic activation occurs earlier and faster than bailouts operated by the government (thus leading to fewer bank failures, lower total bailout costs and higher capital ratios). This must be put into perspective with the theoretical debates presented in the literature review in section 1.2.1. While Delivorias (2016) and Pazarbasioglu et al. (2011) raised concerns about the ability of CoCos to be an effective loss-absorbing mechanism when banks really need them, it appears that they do make a difference, even if they do not completely prevent bank failures and bailouts at the expense of the taxpayer. The results are in line with Helberg and Lindset's claim that "CoCos can take up the role as the first line of defence and public bail-in may be a complementary tool for banks that will likely remain distressed after the conversion"

⁵¹ We implement Mann-Whitney nonparametric tests since we have unpaired samples and the time series change between runs of simulations, partly due to the random path of the model and partly due to our parameter sweep.

⁵² Nevertheless, we continue to see bankruptcies and therefore bailouts. CoCos make it possible to reduce them but not to prevent them entirely.

(Helberg & Lindset, 2014), as well as the literature that states that CoCos improves the solvability of the banking sector (Calomiris & Herring, 2013; Pennacchi, 2010).

This stabilization of the banking sector during crises has second-order effects on the real economy. Indeed, there is a significant positive effect of the introduction of CoCos on investment and GDP. This effect can be explained by a positive financial accelerator (Bernanke et al., 1999). The fact that banks are relatively less likely to go bankrupt means that they can continue their activities, notably lending to firms to finance their investments and thus GDP. These results are robust to different values of the activation threshold as shown in Figure 46. We perform Mann-Whitney tests for several activation threshold values between 0.60 and 0.70 with a 0.01 increment between each set of 25 Monte Carlo simulations, as well as for a scenario without CoCos. Investment and GDP values are and significantly higher in an economy with CoCos than in an economy without, whatever the value of the activation threshold tested. This is in line with the academic literature that sees CoCos as an advantage for the real sphere (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009; Vallée, 2019).

It should be noted that the effects on consumption are ambiguous and not significant.⁵³ We know that households benefit from the positive second-order effects of stabilizing the banking sector in a crisis scenario. They are less likely to bear bailouts, and the relative increase in investment and GDP positively affects their wages. The ambiguous and non-significant results for consumption reported by the Mann-Whitney tests can therefore be explained by a counterbalancing negative effect. As the activation of CoCos leads to a transfer of net wealth from investors (households) to banks, the banks' creditors see part of their asset portfolio melting away. They will never get their principal back. And they will not receive the interests they should have received on the CoCos they held. All this negatively affects their consumption, which depends on both their income and their net wealth, as we saw in the presentation of the model.

⁵³ Exact p-values for the Mann-Whitney baseline and robustness checks can be found in the corresponding section of the online appendix: https://github.com/elskr/sfc-abm_cocos/tree/main/paper

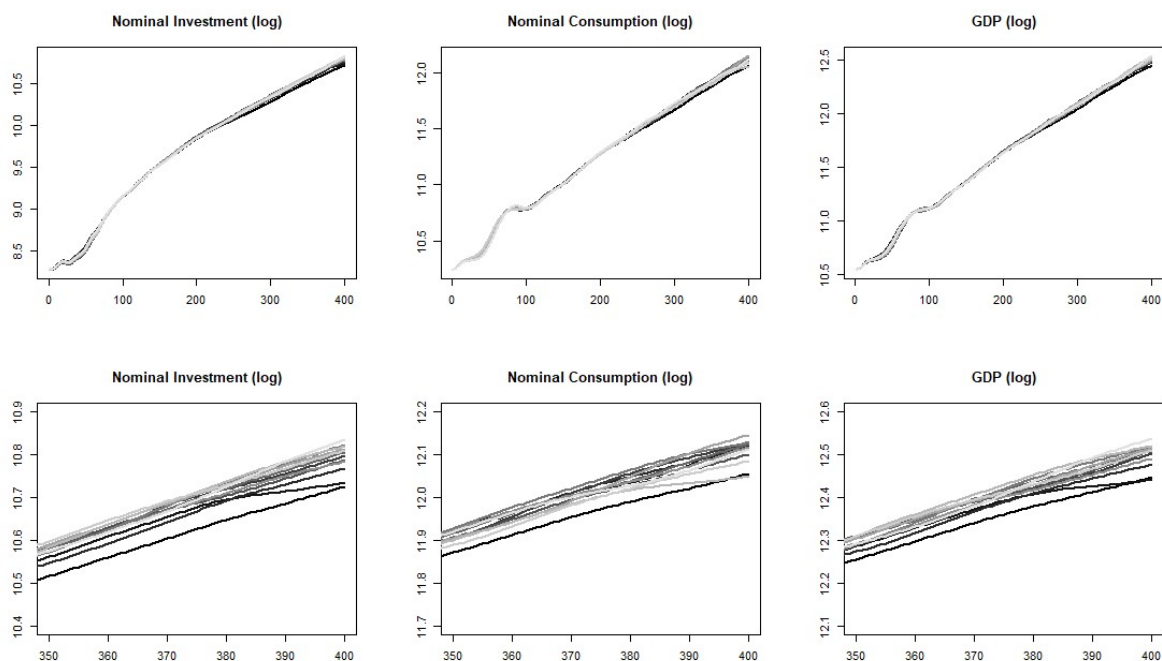


Figure 46: Different threshold of activation: lighter grey corresponds to higher threshold. Black (the lowest line in the bottom three graphs) corresponds to the scenario without CoCos. Top and bottom left: log of nominal investment. Top and bottom centre: log of nominal consumption. Top and bottom right: log of nominal GDP.

3.3.3 Policy experiment 2: testing the effects of the quantity of CoCos in circulation for different values of the activation threshold

We have shown in the previous section that the increased stabilization of the banking sector following the activation of CoCos in the event of a crisis generates positive second-order effects for the rest of the economy. However, we have also shown that these bail-ins do not have only positive effects. By shifting the burden of debt rescue, they introduce destabilizing mechanisms that can counteract these positive second-order effects, making the net effect for the economy as a whole ambiguous. In this section, we examine one of the determinants of this net effect: the quantity CoCos in circulation at the time of activation.

For bail-ins to be effective, the quantity of CoCos in circulation at the time of activation must be sufficiently large. Not enough and the contingent inflow of capital does not allow banks to sufficiently absorb the shocks they face. Fewer bankruptcies are avoided. The interruption of banking activity then has negative repercussions on the real sphere (consumption, investment and GDP) and the government has to deploy bailouts that weigh even more on the real sphere insofar as these have to be financed by the taxpayer. We can therefore put forward a first

hypothesis. One can expect, at least up to a certain point, a positive relationship between the outstanding quantity of CoCos at the time of activation and the macroeconomic aggregates: the larger the outstanding volume, the greater the magnitude of the positive effects highlighted in section 3.2.

However, the larger the volume of CoCos in circulation, the more investors (in this case households) are harmed in the event of an activation, which is likely to weigh on consumption as also highlighted in section 3.2. We can therefore put forward a second hypothesis. One can expect, at least from a certain point, a negative relationship between the outstanding quantity of CoCos at the time of activation and the macroeconomic aggregates. The economy can end up in a situation where the volume of CoCos is too high and the net effects of an activation become negative for the real sphere.

These two hypotheses taken together suggest nonlinear effects of the amount of CoCos in circulation. To test these hypotheses, we first estimate three linear models with a quadratic term explaining consumption (23), investment (24) and GDP (25) by the amount of CoCos circulating in the economy. We set the time dimension to $t=300$ to get panel data of dimension 2 (threshold of activation p^{54} ; Monte Carlo run i). η denotes random effects and ε designates error terms. Dependent variables are stationary. The results of the linear regressions with quadratic term are shown in Table 9.

$$C_{p,i} = \alpha_0 + \alpha_1 \cdot COCO_{p,i} + \alpha_2 \cdot COCO_{p,i}^2 + \sum_{p=1}^{11} \eta_{p,i} + \varepsilon_{p,i} \quad (23)$$

$$I_{p,i} = \alpha_0 + \alpha_1 \cdot COCO_{p,i} + \alpha_2 \cdot COCO_{p,i}^2 + \sum_{p=1}^{11} \eta_{p,i} + \varepsilon_{p,i} \quad (24)$$

$$Y_{p,i} = \alpha_0 + \alpha_1 \cdot COCO_{p,i} + \alpha_2 \cdot COCO_{p,i}^2 + \sum_{p=1}^{11} \eta_{p,i} + \varepsilon_{p,i} \quad (25)$$

Two results should be noted. First, the amount of CoCos has a significant positive effect on consumption, investment and GDP. This positive effect is consistent with the second-order effects described above. But more interestingly, the quadratic amount of CoCos in circulation has a significant negative effect on consumption and GDP (albeit of less significance relative to GDP). It would therefore appear that nonlinearities play a role in the net effect of an activation on the real sphere of the economy.

⁵⁴ For robustness's sake, we perform 11 Monte Carlo experiments for 11 values of threshold of activation between 0.59 and 0.70 with a 0.01 increment between each experiment. Each experiment is run 25 times over 400 periods.

Table 9: Linear models with quadratic term

	Dependent variable:		
	Consumption (23)	Investment (24)	GDP (25)
COCO	0,854*** (4,129)	0,121* (1,727)	0,710*** (2,627)
COCO ²	-0,002*** (-4,145)	-0,003 (-1,648)	-0,002** (-2,473)
Observations	299	299	299
R ²	0,106	0,069	0,090
Adjusted R ²	0,066	0,027	0,049
Residual Std. Error (df=285)	6,694.050	2,266.830	8,747.567
F Statistic (df=13;285)	2,612***	1,637*	2,170**

Note: **p*-value<0,05; ***p*-value<0,01; ****p*-value<0,001

To confirm this hypothesis, we then estimate two nonlinear penalized spline regression models (for the method, see Kauermann et al., 2009 ; for another application to ABM models, see, e.g. Dawid et al., 2014): one for consumption (26) and one for GDP (27).⁵⁵ η designates random effects and ε designates error terms. s designates the spline function (it is no longer a fixed parameter as in linear regressions but a third-order polynomial depending on the amount of CoCos in circulation). The results of the nonlinear penalized spline regressions are shown in Table 10.

$$C_{p,i} = \alpha_0 + s(COCO_{p,i}) + \sum_{p=1}^{11} \eta_{p,i} + \varepsilon_{p,i} \quad (26)$$

$$Y_{p,i} = \alpha_0 + s(COCO_{p,i}) + \sum_{p=1}^{11} \eta_{p,i} + \varepsilon_{p,i} \quad (27)$$

The quantified parameters estimated in this penalized spline regression cannot be interpreted directly. However, two things can be noted. First, both smooth terms are significant (i.e., there is indeed a significant non-linear effect of the amount of CoCos in circulation on consumption and GDP). Secondly, the adjusted R²s are higher than with the linear models with quadratic terms (which also weighs in favour of a nonlinear interpretation of the relationship between the quantity of CoCos in circulation in the economy and the macroeconomic aggregates). Figure 47 shows the graphical representation of these nonlinearities.

⁵⁵ We drop the investment variable as the effect of the quadratic term for it was not significant in the linear model.

Table 10: Nonlinear penalized spline models

Penalized spline model – Consumption (26)				
A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	121533.9	1317.9	92.221	< 0.0001
B. smooth terms	edf	Ref.df	F-value	p-value
S(COCO)	5.101	5.101	9.249	<0.0001
Adjusted R ² : 0,155				
Penalized spline model – GDP (27)				
A. parametric coefficients	Estimate	Std. Error	t-value	p-value
(Intercept)	177861.7	1765.3	100.752	< 0,0001
B. smooth terms	edf	Ref.df	F-value	p-value
S(COCO)	3.82	3.82	5.045	<0.0001
Adjusted R ² : 0,0876				

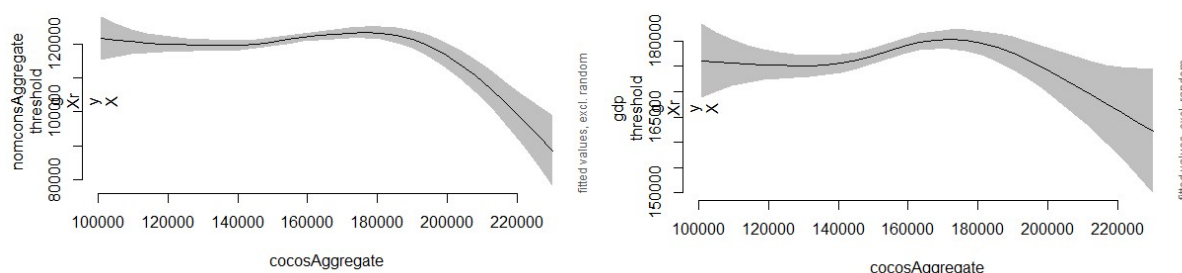


Figure 47: Graphical representation of the estimated non-linear penalized spline models. Left: effect of the quantity of CoCos on aggregate consumption. Right: effect of the quantity of CoCos on GDP. In light grey: confidence bands.

The issuance of CoCos and their activation allow banks to be more resilient in the event of a crisis and to maintain their activities. They can continue to lend to firms, which has a positive second-order effect on investment. This fuels GDP and consumption growth up to a certain point (as shown by the initial rise of consumption and GDP as the quantity of CoCos increases). However, the more CoCos in circulation, the greater the net wealth transfer when bail-ins occur. Beyond a certain amount (reached at the top of the two curves), the negative effect on consumption start to outweigh the positive second-order effects and this eventually affects GDP as well (hence the final decline in both curves).

3.4 CONCLUSION

The goal of this chapter is to analyse the extent to which the issuance of CoCos since the 2008 is likely to foster stability in the banking sector during a crisis and reducing the need for bailouts without posing a risk to the economy as a whole. I have shown that the bail-ins resulting from the activation of CoCos in a crisis not only partly replace bailouts that are costly for the taxpayer, but also effectively prevent bank failures and contribute to higher average capital adequacy ratios. This stabilization of the banking sector is positive for the economy as a whole, its aggregate consumption, its aggregate investment and its GDP as long as the amount of CoCos in circulation is not too high. The larger the volume of outstanding CoCos, the greater the adverse effects on investors' net wealth. Above a certain volume, their activation negatively affects consumption and ultimately GDP. CoCos therefore contribute to reinforcing the effects of a crisis rather than mitigating them. It is therefore in the regulator's interest to control the expansion of the CoCos market.

Adjusting the degree of substitutability between Tier 1 and Additional Tier 1 could be a way to control the lower bound of the volume of CoCos in circulation, thus ensuring that enough are issued to limit the need for bailouts in the event of a crisis. Banks have an interest in taking advantage of this opportunity to meet the Basel III solvency criteria, which they often denounce as too restrictive. Since CoCos are also used to send a strong positive signal to investors, as illustrated by Deutsche Bank in 2020, and since the demand for them is high given their attractive interest rates, banks may have an incentive to issue more than what is accounted as Additional Tier 1. Setting a maximum issuance ceiling and discouraging banks from using them as a screening device could be a way to control the upper bound of the volume of outstanding CoCos, thereby ensuring that potential bail-ins would not be too destabilizing for the economy when a crisis occurs.

These results have been obtained through Monte Carlo simulations on an extension of the JMAB model developed by Caiani et al. (2016). This model is designed to study the ex-post macroeconomic effects of a CoCo bonds write-off (principal write-down type). It features six institutional sectors (households, consumption firms, capital firms, banks, a government and a central bank). Each sector is populated by individual agents following microfounded behavioural rules. Initially, the agents are all identical. Their decentralized interactions and the adaptive revision of their strategies over time gradually bring out heterogeneity in the model. After a few periods, the balance sheets of each agent differ. They face different prices and

interest rates. Some households are fired and others hired, some firms and banks go bankrupt while others continue to operate.

CoCos are explicitly introduced in the model. They are demanded by households only. Demand depends on a trade-off between the rate of return on a safe asset (bank deposits) and the rate of return on a risky asset (CoCos) weighted by the share of activations in previous periods. The supply is such that banks take advantage of macroprudential rules on Additional Tier 1. The price equalises supply and demand. The interest rate is flexible and specific to the liquidity ratio of each bank (the more liquidities banks have, the more they can afford to raise their rates to attract investors, and vice versa). Market matching is done by connecting banks with investors. The latter compare the interest rates offered and choose the most advantageous. The activation of CoCos follows the same logic as in Chapter 2. It takes place when the capital adequacy ratio of banks falls below a given threshold value. In this case, principal repayments and interest payments for outstanding issues are cancelled.

Two policy experiments were conducted. The first one focuses on the effects of the introduction of CoCos in the economy and of different activation threshold values. Comparing an economy where banks issue non-convertible bonds with an economy where they issue CoCos, it is found thanks to Mann-Whitney non-parametric tests that the existence of an Additional Tier 1 buffer strengthens the capital ratios of banks. The risk of bank failures is lower, which means fewer bailouts and therefore lower costs for taxpayers. The greater resilience of banks allows them to maintain their operations in times of crisis. They can therefore continue to lend to the real economy, which generates positive second-order effects for the major macroeconomic aggregates of investment and output. These effects rely on a positive financial accelerator (Bernanke et al., 1999). Surprisingly, despite this positive financial accelerator, the effects on consumption are ambiguous. This ambiguity is explored in a second policy experiment. Using a penalized spline regression, it is shown that the volume of CoCos in circulation in the economy has non-linear effects on consumption and incidentally on GDP. The larger the volume of outstanding CoCos, the greater the adverse effects on investors' net wealth. Above a certain volume, their activation negatively affects consumption and ultimately GDP.

Caution should be exercised given the simplified nature of the model and its limitations. Some features of this new extension of the JMAB model need to be further investigated. Caution should be exercised given the simplified nature of the model and its limitations. Some of these investigations are carried out in Chapter 4. Others are left for later work.

First, further research and additional data on CoCos (especially microeconomic data on investor preferences and bank activation thresholds) are needed to estimate the optimal size of the CoCo market, and the exact level of substitutability between Additional Tier 1 and Tier 1 and the issuance ceiling that would help getting close to the optimal size.

Secondly, attention should be paid to future market developments as interest rates tend to rise in an inflationary context. As discussed in section 1.1.6, banks are currently forced to offer CoCos at ever higher rates to continue to attract investors. This may raise the question of the sustainability for banks of maintaining an increasingly costly regulatory level of Additional Tier 1 Capital. One could expect CoCos to have an additional perverse effect in periods of high interest rates. Intended to strengthen the capital of banks, they could instead weaken them through excessive interest payments. Based on future market developments and by complexifying the public sector in JMAB (and in particular the central bank and its monetary policy), it may be possible to model the impact of rising CoCo interest rates on the balance sheets of banks and investors. In the current version of the JMAB model, the central bank rate is fixed and bank rates (including CoCo interest rates) only fluctuate according to the liquidity and capital ratios of each bank.

Third, moral hazard may contribute to partly alter the picture presented in this chapter. The ex-ante role of CoCos is missing. The existing literature warns of the risk of increased risk-taking and moral hazard as banks know that they will be bailed-in by investors if not bailed-out by governments (Berg & Kaserer, 2015; Flannery, 2016; Hilscher & Raviv, 2014; Martynova & Perotti, 2018). These ex-ante effects are, however, difficult to take into account in JMAB because banks do not have much room in the model to take risks. Indeed, there is no large-scale financial market. Further work should be done to improve this part of JMAB in order to unlock new possibilities for analysing CoCos, in particular regarding the moral hazard associated with them.

This thesis focuses primarily on the ex-post effects of CoCos activations. There are improvements within reach for the model in this respect. We have only considered CoCo activations due to bank crises. But the model does not take into account the disturbances occurring on the CoCos market itself, especially panics and contagion effects affecting their price and thus their activation, resulting in a domino effect. These aspects of CoCos makes them potentially an even more destabilizing financial asset than presented here. Assessing it at a

macroeconomic level requires modifications to the formation of investors and banks' expectations in the model, which is done in the next chapter.

Finally, the model in its current version offers only an approximate view of what would happen in the event of widespread activations. While an isolated activation is likely to cause some turmoil quickly forgotten by investors, what could be expected if a lot of them occur at the same time? It is unlikely that investors would move past the event as quickly as they would after an isolated activation and one may suspect the existence of non-linearities. The portfolio arbitrage equation takes it into account in an approximate way but further work is needed to make it more complex with more sophisticated learning behaviours. The introduction of such behaviours is partially addressed in Chapter 4.

CHAPTER 4: CONTINGENT CONVERTIBLE BONDS AND MACROECONOMIC STABILITY IN STOCK-FLOW CONSISTENT AGENT-BASED MODEL, AUGMENTED BY A DYNAMIC OPINION COMPONENT AND INVESTOR LEARNING

4.1 INTRODUCTION

Chapter 3 provides quantitative results on the effectiveness and limitations of CoCo bail-ins based on an SFC model coupled with agent-based microfoundations. By adding to JMAB this additional financial asset, with its demand and supply sides, interest rate and price determination, and market interactions, I show that CoCos seem to be an effective loss-absorbing mechanism and make a difference at the macro level for the stability and the solvability of the banking sector, in line with the work of Calomiris & Herring (2013) and Pennacchi (2010). This version of the model also shows that CoCo issuances provide banks with a first line of defence in case of difficulties, allowing them at best to avoid bankruptcy, or at worst to delay it (Helberg & Lindset, 2014). They can continue to lend to firms, which fuels investment and GDP in the presence of a positive financial accelerator (Bernanke et al., 1999). These findings are consistent with the literature in favour of CoCos (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009; Vallée, 2019). However, depending on the amount of CoCos circulating in the economy, the macro-level cost-benefit balance could be reversed. The net-value transfer resulting from an activation of too much CoCos could be negative for the real sphere.

It appears that in some circumstances the disadvantages of CoCos may outweigh their advantages. But the version of the JMAB model proposed in Chapter 3 does not allow to say more. Indeed, it is limited by two sets of factors. First, it only takes into account CoCo activations and not the other types of disturbances that may occur in the CoCo market such as delays in repayment decided by banks. Yet, these disruptions have been numerous in recent years and have not been without consequences. Bologna et al. (2020) use empirical data to show how the difficulties faced by Deutsche Bank in 2016 (see section 1.1.6) spread to the entire

banking sector through a CoCo-specific contagion channel on the part of investors. It seems that isolated events can affect the whole market and the model as it stands does not allow for these possibilities. The second problem with the model is the formation of investor expectations. They do not adapt and only react. Faced with repeated disturbances, learning phenomena could be expected and the model should be able to display such kind of process.

If market disruptions and their negative consequences make CoCos potentially an even more destabilising financial asset, learning behaviours are likely to mitigate this.

The goal of this chapter is to take the JMAB version presented in Chapter 3 and make two substantial additions to it. The first one is a dynamic-opinion component similar to Salle & Seppecher (2015). It captures herding patterns and financial contagion risks through information spillovers⁵⁶. The second one is learning behaviours from investors following a modified Roth-Erev algorithm (Nicolaisen et al., 2001). It addresses the fact that investors learn and adapt from the disruptions taking place in the market rather than naively reacting in the same way all the time.

These two JMAB extensions provides further insights into some of the questions discussed in the previous chapters, but from a different perspective. CoCos are an effective absorption mechanism when triggered. But could it be that under certain conditions, informational disruptions in the market induce financial contagion effects, destabilize the banking sector and actually increase systemic risk with negative consequences on the real sphere?

Section 4.2 explains in further detail the motivation behind incorporating dynamic opinions and learning behaviours by reviewing the literature of information-based financial contagion and the limitations of the model presented in Chapter 3. Section 4.3 gives a presentation of the model. Section 4.4 presents the simulations and their results. Section 4.5 provides a final discussion.

⁵⁶ See Acharya & Yorulmazer (2008) for more details on information-based financial contagion. This is also discussed in more detail in section 4.2.

4.2 CONVERTIBLE CONTINGENT BONDS AS A FACTOR OF SYSTEMIC RISK AND FINANCIAL CONTAGION

The contingent convertible bond market has experienced significant disruptions over the past four years (see section 1.1.6 for more details). The most notable ones involved banks that were suspected by investors of not being able to repay maturing CoCos, or that actually decided to delay repayment.

In January 2016, Deutsche Bank announced expected negative results⁵⁷. A few months later, in September 2016, it received a large fine from the US Department of Justice⁵⁸. After these two events, not only did Deutsche Bank's CoCos yield-to-maturity reach historical highs, but it also created tensions in the entire market, affecting all major European banks' CoCos. After these two events, investors feared that Deutsche Bank would not be able to repay its contingent convertible debt. This not only caused a historic spike on Deutsche Bank's CoCos yield-to-maturity, but it also created tensions in the entire market, affecting all major European banks' CoCos. In 2019, Banco Santander temporarily postponed the call of 1.5 billion euros in CoCos and destabilized the whole market as well⁵⁹. In February 2020, Deutsche Bank announced that it would delay the repayment of \$1.25 billion of a CoCo debt⁶⁰. The value of the recently sold CoCo bond fell to approximately 50% of its face value. At the same time, investors tried to protect themselves from risks by buying massively CDS on Deutsche Bank's debt as well as CDS on other banks' debt. As a result, at the end of March, the global investment management firm Pimco saw its \$8bn capital securities melt– which had CoCos as its top five holdings at the end of 2019 – down by nearly 13 per cent for the year through. On May 2020, Lloyds Banking Group, whose first quarter profits had heavily decreased because of provisioning for predictable bad loans due to the crisis, told investors it would not call back a 750-million-euro CoCo bond.⁶¹

⁵⁷ DB's own announcement of its poor results: https://www.db.com/newsroom_news/2016/medien/deutsche-bank-reports-preliminary-full-year-and-fourth-quarter-2015-results-en-11368.htm

⁵⁸ News article reporting on the fine: <https://www.theguardian.com/business/2016/sep/16/deutsche-bank-14bn-dollar-fine-doj-q-and-a>

⁵⁹ News article reporting on Banco Santander's repayment delay: <https://www.ft.com/content/8539f7b4-2ad9-11e9-a5ab-ff8ef2b976c7>

⁶⁰ News article reporting on DB's announcement: <https://www.ft.com/content/29988546-67a6-11ea-800d-da70cff6e4d3>

⁶¹ News article reporting on Lloyd's decision: <https://www.reuters.com/article/lloyds-bonds/update-1-lloyds-wont-redeem-750m-euro-coco-bond-amid-covid-19-crisis-idUSL8N2D4308>

These incidents highlighted that an isolated disruption could cause investors to suddenly fear systemic risks and flee from CoCos, inducing financial contagion, destabilizing the market and exacerbating the original problem.

This volatility may seem surprising at first. The CoCos contracts and the information documentation made available by the banks are very clear on the functioning of these assets⁶². The activation thresholds and the type of loss-absorption mechanism are explicitly specified. The possibility for banks to postpone the repayment of maturing CoCos is agreed upon in advance. In addition, the third pillar of the Basel regulatory framework, the disclosure requirements, requires that banking activities be transparent to the public. Banks must provide sufficient information on the state of their balance sheet.

Everything is designed to ensure that investors are fully aware of the situation and the risks surrounding the CoCos. Therefore, everything is done to ensure that investors are fully aware of the situation and risks surrounding CoCos. With well-informed, time-consistent and rational investors, there should be no destabilizing sudden adjustments. And yet there are some. What explains these market disruptions? What could be their consequences on the rest of the economy?

To answer these questions in the remainder of this section, I bring together the existing literature on CoCos with the theoretical literature on systemic risk and financial contagion. I argue that the latter is able to provide explanations for the recent empirical findings of the former.

4.2.1 CoCo-market disruptions as seen through the lens the existing CoCo literature

H. Allen (2012) argues that such disruptions occur precisely because investors do not behave in a temporally consistent and rational manner in the face of CoCos.

CoCos are hybrid assets that are initially issued by banks as debt instruments. Their triggering occurs only with a low probability in a high-consequence tail event. However, investors are known to minimise the risk of tail events (Thaler & Sunstein, 2009). Investors do not buy CoCos to become shareholders. They want to earn high interests and assume that an activation will not happen because the regulator will not let the banks' balance sheet deteriorate. According to Allen, investors clearly underestimate the risks associated with CoCos. They are

⁶² An example among others is the information made available by Credit Suisse on its current CoCos issuances: https://www.credit-suisse.com/about-us/en/investor-relations/debt-investors/bonds-securities/capital-instruments.html?t=910_0.8400251504923708

behaving as if they are a simple debt instrument that pays more than standard bank bonds. In this context, the yield of contingent convertible bonds does not reflect the cost of risk of an activation and revaluations are likely to be abrupt in case of activation or activation risk. The initial yield of contingent convertible bonds does not reflect the cost of risk of an activation and the market regularly undergoes sudden revaluations when there is uncertainty about the ability of banks to continue making interest payments and principal repayments.

These concerns are found in other works (Admati et al., 2013; Goodhart, 2010; Sundaresan & Wang, 2015) but were mostly speculative until now. The recent market disruptions have reignited them and have been used as treatment experiments in two empirical papers.

Mendes et al. (2022) propose an empirical analysis of CoCos based on three systemic risk measures: SRISK, SES and ΔCoVaR . They show that when banks issue CoCos for the first time, it helps to mitigate systemic risk. This is due to the fact that Additional Tier 1 helps to strengthen the solvency of banks (which is consistent with the findings of the previous chapters of this thesis). However, they show that systemic risk increases when banks pile up several issuances. The authors outline a possible explanation: investors could be afraid that banks are raising too much capital, or that they are reissuing CoCos because they are distressed. They do not elaborate on how this would generate additional systemic risk and suggest further investigation.

Bologna et al. (2020) analyse the two stress episodes experienced by Deutsche Bank in 2016 (described in section 1.1.6). They regress the daily yield-to-maturity (YTM) of the CoCos of European banks (excluding Deutsche bank) on two sets of controls:

- The banks' stock return and the YTM of their senior bonds. This set captures the extent to which the CoCo YTM can be explained by fundamental contagion related to two fundamental variables: the solvency risk (proxied by the YTM of the banks' senior bonds) and the expected profitability (proxied by the banks' equity return).
- The YTM of Deutsche Bank's CoCos and its interaction with a dummy for each of the two stress events. This set captures interdependence between DB's CoCos and CoCos of other banks (specific contagion channel during the stress periods).

They show that the overreaction of the YTM on the CoCo market compared to the behaviour of the YTM on the senior bond market seems to validate the existence of a channel

of contagion which is specific to CoCos. They show another important result: the CoCo-specific contagion channel seems to weaken with time as investors get more familiar with CoCos.

These two empirical papers therefore show that CoCos are associated with significant risks. But this is only an empirical observation and does not explain the mechanisms at work. The theoretical literature on systemic risk and financial contagion provides more insight on this subject.

4.2.2 The theoretical literature on systemic risk and financial contagion

As Aymanns et al. (2018) points out, two different readings of the 2008 crisis tend to conflict. The first is to see it as the consequence of the bursting of the housing bubble. By relying on MBS, banks became more and more confident and felt more and more secure. This led to an increase in lending to households and the purchase of financial securities on credit by banks. This fuelled the housing bubble, which eventually burst, causing massive losses for the banks that held a lot of MBS. The credit market froze. The banking crisis spread to the real world, resulting in an economic crisis. The second interpretation consists in seeing it as an emerging phenomenon resulting from an accumulation of systemic risks favoured by a procyclical backward-looking risk management of financial institutions. The bursting of the real estate bubble is what started the fire, but the spark could have come from elsewhere.

This second reading of the 2008 crisis emphasizes the interconnection between the banks that make up the financial sector. Banks are not isolated. They form networks as empirically demonstrated in several countries: Langfield et al. (2014) for the United Kingdom, Mahdavi Ardekani (2020) for France, Craig & von Peter (2014) for Germany, Degryse & Nguyen (2007) for Belgium or van Lelyveld & Liedorp (2006) for the Netherlands.⁶³

This interconnectedness is likely to exacerbate the fragility of the banking sector (Allen & Gale, 2000) as it produces two effects. On the one hand, the decisions taken by individual banks, all of which are individually prudent, are likely to create risks at the scale of the entire system that do not correspond to the simple combination of individual risks. This is referred to as systemic risk. On the other hand, difficulties of one financial institution can spread to other financial institutions that are directly or indirectly related to it. This is referred to as financial contagion and the mechanisms through which this takes place are called contagion channels. Aymanns et al. (2018) lists four different ones:

⁶³ A more exhaustive empirical literature review on bank networks can be found in Iori & Mantegna (2018).

- Overlapping portfolio contagion: This is caused when a troubled bank sells its assets to restore its liquidity ratio, causing prices to fall and forcing it to sell even more. This affects the value of the assets of the entire banking sector. If two banks have invested in the same asset and one of them is in trouble (e.g., a sudden drop in the value of its assets), it will react by triggering fire sales, further depressing the price, which will affect the portfolio of the other, previously solid bank.
- Counterparty loss contagion: This is caused by bilateral contracts. The assets of one bank are the liabilities of another. When a borrower is unable to repay, the lender's balance sheet is affected. This can be transmitted to other agents. This type of contagion also affects the asset value of the entire banking sector. If bank A has lent to bank B, and bank B is in trouble, then the value of bank B's assets will plummet and the market value of the money lent will plummet. There is a risk that it will not be able to pay back some or all of the loaned money. If this loss is greater than the equities of bank A, it too may fail.
- Funding risk contagion: This is caused when a lender is in difficulty and its regular debtors no longer have access to financing that they normally receive. This affects the availability of financing. A bank in trouble refuses to lend to other banks, which may then get into trouble and themselves refuse to lend to other banks and so on until the credit market is frozen.
- Information contagion: It is caused when a negative signal is sent by a bank (information spillovers). Investors draw a conclusion about the general state of the sector and their own bank (even if it is not necessarily the one in trouble). Banks then have to borrow at higher rates. This contagion is therefore strongly linked to the general state of confidence of the market.

It thus appears that Bologna et al. (2020) and Mendes et al. (2022) describe without naming it a phenomenon of financial contagion through information spillovers. As H. Allen (2012) suspected, it seems that investors behave irrationally towards CoCos given their low activation risk. They bet on their low activation risk and panic at the slightest sign of difficulty on the part of banks. Yet CoCos were designed to bail in banks when they need it. If investors get rid of them at times that are critical for troubled banks and in doing so affect previously strong banks, it is questionable whether CoCos are not turning against the financial sector.

4.3 PRESENTATION OF THE MODEL⁶⁴

Systemic risk and financial contagion through information spillovers are not captured at all by the JMAB extension proposed in Chapter 3. In particular, there is no possibility for banks to delay the repayment of their CoCo principals when they fear for their solvency, like Deutsche Bank Lloyds Banking Group did recently (see section 1.1.6). Despite the fact that such possibilities are foreseen in contracts, they come as a surprise to investors and produce effects on the CoCo market via information spillovers. According to Bologna et al. (2020), these effects diminish as new disruptions occur and as investors learn from what is happening. This type of financial contagion is likely to produce non-linear interactions that generate positive feedback loops likely to generate endogenous dynamics. While the simple adaptive expectations showed in equation 1 in section 3.3.2 make sense for a number of behavioural rules and are used in other agent-based models (e.g. Assenza et al., 2015; Dosi et al., 2010), they are too simplistic to account for these nonlinearities.

A comprehensive assessment of contingent convertible bonds in a stock-flow consistent agent-based model therefore requires a further extension of the JMAB model, focusing on expectation formation. This section details such an extension.

4.3.1 Overall structure

The overall structure of the model is the same as in Chapter 3. The same flow matrix applies and is again shown below in Figure 48 as a reminder. The economy is populated by the same types of agents:

- A set of households who work for capital and consumption firms and receive wages in return. They consume and make portfolio arbitrage between bank deposits and banks' contingent convertible bonds. Households pay taxes on their gross income and own shares in banks, consumption firms and capital firms from which they receive dividends. Finally, unemployed households receive unemployment benefits from the government.
- Two sets of firms: consumption firms and capital firms. Consumption firms produce consumption goods sold to households, using labour and capital goods produced by capital firms. Firms borrow from banks to finance their investment and production. Retained earnings are held as deposits.

⁶⁴ A list of the mentioned parameters can be found in Appendix E

- A set of banks that collect deposits from capital firms, consumption firms and households, purchase government-issued bonds, provide credit to both types of firms and issue contingent convertible bonds sold to households. They are subject to liquidity and capital adequacy constraints. Banks can request cash advances from the Central Bank when they lack the liquidity to meet these requirements. Issuing credit results in a contingent increase in the size of their balance sheets. As loans create deposits, the quantity of money in the model is determined endogenously.
- A public sector consisting of a central bank and a government. The central bank holds both banks' reserve accounts and the government's account. It supplies advances to banks at a fixed exogenous rate and buys residual government bonds that have not been purchased by banks. Its profits are transferred to the government. The government issues bonds to cover its deficit and collects taxes from banks, capital firms, consumption firms and households. It also pays unemployment benefits to unemployed households.

Regarding the behaviour of the different agents, no changes are made to the firm sector and the public sector. There are also no changes to bank and household behaviours unrelated to CoCos. The reader is referred to the corresponding sections of Chapter 3 for more details (section 3.3.2 on Agent's behaviour) and to the online appendix for the full model code⁶⁵.

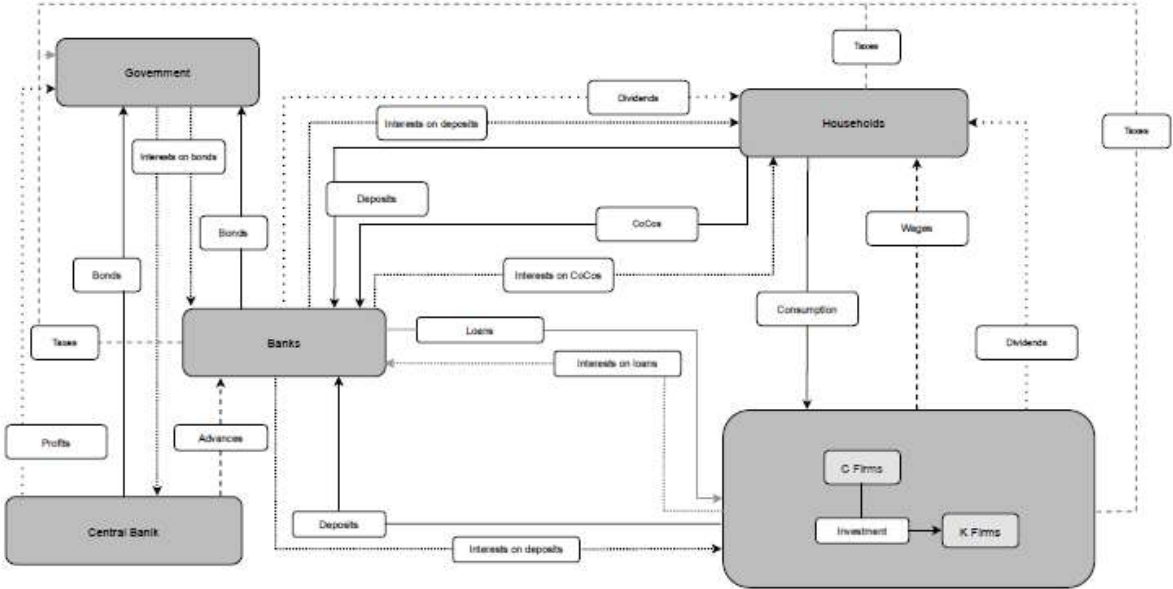


Figure 48: Flow diagram of the model. Arrows point from paying sector to receiving sector

⁶⁵ The full code can be found online: https://github.com/elskr/sfc-abm_coco_contagion

4.3.2 The contingent convertible bond market

4.3.2.1 Issuances

CoCo supply still follows the same rule. Banks issue CoCos up to 1.5% of their net worth in order to optimize their Additional Tier 1 Capital. The individual real supply and aggregate real supply of CoCos are therefore given by equation (A) and (B).

$$coco_{b,t} = \frac{AddT1^T NW_{b,t-1}}{pbc^T} \quad (A)$$

$$coco_t = \frac{AddT1^T NW_{t-1}}{pbc^T} \quad (B)$$

With:

- $coco_{b,t}$: the real supply of CoCos of bank b in period t
- $coco_t$: the aggregate real supply of CoCos in period t
- $AddT1^T$: the substitutability between Additional Tier 1 capital and Tier 1 capital decided by the regulator (1.5% here)
- $NW_{b,t-1}$: the net wealth of bank b in period $t-1$
- NWB_{t-1} : the net wealth of the banking sector in period $t-1$
- pbc^T : the announcement price of CoCos (exogenous and fixed)

4.3.2.2 Deferral of principal repayment

This is the first major addition to the model. Consistent with previously mentioned empirical observations, banks should be able to delay repayment of the principal of soon-to-be-matured CoCos when they fear for their solvency. This means that each bank b has a capital adequacy ratio threshold CAR_b^T below which it delays principal repayment.

What capital adequacy ratio banks consider too low depends on whether they are optimistic or cautious about the economic situation and their liquidity capacity. For example, banks were much more cautious during the Covid-related economic crisis (hence the disruptions seen in the market) than before the crisis. Let $\overline{CAR^T}$ and $\underline{CAR^T}$ be respectively the optimistic and pessimistic exogenous capital adequacy thresholds under which banks decide to defer CoCo principal repayment, with $\overline{CAR^T} < \underline{CAR^T}$ (the criteria for deferral are more restrictive when banks are cautious).

Non-linear dynamic opinion are introduced, similar to what Salle & Sepecher, (2015) did for households and firms in an agent-based model. Each bank's opinion, whether cautious

or optimistic, depends on both its own situation and the prevailing majority sentiment among the banking sector.

- With a probability of $1-p$, the bank relies on its own situation and looks at its liquidity ratio at the beginning of the period. If it is high enough (above a threshold LR^T), the bank is confident in its ability to repay CoCo principals ($CAR_b^T = \overline{CAR^T}$). If it's too low (below a threshold LR^T), the bank is more cautious ($CAR_b^T = \underline{CAR^T}$).
- With a probability p , the bank relies on the prevailing majority opinion among $b < size_B$ other banks. If most are confident, the bank is confident as well ($CAR_b^T = \overline{CAR^T}$). If most are cautious, the bank is cautious too ($CAR_b^T = \underline{CAR^T}$).

In practice, banks defer repayment as long as they feel they are in a critical solvability situation. And there will be activation of CoCos if they do not get out of this situation (delaying does not increase the net worth of the banks but prevents it from falling further).

4.3.2.3 Demand

CoCo demand still follows the same Tobin portfolio allocation, with one adjustment highlighted in bold in equation (B).

$$lp_{h,t} = \begin{cases} [\mathbf{1} + \xi_{h,t} \cdot \mathbb{1}_{delay;t}] \cdot \sigma_1 \cdot \exp\left(-\sigma_2 \left[\frac{\overline{BCO}}{i_t^{BCO}} (1 - Pr_t^{activation}) - \bar{i}_t^d\right]\right) & \text{if } \frac{\overline{BCO}}{i_t^{BCO}} \geq \bar{i}_t^d \\ [\mathbf{1} + \xi_{h,t} \cdot \mathbb{1}_{delay;t}] \cdot \sigma_1 & \text{if } \frac{\overline{BCO}}{i_t^{BCO}} < \bar{i}_t^d \end{cases} \quad (B)$$

$$\mathbb{1}_{delay;t} = \begin{cases} \mathbf{1} & \text{if some principal repayment got delayed in period } t \\ \mathbf{0} & \text{if no principal repayment got delayed in period } t \end{cases} \quad (C)$$

$$D_{h,t} = lp_{h,t} NW_{h,t} \quad (D)$$

$$COCO_{h,t} = (1 - lp_{h,t}) NW_{h,t} \quad (E)$$

With:

- σ_1 such as $0 < \sigma_1 < 1$, an exogenous upper bound to the share of wealth that households want to hold in the form of deposits.
- σ_2 such as $0 < \sigma_2 < 1$, a fixed parameter acting as a proxy for how sensitive households' portfolio arbitrage is to changes in expected rate of return and perceived risk of CoCos.
- $\frac{\overline{BCO}}{i_t^{BCO}}$: the average interest rate on CoCos in period t

- \bar{i}_t^d : the average interest rate on deposits in period t
- $(1 - Pr_t^{activation})$: the probability CoCos won't activate in period t
- $\xi_{h,t}$ such as $0 < \xi_{h,t} < 1$, the size of households' reaction to a repayment delay announcement from banks
- $COCO_{h,t}$: the nominal demand for CoCos of household h in period t
- $NW_{h,t}$: the net wealth of household h in period t

If a bank announces a delay in repayment of CoCos, then the indicator function $\mathbb{1}_{delay,t}$ (equation C) takes the value 1 and the nominal demand of household h in period t for deposits is adjusted according to the parameter $\xi_{h,t}$. Since households' savings are allocated between deposits and CoCos, this adjustment $\xi_{h,t}$ affects the demand for CoCo in the opposite direction. This means that if any bank announces a delay in the repayment of its CoCos, this will trigger an information spillover process. Investor households will do the same thing they did in 2016 following the Deutsche Bank announcement: they will turn away from the CoCos market and suddenly readjust their portfolio allocation.

We now need to specify the size of this adjustment $\xi_{h,t}$. We could consider it as a fixed exogenous parameter. But the existing literature would contradict such a decision. Consistent with the findings of Bologna et al. (2020), the information-based financial contagion channel appears to fade over time as investors learn about what is happening on the market. Hence the second major addition to the model: learning behaviours from investors. It is not realistic that investors always react naively in the same way to the announcement of a deferral of repayment. Rather, it appears that they initially overreact and then adjust their portfolio reallocation.

Formally, we introduce stochastic reactive reinforcement learning into the model with a modified Roth-Erev algorithm.⁶⁶ We allow households to explore 7 possible reactions to the announcement of delayed repayment: a 60%, 50%, 40%, 30%, 20%, 10% decrease in the proportion of their savings devoted to CoCos, as well as no decrease at all⁶⁷. Each reaction j (with j an integer between 0 and 6) is associated with a propensity q_j to choose it. After being set exogenously to initialize the model, they are updated according to the following endogenous process:

⁶⁶ For full details, see Nicolaisen et al. (2001) who proposed this modified version of the Roth-Erev algorithm for the first time.

⁶⁷ $\xi_{h,t}$ can take the values 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1 and 0.0

$$q_{j;t+1} = \begin{cases} [1 - r] \cdot q_{j;t} + Interests_{j;t}^{TOT} \cdot [1 - e] & \text{if action } j \text{ has been chosen} \\ [1 - r] \cdot q_{j;t} + q_{j;t} \cdot \frac{e}{N} & \text{if another action has been chosen} \end{cases} \quad (F)$$

With:

- r such as $0 < r < 1$, the so-called recency parameter.
- e such as $0 < e < 1$, the so-called experimentation parameter $\overline{i_t^{BCO}}$: the average interest rate on CoCos in period t
- N the number of possible actions (here, $N = 7$)
- $Interests_{j;t}^{TOT}$: the payoff associated with the choice of action j (i.e., the total interests earned in period t by the investor making this decision, equal to the sum of CoCo interests and deposit interests)

A number of things need to be clarified at this point:

- First, the propensities to choose a stock in period t depend on the value of these propensities in period $t-1$. The initialization of the parameters thus makes it possible to guide the initial choices made by the investors. If we want to model an over-reaction in portfolio allocation following a delay announcement, we have to calibrate the initial propensities in favour of the higher intensity adjustment.
- Second, once the model is initialized, the propensity to choose action j is updated according to what that choice yields ($Interests_{j;t}^{TOT}$). The exploration parameter e encourages investors to explore different options. If e tends towards zero, then choosing action k over action j has no positive effect on the propensity to choose j . Only the propensity of action k is updated. Once an action begins to be preferred, it remains so. As e increases, there are more spillovers of reward and the other actions still have a greater chance of being explored.
- Investors are likely to forget what they learn. This is the role of the recency parameter r . If r tends towards 1, more weight is given to recent payoffs (in the extreme case where $r = 1$, investors no longer take into account what has happened so far). If r tends towards zero, equal weight is given to all payoffs received to date.

In the model, these propensities are updated each time the CoCos market is disrupted by a repayment delay. Once they are all calculated, probabilities of choosing each action are deduced. The probability of choosing action j thus depends on the relative propensity of action j compared to the total sum of propensities. It is given by the following formula:

$$p_{j;t} = \frac{q_{j;t}}{\sum_{n=0}^{N-1} q_{n;t}} \quad (G)$$

This is done for each household, resulting in completely heterogeneous behaviours when faced with a refund announcement. No reaction is imposed in an *ad hoc* manner. Households explore on their own the option that brings them the most benefit. This exploration is done stochastically. There is no guarantee that they will all arrive at the same "optimal" reaction. But we will be able to observe trends in the section devoted to simulations.

4.3.2.4 Contingent convertible bond interest rate

CoCo interest rate setting works in exactly the same way as presented in Chapter 3. Banks compete in the contingent convertible bond market by choosing their interest rate on CoCos (see equation H). It depends on the difference between banks' current liquidity ratio and the target liquidity ratio (determined as the sector average for the past period). When their liquidity ratio is above the target, banks set their interest rate on contingent convertible bonds with a positive mark-up over the average CoCo interest rate to attract investors. When their liquidity ratio is below target, banks lower their interest rate on contingent convertible bonds to limit interest payments and thus restore their liquidity ratio. Thus, it is the CoCos of the most stable banks that tend to attract the most investors (consistently with observations made by Avdjiev et al. (2020)). A bank in an already fragile situation may issue CoCos but it will not be able to afford to pay high interest on them. Its CoCos will then be relatively less attractive to investors.

$$i_{b,t}^{BCO} = \begin{cases} \overline{i_{t-1}^{BCO}} (1 + FN) & \text{if } LR_{b,t} \geq LR_t^T \\ \overline{i_{t-1}^{BCO}} (1 - FN) & \text{if } LR_{b,t} < LR_t^T \end{cases} \quad (H)$$

With:

- $i_{b,t}^{BCO}$: the interest rate on CoCos of bank b in period t
- $\overline{i_{t-1}^{BCO}}$: the average interest rate on CoCos in period t-1
- FN : draw from a folded normal distribution $(\mu_{FN}, \sigma_{FN}^2)$
- $LR_{b,t}$: the liquidity ratio of bank b in period t
- LR_t^T : the target liquidity ratio

4.3.2.5 Contingent convertible bond pricing

CoCo price setting follows the same rules as in Chapter 3. The final price at which CoCos are traded is different from the announcement price p_{bco}^T . This is a market clearing price which balances aggregate supply and demand. We have:

$$pbco_t = COCO_t/coco_t \quad (22)$$

With:

- $pbco_t$: the market clearing price for CoCos in period t
- $COCO_t$: the aggregate nominal demand for CoCos in period t
- $coco_t$: the aggregate real supply for CoCos in period t

4.3.2.6 Contingent convertible bond market matching mechanism

The market matching mechanism includes an addition. As long as a bank is in the process of deferring a principal repayment, it no longer has any probability of being selected as a CoCo supplier. This means that the reaction of investors to a market disruption is twofold: it concerns both all banks as nominal demand for CoCos decreases, as well as the distressed bank which is temporarily excluded from the CoCos market.

Otherwise, the market matching mechanism is the same as in chapter 3. Following Riccetti et al. (2015), households are allowed to observe the interest rates charged by a random subset of banks (whose size depends on the degree of imperfect information investors face: they compare all interest rates if they have access to perfect information, or only a few otherwise). Following Delli Gatti et al. (2010), households switch from their previous partner to the best potential partner with a certain probability given by a non-linear function of the distance between the two compared interest rates. This means that households do not necessarily switch banks to buy their CoCos, even if they find a higher interest rate elsewhere. This inertia reflects their habits.

Households may exhaust the stock of CoCos available at a given bank. In this case, they look for other suppliers in the randomly selected subset.

4.4 NUMERICAL SIMULATIONS

The model is initialized by first numerically solving an aggregate version that converges towards a real stationary state and a balanced nominal growth path. At this stage, all agents are identical. Only then do microeconomic interactions begin and bring out heterogeneity.

A Hodrick-Prescott filter is applied on each time series to separate their cyclical component from their trend component. As a result, the statistical tests and econometric analyses conducted in the following sub-sections are performed on stationary time series. Otherwise, the tests would be invalid and the estimates spurious.

4.4.1 Empirical validation

The first step is to empirically validate the model and check whether this new extension of the JMAB model affects its ability to reproduce the stylized facts presented in section 3.4.1. The introduction of dynamic opinions and learning behaviours into JMAB should not unduly disrupt its ability to capture economic phenomena that are observable in the real world. Since the different parameters added to this extension of the model cannot be directly estimated, it is also a way to justify their value setting for the baseline scenario.

The baseline scenario consists in 100 Monte Carlo Simulations of 400 periods each. We use the results of these simulations to check whether the model is able to reproduce the same stylized facts as the original JMAB model. This is done by comparing the properties of our artificially produced time series with those of real time series, following the same method as Caiani et al. (2016).

These simulations produce similar results to those presented in Chapter 3, suggesting that this new extension of JMAB is empirically grounded. At the macro level, inflation is lagging and pro-cyclical (see Figure 49). Firms' total debt and leverage are pro-cyclical (see Figure 50, top and bottom left, and bottom right). Banks' leverage is pro-cyclical (see Figure 50, top right).

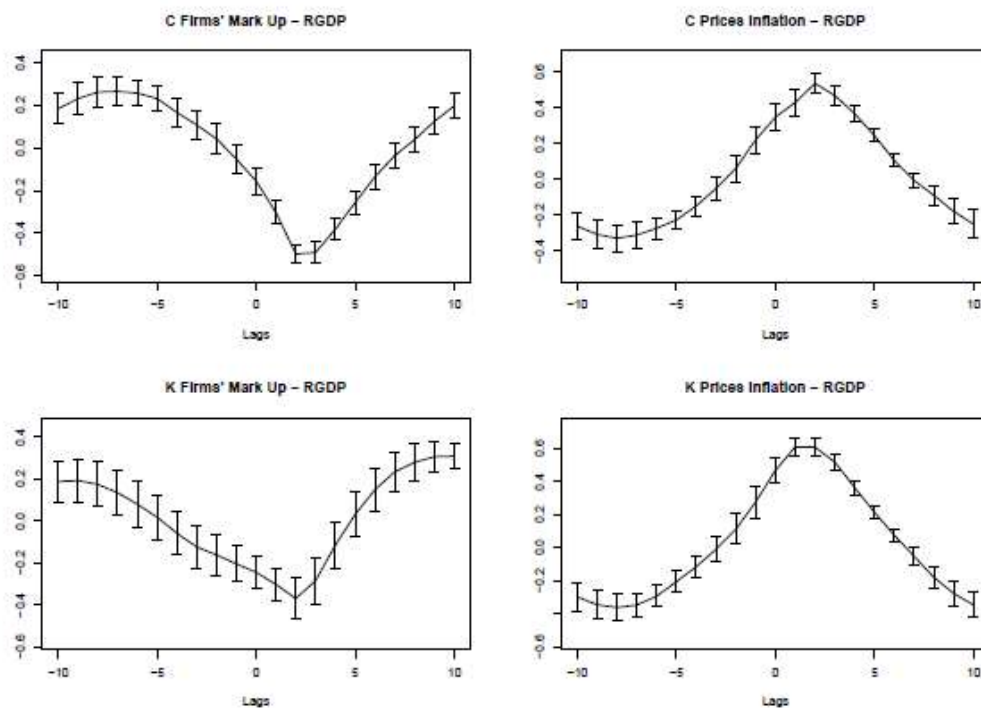


Figure 49: Average artificial cross-correlations of the markup and price de-trended series up to the 10th lag. Segments show the standard deviations of Monte Carlo average cross-correlations.

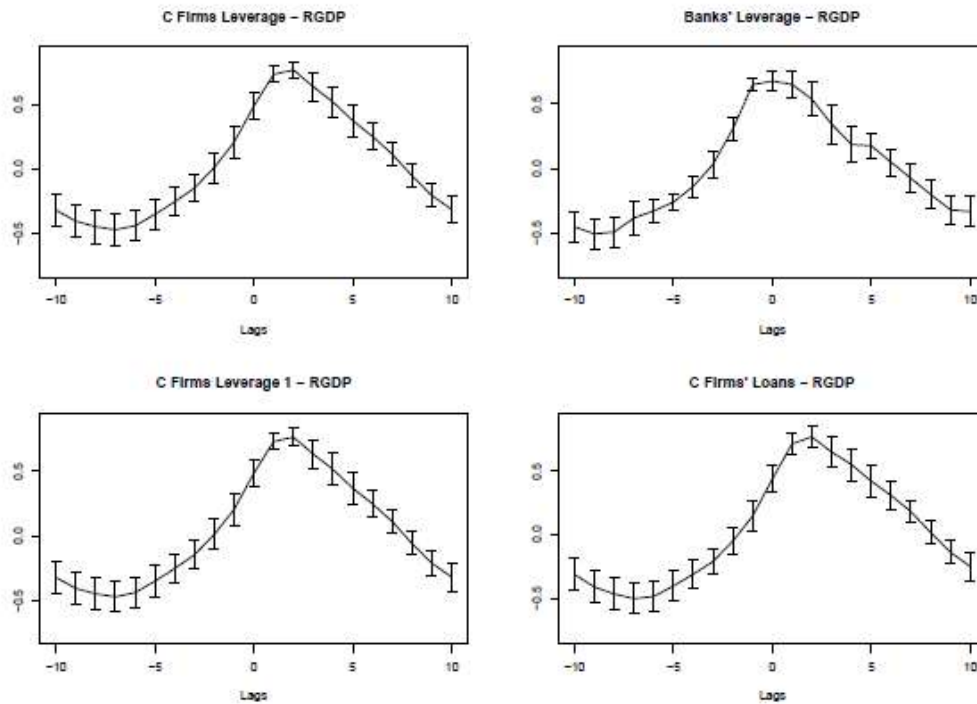


Figure 50: Average artificial cross-correlations of the markup and price-detrended series up to the 10th lag. Segments show the standard deviations of the Monte Carlo average cross-correlations.

At the micro level, we again observe the lumpiness property of the investment (see Figure 51), as well as the high persistency in firms' market shares (see Figure 52 and Figure 53 for respectively capital firms and consumption firms).

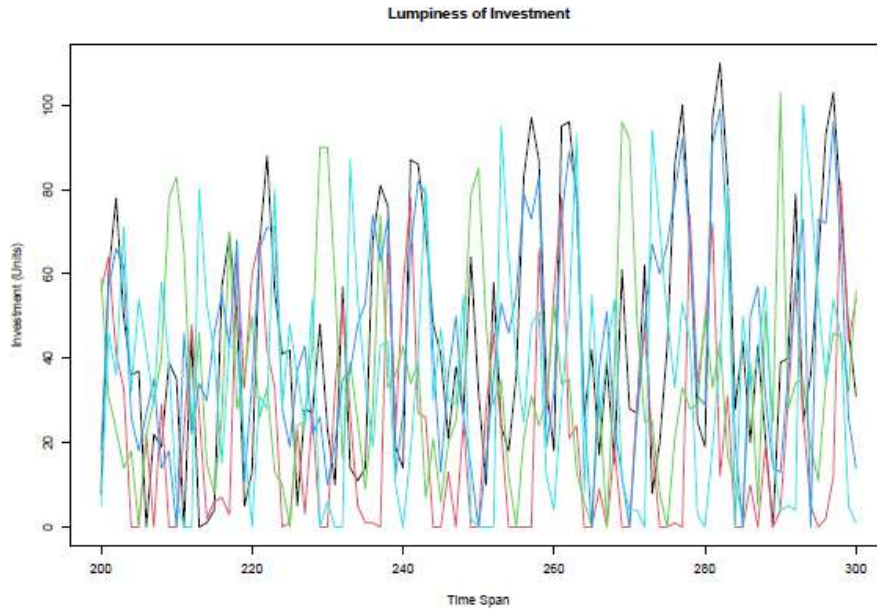


Figure 51: Hump-shaped investment. Lines show 5 consumption firms between periods 200 and 300 of a single simulation run.

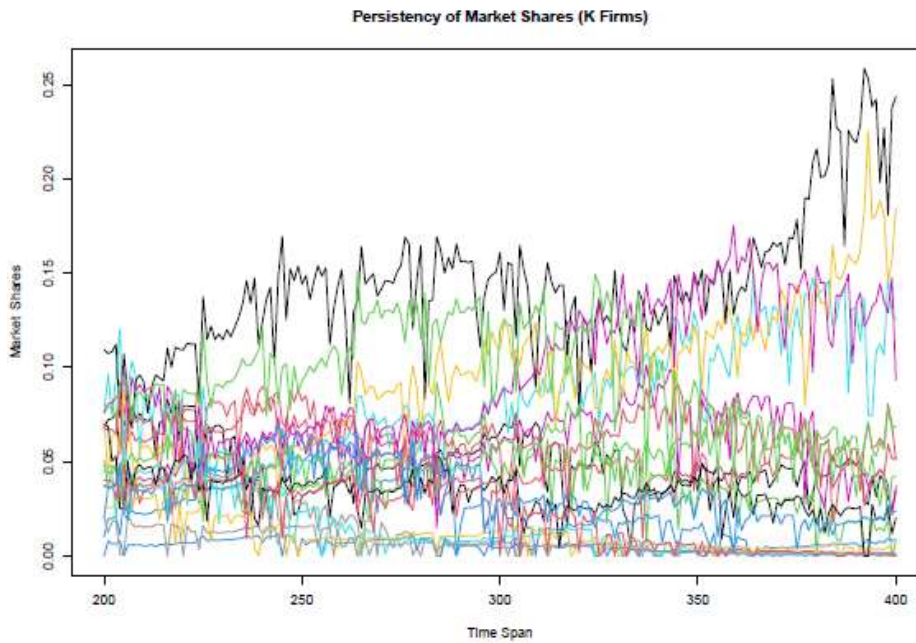


Figure 52: Market shares persistency for capital firms. Lines show 20 capital firms between periods 200 and 400 of a single simulation run.

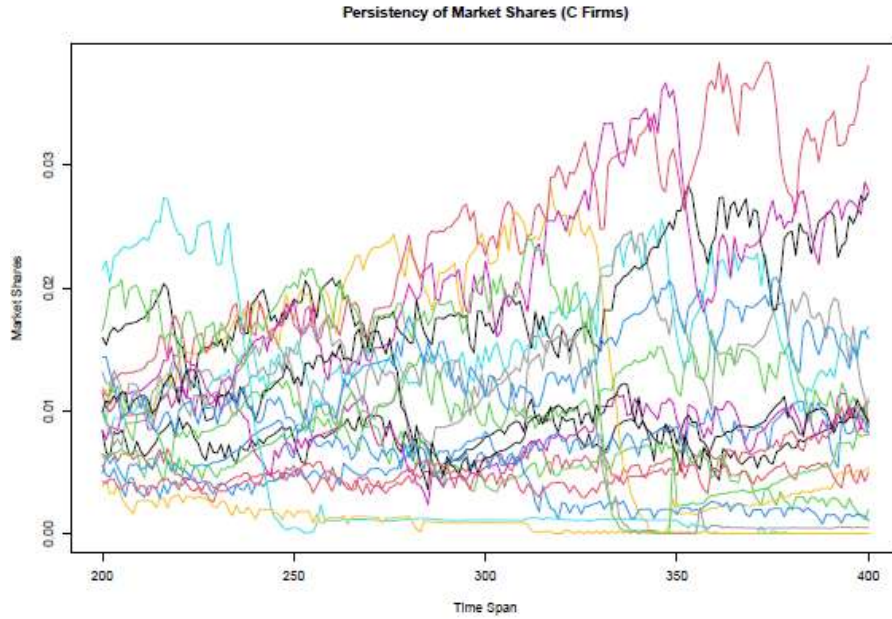


Figure 53: Market shares persistency for consumption firms. Lines show 20 capital firms between periods 200 and 400 of a single simulation run.

Similar results are also found for the size distribution of capital and consumption firms, as measured by their total sales. In order not to overload this section, Table 11 summarizes the shape parameters and the results of the statistical tests performed. The size distribution is still leptokurtic for both types of firms. The Jarque-Bera tests reject in both cases the normal distribution hypothesis. Not much more can be said about the exact fit that the distribution of capital firms follows, but that of consumption firms matches a log-normal fit. Figures 54 and 55 illustrate these results.

Table 11: Summary of the distribution analysis of capital and consumption firms' size (measured by their sales)

	Capital firm size	Consumption firm size
Skewness	1.87	1.38
Excess kurtosis	4.42	2.65
Jarque-Bera p-value	0	0
Jarque-Bera χ^2	2581.3	5015.3
Bootstrap check's p-value	0.88	0
Vuong p-value	0.8806367	-
Vuong likelihood ratio	0.1501621	-

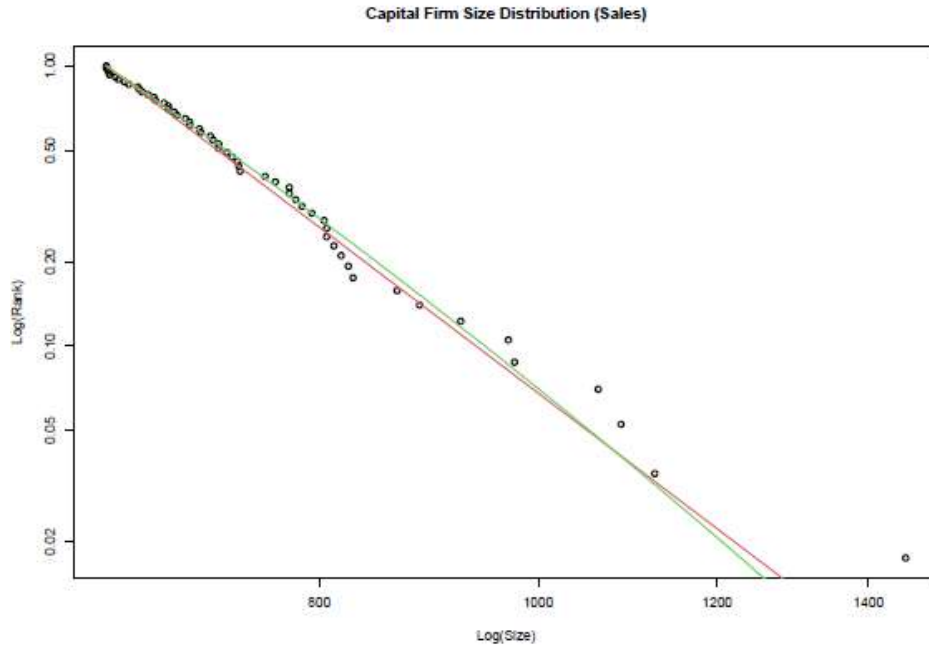


Figure 54: Capital firms upper tail size distribution (dots), log-normal fit (green line) and power-law fit (red)

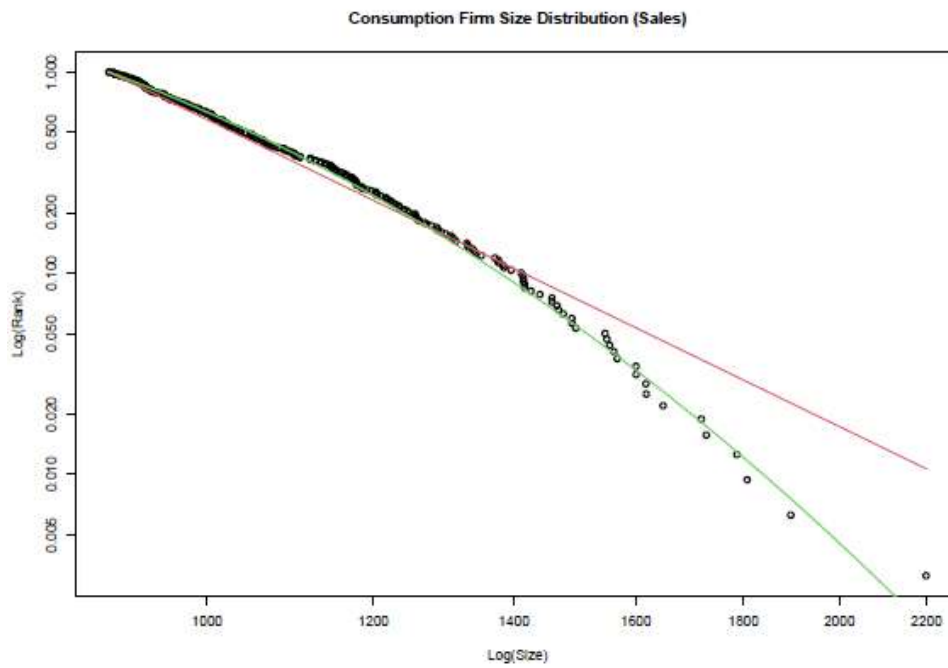


Figure 55: Consumption firms upper tail size distribution (dots), log-normal fit (green line) and power-law fit (red)

This version of the model is also able to reproduce an important financial stylized fact: large changes in asset prices occur more often than would be expected with a normal distribution and rationally behaving investors. More precisely, fat tails are observable in the distribution of asset price variation (Cont, 2001).

Such fat tails can be observed for the price change of CoCos as shown in Figure 56. A Jarque-Bera statistical test yields a p-value equal to 0 and a χ^2 respectively equal to 101551. Thus, the normal distribution hypothesis is unquestionably rejected for CoCo price changes.

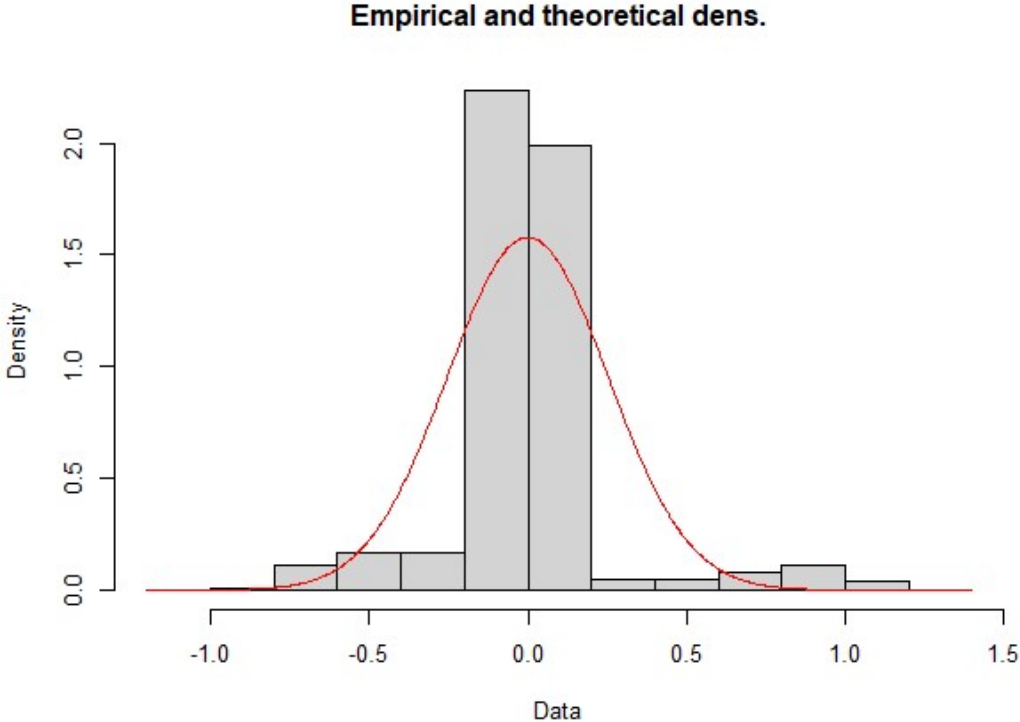


Figure 56: Empirical distribution of CoCo price changes (bars) and theoretical normal distribution (solid curve)

This version of the JMAB model therefore reproduces macro, micro and financial stylized facts. It should be noted, however, that it is not possible to explore the latter in more detail due to the limitations of JMAB. Financial markets are not fully fleshed out. For example, there is no secondary market. Further work to make the financial sphere more complex is needed to open up further possibilities for empirical validation of the model.

4.4.2 The impact of contingent convertible bonds on financial contagion

How information spillovers and learning behaviours work in the model

Before analysing the possible role of CoCos in financial contagion, it is important to describe how the spillover information system and learning behaviours work in the model, and how they are sensitive to parameter changes.

The model is able to reproduce information spillovers on the CoCo market and the resulting learning behaviour. Banks occasionally announce postponements of repayments (see Figure 57, left). With each announcement, there is an information spillover and investors abruptly adjust the share of CoCos they hold in their portfolio arbitrage. The baseline scenario gives a higher initial propensity to the extreme choice of reducing the share of CoCos in one's asset portfolio by 60% (see the baseline calibration in Appendix C). In a typical simulation (shown in Figure 57, right), investors reduce this share by an average of about 38.7% when the first deferral is announced around period 150. But we observe that the size of this adjustment decreases over time. First rapidly, then more slowly, until it converges towards an adjustment of around 21%. This suggests that investors are overreacting in a way that is detrimental to them and their financial income. This is consistent with the existing literature that warns of the temporal inconsistency and irrationality of CoCos buyers (Admati et al., 2013; H. Allen, 2012; Goodhart, 2010; Sundaresan & Wang, 2015). They behave as if the asset were a simple debt instrument with too little chance of being activated and panic when clauses explicitly provided for in the contracts are activated. By withdrawing abruptly from the market, this leads to a loss of income for them. As they realise this, they adapt their behaviour to maximise the interests they receive. This leads to a strategy that is optimal on average across the sector when convergence is achieved, but still involves a downward adjustment in demand for CoCos following market disruptions.

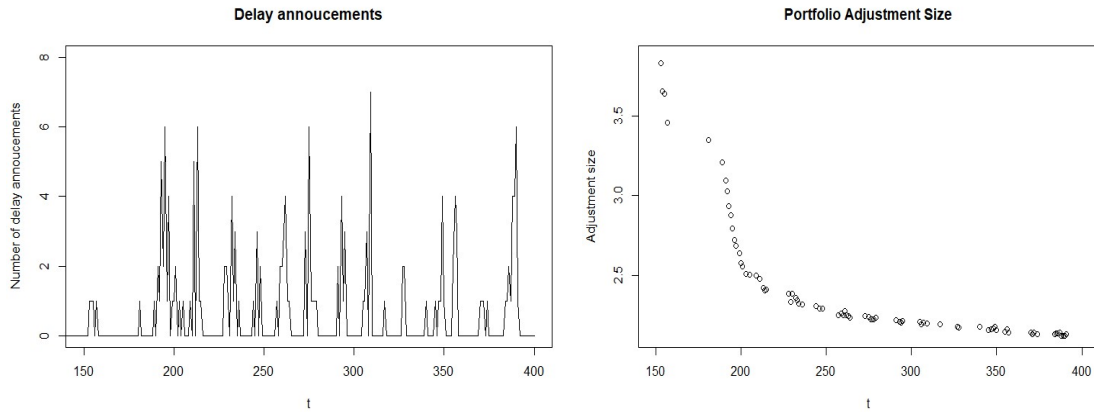


Figure 57: Number of repayment deferrals announced by banks (left) and portfolio size adjustment following a CoCo repayment deferral (right) between periods 100 and 400 for a typical single simulation

Table 12 shows the different parameter sweeps performed for robustness checks. The learning phenomenon is present in the model, regardless of the parameter sweeps performed on the initial propensity assigned to the extreme choice of reducing the share of CoCos in one's financial asset portfolio to 60% (q_6), the recency parameter (r) and the exploration parameter (e).

Table 12: Parameter sweeps

Parameter	Description	Baseline	Increment	Sweep
q_6	Initial propensity of adjustment size = - 60%	8	2	[2 ; 10]
e	Exploration parameter	0.1	0.2	[0 ; 1]
r	Recency parameter	0.2	0.2	[0 ; 1]

Each of these parameters affects the dynamics of learning behaviour in a specific way. Adjusting q_6 changes the magnitude of the investors' initial reaction. The higher the value, the more they will react to a deferral announcement (see Figure 58). Adjusting r changes the time it takes for investors to adapt to disruptions in the market. The higher r is, the less inertia there is in their adjustments and the faster they converge to an optimal reaction after an announcement of a repayment delay (see Figure 59). Finally, adjusting e changes the size of the portfolio adjustment towards which average investor reactions converge. The higher the value of the parameter, the less likely they are to abandon solutions that consist in heavily adjusting their asset portfolio, resulting in a higher convergence value (see Figure 60).

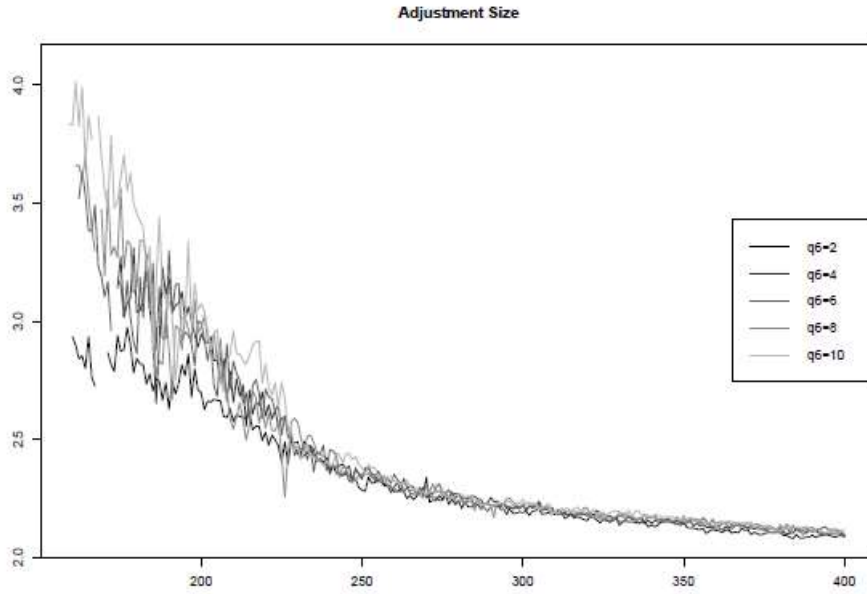


Figure 58 : Portfolio size adjustment following a CoCo repayment deferral (right) between periods 150 and 400 for different values of $q6$ (25 Monte Carlo simulations per parameter value)

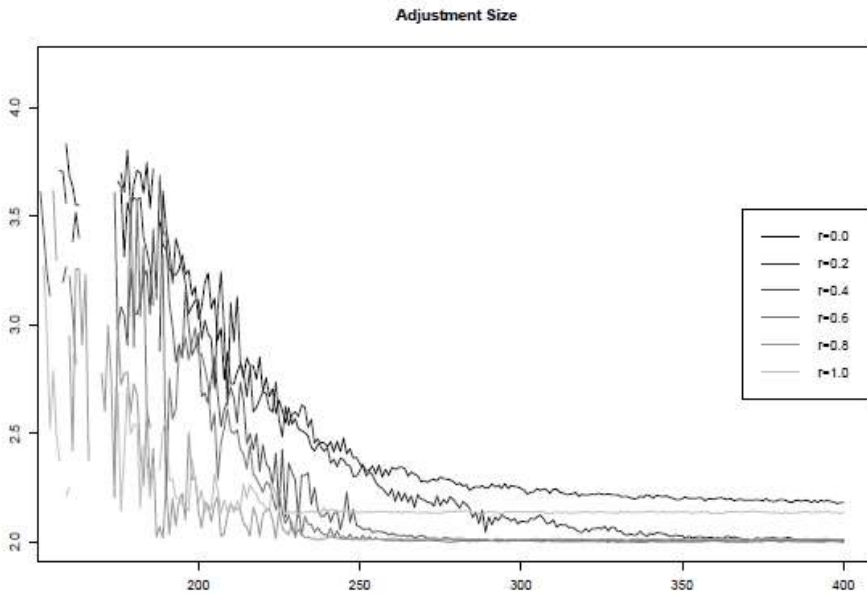


Figure 59: Portfolio size adjustment following a CoCo repayment deferral (right) between periods 150 and 400 for different values of r (25 Monte Carlo simulations per parameter value)

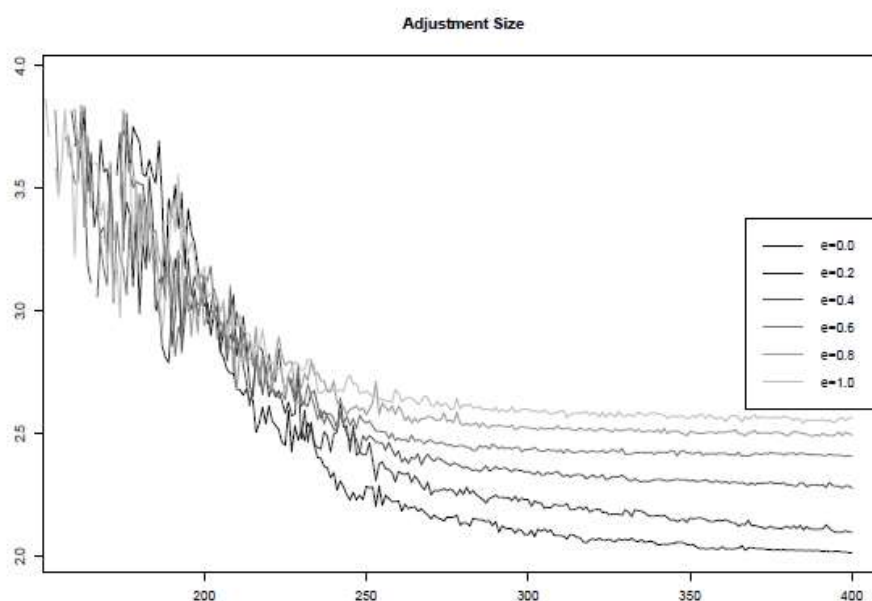


Figure 60: Portfolio size adjustment following a CoCo repayment deferral (right) between periods 150 and 400 for different values of e (25 Monte Carlo simulations per parameter value)

Contingent convertible bonds and information-based financial contagion

The model is able to reproduce what was observed by Bologna et al. (2020). A non-refund announcement induces a sharp drop in the aggregate demand for CoCos. But as the situation is repeated, the adjustment decreases, suggesting that investors are learning. The question is whether these information spillovers are likely to generate financial contagion in the model. To answer it, we need to rely on a measure of financial contagion. Several are used in the literature and are listed by Acharya & Yorulmazer (2008):

- Intertemporal correlation of bank events
- Risk premiums of bank debt
- Deposit flows
- Stock price reaction

The selection of the financial contagion measure is dictated by the limitations of JMAB. There is no interbank market, so we cannot look at risk premiums on bank debt. There are no deposit runs (households decide which bank to give their deposits to, solely on the basis of the interest rate they offer), so we cannot look at deposit flows. Bank shares are not priced on a secondary market, so we cannot watch their price evolution. But we can look at intertemporal correlation of bank events such as CoCo activations.

I check in the Baseline scenario if the activation of CoCos in period t can be explained by the activation of CoCos in previous periods (which captures a potential domino effect), announcements of delayed repayment (which capture a potential financial contagion through information spillovers), real GDP, loans, capital good inflation and consumption good inflation (to control for the macroeconomic situation). Since we are trying to explain the number of occurrences of an event (CoCos activations) based on panel data (two dimensions: simulation run i , and period t), we need to use a Poisson autoregressive model. A similar approach can be found in Schoenmaker (1996). The R package used is *pglm*.

The first step is to ensure that the time series of the variables selected do not have a unit root, and if so, to transform them so that they do not. Using an augmented Dickey-Fuller (similar to what can be found in Levin et al., 2002), the unit root hypothesis cannot be rejected for GDP and both price levels. But it can be rejected in the changes of these variables. The period-to-period changes in logarithms are therefore used to ensure the absence of unit roots. Formally, I estimate the following models:

$$Y_{t,i} = \alpha_0 + \alpha_1 \Delta GDP_{t,i} + \alpha_2 \Delta GDP_{t,i} + \alpha_3 \Delta P_{t,i}^C + \alpha_4 \Delta P_{t,i}^K + \alpha_5 \Delta DELAY_{t,i} + \alpha_6 \Delta_2 DELAY_{t,i} + \alpha_7 \Delta_3 DELAY_{t,i} + \alpha_8 \Delta_4 DELAY_{t,i} + \alpha_9 Y_{t-1,i} + \alpha_{10} Y_{t-2,i} + \alpha_{11} Y_{t-3,i} + \alpha_{12} Y_{t-4,i} + \eta_{t,i} + \varepsilon_{t,i} \quad (1)$$

$$Y_{t,i} = \beta_0 + \beta_1 \Delta GDP_{t,i} + \beta_2 \Delta LOANS_{t,i} + \beta_3 \Delta P_{t,i}^C + \beta_4 \Delta P_{t,i}^K + \beta_5 \Delta DELAY_{t,i} + \beta_6 \Delta_2 DELAY_{t,i} + \beta_7 \Delta_3 DELAY_{t,i} + \beta_8 \Delta_4 DELAY_{t,i} + \beta_9 Y_{t-1,i} + \beta_{10} Y_{t-2,i} + \beta_{11} Y_{t-3,i} + \beta_{12} Y_{t-4,i} + \eta_{t,i} + \varepsilon_{t,i} \quad (2)$$

$$Y_{t,i} = \gamma_0 + \gamma_1 \Delta GDP_{t,i} + \gamma_2 \Delta GDP_{t,i} + \gamma_3 \Delta LOANS_{t,i} + \gamma_4 \Delta P_{t,i}^C + \gamma_5 \Delta P_{t,i}^K + \gamma_6 \Delta DELAY_{t,i} + \gamma_7 \Delta_2 DELAY_{t,i} + \gamma_8 \Delta_3 DELAY_{t,i} + \gamma_9 \Delta_4 DELAY_{t,i} + \gamma_{10} Y_{t-1,i} + \gamma_{11} Y_{t-2,i} + \gamma_{12} Y_{t-3,i} + \gamma_{13} Y_{t-4,i} + \eta_{t,i} + \varepsilon_{t,i} \quad (3)$$

With:

- $Y_{t,i}$: the number of activated CoCos in period t , run i
- $\Delta GDP_{t,i}$: difference of the real GDP in period t , run i
- $\Delta LOANS_{t,i}$: difference of loans in period t , run i
- $\Delta P_{t,i}^C$: difference of consumption good inflation in period t , run i
- $\Delta P_{t,i}^K$: difference of capital good inflation in period t , run i
- $\Delta DELAY_{t,i}$: difference of delay announcements in period t , run i

- $\Delta_2 DELAY_{t,i}$: difference lagged twice of delay announcement in period t, run i
- $\Delta_3 DELAY_{t,i}$: difference lagged three times of delay announcement in period t, run i
- $\Delta_4 DELAY_{t,i}$: difference lagged four times of delay announcement in period t, run i
- $Y_{t-1,i}$: the number of activated CoCos, lagged once, run i
- $Y_{t-2,i}$: the number of activated CoCos, lagged twice, run i
- $Y_{t-3,i}$: the number of activated CoCos, lagged three times, run i
- $Y_{t-4,i}$: the number of activated CoCos, lagged four times, run i
- $\eta_{t,i}$: random effects
- $\varepsilon_{t,i}$: residuals

The null hypothesis is that the CoCo activations are unrelated to each other. If this is the case, one should find associated estimated coefficients that are not significantly different from zero. Conversely, if these estimated coefficients are significantly different from zero and positive, then a CoCo activation in period t causes a domino effect and is likely to lead to additional activations (controlled for the macroeconomic environment).

When analysing results from Poisson autoregressive models, an indicator equivalent to R-squared is not directly available. McFadden's Pseudo R-squared is used as an alternative. The log likelihood of the null model (the model with only an intercept and no covariates) is treated as a total sum of squares while the log likelihood of the full model is treated as the sum of squared errors. By taking the ratio of the full-model likelihood over the null-model likelihood, one can check the level of improvement over the intercept model offered by the full model.

The summaries of each regression are presented in Table 13. Two key results should be noted. The first relates to the CoCo activations in the previous periods. Controlling for macroeconomic conditions and no matter which model specification is chosen, the estimated coefficient for the first lag is always positive and significant at the 1% level. This means that activations have domino effects from one period to the next. However, these persistent effects do not seem to extend beyond one quarter in the model as the estimated coefficients for the second, third and fourth lags are not significantly different from zero.

The second important result relates to the postponement of CoCo repayments. Controlling for macroeconomic conditions and regardless of the model specification chosen, the estimated coefficients for lags 1 to 4 are always positive and significant at the 1% level.

This means that an increase in postponements of CoCos repayment have persistent effects from one period to another (four quarters in the model).

The comparison of the pseudo R-squared indicates better performance by the third model. It is therefore chosen to complete the analysis of the results and in particular to discuss the residuals. The *pglm* package is relatively underdeveloped and does not allow for direct extraction of residuals or for testing serial correlation in them. It is therefore necessary to proceed indirectly. The package allows to obtain the fitted values. This makes it possible to calculate the residuals by subtracting these fitted values from the observed values. The residuals can then be regressed on their lag of one period to verify the presence of an AR(1) process. The p-value of the coefficient found is equal to 0.51 so there is insufficient evidence in the sample to conclude that a serial correlation in the residuals exists. This is confirmed by inspection of the autocorrelation plot of the residuals (Figure 61). This further ensures the robustness of the results presented.

Table 13: Results for the Poisson autoregressive models

	(1)	(2)	(3)
Intercept	-4.67*** (44.23)	-3.71*** (38.60)	-4.06*** (38.95)
Y_{t-1}	0.25*** (5.70)	0.22*** (5.00)	0.20*** (4.67)
Y_{t-2}	0.01 (0.08)	-0.33 (1.59)	-0.06 (0.50)
Y_{t-3}	0.24 (1.45)	-0.06 (0.47)	0.07 (0.45)
Y_{t-4}	0.04 (0.23)	-0.20 (1.01)	-0.21 (1.08)
$\Delta DELAY_t$	0.71*** (41.12)	0.70*** (41.87)	0.61*** (34.26)
$\Delta DELAY_{t-1}$	0.54*** (15.40)	0.46*** (12.73)	0.45*** (12.54)
$\Delta DELAY_{t-2}$	0.56*** (15.26)	0.45*** (12.33)	0.46*** (12.69)
$\Delta DELAY_{t-3}$	0.67*** (15.31)	0.57*** (13.59)	0.55*** (13.15)
$\Delta DELAY_{t-4}$	0.59*** (14.6)	0.45*** (11.75)	0.46*** (12.19)
ΔP_t^C	51.72** (2.88)	72.21* (3.73)	98.91*** (5.13)
ΔP_t^K	12.95 (0.95)	-20.41 (1.53)	-4.63 (0.36)
ΔGDP	18.03*** (13.24)	-	15.83*** (12.12)
$\Delta LOANS$	-	-5.37** (2.72)	-5.15** (2.68)
Log-likelihood	-1770.57	-1635.89	-562.756
Pseudo R²	0.54	0.58	0.60

Notes: *p-value<0,05; **p-value<0,01; ***p-value<0,001 ; t-stats in parentheses (absolute values)

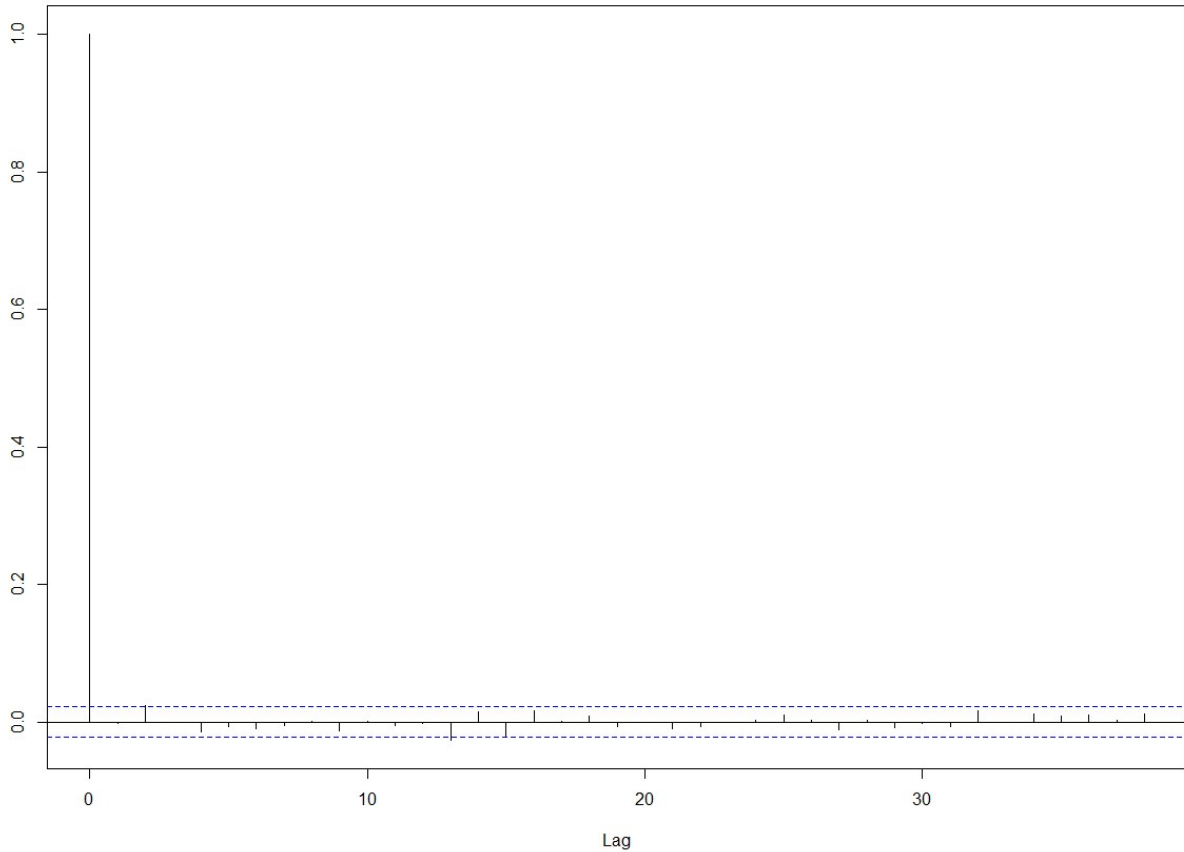


Figure 61: Autocorrelation plot of the residuals of the third regression

4.5 CONCLUSION

While Chapters 2 and 3 focused on the effects of CoCo activations and the resulting net worth transfers and showed that they are always positive for banks, Chapter 4 focuses on the consequences of disruptive announcement effects in the market. It shows that CoCos are likely to play a destabilising role for the financial sphere. When banks decide to delay repayment of principal because they are cautious about their solvency, investors may react to such announcements by turning away from the CoCo market. This creates a feedback loop: because of these information spillovers, it becomes harder for banks to set aside Additional Tier 1 capital, which leads to CoCo activations due to a specific contagion channel that seems to be weakening as buyers adapt their behaviour.

Two recommendations for prudential regulation follow: 1. The Basel framework should consider more carefully the role of CoCos in the Tier 1 capital compartment. While the Additional Tier 1 capital cushion can, all other things being equal, absorb some shocks and limit the use of bailouts, it can also create opportunities for the difficulties of individual banks to spread to the rest of the sector. 2. Every effort should be made to ensure that the way in which

CoCos operate is as clear as possible to investors who buy them. This may mitigate over-adjustments in the market in case of disruptions. This is a pressing issue as market disruptions have become increasingly frequent in recent years and doubts about the ability of some banks to sustain repayment of their maturing AT1s are growing.

These results have been obtained through Monte Carlo simulations on an extension of the JMAB model developed by Caiani et al. (2016). This model is designed to study the ex-post macroeconomic effects of information spillovers on the CoCo market. It features six institutional sectors (households, consumption firms, capital firms, banks, a government and a central bank). Each sector is populated by individual agents following microfounded behavioural rules. Initially, the agents are all identical. Their decentralized interactions and the adaptive revision of their strategies over time gradually bring out heterogeneity in the model. After a few periods, the balance sheets of each agent differ. They face different prices and interest rates. Some households are fired and others hired, some firms and banks go bankrupt while others continue to operate.

A dynamic opinion mechanism similar to Salle & Seppecher (2015) is introduced to allow banks to be cautious when a CoCos repayment would threaten their liquidity ratio. In this case, they decide to postpone the payment of the principal of maturing CoCos. A similar mechanism is applied to investing households to allow them to be pessimistic when they feel the market is at risk. In this case, they reconsider their portfolio arbitrage. To further extend the model, I implement stochastic reactive reinforcement learning with a modified Roth-Erev algorithm similar to Nicolaisen et al. (2001). Households are allowed to explore different possible reactions to the announcements of delayed repayments, including no reaction at all. Each reaction is associated with a propensity to choose it and is updated according to an endogenous reward process based on earned financial interests. These propensities are modified each time the CoCo market is disrupted. This is done for each investor, resulting in fully heterogeneous behaviours. No reaction is imposed in an *ad hoc* manner. Households explore on their own the better option that brings them the most benefits. This exploration is done stochastically. There is no guarantee that they will all arrive at the same "optimal" reaction but repetitive patterns can be observed.

Each announcement of repayment delay creates a wave of pessimism among investors who suddenly turn away from the market. This decision is irrational and time inconsistent as evidenced by the reduction in portfolio adjustment. Their initial panic causes them an

unnecessary loss of financial income. As they realise this, they adapt their behaviour to maximise the interests they receive. The size of this adjustment decreases over time. First rapidly, then more slowly, until it converges. This leads to a strategy that is optimal on average across the sector when convergence is achieved, but still involves a downward adjustment in demand for CoCos following market disruptions. In other words, it is beneficial for them to partly withdraw from the market when it experiences disruptions but not as much as they initially do. This is consistent with the existing literature focusing on the time inconsistency and irrationality of CoCos buyers (Admati et al., 2013; H. Allen, 2012; Goodhart, 2010; Sundaresan & Wang, 2015). They behave as if the asset were a simple debt instrument with too little chance of being activated and panic when clauses explicitly provided for in the contracts are activated.

This has negative consequences for the banking sector. It is becoming more difficult for banks, including those that did not cause the isolated disruption, to set aside Additional Tier 1. As demand for CoCos falls, so does their price. Under these conditions, announcements of postponement of CoCos reimbursement have perverse effects. Even though they are decided by the banks to preserve their balance sheet and not to have to repay costly principals, it is still deteriorating. These announcements are likely to trigger activations of contingent convertible bonds, which in turn may cause domino activations.

However, this extension of the JMAB model has some limitations. The macroeconomic consequences of this CoCo-specific contagion channel remain to be explored. A negative financial accelerator can be expected, making the final assessment of CoCos more cautious. Furthermore, work is needed to verify all the factors that are likely to mitigate or exacerbate this channel of financial contagion. Finally, the ex-ante role of CoCos is missing. Whether banks or households, they only react to what happens in the market (although in this extension of JMAB, this reaction is adaptive and therefore more realistic than what is observed in Chapter 3 for example). Complexifying the formation of expectations in the model by seeking to take into account how activation and deferral threats (and not just their occurrence) affect agents' behaviour would provide a more comprehensive assessment of CoCos.

FINAL DISCUSSION

In this thesis, I incorporated in a stock-flow consistent agent-based model the contingent convertible bonds issued by the banking sector since the 2008 crisis, allowing them to build up capital buffers that can be mobilized in the context of bail-ins when their balance sheet deteriorates too strongly.

As no CoCo has yet been activated, their effectiveness remains hypothetical and subject of debates. On the one hand, one can expect positive effects from CoCos issuances: individual banks should be more resilient in times of crises and there should be less need for bailouts. But on the other hand, these theoretical benefits are to be contrasted with expected (and even observed) negative effects such as an increase in moral hazard, sudden and destabilizing market adjustments and potential financial contagion effects. Oster (2020) describes the existing literature as “making everything and nothing possible”. I argue that this inability to provide a comprehensive assessment of contingent convertible bonds is related to the lack of research bridging the gap between microeconomics and macroeconomics.

This leaves three sets of questions open. The first one is related to the effectiveness of CoCo bail-ins. Can CoCos fulfil their mission of stabilizing the banking sector in the event of a financial crisis. Can they prevent bankruptcies? How much capital would be necessary to bail-in banks after a crisis? To what extent do they reduce the need for bailouts?

The second one is related to adverse and beneficial effects for the rest of the economy. Provided CoCos are effective for the banking sector, are they also for the economy as a whole? Could the costs of such bail-ins outweigh their benefits in some situations? Is the risk transfer from taxpayers to investors always a positive outcome? How does this risk shifting translate for the whole economy versus a system without coco bonds? How does CoCo bond issuances impact the systemic risk? Do they indeed reduce it, or simply shift it, or even worse, increase it? Will CoCos play a stabilizing or destabilizing role in the event of another financial crisis? In what situations could CoCos destabilize the economy?

The last one concerns regulators in particular. Are they right to encourage such bail-in mechanisms?

This PhD thesis answers these questions by proposing a credible theoretical model, incorporating the contingent convertible bonds issued by the banking sector since the 2008

crisis. More precisely, this work consists in starting from a stock-flow consistent macroeconomic model and adding agent-based microfoundations to it. I extend the SFC-AB JMAB model developed by Caiani et al. (2016) by adding: 1. a new class of financial asset, 2. learning behaviours on the part of investors, 3. a dynamic opinion component (alternating between optimism and pessimism/prudence on the part of issuing banks and investors) allowing to take into account regime shifts and possible financial contagion effects through information spillovers. This results in the very first agent-based macroeconomic assessment of contingent convertible bonds.

Why such an approach and what are its contributions? As Charles Goodhart notes: "One of the weaknesses of some of the analysis of CoCos is that it concentrates on the effect on a particular troubled bank, rather than also exploring the effects on the market dynamics of the financial system as a whole (one of the key inherent weaknesses of our prior regulatory system)." (Goodhart, 2010). By focusing on the advantages and disadvantages of CoCos at the micro level, the existing literature does not take into account the interconnections between issuing banks and investors. It only provides information on one particular aspect of CoCos at a time and only at the level of an individual bank, which is why it makes "everything and nothing possible". Therefore, any comprehensive assessment of the effectiveness and potential hidden costs of contingent convertible bonds should rely on a macroeconomic framework that takes into account the interactions between the agents that populate the economy.

In Chapter 2, I lay the foundations for a purely stock-flow consistent macroeconomic model. This is an exploratory stage in the thesis that allowed me to develop my thoughts and was a stepping stone towards the use of an SFC-AB model. Two simulations were conducted to provide qualitative results on the effects of a generalized activation of CoCos.

The first simulation focuses on real instability. The shock implemented consists in exogenously increasing the share of defaults on workers' loans. This sharply degrades the net worth of retail banks, which is enough to trigger CoCos issued by retail banks. Their partial activation causes a write-off of part of the bank debt. The good side of CoCos' activation is their disappearance of bank liabilities. It has a beneficial effect because the decrease in their net worth and their profits is less than in the absence of CoCos. The Additional Tier 1 safety cushion makes it possible to postpone the moment when bailouts become necessary and reduce the period over which bailouts are necessary. This results in a decrease in the cost of bailouts for taxpayers. This is likely to have macroeconomic consequences on the real sphere depending on

how bailouts are financed. If we assume one-off increases in debt with pro-cyclical effects that aggravate the current shock, then avoiding them is all the more beneficial. The larger the planned tax increase, the more beneficial it is. This beneficial transitional effect is absent if bailouts are assumed to be financed solely with public debt. Therefore, any comparison between CoCo bail-ins and public bailouts must take into account that the way in which bailouts are modelled can give a more or less flattering picture of CoCos. Meanwhile, CoCo buyers are enduring the cancellation of some of their assets. This amounts to a decrease in their net worth. As a shift in risk from CoCos issuers to CoCos holders occurs, the latter react by restructuring their portfolios, which seems to have an existing but limited impact on the rest of the economy, especially on working households. There is also an impact on the trajectory of the entire economy. Aggregate demand declines, which translates into a slight drop-off in wages and consumption for working households.

The second simulation focuses on financial instability through the effects of a stock market crisis. To induce this simulation, an exogenous negative shock is imposed on share prices, which leads to a deterioration in the balance sheet of investment banks that triggers the activation of their CoCos. As in the first scenario, there is an improvement in the net wealth of banks after activation, at the expense of the net wealth of CoCos holders. However, there are also portfolio reallocations as a result of changes in asset prices, leading to significant volatility which also affects the sector that benefited from the activation of the CoCos.

I conclude from this purely macroeconomic model that CoCos fulfil their primary objective upon activation: they improve banks' balance sheets in an efficient manner without any government intervention. The direct burden of debt rescue is reduced, more focused and shifted from all taxpayers to bank creditors. This aggregate approach also shows that CoCos might destabilize the rest of the economy in two ways. The first one is by shifting too much the costs of rescue to other sectors. The second one is by inducing significant volatility due to portfolio reallocations. Both are explored in Chapter 3 and Chapter 4 respectively.

Agent-based microfoundations are added to the SFC model by extending the JMAB model developed by Caiani et al. (2016). The resulting heterogeneity allows to take into account that not all CoCos activate simultaneously as well as the possibility of isolated bankruptcies. It makes it possible to study more precisely whether CoCo bail-ins are able to prevent these failures and whether there are possible contagion effects. The emergent properties of the agent-based model capture endogenous business cycles and financial crises that are able to trigger

CoCos without any ad hoc assumptions. Investors can react to repeated activations. Furthermore, it allows us to observe how interactions at the micro level such as the supply, demand and activation of individual CoCos can generate unexpected global dynamics such as information diffusion and decreasing waves of adjustments following market disruptions, or non-linearities in macroeconomic effects of activations.

In Chapter 3, CoCos are explicitly introduced in JMAB. Demand depends on a trade-off between the rate of return on a safe asset (bank deposits) and the rate of return on a risky asset (CoCos) weighted by the share of activations in previous periods. The supply is such that banks take advantage of macroprudential rules on Additional Tier 1. The price equalises supply and demand. The interest rate is flexible and specific to the liquidity ratio of each bank (the more liquidities banks have, the more they can afford to raise their rates to attract investors, and vice versa). Market matching is done by connecting banks with investors. The latter compare the interest rates offered and choose the most advantageous. The activation of CoCos follows the same logic as in Chapter 2. It takes place when the capital adequacy ratio of banks falls below a given threshold value. In this case, principal repayments and interest payments for outstanding issues are cancelled.

Two policy experiments were conducted based on Monte Carlo simulations. The first one focuses on the effects of the introduction of CoCos in the economy and of different activation threshold values. Comparing an economy where banks issue non-convertible bonds with an economy where they issue CoCos, it is found thanks to Mann-Whitney non-parametric tests that the existence of an Additional Tier 1 buffer strengthens the capital ratios of banks. The risk of bank failures is lower, which means fewer bailouts and therefore lower costs for taxpayers. These findings are consistent with the existing literature (Calomiris & Herring, 2013; Pennacchi, 2010). The greater resilience of banks allows them to maintain their operations in times of crisis. They can therefore continue to lend to the real economy, which generates positive second-order effects for the major macroeconomic aggregates of investment and output, as predicted by some authors (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009). These effects rely on a positive financial accelerator (Bernanke et al., 1999). The effects on consumption are ambiguous. This ambiguity is explored in a second policy experiment. Using a penalized spline regression, I show that the volume of CoCos in circulation in the economy has non-linear effects on consumption and incidentally on GDP. The larger the volume of outstanding CoCos, the greater the adverse effects on investors' net wealth. Above a certain volume, their activation negatively affects consumption and ultimately GDP.

Chapter 4 investigates the consequences of disruptive announcements in the CoCo market by making anticipation formations more complex. A dynamic opinion mechanism similar to Salle & Seppecher (2015) is introduced for banks and investors. Banks become cautious when a principal repayment would threaten their solvency. In this case, put it off until their situation improves (or deteriorates further until activation). Investing households become pessimistic when they feel the market is at risk. In this case, they reconsider their portfolio arbitrage. To further extend the model, I implement stochastic reactive reinforcement learning with a modified Roth-Erev algorithm similar to Nicolaisen et al. (2001). Households are allowed to explore different possible reactions to the announcements of delayed repayments, including no reaction at all. Each reaction is associated with a propensity to choose it and is updated according to an endogenous reward process based on earned financial interests. These propensities are modified each time the CoCo market is disrupted. Households explore on their own the better option that brings them the most benefits. This exploration is done stochastically.

I show with Monte Carlo simulations that each repayment delay has perverse effects for banks, even though they are set up to preserve their balance sheet and not to have to repay costly principals. They create a wave of pessimism among investors who suddenly turn away from the market. This decision is time inconsistent as evidenced by the reduction in portfolio adjustment. This is supported by the existing literature which focuses on the irrationality of CoCos buyers (Admati et al., 2013; H. Allen, 2012; Goodhart, 2010; Sundaresan & Wang, 2015). They behave as if this asset were a simple debt instrument with negligible chance of being activated and panic when clauses explicitly provided for in the contracts are activated. This causes them an unnecessary loss of financial income. As they realise this, they adapt their behaviour to maximise the interests they receive. The size of the overadjustment therefore decreases over time until it converges. In other words, it is beneficial for investors to partly withdraw from the market when it experiences disruptions but not as much as they initially do. This portfolio reallocation has negative consequences for the banking sector, as highlighted by some theoretical papers on CoCos (Admati et al., 2013; M. Allen et al., 2002; Goodhart, 2010; Sundaresan & Wang, 2015). It is becoming more difficult for banks, including those that did not cause the isolated disruption, to set aside Additional Tier 1. As demand for CoCos falls, so does their price. I show that each repayment delay generates information spillovers that are likely to trigger activations of contingent convertible bonds, which in turn may cause domino activations. This complements the empirical observations of Bologna et al. (2020) by showing that the difficulties of one bank can spread to others through a financial contagion channel.

Based on these findings, I can say that CoCos are indeed fulfilling their initial mission of intermittently strengthening the solvency of the banking sector and reducing the costs of bailouts by soliciting investors. In this respect, they are positive for the macroeconomic aggregates, which benefits from positive second-order spillovers. But by relying on this instrument, regulators are playing a risky game. Their activation could take a heavy toll on the whole economy: the real sphere which could be too badly affected if the volume of CoCos in circulation is too high and the financial sphere which would suffer from possible financial contagion effects by information.

Given these risks, it is necessary to further develop the counterfactual analysis of CoCos in order to better understand them. The various models proposed in this thesis have limitations that need to be overcome. Micro data on CoCos - such as investor preferences and bank activation thresholds - is needed to estimate the optimal size of the CoCo market, the optimal level of substitutability between AT1 and T1 and the optimal issuance ceiling. The demand side of CoCos could be fleshed out with institutional investors introduced as a new sector. In a way like what happened with the securitization of ABS, CoCos could be bought by other actors of the financial sector. Systemic risk might not be reduced but simply shifted to other parts of the financial sector. Further work is also needed to verify all the factors that are likely to mitigate or exacerbate the CoCo-specific contagion channel. The macroeconomic consequences of the CoCo-specific contagion channel remain to be explored. A negative financial accelerator can be expected, making the final assessment of CoCos more cautious. Finally, the ex-ante role of CoCos is missing. Activation risks can be expected to limit banks' risk-taking behaviour, or conversely, the moral hazard associated with the possibility of being bail-in if they are not bail-out could exacerbate it.

Until such improvements are made, I propose a set of policy recommendations that are likely to guide the actions of regulators. Adjusting the degree of substitutability between Tier 1 and Additional Tier 1 could be a way to control the lower bound of the volume of CoCos in circulation, thus ensuring that enough are issued to limit the need for bailouts in the event of a crisis. Banks have an interest in taking advantage of this opportunity to meet the Basel III solvency criteria, which they often denounce as too restrictive. Since CoCos are also used to send a strong positive signal to investors, as illustrated by Deutsche Bank in 2020, and since the demand for them is high given their attractive interest rates, banks may have an incentive to issue more than what is accounted as Additional Tier 1. Setting a maximum issuance ceiling and discouraging banks from using them as a screening device could be a way to control the

upper bound of the volume of outstanding CoCos, thereby ensuring that potential bail-ins would not be too destabilizing for the economy when a crisis occurs. Moreover, regulators should consider more carefully the role of CoCos in Tier 1 capital. While the Additional Tier 1 capital cushion can, all other things being equal, absorb some shocks and limit the use of bailouts, it can also create opportunities for the difficulties of individual banks to spread to the rest of the sector. To mitigate the financial contagion risks, every effort should be made to ensure that the way in which CoCos operate is as clear as possible to investors who buy them. This would prevent over-adjustments in the market in case of disruptions.

Market disruptions have become increasingly frequent in recent years and doubts about the ability of some banks to sustain repayment of their maturing AT1s are growing. The increase in interest rates decided by central banks to fight inflation will increase the cost for banks to keep their CoCos and weigh on their solvency. Ensuring the best possible scenario after a CoCo activation is becoming a pressing issue but is within the reach of regulators.

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APPENDIX A: LIST OF PARAMETERS FOR THE SFC

MODEL

Parameter	Description	Baseline
α_1	Propensity to consume as a function of income	0.75
α_2	Propensity to consume as a function of savings	0.06
β	Parameter related to expectation on real sales	0.5
CAR_{b1}^T	Target capital adequacy ratio of retail banks - Trigger threshold of retail banks CoCos	See simulations
CAR_{gb1}^T	Trigger threshold of retail bank bailouts	See simulations
χ_1	Spread between interest rate on loans and interest rate on advances	0.02
χ_2	Spread between interest rate on checking deposits and interest rate on advances	0.01
χ_3	Spread between interest rate on retail CoCos and interest rate on advances	0.03
χ_4	Spread between interest rate on time deposits and interest rate on advances	0.002
χ_5	Spread between interest rate on investment CoCos and interest rate on advances	0.03
δ	Parameter related to expectation on real disposable income	0.07
δ_{rep}	Ratio of personal loans repayments to stock of loans	0.1
ε	Parameter related to expectation on real disposable income	0.5
ε_1	Parameter related to expectation of worker households on loans supplied to them	0.5
ε_{1i} (with $i \in [0;2]$)	Parameter related to investment banks' demand for treasury bills	0.5; 0.05; 0.05
ε_{2i} (with $i \in [0;2]$)	Parameter related to investment banks' demand for firm shares	0.5; 0.05; 0.05
η_0	Ratio of new loans to personal income - exogenous component	0.05
η_1	Relation between the ratio of new loans to personal income and the interest rate on loans	0.07
γ	Speed of adjustment of inventories to the target level	0.45
γ_0	Exogenous component in the growth of the real stock of capital	-0.06
γ_1	Relation between the capacity utilization rate and the growth of the real stock of capital	0.1
γ_2	Relation between the real interest rate and the growth of the real stock of capital	0.05
γ_3	Relation between the cash flow rate and the growth of the real stock of capital	0.036
γ_4	Relation between Tobin's Q and the growth of the real stock of capital	0.003
gr_g	Growth of government expenditures	0.03
gr_{pr}	Growth of labour productivity	0.06
κ	Sensitivity of investment bank coco activations to shocks	10
$klim_0$	Exogenous component of credit rationing	1
$klim_1$	Relation between worker household leverage and credit rationing	0.3
$klim_2$	Relation between capital adequacy ratio and credit rationing	0.3
λ_{1i} (with $i \in [0;6]$)	Parameter related to investor household's demand for retail bank checking deposits	0.35; 0.25; 0.05; 0.05; 0.05; 0.05; 0.05
λ_{2i} (with $i \in [0;6]$)	Parameter related to investor household's demand for investment bank time deposits	0.1; 0.05; 0.25; 0.05; 0.05; 0.05; 0.05
λ_{3i} (with $i \in [0;6]$)	Parameter related to investor household's demand for treasury bills	0.1; 0.05; 0.05; 0.25; 0.05; 0.05; 0.05
λ_{4i} (with $i \in [0;6]$)	Parameter related to investor household's demand for firm shares	0.25; 0.05; 0.05; 0.05; 0.2; 0.025; 0.025
λ_{5i} (with $i \in [0;6]$)	Parameter related to investor household's demand for retail bank CoCos	0.1; 0.05; 0.05; 0.05; 0.025; 0.2; 0.025
λ_{6i} (with $i \in [0;6]$)	Parameter related to investor household's demand for investment bank CoCos	0.1; 0.05; 0.05; 0.05; 0.025; 0.025; 0.2
$nplw_0$	Exogenous component of non-performing loans	0.1
$nplw_1$	Relation between worker household debt burden and non-performing loans	0.25

Ω_0	Exogenous component of target wage	-0.2
Ω_1	Relation between labour productivity and target wage	1
Ω_2	Relation between employment rate and target wage	2
Ω_3	Speed of wage adjustment	0.2
φ	Mark-up rate	0.3
σ_N	Parameter related to the normal historic unit cost	0.2
σ_{peT}	Trigger threshold of investment banks CoCos	See simulations
σ_T	Target inventories to sales ratio	0.6
τ_{1i} (with $i \in [0;3]$)	Parameter related to firms' demand for treasury bills	0.6; 0.1; 0.15; 0.05
τ_{2i} (with $i \in [0;3]$)	Parameter related to firms' demand for retail bank CoCos	0.2; 0.05; 0.2; 0.05
τ_{3i} (with $i \in [0;3]$)	Parameter related to firms' demand for investment bank CoCos	0.2; 0.05; 0.05; 0.1
θ_0	Taxation rate on household income	0.23
θ_1	Increase in taxation rate on household income in case of bailouts	0.04
z_1	Relation between retail banks' debt and their CoCo issuances	0.05
z_2	Relation between investment banks' debt and their CoCo issuances	0.05
ζ	Share of firm retained profits used for financial investments	0.1

APPENDIX B: LIST OF VARIABLES FOR THE SFC

MODEL

Variable	Description
A_{b1s}	Central bank advances supplied to retail banks
A_{b2s}	Central bank advances supplied to investment banks
B_{b2d}	Treasury bills demanded by investment banks
B_{b2h}	Treasury bills held by investment banks
B_{b2s}	Treasury bills supplied to investment banks
B_{fd}	Treasury bills demanded by firms
B_{fh}	Treasury bills held by firms
B_{fs}	Treasury bills supplied to firms
B_{rd}	Treasury bills demanded by investing-households
B_{rh}	Treasury bills held by investing-households
B_{rs}	Treasury bills supplied to investing-households
B_s	Total supply of treasury bills
$BCO1_{fd}$	Retail bank CoCos demanded by firms
$BCO1_{fh}$	Retail bank CoCos held by firms
$BCO1_{fs}$	Retail bank CoCos supplied to firms
$BCO1_{rd}$	Retail bank CoCos demanded by investing-households
$BCO1_{rh}$	Retail bank CoCos held by investing-households
$BCO1_{rs}$	Retail bank CoCos supplied to investing-households
$BCO1_s$	Total supply of retail bank CoCos
$BCO2_{fd}$	Investment bank CoCos demanded by firms
$BCO2_{fh}$	Investment bank CoCos held by firms
$BCO2_{fs}$	Investment bank CoCos supplied to firms
$BCO2_{rd}$	Investment bank CoCos demanded by investing-households
$BCO2_{rh}$	Investment bank CoCos held by investing-households
$BCO2_{rs}$	Investment bank CoCos supplied to investing-households
$BCO2_s$	Total supply of investment bank CoCos
BO_d	Bailout money demanded by retail banks
BO_s	Bailout money supplied to retail banks
BUR_w	Debt burden of working-households
c_r	Real consumption of investing-households
C_r	Nominal consumption of investing-households
c_w	Real consumption of working-households
C_w	Nominal consumption of working-households
CAR	Capital adequacy ratio of retail banks
CG_{b2}	Capital gains of investment banks
CG_r	Capital gains of investing-households
D_{rh}	Checking deposits held by investing-households
D_{rd}	Checking deposits demanded by investing-households
D_{wh}	Checking deposits held by working-households
D_{wd}	Checking deposits demanded by working-households
D_s	Total supply of checking deposits
e_{b2d}	Firm equities demanded by investment banks
e_{b2h}	Firm equities held by investment banks
e_{b2s}	Firm equities supplied to investment banks
e_{rd}	Firm equities demanded by investing-households
e_{rh}	Firm equities held by investing-households
e_{rs}	Firm equities supplied to investing-households
e_s	Total supply of firm shares
ER	Employment rate
F_{b1}	Profits of retail banks
F_{b2}	Profits of investment banks
FD_{b2f}	Profits distributed by firms to investment banks
FD_{rf}	Profits distributed by firms to investing-households
FU_f	Profits retained by firms

g	Real government expenditures
G	Nominal government expenditures
GL_{wd}	Gross amount of new loans demanded by working-households
gr_k	Growth rate of the real stock of capital of firms
in	Real inventories of firms
in_e	Expected real inventories of firms
in_T	Long-term inventory target of firms
IN	Nominal inventories of firms
inv	Real investment of firms
k	Real stock of capital of firms
K	Nominal stock of capital of firms
$klim$	Share of new loans granted to working-households relative to their demand for new loans
l	Leverage ratio of firms
L_{wd}	Loans demanded by working-households
L_{ws}	Loans supplied to working-households
L_{fd}	Loans demanded by firms
L_{fs}	Loans supplied to firms
$NHUC$	Normal historic unit cost paid by firms
NL_{wd}	Nominal net flow of new loans demanded by working-households
nl_{ws}	Real net flow of new loans supplied to working-households
nl_{wse}	Real net flow of new loans expected by working-households
$nplw$	Share of non-performing working-household loans
$NPLW$	Non-performing working-household loans
NUC	Normal unit cost paid by firms
p	Price level
$pbco1$	Price of retail bank CoCos
$pbco2$	Price of investment bank CoCos
pe	Price of firm equity
pr	Labour productivity
r_b	Interest rate on government treasury bills
r_{BCO1}	Return rate of retail bank CoCos
r_{BCO2}	Return rate of investment bank CoCos
r_{cf}	Cash flow rate of firms
rr_{cf}	Real cash flow rate of firms
r_d	Interest rate on checking deposits
r_K	Return rate on firm shares
r_l	Interest rate on loans
rr_l	Real interest rate on loans
r_q	Tobin's Q of firms
rr_q	Real Tobin's Q of firms
r_{td}	Interest rate on time deposits
REP_w	Loan repayments by working-households
s	Real sales of firms
s_e	Expected real sales of firms
$share_{b1}$	Share of triggered retail bank CoCos
$share_{b2}$	Share of triggered investment bank CoCos
T_r	Taxes on worker investing-household income
T_w	Taxes on working-household income
TD_{rd}	Time deposits demanded by investing-households
TD_{rh}	Time deposits held by investing-households
TD_{rs}	Time deposits supplied to investing-households
u	Rate of capacity utilization of firms
V_{b2}	Net worth of investment banks
v_f	Real net worth of firms
V_f	Nominal net worth of firms
v_r	Real net worth of investing-households
V_r	Nominal net worth of investing-households
v_w	Real net worth of working-households
V_w	Nominal net worth of working-households
W	Nominal wage rate
WB	Nominal wage bill of working-households
y	Real production of firms

yd_r	Real disposable income of investing-households
yd_{re}	Expected real disposable income of investing-households
YD_r	Nominal disposable income of investing-households
yd_w	Real disposable income of working-households
yd_{we}	Expected real disposable income of working-households
YD_w	Nominal disposable income of working-households
YP_r	Nominal income of investing-households
YP_w	Nominal income of working-households
η	Ratio of new loans to personal income for working-households
Π_{b1}	Condition on retail bank CoCo activation
$\Pi_{bis_{b1}}$	Condition on retail bank CoCo activation
Π_{b2}	Condition on investment bank CoCo activation
$\Pi_{bis_{b2}}$	Condition on investment bank CoCo activation
Π_{BO}	Condition on bailout transfers
π	Inflation rate
Ω_T	Nominal wage bargained by workers at the moment of negotiations
σ_{pe}	Standard deviation of the price of firms' equities

APPENDIX C: ADDITIONAL GRAPHS FOR THE SFC

MODEL

In order to make the graphs in section 2.3.1 more readable when analysing the effects of the financing mode of bailouts, a zoom is made on the period immediately following the activation of the CoCos. In the longer term, the variables studied converge towards the value they would have had without any shock. The entire graphs are shown below so that the reader can see this convergence.

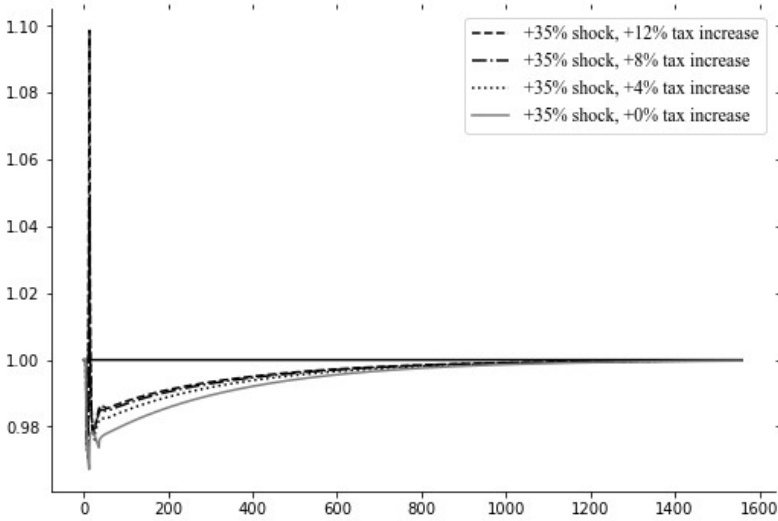


Figure 62: Evolution of the income of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

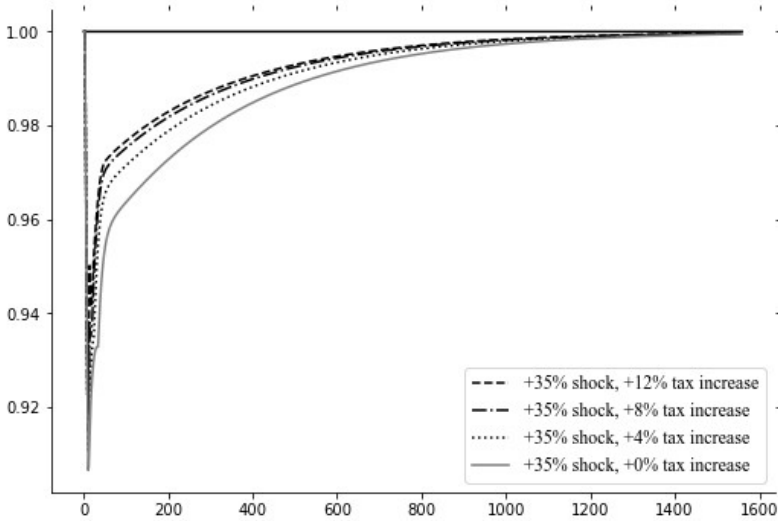


Figure 63: Evolution of the net value of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

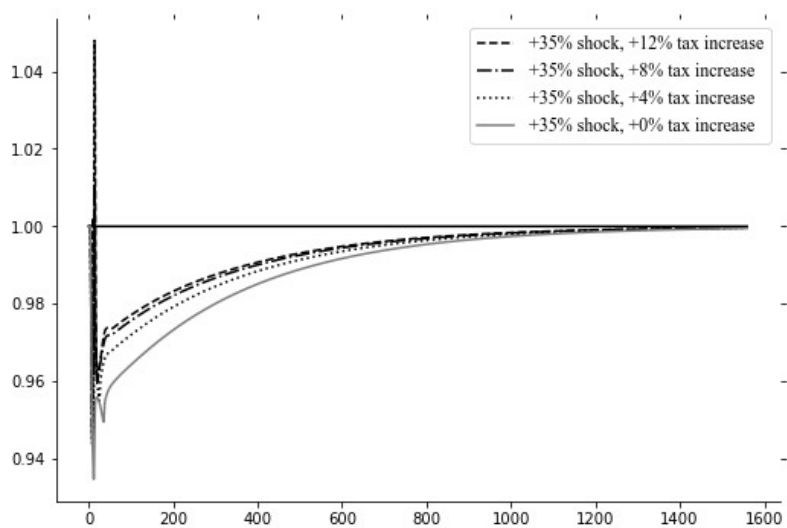


Figure 64: Evolution of the consumption of investing households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

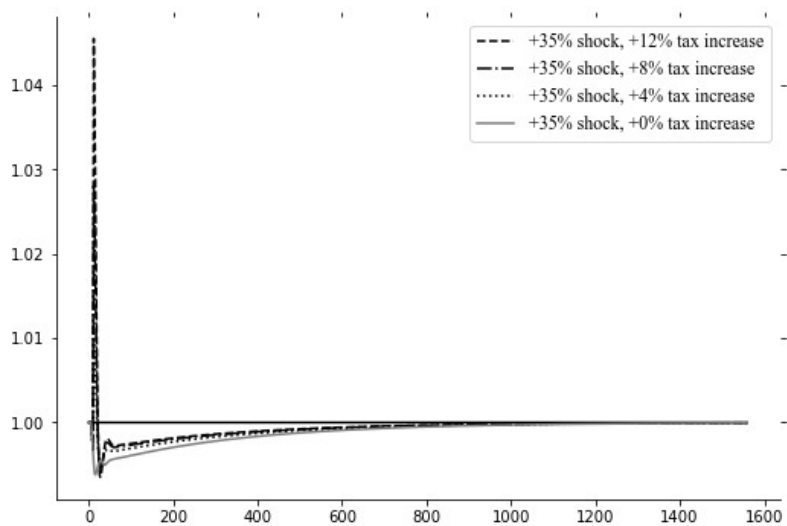


Figure 65: Evolution of the income of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

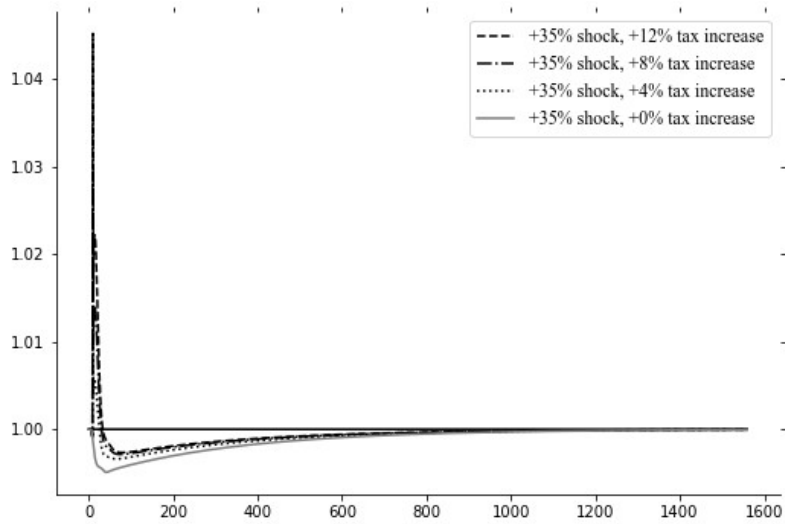


Figure 66: Evolution of the net value of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

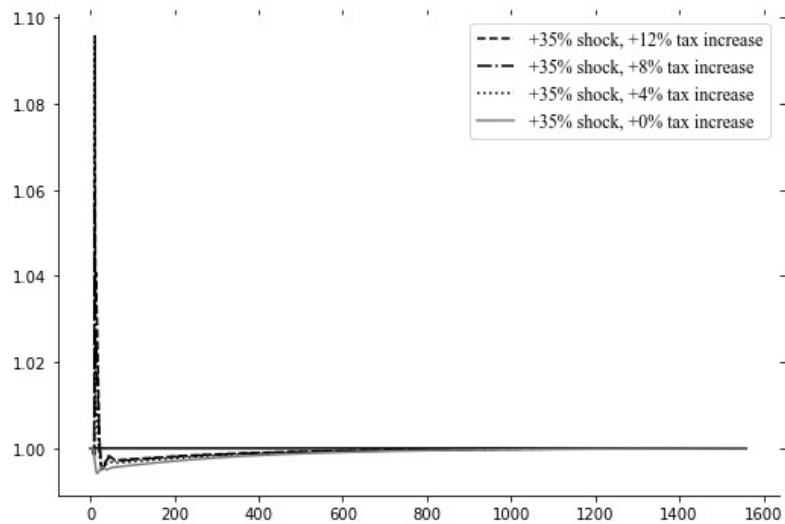


Figure 67: Evolution of the consumption of working households, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

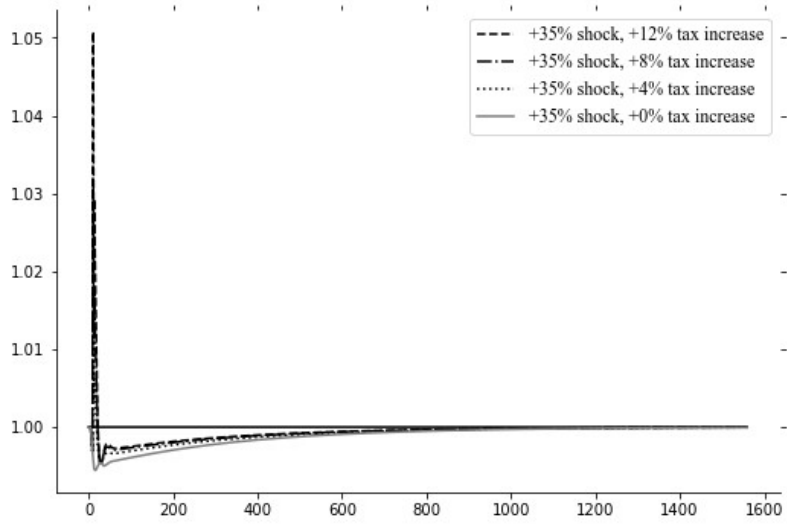


Figure 68: Evolution of firms' sales, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

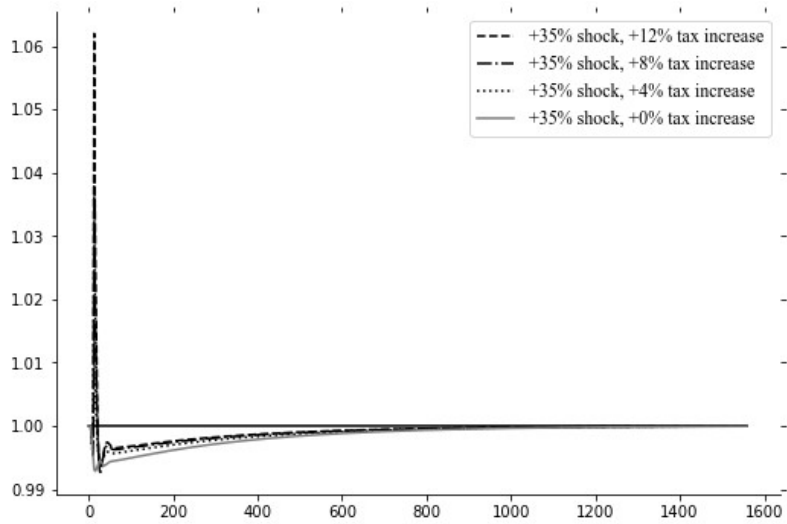


Figure 69: Evolution of firms' investment, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

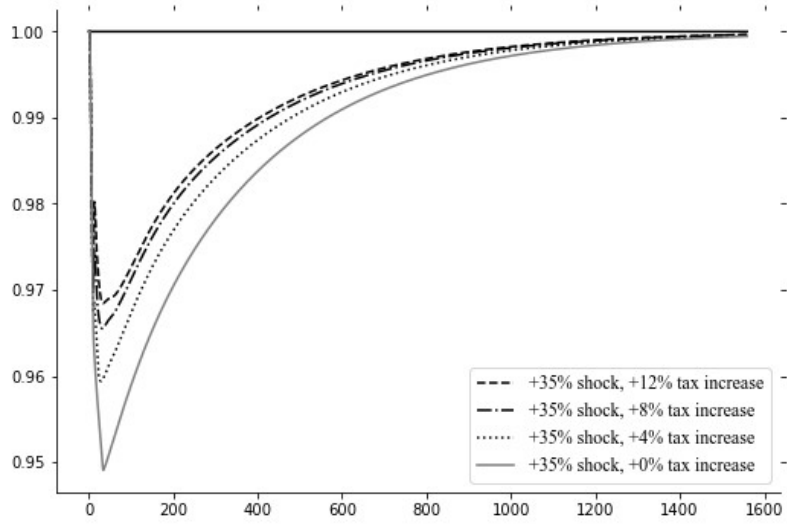


Figure 70: Evolution of firms' net value, relative to the scenario without any activation of coco bonds, following an increase in the share of defaulted loans for different tax increases

APPENDIX D: LIST OF PARAMETERS FOR THE SFC-AB MODELS (WITH AND WITHOUT LEARNING)

The table below lists the interest parameters used in the two SFC-AB models presented in Chapter 3 and 4. It shows when the same parameters and values are used and when others are introduced.

Parameter	Description	Baseline Chapter 3	Baseline Chapter 4
$size_H$	Number of households		8000
$size_C$	Number of consumption firms		100
$size_K$	Number of capital firms		20
$size_B$	Number of banks		10
λ	Adaptive expectations parameter		0.25
ν	Firms' inventories target share		0.1
μ^N	Productivity of labour in K sector		2
l^K	Capital/labour ratio in K sector		6.4
μ_c^K	Productivity of capital		1
γ_1	Profit rate weight (investment function)		0.01
γ_2	Capacity utilization rate weight (investment function)		0.02
\bar{r}	Target profit rate (investment function)		0.04345
\bar{u}	Target capacity utilization rate (investment function)		0.8
ν	Unemployment threshold in wage revision function		0.08
α_1	Propensity to consume out of income		0.38581
α_2	Propensity to consume out of wealth		0.25
σ_1	Deposit share upper bound		0.6
σ_2	Portfolio arbitrage sensitivity parameter		0.2
$(\mu_{FN}, \sigma_{FN}^2)$	Folded normal distribution parameters		(0,0.0094)
$pbco^T$	Announcement price of CoCos		500
$AddT1^T$	Targeted additional tier 1		0.015
CAR^T	CoCo activation threshold		0.6
$i_{b,0}^l$	Initial interest rate on loans		0.0075
$i_{b,0}^d$	Initial interest rate on deposits		0.0025
$i_{b,0}^{BCO}$	Initial interest rate on CoCos		0.0025
q_0	Initial propensity of adjustment size = -0%	-	2
q_1	Initial propensity of adjustment size = -10%	-	2
q_2	Initial propensity of adjustment size = -20%	-	2
q_3	Initial propensity of adjustment size = -30%	-	2
q_4	Initial propensity of adjustment size = -40%	-	2
q_5	Initial propensity of adjustment size = -50%	-	2
q_6	Initial propensity of adjustment size = -60%	-	8
e	Exploration parameter	-	0.1
r	Recency parameter	-	0.2
$\overline{CAR^T}$	Optimistic capital adequacy threshold	-	0.75
$\underline{CAR^T}$	Cautious capital adequacy threshold	-	0.95
LR^T	Liquidity threshold for opinion formation	-	0.60
b	Number of banks observed to form an opinion	-	6
p	Herding probability	-	0.6

RESUME LONG EN FRANÇAIS

CONTEXTE

La genèse des obligations contingentes convertibles

La crise financière de 2008 a mis en lumière les problèmes causés par un secteur financier surendetté. Premièrement, il est susceptible de subir des pertes importantes qui pourraient en définitive être transférées au contribuable. Ensuite, un secteur financier surendetté est encouragé à investir dans des actifs risqués afin de maximiser ses rendements. Enfin, afin d'éviter une dilution de leur pouvoir, les actionnaires des banques s'opposent à l'émission de nouvelles actions susceptibles de rééquilibrer les bilans. Par conséquent, une fois qu'une bulle est amorcée, il est peu probable qu'un retour en arrière se produise. La hausse des prix pousse les investisseurs à s'endetter davantage pour acheter plus d'actifs, ce qui fait grimper les prix (Minsky, 1992b). Cela risque d'avoir des effets négatifs sur les décisions des entreprises, notamment des institutions financières telles que les banques, qui peuvent choisir d'investir de plus en plus dans ces actifs (Minsky, 1992a). L'effet de levier est alors procyclique, ce qui génère de l'instabilité dans le secteur financier et provoque des crises telles que la grande crise financière de 2008. En période de prospérité, le secteur financier se retrouve avec une capacité excédentaire. Pour l'utiliser, il doit accroître la taille de son bilan. Du côté du passif, il s'oriente vers la dette à court terme. Du côté de l'actif, il cherche à acheter et à prêter toujours plus. Dans la période précédant 2008, les bilans ont augmenté si rapidement que le secteur bancaire a prêté à des ménages qui ne pouvaient manifestement pas rembourser leurs dettes. Il en est résulté une crise financière qui s'est ensuite propagée au secteur réel via d'autres effets de bilan (baisse de la valeur nette du secteur des ménages et donc de sa consommation, forte contraction du crédit, etc.) Une telle approche comptable des effondrements financiers est préconisée par le FMI depuis plusieurs décennies (Adrian & Shin, 2010; M. Allen et al., 2002).

En outre, il est désormais reconnu que lorsqu'une crise financière survient, les grandes sociétés financières représentent un risque systémique pour le reste de l'économie (Acemoglu, 2009). Afin d'éviter une crise majeure, le gouvernement n'a d'autre choix que de mettre en place un plan de sauvetage aux frais des contribuables. Face à une telle situation, les États ne laissent généralement pas les grandes banques s'effondrer, car cela causerait des dommages importants au reste de l'économie et à la liquidité du marché. Comme cette garantie implicite est connue de tous, elle équivaut à une forme d'assurance non tarifée pour les grandes sociétés financières.

Pour reformuler la question dans les termes de la finance moderne, avec les plans de sauvetage, les gouvernements fournissent gratuitement des options d'achat aux grandes institutions financières, mais ces pertes potentielles ne sont pas reflétées dans le budget public (Bryan et al., 2020; Bryan & Rafferty, 2006; Martin, 2014). Du point de vue du contribuable, un renflouement potentiel représente une hausse des impôts futurs ou une baisse de la qualité ou de la quantité des services publics. Dans ce paradigme du "too big to fail", les dirigeants et les actionnaires des banques peuvent indéfiniment profiter de la possibilité d'infliger d'importantes externalités négatives au reste de l'économie pour prendre des risques et réaliser des bénéfices plus importants, aux dépens des gouvernements et des contribuables. Cela crée une situation d'aléa moral (Alessandri & Haldane, 2011; A. Haldane, 2013; Siegert & Willison, 2015).

Pour éviter que cela ne se reproduise, les régulateurs nationaux et internationaux favorisent les "mécanismes de deuxième génération" en obligeant les banques à traiter ce type de problème ex ante (Tropeano, 2011). Deux solutions ont été plus particulièrement envisagées dans le cadre de Bâle III depuis la crise de 2008. La première solution consiste à faire en sorte que les banques puissent y faire face seules. Ainsi, elles sont encouragées à mettre de côté des fonds propres plus importants et de meilleure qualité et à réduire leur endettement (Blundell-Wignall & Atkinson, 2010; Howarth & Quaglia, 2016). Par ailleurs, l'accord permet d'inclure les instruments de dette contingente dans un compartiment spécial appelé Additional Tier 1 (AT1) qui peut se substituer jusqu'à 1,5 % des fonds propres en Tier 1. La deuxième solution consiste à transférer une partie du risque à des investisseurs privés. Dans la zone euro, cela s'est traduit par la mise en œuvre de la directive Recovery and Resolution en mai 2014 : lorsqu'une banque menace de faire faillite, les détenteurs d'obligations sont mis à contribution (Howarth & Quaglia, 2014; Thole, 2014).

En conséquence, le secteur bancaire a créé un nouveau type d'actif : les obligations contingentes convertibles ("obligations CoCo" ou "CoCos"). Pour comprendre comment le cadre réglementaire de Bâle III a créé les conditions favorables à l'émergence des CoCos, il faut d'abord expliquer ce qu'elles sont et comment elles fonctionnent.

Qu'est-ce qu'une obligation contingente convertible ?

Une obligation CoCo est un instrument financier hybride qui présente les caractéristiques d'une dette et d'une action. En temps normal, elle fonctionne exactement comme une obligation standard. Une banque en émet lorsqu'elle a besoin de fonds. Les investisseurs les achètent et ont droit au paiement des intérêts et récupèrent le capital à l'échéance de l'obligation. En cas de

crise, lorsque les fonds propres des banques franchissent un certain seuil, ces obligations sont converties en actions ou annulées (principal write-down, ou PWD), ce qui renforce la capitalisation des émetteurs. Le PWD peut être total ou partiel. Ces deux possibilités (conversion vs. PWD) définissent le mécanisme d'absorption des pertes et permettent la recapitalisation des banques. Les CoCos ont pour but d'apporter plus de stabilité aux grandes entreprises financières et de les empêcher de transférer leurs propres risques et déséquilibres au reste de l'économie. Au lieu d'essayer de réduire la taille des actifs par des ventes en urgence d'actifs lorsque leur solvabilité diminue, les CoCos créent un mécanisme qui modifie la composition de la partie droite du bilan des émetteurs en substituant des capitaux propres à la dette dès que le ratio de solvabilité dépasse un certain seuil. Un tel dispositif met une limite explicite à l'effet de levier dont peuvent profiter les banques. En d'autres termes, une société financière qui émet des CoCos ne peuvent s'appuyer que dans une mesure limitée sur la dette et l'effet de levier. Le gouvernement n'est pas tenu d'assumer entièrement le sauvetage des banques en cas de nouvelle crise financière, car les CoCos permettent théoriquement aux banques de lever des capitaux très rapidement (Avdjiev et al., 2013).

En quoi les CoCos diffèrent-ils des obligations convertibles, dont certaines existent depuis plus d'un siècle (Lummer & Riepe, 1993)? Les obligations convertibles sont principalement émises par des entreprises. Le détenteur d'une obligation convertible a le droit de convertir son obligation en un nombre déterminé d'actions de la société émettrice à un prix d'exercice. Ce type de titre peut être interprété comme une combinaison d'une obligation ordinaire et d'une option d'achat des actions de l'émetteur à un prix ou un ratio prédéterminé, et certaines obligations convertibles sont explicitement conçues de cette manière. Très souvent, le prix de conversion est supérieur au prix de l'action au moment de l'émission. Comme le droit de conversion augmente la valeur de l'obligation convertible par rapport à une obligation normale, l'intérêt payé par l'émetteur peut être plus faible. En plus d'une réduction des paiements d'intérêts, un autre avantage pour l'émetteur est que la dette disparaît lorsque les obligations sont converties en actions. Mais l'inconvénient est qu'une dilution relative est attendue, ce qui réduit la valeur des actions. Les investisseurs peuvent parier sur une hausse du cours de l'action de l'émetteur tout en bénéficiant des avantages habituels d'un titre de créance. Ce type d'actif hybride est traditionnellement utilisé par les entreprises comme moyen de gestion de la dette. Par exemple, les obligations contingentes peuvent être utilisées pour restructurer des entreprises illiquides mais solvables et criblées de dettes. Elles présentent également un certain intérêt pour les start-ups au tout début de leur développement, car elles permettent de retarder la valorisation

de l'entreprise. Si la start-up a du succès, le cours de l'action dépasse le prix d'exercice. Cela incite les détenteurs de dettes à transformer leurs obligations convertibles en actions. Cela rapporte potentiellement plus d'argent aux investisseurs que le modeste taux d'intérêt des obligations convertibles et, en même temps, la conversion nettoie le bilan de l'entreprise de ses dettes, ce qui stimule encore son expansion. Si le cours de l'action est inférieur au prix de conversion, l'obligataire a intérêt à demander le remboursement de son obligation à la parité (certaines obligations sont automatiquement converties à l'échéance, ce qui revient à vendre des actions à terme).

Alors que les obligations convertibles sont faites pour déclencher la conversion à la hausse, les CoCos sont conçus pour déclencher la conversion à la baisse. Les obligations convertibles sont un instrument pour favorisant le développement de nouvelles entreprises dont on peut attendre des rendements très élevés, tandis que les Cocos sont un instrument pour le renflouement des banques en situation de détresse. Plus précisément, les Cocos envoient le signal que l'émetteur se conforme de manière crédible à Bâle III.

Comment fonctionnent les obligations convertibles contingentes ?

Les principales caractéristiques techniques détaillées des CoCos ont été décrites par Avdjiev et al. (2013). Contingent convertible bonds feature both a trigger mechanism and a loss absorption mechanism.

Les obligations contingentes convertibles comportent à la fois un mécanisme de déclenchement et un mécanisme d'absorption des pertes. Le mécanisme de déclenchement détermine le moment où l'activation a lieu. Les déclencheurs peuvent être classés en deux catégories distinctes : discrétionnaires ou mécaniques. Les CoCos peuvent être activés sur la base de l'évaluation de la solvabilité de l'émetteur par le régulateur. C'est ce qu'on appelle un déclencheur discrétionnaire ou un déclencheur de point de non-viabilité (PONV). En ce qui concerne les déclencheurs mécaniques, l'activation des CoCos se produit lorsque les fonds propres de la banque émettrice tombent en dessous d'une fraction de ses actifs pondérés en fonction des risques. Cette fraction est spécifiée à l'avance lors de l'émission des obligations et reste fixe. Le capital de la banque peut être mesuré de deux manières différentes : soit en fonction de la valeur comptable, soit en fonction de la valeur de marché. Les déclencheurs basés sur la valeur comptable sont franchis lorsqu'un ratio qui reflète l'état du bilan de l'émetteur passe en dessous d'un certain seuil. Le plus couramment utilisé est le ratio de fonds propres de base de catégorie 1 pondéré en fonction des risques. Mais d'autres types de ratios d'adéquation des

fonds propres, ainsi que le ratio de levier ou les ratios de liquidité sont parfois utilisés également. Les déclencheurs basés sur la valeur de marché sont franchis lorsque le cours de l'action de la banque émettrice tombe en dessous d'un certain seuil. Plus précisément, ils sont basés sur le ratio capitalisation boursière/actifs.

L'absorption des pertes peut se faire de deux manières : l'annulation du principal ou la conversion en actions. Dans les deux cas, l'absorption des pertes entraîne une augmentation du capital. Dans le cas d'une annulation de principal, l'augmentation du capital se produit lorsque les CoCos deviennent nuls et non avendus. Le paiement de leurs intérêts et de leur principal sont annulés et l'émetteur peut les conserver comme fonds propres. L'annulation peut être partielle ou totale, temporaire ou permanente. Dans le cas d'une conversion en actions, l'augmentation du capital se produit lorsque les CoCos se transforment en actions. Le taux de conversion est prédéfini dans le contrat et dépend soit du prix de vente des actions au moment de l'émission, soit du prix du marché boursier au moment de l'activation, soit d'une combinaison des deux.

Maintenant que nous avons vu ce que sont les obligations convertibles contingentes et comment elles fonctionnent, examinons leurs avantages, la façon dont elles ont été intégrées dans le cadre réglementaire de Bâle III et comment elles ont favorisé la croissance du marché.

L'intégration des CoCos dans le cadre réglementaire de Bâle III

Après la crise de 2008, les autorités nationales et internationales se sont coordonnées pour à la fois réduire les incitations des banques à prendre des risques excessifs et réduire l'impact de la faillite de sociétés financières systémiques. Les régulateurs ont mis en place des règles prudentielles plus strictes encourageant, entre autres, des ratios de fonds propres plus élevés. Le problème d'une telle contrainte unique en matière d'adéquation des fonds propres est que lorsque le ratio de solvabilité d'une société financière diminue, ses actionnaires sont incités à réduire les actifs au lieu de réduire le ratio dette/fonds propres en émettant de nouvelles actions. Cela contribue à déstabiliser davantage les marchés financiers et les autres institutions en cas de ventes en urgence. Comment faire supporter les pertes aux demandeurs privés - actionnaires et détenteurs de dettes - en cas de faillite sans déstabiliser l'ensemble de l'économie ? Un problème secondaire est que les procédures de faillite prennent du temps. Cela pourrait compliquer une résolution car les clients des institutions insolubles sont également des créanciers et ils pourraient être encouragés par une défaillance potentielle de leur banque à déplacer leur activité (Flannery, 2014).

C'est là que les CoCos sont importants. Leur caractéristique est de mettre en place un bail-in qui est prévu à l'avance, avant le défaut. Grâce aux CoCos, les sociétés financières peuvent rapidement se désendetter sans vendre leurs actifs. Ce type de dette hybride est un outil de recapitalisation automatique qui réduit la probabilité d'un renflouement financé par les contribuables puisque le risque est transféré des contribuables aux investisseurs. Les CoCos sont donc utiles à la société ex post car leur déclenchement améliore la solvabilité du secteur bancaire (Calomiris & Herring, 2013; Pennacchi, 2010). Ils peuvent également contribuer à réduire la probabilité de défaut ex ante lorsqu'ils sont utilisés comme un dispositif permettant de façonner les pratiques de rémunération afin que les dirigeants des sociétés financières évitent de prendre des risques excessifs. Dudley (2013) propose qu'afin de dissuader les dirigeants de prendre des risques excessifs, une partie importante de leurs bonus soit mise de côté chaque année afin de couvrir les futures pertes en capital en investissant par exemple dans des CoCos PWD.

Il a donc été dans l'intérêt du régulateur de leur faire une place dans le dispositif d'adéquation des fonds propres de Bâle III. Son objectif est d'assurer la réglementation prudentielle des banques dans le monde entier. Ce cadre a évolué au fil du temps et est passé par trois phases, correspondant aux trois accords de Bâle (Bâle I, Bâle II et Bâle III). Le premier accord de Bâle date de 1988 et a mis en place des exigences de fonds propres basées sur les risques de crédit, à savoir les pertes dues aux défaillances des dettes contractées par les emprunteurs des banques.

Le cadre de Bâle est l'ensemble des normes établies par le Comité de Bâle sur le contrôle bancaire. Son objectif est d'assurer la réglementation prudentielle des banques dans le monde entier. Ce cadre a évolué au fil du temps et est passé par trois phases, correspondant aux trois accords de Bâle (Bâle I, Bâle II et Bâle III). Le premier accord de Bâle date de 1988 et a mis en place des exigences de fonds propres basées sur les risques de crédit, à savoir les pertes dues aux défaillances des dettes contractées par les emprunteurs des banques. Il a été suivi par le deuxième accord de Bâle en 2004. Son objectif était d'étendre les normes réglementaires à un plus grand nombre de pays, ainsi que d'étendre ces normes pour couvrir davantage de risques auxquels les banques sont confrontées (tels que les risques de marché et les risques opérationnels). C'est cet accord qui a donné naissance aux trois piliers réglementaires encore en vigueur aujourd'hui : les exigences minimales de fonds propres (pilier 1), la surveillance prudentielle (pilier 2) et la discipline de marché (pilier 3).

Toutefois, le cadre réglementaire de Bâle II n'a pas permis d'éviter la crise financière de 2008. L'accord de Bâle III, qui date de 2010, est une tentative de renforcer les exigences en matière d'adéquation des fonds propres en ce qui concerne la quantité et la qualité des capitaux que les banques doivent mettre de côté afin d'absorber les pertes.

Le capital total des banques est subdivisé en deux compartiments : les fonds propres de catégorie 1 et les fonds propres de catégorie 2. La catégorie 1 regroupe ce qu'on appelle les fonds propres de base et se compose principalement d'actions et de réserves déclarées. Si une banque subit des pertes importantes, les fonds propres de catégorie 1 constituent un matelas de sécurité qui peut lui permettre de poursuivre ses activités. La catégorie 2 fait référence aux fonds propres supplémentaires des banques et comprend des instruments de dette subordonnée non garantis ainsi que des réserves non déclarées.

L'accord de Bâle II stipulait que les fonds propres totaux minimum (catégorie 1 + catégorie 2) qu'une banque devait mettre de côté devait couvrir 8 % du total de ses actifs pondérés en fonction des risques, avec un ratio minimum de fonds propres de catégorie 1 de 4 %. L'accord de Bâle III maintient ce ratio total de 8 % mais en révisé la composition pour donner plus d'importance aux fonds propres de catégorie 1, considérés comme plus sûrs que les fonds propres de catégorie 2. Le ratio minimum de fonds propres de catégorie 1 est passé de 4 à 6 %.

Une autre modification a été apportée et c'est précisément celle-ci qui est intéressante en ce qui concerne les obligations contingentes convertibles. Le compartiment Tier 1 lui-même a été subdivisé en deux sous-compartiments. Le premier est appelé Common Equity Tier 1 capital (CET1). Il s'agit de la plus haute qualité de capital réglementaire car il est toujours disponible pour les banques. Il comprend les actions ordinaires et les réserves déclarées et couvre au moins 4,5 % des actifs pondérés en fonction des risques. Le second est appelé Additional Tier 1 (AT1) et consiste en des capitaux hybrides présentant des propriétés à la fois de titres de créance et de capitaux propres. Il s'agit d'un capital réglementaire qui ne se matérialise que lorsque les banques subissent un niveau minimum de pertes. Il est principalement constitué d'obligations convertibles contingentes émises par les banques et couvre au moins 1,5 % des actifs pondérés en fonction des risques.

Cela signifie que l'accord de Bâle III a conféré aux obligations contingentes convertibles un statut privilégié dans le bilan des banques. Elles leur permettent de répondre en partie aux exigences en matière de fonds propres réglementaires.

Les avantages théoriques des CoCos et comment ils ont favorisé la croissance du marché

En étant comptabilisés comme Additional Tier 1 dans le calcul global du Tier 1 (CET1 + AT1), les CoCos aident les banques à se conformer aux exigences réglementaires sans sacrifier trop de rentabilité. En effet, puisque les CoCos sont considérés comme AT1, cela signifie pour les banques qu'elles peuvent se rapprocher des exigences réglementaires sans avoir à mettre de côté des fonds propres, simplement en émettant ces obligations qui sont moins coûteuses pour elles que les actions. Leurs défenseurs affirment que cela permet d'éviter les effets négatifs sur les prêts à l'économie réelle (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009; Vallée, 2019). Comme les banques n'ont pas à mettre de côté des fonds propres supplémentaires coûteux, elles peuvent prêter davantage à l'économie réelle, soutenant ainsi l'activité économique.

En ce qui concerne les investisseurs, les CoCos présentent deux avantages principaux. Premièrement, ils sont prioritaires par rapport aux actions ordinaires en termes de priorité de remboursement, conformément à la Directive sur le redressement et la résolution, au Règlement sur les exigences de fonds propres et à la directive IV sur les exigences de fonds propres. Deuxièmement, les CoCos sont associés à des rendements élevés car il existe une prime de risque basée sur cinq composantes :

- Une composante d'intérêt : Les taux d'intérêt étaient plutôt faibles jusqu'à récemment.
- Une composante de liquidité : Les CoCos sont une classe d'actifs dont la liquidité n'est pas totale.
- Une composante de risque d'extension : La plupart des CoCos sont appelés et remboursés fréquemment par les banques, mais celles-ci peuvent décider de ne pas le faire en cas de difficultés.
- Une composante de risque d'annulation de coupon : Pour certains CoCos, les coupons sont annulables à la discrétion de l'émetteur et/ou du régulateur.
- Une composante de conversion : Celle-ci compense le cas où les obligations CoCos pourraient être converties en actions ou annulées.

Ainsi, depuis 2008, toutes les conditions sont réunies pour favoriser la croissance du marché : un cadre réglementaire favorable qui incite les banques à émettre des CoCos dont les investisseurs sont friands compte tenu de leurs rendements élevés. Les CoCos sont apparus là où les exigences en matière d'actifs hybrides absorbant les pertes ont été mises en œuvre en premier, à savoir au Royaume-Uni et en Suisse. Un tournant s'est produit en juillet 2013 avec

la directive IV sur les exigences de fonds propres, qui a transposé Bâle III en droit européen. À partir de ce moment-là, de plus en plus de banques de l'UE ont commencé à émettre des CoCos. notent que la majorité des CoCos européens (qui constituent l'essentiel du marché des CoCos) sont détenus par des investisseurs étrangers dont le statut exact est difficile à connaître. Les ménages ont une exposition indirecte bien plus importante par le biais de fonds communs de placement européens ou d'entités non européennes qu'un premier coup d'œil aux données disponibles sur les détenteurs primaires ne le laisse supposer (Götz & Tröger, 2016) . En définitive, on constate un manque crucial d'informations à cet égard (Avdjiev et al., 2020).

Bien qu'il puisse exister une multitude de combinaisons de mécanismes de déclenchement, de niveaux de déclenchement et de mécanismes d'absorption des pertes, on constate une concentration d'un type spécifique de CoCos : les PWD permanents avec une clause PONV et un déclenchement fixé précisément à 5,125 % en termes de CET1/RWA. Il ne s'agit pas d'une coïncidence. La clause PONV est nécessaire pour que les CoCos puissent être qualifiées en tant qu'AT1. Mais une clause PONV seule rebute les investisseurs en raison de l'incertitude accrue. C'est pourquoi elle est associée à un mécanisme mécanique d'absorption des pertes. Celui-ci tend à être davantage de type PWD - 60 % des CoCos émis (Vullings, 2016) et ce pour deux raisons. Premièrement, les actionnaires bancaires poussent vers plus d'émissions de PWD car ils sont sous la menace d'une dilution de leur pouvoir et de leurs dividendes en cas de déclenchement de CoCos convertibles (Avdjiev et al., 2013). Deuxièmement, on constate une demande croissante de CoCos de la part d'investisseurs à revenu fixe à qui il est contractuellement interdit de détenir des CoCos convertibles en actions. Enfin, en ce qui concerne le seuil de déclenchement de 5,125 % CET/RWA, il est particulièrement intéressant pour les banques car il s'agit du seuil de qualification pour les fonds propres AT1. En s'en tenant au strict minimum, les banques minimisent les coûts de leurs émissions par rapport à ce qu'impliqueraient des seuils de déclenchement plus élevés.

Les perturbations récentes sur le marché des CoCos

Dans un article récent, Avdjiev et al., (2020) fournissent des observations empiriques sur l'émission de CoCos par les banques entre janvier 2009 et décembre 2015. Ils constatent que les banques du monde entier ont émis 521 milliards de dollars de CoCos à travers 731 émissions différentes, auxquels s'ajoutent environ 220 milliards de dollars entre 2015 et début 2021. Ce chiffre est modeste au regard de la taille du marché obligataire - estimé à environ 100 130 milliards de dollars en 2017 par la banque des règlements internationaux - mais représente néanmoins un segment suffisamment important pour produire des données intéressantes et

alimenter une littérature académique en pleine expansion (pour une discussion statistique approfondie sur l'augmentation des contributions sur ce sujet, voir l'étude systématique de la littérature par Oster, (2020)).

Bien qu'en pleine expansion et signe théorique de la bonne santé des banques qui les émettent, le marché des obligations contingentes convertibles a été confronté à de nombreux défis au cours des quatre dernières années.

En janvier 2016, la Deutsche Bank a annoncé des résultats négatifs escomptés. Quelques mois plus tard, en septembre 2016, la presse a annoncé que la Deutsche Bank avait reçu une importante amende du ministère américain de la Justice. Après ces deux événements, non seulement le rendement à l'échéance des CoCos de Deutsche Bank a atteint des sommets historiques, mais il a également créé des tensions sur l'ensemble du marché, affectant les CoCos de toutes les grandes banques européennes. Cet incident a mis en évidence qu'une perturbation isolée pouvait amener les investisseurs à craindre soudainement des risques systémiques et à fuir les CoCos, induisant une contagion financière, déstabilisant le marché et exacerbant le problème initial.

En juin 2017, les autorités européennes ont décidé, par le biais du mécanisme de résolution unique européen, d'approuver l'acquisition par Santander de Banco Popular (la sixième banque d'Espagne à l'époque). Cette dernière était confrontée à des difficultés économiques dues à une forte concentration de créances douteuses et n'était pas en mesure de lever des capitaux après le krach boursier de ses actions et la fuite de ses déposants. Toutes les actions existantes de Banco Popular et leurs obligations contingentes convertibles ont été dépréciées, ce qui a entraîné l'annulation de 1,25 milliard d'euros de CoCos. C'était la toute première fois que des obligations convertibles contingentes étaient annulées, bien qu'en raison d'une décision discrétionnaire prise dans le cadre d'une fusion entre banques. En 2019, Banco Santander a de nouveau déstabilisé le marché en reportant temporairement le rappel de 1,5 milliard d'euros de CoCos 6,25% .

Mais c'est surtout la crise économique provoquée par la pandémie de SRAS-CoV-2 qui a entraîné le plus de perturbations. Encouragées par les gouvernements, les banques ont prêté massivement aux entreprises pour soutenir l'économie, entraînant une forte augmentation de la dette privée. Face au risque d'une augmentation des défauts de paiement, certaines banques centrales ont demandé aux banques nationales de suspendre le remboursement de coupons CoCo, afin de préserver solvabilité compte tenu de l'incertitude économique générale. Ce fut le

cas de la Banque centrale de Nouvelle-Zélande en avril 2020. De même, à la fin du mois de décembre 2020, la Piraeus Bank n'a pas reçu l'autorisation de la banque centrale européenne de rembourser les CoCos émis en 2015 et dont le coupon était dû le 2 décembre 2020. Cela a déclenché la conversion en actions. Cependant, il s'agissait d'un cas très spécifique car les obligations convertibles contingentes déclenchées étaient détenues par le gouvernement grec. Cette activation a fait de la Piraeus Bank une banque publique.

Certaines banques nationales ont choisi de reporter elles-mêmes le remboursement du coupon des CoCo. Bien que les contrats CoCo prévoient cette possibilité, cela a provoqué de nouvelles perturbations sur le marché. Un mois seulement après le succès de sa première émission de CoCo en 6 ans, en février 2020, la Deutsche Bank a annoncé qu'elle retarderait le remboursement de 1,25 milliard de dollars de la dette CoCo à 6,25 %. La valeur de l'obligation CoCo récemment vendue est tombée à environ 50 % de sa valeur nominale. Dans le même temps, les investisseurs ont tenté de se protéger des risques en achetant massivement des CDS sur la dette de la Deutsche Bank ainsi que des CDS sur la dette d'autres banques. En conséquence, à la fin du mois de mars, la société de gestion d'investissements Pimco a vu son fonds de titres de capital de 8 milliards de dollars - qui comptait les CoCos parmi ses cinq principales positions à la fin de 2019 - baisser de près de 13 % pour l'année écoulée. En mai 2020, Lloyds Banking Group, dont les bénéfices du premier trimestre ont fortement diminué en raison du provisionnement pour des créances douteuses dues à la crise, a déclaré aux investisseurs qu'il ne rappellerait pas une obligation CoCo de 750 millions d'euros.

Les mauvaises perspectives économiques, le risque d'activation des CoCos et l'intervention des banques centrales dans les décisions de les racheter ou non ont entraîné une forte contraction du marché au début de 2020. Mais depuis, les banques ont fait état d'exigences de fonds propres suffisantes pour rassurer les investisseurs. Cela a conduit à une récupération presque complète du marché à la fin de 2020.

Néanmoins, le marché des CoCo connaît de nouvelles turbulences depuis 2022. Après des années de taux d'intérêt très bas, les banques centrales les relèvent pour contrer l'inflation. Tant que les taux étaient proches de zéro, les CoCos offraient aux investisseurs une opportunité de rendement élevé et la demande était forte. Afin de continuer à attirer les investisseurs, les banques doivent maintenant payer de plus en plus d'intérêts sur leurs CoCos. Un record a été établi lorsque le Credit Suisse a émis 1,6 milliard d'euros de CoCos à un taux d'intérêt de 9,75 %. A titre de comparaison, la dernière émission de CoCos par Credit Suisse remonte à 2020

pour un montant de 1,5 milliard d'euros et un taux d'intérêt de 4,5%. Cette tendance est confirmée par l'évolution de l'indice ICE BofA Contingent Capital sur le spread ajusté des options (OAS). La différence entre le rendement des CoCos après ajustement de leur option et les taux actuels du Trésor américain a augmenté. La question est de savoir si cette hausse des taux sera durable pour les banques, car le maintien de leurs niveaux d'AT1 deviendra de plus en plus coûteux.

ENJEUX

Revue de littérature

Les obligations convertibles contingentes font depuis des années l'objet de débats théoriques qu'Oster (2020) résume comme " rendant tout et rien possible ". Passer en revue les principaux jalons de la littérature existante remplit un triple objectif : 1. Cela met en contexte cette thèse de doctorat en soulignant les recherches précédemment effectuées et sur lesquelles mon travail s'appuie. 2. Cela souligne le manque de certitude quant aux effets potentiels d'une activation généralisée des CoCos en cas de nouvelle crise financière. 3. Cela met en évidence un certain nombre d'angles morts que cette thèse cherche à combler et à justifier la méthodologie employée.

La littérature existante peut être divisée en deux courants. Le premier concerne principalement la conception optimale des CoCo afin de rendre leur utilisation par le secteur bancaire plus efficace. Le second porte sur les avantages et les inconvénients de l'émission et de l'activation des CoCo.

Littérature sur la conception optimale

Au cours des jeunes années du marché, les auteurs se sont attachés à essayer de trouver la conception optimale des CoCos et ont discuté des effets pervers que des mécanismes de déclenchement et d'absorption des pertes mal conçus pourraient avoir. Avec des déclencheurs mécaniques, les ratios comptables ne sont pas calculés très fréquemment (Plosser, 2013) et sont mesurés de manière rétrospective en plus d'être soumis à des pressions politiques (McDonald, 2010). Cela peut conduire à un manque d'information pour les investisseurs et à une activation trop tardive, comme l'a montré Duffie (2009) dans une analyse de ce qui se serait passé pour la banque d'investissement américaine CityGroup en 2008 si elle avait émis des CoCos avec un déclencheur comptable.

Bien que les déclencheurs mécaniques basés sur les valeurs de marché puissent être calculés à une fréquence beaucoup plus élevée, ce qui permet de contourner les inconvénients des déclencheurs comptables, ils présentent leurs propres inconvénients. Tout d'abord, ils peuvent inciter les investisseurs à vendre à découvert les actions de l'émetteur afin de générer une spirale auto-réalisatrice, faisant baisser le prix de l'action et déclenchant les CoCos (Hillion & Vermaelen, 2004). Il y a également un problème possible avec les équilibres de prix multiples, ce qui les rend vulnérables aux attaques spéculatives, comme le montrent Calomiris & Herring (2013), Pennacchi et al., (2014) et Sundaresan & Wang, (2015). Enfin, les déclencheurs basés sur les valeurs de marché peuvent entraîner des distorsions du contenu informationnel des prix (Berg & Kaserer, 2015; Bond et al., 2010; Faure-Grimaud, 2002; Glasserman & Nouri, 2016). Tous ces inconvénients expliquent pourquoi les déclencheurs basés sur les valeurs de marché sont restés une option théorique, uniquement explorée par la littérature académique. Dans la pratique, tous les CoCos qui ont été émis jusqu'à présent utilisent un déclencheur basé sur la valeur comptable.

Les déclencheurs purement discrétionnaires ont également leur lot de problèmes. Certes, il n'y a pas de problème de moment d'activation, puisque le régulateur peut le décider à tout moment. Il n'y a pas non plus d'incitation à manipuler le cours des actions ou la fixation des prix en fonction d'équilibres multiples. Cependant, la nature arbitraire de cette décision introduit beaucoup d'incertitude pour les investisseurs qui ne savent pas quand et comment l'activation aura lieu.

Les déclencheurs purement discrétionnaires ont également leur lot de problèmes en lien avec le débat entre règle et décision discrétionnaire. Certes, il n'y a pas de problème de moment d'activation, puisque le régulateur peut le décider à tout moment. Il n'y a pas non plus d'incitation à manipuler le cours des actions ou la fixation des prix en fonction d'équilibres multiples. Cependant, la nature arbitraire de cette décision introduit beaucoup d'incertitude pour les investisseurs qui ne savent pas quand et comment l'activation aura lieu. Une autre question importante ici est la crédibilité de l'intervention du régulateur en raison du problème du "too-big-to-fail" (Aiyar et al., 2015). Si la conversion dépend uniquement du pouvoir discrétionnaire du régulateur, intervient souvent trop tard et seulement lorsque la solvabilité de l'institution financière est déjà sérieusement dégradée (Consiglio & Zenios, 2018). Bulow & Klemperer (2013) affirment que l'échec de la réglementation bancaire est dû au fait que le système réglementaire de fonds propres n'est capable de refléter les changements dans la stabilité financière que très lentement. En outre, les auteurs soulignent un excès structurel de laxisme

réglementaire. Il est difficile pour un tiers de savoir quelle est la situation exacte d'une banque. Compte tenu de cette incertitude, il peut être difficile de pas céder à la tentation d'attendre plus d'informations et de ne rien faire (Posner, 2010). Par conséquent, une combinaison de déclenchement discrétionnaire et mécanique plutôt qu'un déclenchement purement discrétionnaire est susceptible de garantir une meilleure crédibilité de l'engagement de l'émetteur. En pratique, c'est la raison pour laquelle la plupart des déclencheurs de CoCos sont hybrides (Avdjiev et al., 2013).

En ce qui concerne le mécanisme d'absorption des pertes, Bulow and Klemperer (2013) montrent qu'une conversion en actions entraîne un afflux soudain de nouveaux actionnaires et donc une dilution du pouvoir des actionnaires. Avdjiev et al. (2013) développent davantage : lorsque la conversion se fait en fonction du cours de l'action au moment de l'activation, elle génère plus de nouvelles actions car le cours de l'action est très bas, ce qui accroît la dilution. Les actionnaires sont alors incités à éviter que le bilan de la banque ne se détériore trop. Par conséquent, comme le suggère Dudley (2013), la conversion des CoCos en actions peut être utilisée pour contrôler efficacement l'aversion au risque des dirigeants de la banque et réduire la probabilité ex ante d'une faillite. Si Admati et al. (2013) montrent que les CoCos PWD introduisent un risque d'aléa moral plus élevé que les CoCos convertibles dans la mesure où les actionnaires des banques sont moins incités à éviter l'activation, d'autres auteurs préconisent leur utilisation. Li et al. (2018) affirment qu'ils contribuent à stabiliser le secteur financier en améliorant la solvabilité des banques, tandis que Vallée (2019) montre qu'ils ne sont pas associés à un quelconque risque de « cercle vicieux », car il n'est pas nécessaire pour les investisseurs à revenu fixe de procéder à des ventes en urgence à la suite d'un déclenchement.

Littérature sur les avantages et inconvénients

Il apparaît donc que 11 ans après les premières émissions de CoCos, il n'y a toujours pas de consensus sur ce que devrait être une conception optimale. Mais le débat académique sur les CoCos va plus loin. Si certains auteurs y voient un outil utile pour stabiliser le secteur bancaire en cas de crise, d'autres vont jusqu'à remettre en question leur utilisation et mettent en garde contre certaines situations où les CoCos pourraient s'avérer déstabilisants pour l'économie.

Certains auteurs affirment qu'ils devraient améliorer la solvabilité du secteur bancaire et diminuer la probabilité d'un renflouement financé par le contribuable (Calomiris & Herring, 2013; Pennacchi, 2010). D'autres auteurs insistent sur le fait que les CoCos réduisent la nécessité de procéder à des ventes en urgence d'actifs lorsque la solvabilité des banques se

dégrade trop, ce qui limite le risque de cercle vicieux et de contagion financière (Vallée, 2019). Enfin, leurs défenseurs affirment qu'ils atténuent les effets d'entrave de la réglementation sur la rentabilité des banques, leur permettant toutes choses égales par ailleurs d'augmenter les prêts à l'économie réelle (Duffie, 2009; Flannery, 2016; Squam Lake Working Group, 2009).

Mais les CoCos ont aussi des détracteurs. Du côté des inconvénients, plusieurs travaux de recherche mettent en garde contre une augmentation potentielle de la prise de risque et de l'aléa moral, car les banques savent qu'elles seront renflouées par les investisseurs si elles ne le sont pas par les gouvernements (Berg & Kaserer, 2015; Flannery, 2016; Hilscher & Raviv, 2014; Martynova & Perotti, 2018). Certains auteurs montrent comment les réévaluations soudaines des risques par les investisseurs en raison de la complexité des CoCos pourraient avoir des effets déstabilisants sur le secteur financier (Admati et al., 2013; M. Allen et al., 2002; Goodhart, 2010; Sundaresan & Wang, 2015). D'autres se concentrent sur la manière dont le mécanisme d'absorption des pertes déclenché par l'activation des CoCos peut intervenir trop tard, limitant ainsi leur utilité (Delivorias, 2016; Pazarbasioglu et al., 2011). Certains craignent également que les CoCos ne réduisent pas le risque réel auquel le secteur bancaire est confronté, mais le déplacent simplement vers d'autres secteurs de l'économie (Avdjiev et al., 2013). Enfin, un article empirique récent de Bologna et al. (2020) montre l'existence d'un canal de contagion financière spécifique aux CoCos.

La littérature existante est donc particulièrement divisée. D'une part, on peut s'attendre à des effets positifs des émissions de CoCos : les banques individuelles devraient être plus résilientes en période de crise et il devrait y avoir moins de besoin de renflouements payés par le contribuable. Mais d'un autre côté, ces avantages théoriques sont à mettre en contraste avec les effets négatifs attendus (et même observés) tels que l'augmentation de l'aléa moral, les ajustements soudains et déstabilisants du marché et les effets potentiels de contagion financière.

Questions de recherche

L'examen de la littérature existante dans la section précédente montre que si les CoCos présentent divers avantages théoriques, ils semblent également provoquer des effets incertains et indésirables au niveau macroéconomique. Cette incertitude est d'autant plus aggravée que, jusqu'à présent, "nous ne connaissons pas le delta entre la théorie et la pratique" (Oster, 2020). En effet, les CoCos n'ayant encore jamais été activés, nous ne disposons pas de données empiriques pour procéder à une évaluation économétrique globale qui permettrait de trancher au moins une partie de ces débats.

Cela laisse trois ensembles de questions sans réponses. Le premier est lié à l'efficacité des obligations CoCos. Peuvent-elles remplir leur mission de stabilisation du secteur bancaire en cas de crise financière. Peuvent-elles empêcher les faillites ? Quelle quantité serait nécessaire pour renflouer les banques après une crise ? Dans quelle mesure réduisent-ils le besoin de renflouement par les gouvernements ?

Le deuxième ensemble de questions concerne les effets négatifs et bénéfiques pour le reste de l'économie. Si les CoCos sont efficaces pour le secteur bancaire, le sont-ils également pour l'économie dans son ensemble ? Les coûts de ces activations pourraient-ils être supérieurs à leurs bénéfices dans certaines situations ? Le transfert de risque des contribuables vers les investisseurs constitue-t-il toujours un résultat positif net ? Comment ce transfert de risque se traduit-il pour l'ensemble de l'économie par rapport à une économie sans obligations CoCos ? Quel est l'impact des émissions d'obligations CoCos sur le risque systémique ? Le réduisent-ils, ou le déplacent-ils simplement, ou pire encore, l'augmentent-ils ? Les CoCos joueront-ils un rôle stabilisateur ou déstabilisateur en cas de nouvelle crise financière ? Dans quelles situations les CoCos pourraient-ils déstabiliser l'économie ? Et enfin, compte tenu de toutes ces incertitudes, les régulateurs ont-ils raison d'encourager ces mécanismes de renflouement via les investisseurs ?

Et enfin, compte tenu de toutes ces incertitudes, les régulateurs ont-ils raison d'encourager les banques à émettre des obligations contingentes convertibles ?

METHODOLOGIE

L'hypothèse clé sur laquelle repose cette thèse de doctorat est que l'incapacité de la littérature existante à répondre aux questions soulevées dans la section précédente est due au manque de recherche comblant le fossé entre la microéconomie et la macroéconomie. Je considère que le type de modèle le plus approprié pour accomplir cette tâche est un modèle stock-flux cohérent basé sur agents (SFC-ABM).

Comme le fait remarquer Charles Goodhart : "L'une des faiblesses de certaines analyses des CoCos est qu'elles se concentrent sur l'effet d'une activation sur une unique banque en difficulté, plutôt que d'explorer également les effets sur la dynamique du système financier dans son ensemble (l'une des principales faiblesses inhérentes à notre système réglementaire antérieur)." (Goodhart, 2010). En effet, l'essentiel de la littérature théorique existante se concentre sur les avantages et les inconvénients des CoCos à un niveau micro. Ce faisant, ces

analyses ne permettent pas de conclure si les CoCos sont utiles ou dangereux pour l'économie dans son ensemble. Elles ne fournissent des informations que sur un aspect à la fois des CoCos et uniquement au niveau d'une banque isolée.

Or, ce qui est valable pour une banque isolée ne l'est pas nécessairement pour l'ensemble du secteur - comme autant de répétitions agrégées d'un même phénomène. Dans un secteur où l'importance de ses agents peut être systémique et où chaque décision peut avoir de profondes répercussions à l'échelle macroéconomique, comme l'a montré la crise de 2008, les banques sont interdépendantes. Par conséquent, des interactions locales simples et prévisibles bien documentées peuvent générer des mécanismes globaux complexes et inattendus. Par exemple, si deux banques ont investi dans le même actif et que l'une d'entre elles se trouve en difficulté en raison d'une chute soudaine de la valeur de ses actifs, elle réagira en déclenchant des ventes en urgence d'actifs, accentuant encore plus la baisse des prix, ce qui affectera le portefeuille de l'autre banque qui était jusque-là solide.

Par conséquent, toute évaluation exhaustive de l'efficacité et des coûts cachés potentiels des obligations contingentes convertibles, doit s'appuyer sur un cadre macroéconomique qui tient compte des interactions entre les agents qui peuplent l'économie. Comme il n'y a pas encore eu d'activations classiques de CoCos, on ne peut pas s'appuyer sur des données empiriques ; on doit donc simuler ce qui se passerait si les CoCo étaient activées dans une économie suffisamment proche de ce qui est observé dans la réalité. Cela nécessite l'utilisation d'un modèle théorique contrefactuel mais ancré empiriquement. Le modèle doit être capable de tirer des conclusions macroéconomiques sur la base d'interactions microéconomiques.

Pour arriver à un tel modèle, je commence par construire son cadre macroéconomique. Il en résulte le modèle stock-flux cohérent (SFC) présenté dans le Chapitre 2. Ce modèle purement agrégé est une étape préliminaire et doit être considéré comme tel. Son but est de fournir quelques résultats qualitatifs et de préparer le terrain pour les deux chapitres suivants qui constituent le cœur de la thèse. Dans le Chapitre 3, j'ajoute au cadre SFC des fondements microéconomiques à base d'agents hétérogènes (AB). Dans le Chapitre 4, je complexifie ces fondements microéconomiques en introduisant des comportements d'apprentissage.

STRUCTURE DE LA THESE

Chapitre 1 : Contexte, enjeux et méthodologie

Ce chapitre sert d'introduction approfondie à cette thèse de doctorat. Je reviens sur la genèse des CoCos. Je décris leur fonctionnement et la manière dont ils s'inscrivent dans le cadre réglementaire de Bâle III avant d'examiner les évolutions du marché, de son essor initial aux perturbations plus récentes. Je procède ensuite à une revue de la littérature sur les obligations convertibles contingentes afin de mettre en évidence les recherches effectuées précédemment et sur lesquelles mon travail s'appuie, d'illustrer le manque de certitude quant aux effets de l'activation des CoCos et d'identifier un certain nombre d'angles morts que cette thèse cherche à combler. Je justifie ensuite les choix méthodologiques retenus dans les chapitres suivants, et en particulier les types de modèles utilisés.

Chapitre 2 : Obligations contingentes convertibles et stabilité macroéconomique dans un modèle stock-flux cohérent

Ce chapitre étudie une économie kaleckienne dans un modèle stock-flux cohérent afin d'évaluer l'effet des activations d'obligations contingentes convertibles en ce qui concerne la stabilité macroéconomique. Les caractéristiques distinctives du modèle sont un double secteur des ménages (travailleurs et investisseurs) et un double système bancaire (banques de détail et banques d'investissement). Deux séries de simulations sont mises en œuvre. L'une se concentre sur une augmentation des défauts de paiement sur les prêts des ménages travailleurs qui déclenche une annulation des CoCos émis par les banques de détail et l'autre sur une baisse des prix des actions des entreprises qui déclenche une annulation des CoCos émis par les banques d'investissement. Les effets globaux sont qualitativement similaires. Il y a un transfert des coûts de risque et d'ajustement des émetteurs vers les détenteurs de CoCos. Cela réduit la consommation des ménages investisseurs et l'investissement des entreprises. Les simulations montrent que l'activation des CoCos a un effet positif sur le bilan des émetteurs de CoCos. L'activation réduit également le coût des renflouements publics. La contrepartie est une augmentation de l'instabilité réelle et financière. Deux recommandations réglementaires découlent de ce travail : (1) Les banques pourraient être tenues d'émettre une fraction de leur dette en CoCos afin de réduire les coûts de renflouement. (2) Lorsque les CoCos sont activés, leur émetteur pourrait être contraint de ne pas intervenir sur tout ou partie des marchés financiers, pour une période de temps et/ou un montant prédéfini afin de limiter la déstabilisation des prix des actifs

Chapitre 3 : Obligations contingentes convertibles et stabilité macroéconomique dans un modèle stock-flux cohérent à base d'agents

Ce chapitre vise à fournir des fondements microéconomiques au cadre macroéconomique présenté dans le Chapitre 2. L'analyse s'appuie sur une extension du modèle JMAB développé par Caiani et al. (2016). La dynamique et les variables macroéconomiques découlent du comportement adaptatif et des interactions d'agents hétérogènes. L'offre, la demande, la fixation des taux d'intérêt et l'organisation du marché des CoCos sont affinés. Le modèle est validé empiriquement en vérifiant que l'extension est capable de reproduire les faits stylisés microéconomiques et macroéconomiques initialement reproduits par le modèle original JMAB. Un balayage de paramètres est effectué pour différentes valeurs du seuil d'activation des CoCos. Les simulations Monte Carlo montrent que les renflouements résultant de l'activation des CoCos en cas de crise non seulement se substitue partiellement à des renflouements coûteux pour le contribuable, mais limite aussi de manière efficace les faillites bancaires et contribuent à des ratios d'adéquation des fonds propres plus élevés. Cette stabilisation du secteur bancaire est positive pour l'économie dans son ensemble tant que le volume des CoCos en circulation n'est pas trop élevé. On observe des effets positifs de second ordre sur l'investissement et le PIB. En effet, comme il y a moins de faillites bancaires, les banques peuvent maintenir leurs activités, notamment les prêts aux entreprises pour financer leurs investissements et leur production. Au-delà d'un certain volume, les activations affectes négativement les agrégats macroéconomiques. Plus il y a de CoCos en circulation, plus le transfert de valeur nette est important lorsqu'ils sont déclenchés. Au-delà d'un certain montant, les effets négatifs sur la consommation commencent à l'emporter sur les effets positifs de second ordre et cela finit par affecter également le PIB. Dans certaines situations, les CoCos peuvent contribuer à renforcer les effets d'une crise plutôt qu'à les atténuer. Il est donc dans l'intérêt du régulateur de contrôler l'expansion du marché des CoCo.

Chapitre 4 : Obligations contingentes convertibles et stabilité macroéconomique dans un modèle stock-flux cohérent à base d'agents, augmenté d'une composante d'opinion dynamique et de comportements d'apprentissage

Ce chapitre propose une extension du modèle présenté dans le Chapitre 3 qui consiste à ajouter une composante d'opinion dynamique (similaire à Salle & Seppecher, 2015) ainsi que des comportements d'apprentissage des investisseurs suivant un algorithme de Roth-Erev modifié (Nicolaisen et al., 2001). Le modèle est validé empiriquement en vérifiant que cette extension est capable de reproduire des faits stylisés pertinents sur le plan microéconomique,

macroéconomique et financier. Un modèle autorégressif de Poisson est utilisé pour montrer que les activations de CoCos sont sujettes à des effets dominos et à une contagion financière par le biais de la diffusion d'informations suite à des annonces de report de remboursement des CoCos. Un balayage de paramètres est effectué pour montrer que cette diffusion d'informations se produit pour différents comportements d'apprentissage. Les CoCos sont susceptibles de jouer un rôle déstabilisateur pour la sphère financière. Lorsque les banques décident de retarder le remboursement de CoCos parce qu'elles sont prudentes quant à leur solvabilité, les investisseurs peuvent réagir à ces annonces en se détournant du marché des CoCos. Cela crée effet rétroactif : en raison de cette diffusion d'informations, il devient plus difficile pour les banques de mettre de côté des fonds propres AT1, ce qui entraîne des activations de CoCo dû à canal de contagion spécifique qui semble toutefois s'affaiblir au fur et à mesure que les investisseurs adaptent leur comportement. Deux recommandations de réglementation prudentielle en découlent : (1) Les accords de Bâle devrait examiner plus attentivement le rôle des CoCos dans la catégorie 1 de fonds propres. En effet, si le matelas de sécurité constitué par l'AT1 permet, toutes choses égales par ailleurs, d'absorber certains chocs et limiter le recours aux renflouements, il peut également multiplier les risques que les difficultés de certaines banques se propagent au reste du secteur. (2) Tout doit être fait pour que le mode de fonctionnement des CoCos soit aussi clair que possible pour les investisseurs qui les achètent. Cela peut atténuer les surajustements qui surviennent sur le marché en cas de perturbations.