ESSAY ON EUROZONE CRISIS

THÈSE

Pour obtenir le grade de
Docteur de l'Université de Strasbourg
en
Sciences Économiques

Présentée
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26 Septembre, 2014

Acknowledgements

I wish to thank my advisors Frédéric DUFOURT and Meixing DAI for their support, encouragement and inspiration during these years. Their leniency towards subordinates, such as a beginner in economics like me, makes them the example of how to conduct myself; their rigorous attitude in research serves as the role model for my future career, and their achievements are goals in my future research.

I would like to thank Yun, my life companion. We had experienced joy, sorrows and suffering, but we remain united during this wonderful discovery of our life. . .

I would also like to thank the University of Strasbourg for providing me such a great environment to acquire knowledge and for financing my Ph. D study. Thanks for these unforgettable and wonderful years.

To Yun

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Abstract

    In this Ph. D. thesis, we analyze the conditions for the emergence and the aggravation of the recent crisis in Europe from 2008 to 2012. The major objective of this Ph. D. thesis is to develop theoretical models which will be effective in investigating the twin banking and sovereign debt crises in a monetary union with a broadly similar institutional design to the EMU before 2012. Different from 'traditional' financial crisis models that shed light on the role of the central bank in crisis policy response, the models developed in this thesis investigate and underline the importance of fiscal crisis management. While accentuating financial vulnerability, we explore the relationship between the banking sector, the real economy and the public budget in the context of a monetary union. This thesis consists of four theoretical models of the banking crisis, with the first framework depicting the financial crisis which burst in 2008 in small European economies outside the EMU and the next three models elucidating the crisis situation in the Eurozone from early 2009 until August 2012. This structure, composed of two types of crises that erupted in Europe, on the one hand corresponds to the chronology of the European financial crisis and on the other hand, permits a deeper understanding of the Eurozone crisis and its distinctive features.

Chapter 1 General Introduction

The financial system is pivotal for the functioning of the economy as a whole, and the banking sector lies at its heart. A sound financial system permits the efficient allocation and deployment of economic resources, both in terms of space and time, in an uncertain environment. A. Hamilton (1781) stated that "banks were the happiest engines that ever were invented for creating economic growth." By pooling the resources of economic actors, banks transform short-term liabilities into long-term investment and ultimately boost economic growth, while allowing investors access to their savings at short notice (Diamond and Dybvig, 1983; Levine, 1992). These inherent characteristics of financial intermediaries, while underpinning the positive role of finance, can also be a source of risk and fragility. The evolution of finance is a history of 'ups and downs' punctuated by bank failures, currency and sovereign debt crises (Reinhart and Rogoff, 2009).

The recent global financial crisis has brought financial fragility under the spotlight and has become the predominant concern of policy makers and economists. Manifested since August 2007 in the United States by a rise in subprime mortgage foreclosures, this crisis soon affected major American financial institutions, and after the collapse of Lehman Brothers in September 2008, it spilled over across the industrial world. In Europe, small economies outside the EMU, such as Iceland, and several Central and Eastern European (CEE) countries, were the first 'victims' of this global crisis, partially due to the abrupt investment reversals of northern European countries in a movement of 'flight-to-quality'. These small economies thus became embroiled in a systemic banking and currency crisis and experienced crisis situations comparable to those of East Asian and Latin American countries in 1990s. In Eurozone, the large impact of the global crisis was postponed until late 2009, when Greece entered a broader economic and sovereign debt crisis. This delay could be attributed to the elimination of currency crisis and market participants'

confidence that the monetary union is too big to fail. Nonetheless, once market participants perceived the flaw in EMU's architecture that lay at the root of the incompatibility between financial integration and fiscal independence, the collapse in market confidence opened the door to self-fulfilling and mutually reinforcing systemic banking and sovereign debt crises.

Although having been resolved elsewhere by now, the global crisis left an ongoing concern in Eurozone countries. Before the eruption of the crisis, financial fragility played a limited role in the theory and practice of advanced countries' macroeconomic policy. Studies in this area generally serve to examine the interactions between rapid financial liberalization and the vulnerability of countries in transition which are facing increasingly important banking sectors. The financial aspect was arguably secondary in concerns about the initial architecture of the EMU. Most of the attention was given to monetary and fiscal policies and structural reform in non-financial sectors (Obsfeld, 2013). Consequently, the necessity for a profound re-evaluation of the role of financial fragility in industrialized countries' macroeconomic policy, and especially in the dynamics of the EMU, has clearly been revealed by the unfolding Eurozone crisis.

In this Ph. D. thesis, we analyze the conditions for the emergence and the aggravation of the recent crisis in Europe from 2008 to 2012. Except for one chapter devoted to studying the banking and currency crises in small European countries outside the EMU to provide a tangible comparison with the Eurozone crisis, the thesis focuses on the crisis situation in Eurozone and the major problems entangling its member states, especially those in the 'Euro-periphery'. Through three theoretical models, we analyze several distinctive while long-ignored factors which have contributed to the genesis and the persistency of the Eurozone crisis. Spurred on by deepening financial integration, ample global liquidity and eased collateral borrowing constraints, the first decade of the Euro was marked by the rapid development in financial markets associating with considerable expansions in capital flows and in the banking sector. Nevertheless, under the

unique monetary policy, the interdependence of financial systems and the independence of fiscal policy have made the financial safety net, provided by national governments in sovereign debt distress, ineffective following the onset of the crisis. As indicated by Schoenmaker (2013) and Obsfeld (2013), the Eurozone countries became entangled in a financial trilemma whereby it appeared to be impossible for an economy to maintain financial integration, financial stability and fiscal independence at the same time. Shambaugh (2012) developed a similar idea to depict what was happening in the Eurozone as three interlocking crises burst simultaneously onto the financial system, the real sector and the public budget. In this Ph. D. thesis we consider that the financial-fiscal intertwining was actually at the heart of the Eurozone banking and sovereign crises. We take into account the link between the banking system, the real economy and fiscal revenues, and show that an increasingly enlarged banking sector can undermine a government's capacity to credibly safeguard financial stability by purely fiscal means when it only has limited room for maneuver. Thus, financial turbulence in one particular sector can easily become a general crisis. We also suggest that the deepening financial integration in Eurozone can serve as a catalyst to magnify the contagion effects which spread from one member state to another.

1.1 Several Major Features of Eurozone Crisis

Since its eruption in September 2009, the Eurozone crisis has been the focus of attention of economists and policymakers. The major objective of this Ph. D. thesis is to develop theoretical models which will be effective in investigating the twin banking and sovereign debt crises in a monetary union with a broadly similar institutional design to the EMU before 2012. Different from 'traditional' financial crisis models that shed light on the role of the central bank in crisis policy response, the models developed in this thesis investigate and underline the importance of fiscal crisis management. While accentuating financial vulnerability, we explore the relationship between the banking sector, the real economy and the public budget in the context of a monetary

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union. For investigating the roots of the Eurozone crisis, we take into account several major factors that contribute to the eruption of the twin banking and sovereign debt crises which were either unforeseen or disregarded by policymakers when they envisioned and built the monetary union.

We consider the rapid expansion of the banking sector as another important factor resulting in the vulnerability of the European financial system. The size of the European banking sector increased substantially in the period before the global crisis. In the Euro-periphery countries, the introduction of the single currency and payments system accelerated and aggravated their banks' dependence on northern European banks. The claims of the latter on Euro-periphery countries experienced a sharp upsurge from 1999 until the onset of the crisis in 2009 (OECD, 2012). Therefore, a small adverse shock affecting international markets can transform into a severe liquidity shortage in dependent countries. Also, the sheer size of the banking sector determines that its minor difficulty could lead to a downward drift in the entire economy.

We regard the unstable funding structure adopted by European banks as the second factor contributing to the fragility of the banking system. An abundant liquidity supply and relaxed borrowing constraints have encouraged European banks to expand their balance sheets through cheap but unsecured funding sources, such as wholesale funding. However, these may be inexpensive in terms of interest rates but they tend not to be low-cost in terms of social welfare. What happened or is happening in several Euro-periphery countries (i.e., Ireland, Spain, Portugal, Italy and Greece) is evidence that such uninsured short-term funding is more subject to confidence crisis and thus more prone to run. This undermines the stability of these countries' banking systems in difficult times.

These first two factors, though made vividly manifest in the Eurozone crisis, are rather common characteristics of financial crises. They can also depict basic conditions for the eruption of crisis in

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small European countries outside the Eurozone. Of course, to examine the crisis situation in these countries, we should also take account of the role of local currency and thus the monetary policy response of the central banks, and the interaction between the currency and maturity mismatches in banks' balance sheets. During the 2000s, the buildup of financial vulnerability was nourished by relatively loose monetary condition, a generally stable macro environment, and deepening financial liberalization. The worldwide evolution of the banking sector was characterized by increasingly enlarged engagements in maturity transformation promoted by abundant global liquidity (Tirole, 2011). Lending in the short-term and investing in the long-term implies that banks can hardly achieve the synchronicity between liquidity needs and offer in a 'sudden' reversal of capital flows. Except for the Eurozone, where the intervention by the ECB was considered to be belated and insufficient, the major central banks of the industrial world promptly sustained their governments to carry out large scale bailouts in the wake of the crisis. Five years after the collapse of the Lehman Brothers, when a number of countries elsewhere have got rid of their various predicaments, the global crisis remains an ongoing concern in the Eurozone, whose peripheral members remain immersed in the twin banking and sovereign debt crises. Thus, to examine the crisis situation in Eurozone, we capture the two following distinct features of the financial crisis in the monetary union.

We consider the massive cross border sovereign bond holdings as the third factor destabilizing Eurozone banks. Since their entry into the EMU, the Euro-periphery countries have experienced the convergence of sovereign yields towards Germany's borrowing rate from widely disparate levels. Nevertheless, following the disclosure of the Greek sovereign debt crisis, the government bond spreads of many Eurozone countries against Germany raised abruptly and became broadly divergent (Gerlach et al., 2010). The potential sovereign risk of Eurozone countries was largely ignored by both policymakers and market participants before the explosion of the recent

global crisis. Under EU Capital Requirement Directives, the sovereign bonds of all Eurozone countries are attributed the zero-risk weight. Also their credit ratings were comfortable enough to ensure them favorable market borrowing terms. Even Greece and Portugal were granted the 'investment-grade' by all three major credit rating agencies before 2009. The significant scale of intra-EMU bond holdings makes Eurozone banks highly sensitive to the sudden depreciation of sovereign debts of both national and other Eurozone countries. The contagion through interconnected banking sectors from periphery to core Eurozone countries has become a major concern of policymakers and economists in the EMU and across the world.

We consider the lack of a credible policy response to be another distinctive factor contributing to the genesis of Eurozone crisis. Under the deep financial integration, banks in the Eurozone are characterized by a high degree of interdependence and their substantially important size relative to the scale of their national GDP. The Maastricht Treaty left the responsibility for banking regulation and crisis management largely to national governments. While the role of the ECB as the lender of last resort was omitted, the Maastricht Treaty's explicit no-bailout clause prohibited the ECB from providing financial support to national governments with fiscal deficits. Provided that fiscal revenues are limited by the tax base that is proportional to the GDP level, the lack of seigniorage revenue implies that fiscal resources can be inadequate relative to the scale of crisis. Therefore, a pure fiscal crisis response by national governments can be highly dubious. In such a circumstance, issuing more sovereign debts in the process of crisis intervention can induce market participants to reassess the value of sovereign bonds of related governments downwardly. This in turn weakens the balance sheets of banks which hold massive national government bonds (Bolton and Jeanne, 2011; De Grauwe, 2012 and Lane, 2012). Furthermore, the credibility deficit of a national government undermines its market borrowing terms while also inducing even harsher conditions for national banks to fund through market liquidity.

Summarizing these four main factors provides a financial outline of the Eurozone crisis in its first phase before ECB's announcement, in August 2012, of the purchase of unlimited sovereign bonds of member states under great fiscal stress. We suggest that the Eurozone crisis is the byproduct of the incompatibility between interdependent banking sectors and decentralized banking supervision by national governments without monetary sovereignty. This incompatibility intensifies the link between the banking sector and the government budget, which thus becomes a channel of contagion and finally facilitates the occurrence of twin banking and sovereign debt crises rooted in the trouble in either sector. In Spain and Ireland, the government debt/GDP ratios before the onset of the crisis were 36% and 25% respectively, and their average sovereign spreads against Germany's bonds were only slightly positive. However, in the absence of monetary financing, their relatively strong fiscal positions were deteriorated after several attempts in bailing out their big but fragile banking systems. Both countries have suffered great tension, including sovereign rating downgrades and sharply upward bonds spreads, and have been urged to restore their public finances to avoid self-fulfilling debt crises. In the meantime, the banking sector of both countries, although evading the materialization of systemic turmoil largely attributed to EU-IMF rescue packages, remains highly vulnerable. In Greece and Portugal, the balance sheet of banks is moderate in terms of its size and relatively safe in terms of its structures. The main culprit of the crisis was the large negative fiscal balance that the governments recklessly conducted since the countries' entry to the EMU. As national banks hold substantially sovereign bonds of their own countries, closely following the disclosure of the government debt crisis, their financial condition became doubtful for market participants. Accordingly, these prudent banks required external assistance to tide them over the liquidity shortage caused by the depreciation of bond holdings, and the abruptly deteriorated market borrowing terms resulting from tarnished national sovereign reputations.

In a financially integrated monetary union, the risk of contagion will not be confined within a single country. Both financial institutions' cross border bond holdings and large scale investments from Euro-core to Euro-periphery countries can give rise to crisis spillover from one member state to others. This can be justified by the recent experiences of many major banks in France and Germany that have suffered huge losses due to the cross border contagion within the Eurozone.

The global financial crisis which burst in 2007 aroused concerns about the financial fragility of advanced countries. However, the analysis of the financial crisis has long been focused on investigating crises occurring in Latin America, Asia and other developing countries. Three generations of models of financial crisis, developed during the past four decades, have typically accentuated the currency dimension. The first generation of models stresses that the national fiscal and monetary imbalances can induce speculative attacks against a fixed or pegged exchange rate regime (Paul Krugman, 1979 and Flood and Garber; 1984). The second generation of models shows that doubts about the willingness of a government with contradictory objectives to sustain exchange rate peg can lead to multiple equilibria and currency crises (Obstfeld, 1986 and Eichengreen et. al., 1996), and the third generation of crisis models indicates that deteriorations in banks' balance sheets associated with asset price fluctuations can result in currency crises (Kaminsky and Reinhart, 1999 and Chang and Velasco, 2000). These scenarios are largely different from what has happened recently in the Eurozone, and these models are hence irrelevant for the analysis of the Eurozone crisis. From a theoretical perspective, very few models permit to capture the main characteristics of the Eurozone crisis. Only recently have a handful of papers addressed the interaction between banking and sovereign debt crises (i.e., Bolton and Jeanne, 2011; Acharya et al. 2013, and Corsetti and Dedola, 2013). In addition, although the role of the government in crisis response has been explored by several theoretical and empirical studies (Reinhart and Rogoff, 2008; Laeven and Valencia, 2012, and Kollman et al. 2013), barely have

any studies considered how the fiscal bailout could be optimally designed prior to the crisis. This thesis provides theoretical analyses of financial crises in advanced countries engaged in a monetary union and investigates the link between banks, government budget and the role of fiscal crisis management.

1.2   The Outline of the Ph.D. Thesis

This Ph.D. thesis consists of four theoretical models of the banking crisis, with the first framework depicting the financial crisis which burst in 2008 in small European economies outside the EMU and the next three models elucidating the crisis situation in the Eurozone from early 2009 until August 2012. This structure, composed of two types of crises that erupted in Europe, on the one hand corresponds to the chronology of the European financial crisis and on the other hand, permits a deeper understanding of the Eurozone crisis and its distinctive features.

Chapter 2, Money and the banking crisis in a small open economy, develops an analytical framework to investigate the crisis situation in small open economies which are closely related to but lie outside the EMU. The model takes into account the role of national currency and international capital flows in evaluating the fragility of the banking system during global financial crises and sheds light on the financial vulnerability caused by the maturity and currency mismatches. Our setup also elucidates how a liquidity shock in foreign creditor countries can affect the value of national currency and the activity of a small country through its commercial banks. The positive effects of the banking capital and the regulatory capital requirement on the stabilization of banking system are also examined. Furthermore, the existence of the informal sector is an important factor against the development of the formal economy, the value of the national currency and the stabilization of financial system. Integrating this model into a thesis essentially dedicated to the analysis of the Eurozone crisis is carried out for the purpose of highlighting the distinctive features of the Eurozone crisis through a tangible comparison.

In three following chapters, we develop three theoretical models to analyze the Eurozone crisis, characterized by the four features presented in the last subsection. Each framework has its own points of emphasis.

Chapter 3, The banking crisis with interbank market freeze, studies banking crises characterized by interbank market freezes, fire sales and contagion in a theoretical financial crisis model with collateralized interbank loans. We analyze the role of the interbank market in spreading and amplifying crises by distinguishing three sources of liquidity risks, i.e., panic-induced run, gambling behavior and foreign sovereign debt crisis. Our results underline that market discipline (including capital and liquidity requirement) is more appropriate for covering the predictable idiosyncratic risks confronted by individual banks than for alleviating the aggregate risk encountered by the banking sector as a whole. The malfunctioning of the interbank market in crisis times is usually linked to insufficient bank capital and/or liquidity reserves being implemented in consistence with market discipline in euphoric times. We suggest that, given the complexity and uncertainty within the financial system, market discipline cannot always stabilize the banking sector in times of crisis. On the contrary the interbank market in reinforcing the interconnection between banks, can be a channel of contagion and thus further undermine banks liquidity position and induce a systemic crisis. However, implementing more restrictive prudential regulations which override the discipline imposed by the market for reinforcing banks' resilience to shocks could hamper the role of banks as financial intermediaries. In the absence of the lender of last resort obligation for the central bank, we consider that credible crisis management by national government an indispensable backstop for restoring both confidence among market participants and normal conditions in the banking sector. The fiscal policy arrangements are efficient as long as the scope of bailout is sustainable, in the sense of not compromising the soundness of its budgetary positions.

Chapter 4, Banking and sovereign debt crises in a monetary union without central bank intervention, provides a model to analyze the conditions for emergence of a twin banking and sovereign debt crisis in a monetary union. We show that when the Central Bank does not have a lender of last resort obligation and, consequently, that government bonds are incorrectly considered as safe assets, the two main tools against systemic banking crises – financial regulation and government deposit guarantee – may have a perverse effect, and may favor, rather than mitigate, the risk of emergence of a twin crisis. Changes in investors' expectations in the face of a government commitment to rescue domestic banks may lead to a surge in risk premia on government bonds that not only decreases the market price of such bonds (thus weakening the balance sheet of private banks) but also burdens the cost of the bailout package for the government. A twin banking and sovereign debt crisis may then emerge, even though the financial safety net was effective in 'normal times'. We also use our setup to discuss related issues associated with the Eurozone crisis pertaining to the role of Credit Rating Agencies, potential contagion effects, and proposed policy options.

Chapter 5, Banking crisis, moral hazard and fiscal policy responses, examines the role of the fiscal policy as prudential instruments in preventing the over risk-taking of banks in an economy within a monetary union. The latter deprives the seigniorage revenue of its member states while ensuring them a relatively stable monetary condition. While banking regulation and crisis management are largely carried out at national level, fiscal policy becomes a principal measure available to a government to guard against financial fragility. We show that a credibly committed fiscal policy including a well-defined bailout program can incite banks to voluntarily keep sufficiently large liquidity reserves and a low financial leverage ratio, disregarding how lucrative risky activities are and whether incremental regulations are imposed or not. Our model shows that policymakers' liberty of maneuvering the fiscal policy decreases with the weight of the banking

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sector, while the moral hazard increases with it. To avoid the moral hazard and phenomena of 'too big to fail', the fiscal policy should be pre-committed and time-consistent and must take into account the expectations of banking entrepreneurs. A pre-announced policy of public lending, by reducing moral hazard incentives and adding supplementary costs for moral-hazard banks, can be an efficient complement to tax rate policy responses to crises. Accordingly, we argue that, in the absence of an autonomous national monetary policy, what the Euro-zone needs might be a time-consistent and well-conceived fiscal policy and a credibly pre-committed fiscal bailout policy.

To summarize, the contents of the thesis are organized as follows: Chapter 2 investigates the crisis in small European economies lying outside the Eurozone. We emphasize the link between the banking and currency crises and the effectiveness of monetary policy response. Chapter 3 examines the destabilizing effects of interbank market discipline. Without monetary support, a credible fiscal backstop is pivotal to ensure financial stability. Chapter 4 underlines the dilemma between financial integration and fiscal independency, and the resulting twin banking and sovereign debt crises. It is argued here that ex-post bailout plans could be effective if the government had adequate fiscal space for maneuver. Chapter 5 investigates the positive role of a time-consistent fiscal policy, including a credibly pre-committed bailout plan, in preventing banks' over risk-taking.

Chapter 2 Money and Banking crisis in a small open economy

2.1   Introduction

This chapter is based on my published paper, Cheng (2012).[1] It investigates, through an open

economic model, the conditions for the emergence of the financial crisis that burst in small

European countries outside the Eurozone following the collapse of Lehman Brothers in 2008.

The main attention of this chapter is focused on the maturity and currency mismatches on private

banks' balance sheet and on the role of the monetary policy in crisis management.

The small European economies outside the Eurozone were the first European 'victims' of

the recent global financial crisis. The eruption of the crisis highlighted the problems that these

economies have accumulated while abruptly liberalizing their financial sector. Despite their

distinct differences, the crisis situation in Iceland and some Central and Eastern European (CEE)

countries was highly comparable to that of Asian and Latin American countries in the 1990s.

The rapid activity growth in these countries was largely fuelled by massive liquidity inflows,

including foreign short-term debt and direct investment (FDI). Similar to Asian countries before

the burst of the crisis, the financial system of Iceland and CEE countries experienced increasing

dependence on foreign investment. However, during crisis times, this significant dependence led

small countries to experience aggravated financial vulnerability to external liquidity shocks.

Several studies on the informal sector show that it occupies an important place in emergent

and transitional countries and has substantially negative impacts on the formal economic sector

(Chaudhuri and Mukhopadhyay, 2013; Nguimkeu, 2014; Ordonez, 2014). In this chapter, we

consider the existence of a large informal sector as another crucial factor contributing to the

monetary and banking crises in European countries outside the monetary union. The nature of the

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[1]   The published version was in French. This chapter is thus a version translated into English.

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informal economy determines that it is not taxable by the government and cannot be controlled by the macroeconomic policy. The outcome of such a sector cannot be included in the GDP. Intuitively, the dynamics of the informal sector can reveal the immaturity of an economic system, undermining the effectiveness of the economic policy and resulting in a banking system that is more vulnerable to capital reversals.

Unlike the Asian crisis of 1997, the equity shares of major banks in CEE countries are mainly held by financial institutions of Western European countries. However, the stability of their financial system has not been significantly improved compared with that of Asian countries. On the one hand, banks in CEE countries generally have significantly high financial leverage. On the other hand, an adverse shock, such as the subprime crisis, in Western banks can induce a sharp reduction of their investments in subsidiary banks in CEE countries (i.e., through loan suspension). This can lead to a credit crunch and thus massive premature liquidation of long-term assets in small open economies.

Many economists (Diamond and Dybvig, 1983; Jagganathan Chari, 1988; Calomiris and Kahn, 1991; Hellwing, 1991) focus on the instability of the capital structure in triggering the financial crisis. Following the Asian crisis in 1997, some economists (i.e., Hardy and Pazarbasioglu, 1998; Kaminsky, 1998; Kaminsky and Reinhart, 1999; Chang and Velasco, 2001) regard the Asian crisis as the outcome resulting from financial fragility and international illiquidity. They suggest that the currency crisis is the by-product of a bank run. The latter is modelled by Diamond and Dybvig (1983) as a self-fulfilling confidence loss that forces financial intermediaries to liquidate their long-term assets prematurely. The model of Chang and Velasco (2001) provides an open economy version of Diamond and Dybvig (1983). It describes the negative effects of foreign liquidity flows, especially in the form of short-term debt, on the stability of the banking system. However, these models ignore the existence of the national currency and therefore the role of the

nominal exchange rate.

In a recent work, Diamond and Rajan (2006) introduce the money and the informal (or illegal) sector into a model of banking crisis in a small closed economy. The originality of their framework can serve to analyze the structure of bank capital and the effects of monetary policy and to explore the interactions between the financial system, the real economy and the national currency.

The empirical studies (i.e., Joyce and Nabar, 2009; Agosin and Huaita, 2012) show that international capital flows play an increasingly crucial role in investments, and this phenomenon is particularly manifest in small open countries. Thus, extending the model of Diamond and Rajan (2006) to an environment of a small open economy permits a better understanding and explanation of the recent crisis in Iceland and several CEE countries.

This chapter consists of an extension of the model of Diamond and Rajan (2006) to the context of a small open economy. Our set-up allows the consideration of the main characteristics of the recent financial crisis in Iceland and several CEE countries. Through highlighting the role of banks in the transfer of liquidity, this model analyzes the distinct impacts of the different means of funding (bank capital, short-term debt and deposit) and the negative effects of maturity and currency mismatches on banks' balance sheet. It exploits the link between the real sector, the financial system and the national currency, as well as their relationships with the informal sector. The model also provides a discussion on the effectiveness of the monetary policy in highly indebted countries that are largely dependent on international financial markets for funding.

The rest of the chapter is organized as follows. The next section will present the basic framework. Section 2.3 will examine the maximization problem of commercial banks and the factors contributing to the onset of a crisis. Section 2.4 will discuss the appropriate policy response when faced with a banking crisis. The final section will summarize the results of this chapter.

2.2 The framework

2.2.1 Basic assumptions

We build our model of banking crisis on the seminal work of Diamond and Rajan (2006). By introducing a nominal exchange rate, we extend their framework to the context of a small economy open to international capital flows and foreign products. We adopt several basic assumptions in their model, such as the role of the national currency, government bonds and commercial banks, as well as the existence of the informal economy. The national currency has two roles in the economy: on the one hand, money as well as maturing government bonds can be used to pay taxes on future dates; on the other hand, only money can be the medium of transaction in the purchases of informal goods.[2] Our small open economy is populated by five types of agents (domestic investors, entrepreneurs of production projects, dealers of informal goods, foreign creditors and banks' shareholders) and lasts for two periods with an initial date and five future dates.

Domestic residents, at the initial date, receive an amount of endowments and entrust them to banks to deploy in investment vehicles. Nevertheless, the available domestic resources are relatively small compared with the projects requiring the investment.[3] National banks may raise funds in international financial markets to support their investments. In our set-up, foreign funds are absorbed in two forms. First, following Chang and Velasco (2001), we consider foreign short-term debts that finance national banks' investments at the initial date, and banks may roll over these debts in the intermediate period. Second, to comply with the situation of CEE countries where national banks are mainly subsidiaries of Western banks, we ignore the role of the domestic capital in banks' own funds. We introduce a role for FDI such that banks' equity capital is held by foreign investors.[4] In addition, the role of the minimum capital ratio is considered in our setting.

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[2]   Money and national currency are interchangeable in this chapter.
[3]   The model of Diamond and Rajan (2006) examines the banking fragility in a small closed economy in which the only source of investment is domestic residents' deposits in national banks.
[4]   The model of Chang and Velasco (2001) adopts the concept of the international liquidity flow in the analysis of the financial crisis. However, their model ignores the role of FDI and thus the equity capital in the banking system. The integration of FDI is crucial to the analysis of recent crises. It is particularly important to the case of CEE countries, where banks' equity share is predominantly held by Western banks. Thus, the expectation of foreign investors plays a vital role in banks' liquidity position in small European countries.

Therefore, the analyses of the financial fragility in a framework considering the role of money, the nominal exchange rate and the foreign capital distinguish our model from that of Chang and Velasco (2001).

To introduce the informal sector, we consider two types of goods: formal goods (or simply products) and cash goods (or illegal goods). Products are freely traded in the formal national and international goods market either by money or by bank claims, and can be consumed or invested. The products generated by early projects are sold at date 1 and delivered to consumers at date 2 and those produced by late projects are sold at date 3 and delivered at date 4. In addition, consumers (depositors) can still buy late products with money at date 4, since producers need it to pay taxes at the final date. Differing from formal goods, the trade of informal goods is not subject to taxation. To hide their identity from the fiscal authority, the dealers of informal goods accept only money for the transaction. Early dealers receive q_1 units of informal goods at date 1, while late dealers receive q_3 units of informal goods at date 3. The utility from consuming one unit of informal goods at date 1 (or 3) is equivalent to that from one unit of formal goods at date 2 (or 4). Therefore, one unit of informal goods is a perfect substitute for one unit of formal products.

Furthermore, we adopted several simplifying assumptions similar to those of Diamond and Rajan (2006). First, for the given amounts of money and goods, the adjustment of the price level is the most direct and effective mechanism to achieve the market equilibria. We thus adopt the assumption of price flexibility in our framework. Second, to justify the transaction of goods, we assume that no one can consume his own endowments or products. In addition, to clarify the role of the national currency, all transactions are subject to the payment in advance constraint. For example, in order to consume one product or informal good at date t, the buyer is obliged to pay the seller at date $t - 1$. After receiving money or bank claims at date $t - 1$, the seller can initiate the transaction of goods destined to be delivered and consumed at date t. This constraint is also

applied to the sale of government bonds and the restructuring of immature projects.

2.2.2 The economic and environmental sequence of actions

2.2.2.1 Agents, endowments, financial assets and tax

In this small economy, only domestic investors are initially endowed with resources, including e units of formal goods, M_0 units of money and nominal government bonds that mature at date 2 in B_2 units of national currency. The money supply remains constant in the first period. At date 2, the government recovers the nominal assets (money and government bonds) that are not used to purchase products in the first period and then issues M_2 units of money and nominal bond of the second period. The latter reaches its maturity at date 4 in B_4 units of national currency.

Banks, as the intermediaries in financial transactions, are at the heart of the economy. All the banks in our model are identical and they do not have their own resources.[5] Endowed with special human capital, banks collect resources and invest them in illiquid projects. To absorb the resources from domestic residents, banks issue demand deposits denoted by d_0 that allow depositors to withdraw whenever they want. Besides, banks have access to international financial markets, in which they can borrow in the short term denoted by D^* and issue common shares.

With funds available for investment, banks finance the projects of domestic entrepreneurs. The latter possess non-transferable technology with a constant return to scale. Without initial endowment, each entrepreneur possessing a project should borrow from a bank one unit of goods before date 0. There are two types of projects in the economy: a proportion α of the total projects maturing at date 2 are called early projects and the remaining projects, maturing at date 4, are late projects. However, at the time of investment, no one can distinguish the type of a project and this information will be revealed only at date 0. Regardless of the maturity date, a maturing

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[5] Banks have special human capital, which allows them to follow the procedure of production from the initial date. Thus, banks have more information than other agents on the arrival of the intermediate date. This human capital gives banks more power in the negotiation with entrepreneurs. If other agents take over the bank to collect the loan, the amount they can recover from a mature project will be smaller than γC. The profits of banks can be interpreted as remuneration for their special human capital. In addition, banks' special human capital is a factor of imperfect competition. However, banks are competitive in the deposit market. See Diamond and Rajan (2001) for more details on the definition of banks' special human capital.

project yields $C(> 1)$ units of goods net of tax. The special ability of banks allows them to collect $\gamma C(\gamma < 1)$ units of goods from a maturing project, and the entrepreneur keeps the residual $(1 - \gamma)C$. In the event of a liquidity shortage, banks may choose to restructure illiquid projects prematurely. Restructuring each immature project delivers only $c(< 1)$ units of goods.[6] We summarize the relationship with the following inequality:

$$c < 1 < \gamma C_t < C_t \tag{2.1}$$

In this small economy, national currency and government bonds are issued at the initial date to boost the domestic production and they will be retrieved by the government through taxation. The government collects taxes with a rate τ from the output of production projects and the tax is paid only in national currency. Given that the general price level at date t is P_t, the nominal amount of tax collected from a maturing project at date t is thus

$$\frac{\tau}{1 - \tau} C_t P_t.$$

However, if a project is restructured, the nominal amount of tax is decreased to

$$\frac{\tau}{1 - \tau} c P_t.$$

Given condition (2.1), it is easy to see that the premature restructuring of illiquid projects is socially inefficient, because it not only induces losses for banks and entrepreneurs, but also leads the tax revenue to plummet.

We consider five dates or two periods in our setting. The time before date 0 is called the initial date, the time between date 0 and date 2 is the first period (or short term) and the time after date 2 corresponds to the second period (or long term).

2.2.2.2 The sequence of actions

Dates 1 and 3 are considered as the times when events happen rather than the calendar dates at

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[6] Restructuring implies the liquidation of immature projects to recover some product units. It can be carried out by both banks and their shareholders. Thus, shareholders will take over banks to repay creditors and keep the profit only if the benefit from doing so is greater than the dividend paid by banks. This means that the dividend distributed to shareholders will be at least equal to the benefit of capital in the case of disintermediation of banks.

regular intervals. They should be, according to Diamond and Rajan (2006), respectively close to dates 2 and 4. The introduction of dates 1 and 3 and the 'cash in advance' constraint is intended to clarify the transaction process and decision-making of the economic agents in each period. We assume that all the activities taking place at date 2 (or 4) must be launched at date 1 (or 3). In particular, depositors may withdraw at date 1 (or 3) and late entrepreneurs can borrow from the banks at date 3.

The initial date: Investors (including depositors, creditors and shareholders) sign contracts with banks in return for bank claims (i.e., deposit, short-term obligation and equity share). Banks extend loans to entrepreneurs based on the amount of funds raised at the initial date. On receiving bank claims, entrepreneurs invest them in their projects.[7]

Date 0: All uncertainties are resolved. The fraction (α) of projects matures at date 2 and the amount of informal goods available at date 1 are known by all the agents. Banks consider new information obtained at date 0 to modify the interest rate on the deposit from date 1 to date 2. Depositors withdraw money from banks if they purchase informal goods.

Date 1: Informal goods sold on date 0 are delivered at date 1. When receiving money, dealers may either consume it or deposit it in banks. Transactions of formal goods that are produced and consumed at date 2 are initiated at date 1 (similar to the situation of date 3). If there is a liquidity shortage, banks collect new funds or restructure some (or all) of their immature projects to satisfy the liquidity demand.

Date 2: Early entrepreneurs repay banks. They also pay the tax with the money obtained from selling products. The government redeems maturing bonds in money and issues new bonds and money of the second period. Banks compensate short-term creditors and depositors, and then share the residual value with their shareholders. Dealers of informal goods initiate the sale of

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[7] It is limited by the fact that the bank must comply with the minimum capital ratio, which is presented in section 2.2.3.1. Moreover, M_0 and B_2 are held by banks as reserves.

goods available at date 3.

Date 3: Late entrepreneurs initiate the sale of products available at date 4. Informal goods sold on date 2 are delivered.

Date 4: The government redeems maturing bonds. The products sold at date 3 are delivered. The entrepreneurs repay the banks. The banks recompense all their remaining obligations and reward their shareholders. The bankers, entrepreneurs and investors all consume. All the currency is used to pay the taxes.

2.2.3   Currency

Money has two roles in the economy. On the one hand, money and maturing government bonds can serve as a store of value in the sense that they can serve to pay future taxes. On the other hand, only money can be the medium of transaction in the purchases of informal goods.

Currency at the initial date

The interest rate on the international financial market is regarded as given by our small open economy. We assume that international inflation rate is zero and the level of international prices is constant and normalized to unity, i.e., $P_0^* = \overline{P}_0^* = 1$ during all periods. The exchange rate on the initial date is assumed to be 1, i.e., $E_0 = 1$.[8] According to the purchasing power parity, the exchange rate at date t needs to verify the condition $E_t = \frac{P_t}{P_t^*}$ and thus the domestic price level at the initial date is such that $P_0 = 1$ in equilibrium. The international gross interest rate of the first period is 1, i.e., $i_{02}^* = 1$, provided that risk-neutral investors are indifferent between consumption on date 0 and consumption on date 2. However, this rate is greater than 1 in the second period, such that $i_{24}^* > 1$, since investors prefer to consume before date 2 rather than after date 2. The international interest rates are attributed to all the contracts signed in the foreign currency. At the initial date, with an optimistic expectation towards the small country's economy, the domestic

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8   Where E is the nominal exchange rate or the price of one unit of foreign currency expressed in terms of the national currency

nominal interest rate is equal to the international interest rate such that $i_0 = 1$.[9]

Currency on five future dates

At date 0, all the information is revealed and investors modify their initial decision made based on their expectation on the initial date.

Foreign creditors continue their investments if they consider that the banks are able to honor their obligations at date 2. In fact, contracts signed in the foreign currency conserve a fixed value, regardless of the economic environment of the small country.[10]

However, in the case of nominal deposits, it is quite possible that investors will withdraw their deposits even if the banks are solvent. In fact, the commitments made in the national currency promise the repayment of a fixed amount of the national currency instead of a fixed real value. When the money supply remains constant, a contraction of activity can increase the national price level at date 2. In the meantime, the operation of the informal market is more or less independent of the activity in the formal sector. The price of informal goods will generally be lower than that of the products in the case of production contraction at date 2. In such a case, depositors withdraw all their money to profit from cheaper informal goods. In the following, we will discuss how the price, interest rate and exchange rate are formed in each period.

The price level at each date is given by the relationship between the supply and the demand of money. Suppose that the total money supply in the second period is constant; then, the money supply at date 4 is equal to $M_2 + B_4$. The total amount of products at date 4 is $\frac{C_4}{1-\tau}$ and the share of products sold for money to pay the tax is equal to $\frac{\tau C_4}{1-\tau}$, which corresponds to the total demand for money at date 4. Thus, the price for the goods sold at date 3 and consumed at date 4 is inversely

proportional to the value of taxes and represented by:

$$P_{34} = \frac{M_2 + B_4}{\frac{\tau C_4}{1 - \tau}}. \tag{2.2}$$

Illegal goods consumed at date 3 are sold at date 2 for M_2 units of money. In the case of a nominal deposit, when the consumption of illegal goods provides higher utility than that of formal products, depositors immediately withdraw money from banks to buy q_3 units of informal goods. Accordingly, the price of informal goods in terms of national currency is $\frac{M_2}{q_3}$. Therefore, the real value of the national currency in the second period is given by

$$\frac{M_2}{P_{24}} = \max[q_3, \frac{M_2}{M_2 + B_4}\frac{\tau C_4}{1 - \tau}] \quad \text{or} \quad P_{34} = \min\{\frac{M_2}{q_3}, P_{34}\}. \tag{2.3}$$

When $q_3 > \frac{M_2}{M_2 + B_4}\frac{\tau C_4}{1 - \tau}$, money is worth more in its role as the medium of exchange (albeit informal) than as the store of value (to pay the tax on a future date). In this situation, to prevent holders of nominal deposits from withdrawing all their money, banks need to readjust the nominal interest rate on deposits to satisfy the following equation:

$$i_{24} = i_{23} = \frac{P_{34}}{P_{24}} = \frac{q_3}{M_2 \frac{\frac{\tau C_4}{1 - \tau}}{M_2 + B_4}}, \tag{2.4}$$

where i_{23} is the domestic nominal gross interest rate from date 2 to date 3 and i_{24} is the domestic nominal gross interest rate of the second period.[11]

At date 2, the total money supply is $M_0 + B_2$. At the end of the first period, a fraction of $M_0 + B_2$ is used to pay the tax and the rest is used to by the nominal financial assets of the second period $M_2 + B_4$. The national currency in terms of value at date 2 is therefore:

$$\frac{M_0 + B_2}{P_{12}} = \frac{\tau C_2}{1 - \tau} + \frac{M_2 + \frac{B_4}{i_{24}}}{i_{24}^* P_{24}} \quad \text{or} \quad P_{12} = \frac{M_0 + B_2}{\frac{\tau C_2}{1 - \tau} + \frac{M_2 + \frac{B_4}{i_{24}}}{i_{24}^* P_{24}}}, \tag{2.5}$$

where $\frac{\tau C_2}{1 - \tau}$ means the part of goods produced at date 2 and sold in national currency to pay the tax of the first period. The term $\frac{B_4}{i_{24}}$ represents the actualized nominal value of government bonds in the second period, when the nominal gross interest rate i_{24} is applied to these bonds. The term

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[11] Given that during this period, there is no other role for the national currency than paying the tax at date 4, there is no incentive for banks to pay nominal obligations from date 3 to date 4 with a rate greater than 1. Consequently, $i_{24} = i_{23}$ or implicitly $i_{34} = 1$. We can explain why $i_{02} = i_{12}$ for the same reason.

$\frac{M_2 + \frac{B_4}{i_{24}}}{i_{24}^* P_{24}}$ stands for the real present value at date 2 of nominal assets amounting to $M_2 + \frac{B_4}{i_{24}}$ units

of national currency that are not used to pay the tax at date 2, but used to buy the money M_2 and

bonds B_4 for the second period.

In the informal sector, q_1 is the amount of informal goods available at date 1 and $P_{01} = \frac{M_0}{q_1}$ is

the price of illegal goods. Let P_{02} denote the domestic price level from date 0 to date 2; the real

value of the money in the first period is thus

$$\frac{M_0}{P_{02}} = \max[q_1, \frac{M_0}{M_0 + B_2}\frac{\tau C_2}{1 - \tau}] \qquad \text{or} \qquad P_{02} = \min\{\frac{M_0}{q_1}, P_{12}\} \tag{2.6}$$

We can obtain the nominal gross interest rate for the first period in the same way as for the second

period as follows:

$$i_{02} = i_{12} = \frac{P_{12}}{P_{02}} = \frac{q_1}{\frac{M_0}{P_{12}}}. \tag{2.7}$$

At the initial date, the exchange rate is assumed to be 1. On the future dates, under the

assumption of the free movement of capital, the readjustment of the nominal exchange rate can

guarantee the equality between the rate of return from the international financial market and the

rate of return from the national financial market. Therefore, the uncovered interest rate parity must

be verified as follows:[12]

$$\frac{E_i}{E_j} = \frac{i_{ij}^*}{i_{ij}}, \tag{2.8}$$

where i and j represent dates with $i < j$. As the domestic and foreign products are identical, the

purchasing power parity should be verified at each date. At the initial date (before date 0), the

national and international gross interest rates are both equal to 1. When the national rate increases

after date 0, the nominal exchange rate also rises.

2.2.3.1 *Minimum capital requirement*

The deposit is not negotiable. Depositors can withdraw on all dates following a sequential order

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[12] Traditionally, the uncovered interest rate parity takes the following form: $\frac{E_t}{E_{t+1}} = \frac{1+r_t^*}{1+r_t}$, where r_t and r_t^* are respectively the nominal domestic and foreign net interest rates. As we define i_{ij}^* and i_{ij} as the gross interest rate including the principal and interest, uncovered interest rate parity takes the form $\frac{E_i}{E_j} = \frac{i_{ij}^*}{i_{ij}}$ in this chapter.

until the banks deplete all their liquidity reserves and available assets. The holders of short-term debt have the right to request a refund when debts mature. Only the dividends are adjustable, since shareholders (capital) can only share the residual value with banks. These features imply that financing by capital permits the absorption of the losses, mitigates the negative impacts and improves the financial soundness of the banking system.

To ensure the stability of the banking system, the government of a small country impels its banks to respect a minimum capital ratio, denoted by k. This regulatory ratio prescribes that the proportion of the bank's own funds (capital) should not be less than k per cent of the total resources collected by the bank. If the minimum capital level is not satisfied, banks cannot raise new funds.

Let d^u represent the total real value of the bank's obligation, backed by one project maturing at date 4. Therefore, at date 4, the risk-neutral bank creditors require a value of d^u from γC and the shareholders (equity capital) equally share the residual value with the bank, each of them obtaining $(\gamma C - d^u)/2$.[13]

The ability of the bank to raise capital by issuing common shares is determined by the investors' anticipation of the future profit of the bank.[14] Specifically, investors will purchase common shares of banks if they anticipate that their return can at least compensate for their initial investment. Consequently, given the profitability of banks' investment, the maximum capital ratio that a bank can hold is such that

$$k = \frac{\frac{1}{2}[\gamma C - d^u]}{\frac{1}{2}[\gamma C + d^u]}, \tag{2.9}$$

where the numerator on the right-hand side of (2.9) represents the value of capital at date 4 and

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[13] See Diamond and Rajan (2000) for the negotiation on profit sharing between the shareholders and the bank within an extensive form game.

[14] The higher the value a bank can obtain from its investment on future dates, the more capital the bank can raise on the present date. For example, if for each unit invested at date 2, the bank can collect $\gamma C = 1,5$ at date 4, the maximum amount of capital raised at date 2 equals to 0.5. However, this condition does not restrict banks from collecting new funds after date 2, since the dividends distributed to shareholders are negotiable on future dates.

the denominator stands for the bank's total payment at date 4 to its shareholders and creditors.[15]

Backed by the return from a project maturing on date 4, the maximum amount of capital that the bank can raise at date 2 will only be a fraction of its future income.[16] Therefore, the greater the capital ratio is, the less important are the funds that a bank can collect. If we account for the international gross interest rate between date 2 and date 4 (i^*_{24}), the maximum fund that a bank can collect at date 2 while respecting the minimum capital ratio is:

$$\frac{\gamma C}{i^*_{24}(1 + k)} \tag{2.10}$$

Expression (2.10) implies that the ability of a bank to raise capital is also determined by the liquidity situation in the international financial market. An adverse shock on the international financial market can lead to higher interest rates, which will in turn reduce the amount that the bank can raise at date 2. We analyze the impacts of the minimum capital ratio in detail in the next section.

2.3 The maximization problem of banks at date 2

Through the maximization problem of a representative bank at date 2, we examine several major factors affecting the stabilization of the banking system of a small open economy. Furthermore, we pay close attention to the negative impact of shocks from the international financial market and from the informal sector on banks' balance sheet.

2.3.1 Banks' maximization problem at date 2 without a currency mismatch

We first examine the liquidity crisis without a currency mismatch. The crisis is mainly due to the maturity mismatch between banks' short-term debt and their long-term income. In this section, we assume that to avoid the banking fragility caused by monetary vulnerability, banks set all their contracts (both assets and liabilities) in real terms (equivalent to be in terms of foreign

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[15] The total payment of banks on date 2, including the repayment of obligation d^u plus the dividend payment to shareholders $\frac{1}{2}[\gamma C - d^u]$, is equal to $\frac{1}{2}[\gamma C + d^u]$.

[16] Equation (2.9) shows that in the presence of the minimum capital ratio k, the maximum amount of short-term debt is $d^u = \frac{\gamma C(1-k)}{1+k}$ and the total obligation is $1/2(\gamma C + d^u)$. Replacing d^u with $\frac{\gamma C(1-k)}{1+k}$, we obtain $\frac{\gamma C}{1+k}$ as banks' total payment.

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currency).[17] In the next subsection, we will examine the case in which the contracts with domestic agents are in the national currency.

To honor engagements and seek profits, banks should have as high a present value as possible at date 2. We can write the maximization problem of the representative bank at date 2 as follows:

$$\max_{\mu} P^* \left\{ \frac{M_0 + B2}{P_{12}} + (e + I^*) \left[\alpha \gamma C + (1 - \alpha)\mu c + \frac{(1 - \mu)(1 - \alpha)\gamma c}{i_{24}^*} \right] \right\}, \qquad (2.11)$$

where all the terms in brackets are measured in terms of the real value on date 2. The term $\frac{M_0 + B2}{P_{12}}$ represents the real value of nominal assets held by banks. Given that $e + I^*$ is the bank credit to domestic entrepreneurs at the initial date, the term $\alpha \gamma C(e + I^*)$ is the bank's income from early projects at date 2. The third term in brackets indicates the value recovered from liquidating a fraction $\mu(0 \leq \mu \leq 1)$ of late projects, and the last term is the new funding that the bank borrows on date 2 backed by a fraction $1 - \mu$ of late projects continuing and maturing at date 4. Consequently, the sum of the terms in brackets represents the total real value available to the bank at date 2, and multiplied by $P^*(= 1)$ it gives the value in terms of the foreign currency. In fact, given that the foreign price level is maintained as constant, measuring in real terms is equivalent to measuring in foreign currency.

In this model of a small open economy, to ensure the overall balance, the maximization problem of the representative bank must meet three conditions: the equilibrium in the monetary market, the equilibrium in the goods market and the verification of banks' solvency constraint. Banks, being the financial intermediaries, are the link between consumers and domestic entrepreneurs in the transaction of products. Therefore, the satisfaction of the bank's solvency constraint implies

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[17] In practice, small emerging countries can hardly borrow foreign debts in their national currency. In general, their banks sign contracts either entirely or partially in foreign currency. For these countries, the currency mismatch occurs generally when the contracts signed with national agents are denominated in national currency, while the contracts signed with foreign investors are in foreign currency. In this subsection, we study the case without a currency mismatch in the broad sense that all the contracts are in real terms. However, banks still absorb nominal financial assets from domestic depositors, and the value of national currency still affects banks' balance sheet. Nevertheless, compared with the case in which banks' income is in national currency while their debts are denominated in foreign currency, the impact of the currency mismatch is relatively small in the case of the current subsection. Thus, we call the latter the case without currency mismatch.

equilibrium in the goods market.

The solvency constraint of the representative bank at date 2 is such that:

$$V(i_{24}^*, P_{12}, \mu) \geq \max_{\mu} \frac{1}{2}\{V(i_{24}^*, P_{12}, \mu) + i_{02}^*(D^* + d_0 P^*)\}, \qquad (2.12)$$

$$\text{with} \quad V(i_{24}^*, P_{12}, \mu) = P^*\left\{\frac{M_0 + B2}{P_{02}} + (e + I^*)\left[\alpha\gamma C + (1-\alpha)\mu c + \frac{(1-\mu)(1-\alpha)\gamma C}{(1+k)i_{24}^*}\right]\right\},$$

where $d_0 = e + \frac{M_0 + B2}{P_0}$ is the real deposit. It represents the real value of the national resources collected by the bank at the initial date. i_{02}^* is the international gross interest rate in the first period. As the foreign price level remains constant, i_{02}^* also means the real gross interest rate on deposits. Based on the uncovered interest rate parity, the nominal interest rate in the small economy is equal to $i_{02} = i_{02}^* \frac{P_{12}}{P_0}$ in equilibrium. Constraint (2.12) is measured in terms of foreign currency, which is equivalent to its measurement in real terms. The right-hand side of (2.12) describes the total payment to banks' shareholders and creditors, and the left-hand side indicates the maximum assets available to banks. Thus, they respectively stand for the demand and supply of liquidity at date 2.

The equilibrium condition in the money market at date 2 is described by:

$$\frac{M_0 + B2}{P_{12}} = \tau\left\{\frac{e + I^*}{1-\tau}[\alpha C + (1-\alpha)\mu c + \frac{(1-\mu)(1-\alpha)C}{i_{24}^*}]\right\} \qquad (2.13)$$

where the components in brackets represent the aggregate output of the economy during the two periods in terms of the real value on date 2. Multiplied by the tax rate τ, the right-hand side of equation (2.13) represents the value on date 2 of the products sold for money. It also indicates the real demand of the national currency. The left-hand side of equation (2.13) is the real value of the money supply on date 2. The verification of condition (2.13) ensures the equilibrium in the monetary market. It also implies that all the money will be used to pay the tax and at the end of date 4 there will be no money left in the market.

Parameter α is the fraction of projects maturing at date 2. It also measures the degree of maturity mismatch between liabilities and assets on banks' balance sheet. A lower α implies a larger production contraction and thus a higher degree of maturity mismatch. According to

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the two equilibrium conditions given by (2.12) and (2.13), if α is large enough to ensure the satisfaction of the solvency constraint such that $P^*[\frac{M_0+B_2}{P_{12}} + (e+I^*)\alpha\gamma C] \geq i_{02}^*(D^* + d_0 P^*)$, the synchronization between the liquidity demand and the supply permits the bank to repay all of its maturing obligations without raising any new funds. Thus, all the immature late projects can be continued until their maturity at date 4. At date 2, the bank shares the residual value with its shareholders, each party taking $\frac{1}{2}\left\{P^*[\frac{M_0+B_2}{P_{12}} + (e+I^*)\alpha\gamma C] - i_{02}^*(D^* + d_0 P^*)\right\}$. At date 4, the fraction $1 - \alpha$ of projects will mature. Since no new projects will be started after the initial date and no new funds will be raised at the intermediate date, the bank and the capital (shareholders) will each receive a profit equal to $\frac{1}{2}(1-\alpha)\frac{\gamma C}{i_{24}^*}$ on date 4. In this case, without a maturity mismatch, the liquidity condition in the international financial market (reflected by i_{24}^*) only affects the profit of banks and their equity holders instead of the all domestic agents. Therefore, its impact on the stability of the national banking system is relatively limited.

However, when banks' major income is generated by long-term projects (α is small), the short-term liabilities can deeply threaten the stability of the banking sector. There could be a bank run if

$$P^*[\frac{M_0 + B_2}{P_{12}} + (e+I^*)\alpha\gamma C] < i_{02}^*(D^* + d_0 P^*).$$

The above condition depicts the case in which even if all the late projects are prematurely restructured at date 2, there are still unfunded debts. Consequently, banks will be solvent only if they can renew their short-term debt at a reasonably low cost. In other words, the foreign interest rate in the second period must be at a sufficiently low level for the condition $P^*\frac{(e+I^*)(1-\alpha)\gamma C}{(1-k)i_{24}^*} \geq i_{02}^*(D^* + d_0 P^*)$ to hold.

Therefore, even in the absence of a currency mismatch, the incompatibility between short-term obligations and long-term income can increase banks' dependence on the foreign financial market. When the latter is affected by a negative shock, the cost of borrowing from there can rapidly surge.

Consequently, the banks of the small economy may no longer be able to sustain foreign borrowing. Following the subprime mortgage crisis in the United States in 2008, the liquidity position of creditor (usually Western) countries of small economies deteriorated abruptly. Foreign creditors were thus eager to recoup their investments in small countries to satisfy the liquidity demand in their own countries. Small economies (i.e., Iceland and several CEE countries), sank into a liquidity trap. Either their access to the international financial market was completely suspended or the interest rate on their foreign borrowing rose strongly. To answer the liquidity demand, the banks of these small countries were forced to restructure their illiquid assets prematurely.

In intermediate cases, the bank can survive the liquidity shortage. However, its maximization problem at date 2 or its choice between raising new funds and restructuring long-term projects prematurely depends primarily on the level of the international interest rate in the second period. We distinguish the two following cases.

When the foreign gross interest rate in the second period is such that $i_{24}^* \leq \frac{\gamma C}{c}$, the continuation of immature projects is more profitable for a bank than their restructuring. In fact, the gap $\frac{\gamma C}{c} - i_{24}^*$ implies the reward to the bank when it renounces restructuring of one unit of projects and $\frac{\gamma C}{c}$ also means the highest interest rate that the bank can withstand without restructuring. Therefore, for $i_{24}^* = \frac{\gamma C}{c}$, individual banks are indifferent between the two options. However, under the regulatory capital requirement, for $i_{24}^* \leq \frac{\gamma C}{c}$, two sub-situations exist: $i_{24}^* \leq \frac{\gamma C}{c(1+k)}$ and $\frac{\gamma C}{c(1+k)} < i_{24}^* \leq \frac{\gamma C}{c}$. When $i_{24}^* \leq \frac{\gamma C}{c(1+k)}$, no immature project will be restructured and all the funds are raised through borrowing. However, when $\frac{\gamma C}{c(1+k)} < i_{24}^* \leq \frac{\gamma C}{c}$, banks will restructure their late projects to obtain the necessary liquidity, because the amount of funds borrowed backed by projects maturing on date 4 is less than that obtained through restructuring them. However, insofar as $i_{24}^* \leq \frac{\gamma C}{c}$, the continuation provides more value to the economy. We will discuss the appropriate policy response to this situation in section 2.4.

In the case in which $i_{24}^* > \frac{\gamma C}{c}$, banks will restructure all their immature projects, since the actualized value generated by a project maturing at date 4 is lower than that obtained through restructuring it at date 2.

In a nutshell, for a small open economy, a negative shock in the foreign financial market can result in a rise in the domestic interest rate and lead to a liquidity shortfall in the national banking system. To answer the liquidity shortage, banks will prematurely restructure their long-term assets. This has the effect of shrinking the tax base, increasing the price level, depreciating the nominal financial assets and inducing a deep banking crisis.

2.3.2 Banks' maximization problem at date 2 with a currency mismatch

In this subsection, we introduce the currency mismatch on banks' balance sheet. We detect and examine the problems that are likely to arise in this situation. Assume now that banks' income and domestic deposits are denominated in the national currency, while foreign short-term debts are denominated in the foreign currency. Consequently, the maximization problem of a representative bank at date 2 evaluated in terms of the national currency becomes:

$$\max_{\mu}\{M_0 + B_2 + [eP_0 + E_0(K^* + D^*)]\left[\alpha\gamma C + (1-\alpha)\mu c + \frac{(1-\mu)(1-\alpha)\gamma C}{i_{24}^*}\right] \quad (2.14)$$

Expression (2.14) is the total value of the bank at date 2 measured in terms of the national currency. Since the total foreign investment at the initial date is equal to $K^* + D^*$ units of foreign currency, its value converted into national currency at the same date is thus $E_0(K^* + D^*)$. The term eP_0 represents entrepreneurs' project financed by domestic resources measured in national currency. Then, $[eP_0 + E_0(K^* + D^*)]\left[\alpha\gamma C + (1-\alpha)\mu c + \frac{(1-\mu)(1-\alpha)\gamma C}{i_{24}^*}\right]$ corresponds to the bank's nominal income generated by its investments in production projects during the two periods.

The equilibrium condition in the money market at date 2 in this case is as follows:

$$\frac{M_0 + B2}{P_{12}} = \frac{\tau}{1-\tau}\left\{[eP_0 + E_0(K^* + D^*)]\left[\alpha C + (1-\alpha)\mu c + \frac{(1-\mu)(1-\alpha)\gamma C}{i_{24}^*}\right]\right\}$$

Since the exchange rate at the initial date is determined by the purchasing power parity, $P_0 = P^*$.

This equilibrium condition is equivalent to equation (2.13). In fact, the currency mismatch affects the bank's balance sheet while not changing the fundamental role of the national currency in the economy.

We can now write the solvency constraint of the representative bank at date 2 with the currency mismatch as follows:

$$V'(i_{24}^*, P_{12}, \mu) \geq \max_{\mu} \frac{1}{2} \left[V'(i_{24}^*, P_{12}, \mu) + E_2 D^* + i_{02}^* D^* + d_0 P^* \right], \qquad (2.15)$$

with $V'(i_{24}^*, P_{12}, \mu) = (M_0 + B_2) + [P_0 e + E_0(K^* + D^*)] \left[\alpha \gamma C + (1 - \alpha)\mu c + \frac{(1 - \mu)(1 - \alpha)\gamma C}{(1 + k)i_{24}^*} \right]$

Condition (2.15) is structurally similar to (2.12), but is measured in nominal terms. In (2.15), the short-term debt D^* denominated in foreign currency is converted into national currency using the exchange rate at date 2 (E_2). As the bank's assets are denominated in national currency, the volatility of the exchange rate has a direct impact on the bank's balance sheet. Therefore, the bank's liquidity position at date 2 can be seriously damaged by an increase in the exchange rate.

Moreover, as in condition (2.12), the realization of a low level of α can lead to the insolvency of the bank. In fact, a small parameter α indicates the output contraction that will be transformed into a negative shock to the financial system in the sense that it decreases the bank's revenue and increases its engagements at date 2. More precisely, this shock can directly lead to a higher price level. Based on interest rate parity given by equation (2.8), the nominal exchange rate (E_2) also rises, which corresponds to the depreciation of the national currency. Consequently, the bank will face an increase in its liabilities (see (2.15)) caused by a higher E_2. Since the bank credit issued to entrepreneurs is contracted in nominal terms and is not indexed to the price level, the bank's income obtained from the entrepreneurs strongly decreases, caused by a small α and by the resulting currency depreciation. In addition, equation (2.7) implies that the bank will increase the level of the nominal gross interest rate i_{02} if the price increases, thus leading to a further rise on the liability side of the bank's balance sheet.[18] In short, the banking system becomes

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[18] In this model, the bank with a liquidity shortage will fail if the present value of its liabilities exceeds that of its assets.

more vulnerable to the negative effects from higher interest and exchange rates in the case with a currency mismatch than in the case without one.

The informal sector can adversely affect the stability of the banking system. Besides the maturity mismatch, a large-scale informal sector can be another factor that contributes to the increase in nominal gross interest rates. An increase in the size of the informal sector upturns the sensitivity of the nominal gross interest rate (i_{02}) to the price level P_{12} according to equation (2.7). For a given price level, a higher interest rate can be induced by a large informal sector and thus it cannot reflect the economic situation or the liquidity condition of the country. However, the existence of a large informal sector is a reality in many emerging and transitional economies. Trades in the informal market are not subject to taxes. They will reduce the tax revenue of the government and therefore have the effect of lowering the value of nominal financial assets by reducing the purchasing power of each monetary unit. When a small country suffers from such an institutional problem, massive inflows of foreign capital can support economic activity on the one hand, while on the other hand they can make the financial system extremely precarious. The example in section 2.4.4.3 illustrates the negative impact of the informal sector on a bank's balance sheet.

2.4   Economic policies

After introducing the mechanism of a banking crisis, in this section we will discuss appropriate policies to handle the situation of illiquidity in the national banking system.

2.4.1   Intervention in project restructuring

Individual banks are indifferent between restructuring and continuing immature projects if the cost of rolling over the short-term debt is such that $i_{24}^* = \frac{\gamma C}{c}$. However, two options have largely different effects, which are examined through the following example.[19]

Since, in this model, banks will not lend between each other, the problems of the market liquidity and funding liquidity, as examined by Brunnermeier and Pedersen (2009), do not arise here. We will study the role of the interbank market and the impact of market discipline in the next chapter.

[19]   We use the basic framework of the type in section 2.3.1 to interpret numerical examples 1 and 2, in which both the

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Numerical Example 1: Assume that all contracts are signed in foreign currency (equivalent to real terms) and $\overline{P}^* = P_0 = 1$, $\tau = 18\%$, $C = 1,5$, $\gamma = 0.8$, $c = 0.6$, $q_1 = 14$, $K^* = 20$, $D^* = 30$, (therefore $I^* = 50$), $i_{02}^* = 1$ and $d_0 = \frac{M_0 + B_2}{P_0} + e = 45$ (with $e = 25$, $M_0 = 15$, $B_2 = 5$). For $\alpha = 0,4$ and $i_{24}^* = \frac{\gamma C}{c} = 2$, there will be no bank run.[20] The income of the bank from maturing projects is $(I^* + e)\alpha\gamma C = 36$; the tax revenue from these projects is thus $\frac{\tau(I^* + e)\alpha C}{1 - \tau} = 9,8775$. Therefore, the total value of the bank's available liquidity at date 2 is 45.8775, which is less than the value of maturing obligation. The latter amounts to $i_{02}^*(d_0 + \frac{D_0}{P^*}) = 75$.[21] Thus, banks should either collect new funds backed by projects continuing and maturing at date 4 or prematurely restructure these projects at date 2.

In the case in which immature projects are restructured, the bank can recover an amount of liquidity equal to $(I^* + e)(1 - \alpha)C = 27$. The real value of financial assets at date 2 equals $\frac{M_0 + B_2}{P_{12}} = \frac{\tau(I^* + e)}{1 - \tau}[\alpha C + (1 - \alpha)c] = 15,804$. In addition, the price level is given by $P_{12} = \frac{M_0 + B_2}{\frac{\tau(I^* + e)}{1 - \tau}[\alpha C + (1 - \alpha)c]} = 1,2655$. Therefore, the profit of the bank in terms of real value at date 2 is $\frac{1}{2}[V(r_{24}, 1, P_{12}) - (\frac{E_2 D^*}{P^*} + d_0)] = 1,804$. According to the purchasing power parity, the exchange rate at date 2 is $E_2 = \frac{P_{12}}{P_{12}^*} = 1,2655$. Since $P^* E_0 = P_0 = 1$, the previous solutions regarding interest rates, exchange rates and price levels verify the uncovered interest rate parity given by (2.8).[22]

In the case of the continuation of late projects, the income generated by early projects is still 36 and the value of new funds raised at date 2 backed by projects maturing at date 4 is

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assets and the liabilities of the bank are entirely denominated in the foreign currency. In fact, measuring the balance sheet in real terms is equivalent to measuring it in terms of the foreign currency, given that in our setting the foreign currency conserves a constant value during periods.

[20] Given constraint (2.12) and the values of parameters defined in the example, if the proportion of early projects is greater than $\alpha = 0.34$, banks' liquidity supply will be sufficient to meet the liquidity demand.

[21] The dividends to shareholders are flexible depending on the bank's liquidity position. Thus, the minimum liquidity demand on date 2 is constituted by the payment to foreign creditors and domestic depositors.

[22] Given the uncovered interest rate parity and the value of the initial exchange rate $E_0 = 1$, the initial domestic price level, used to calculate the real interest rate on national deposits, is $P_0 = 1$. Furthermore, given $i_{02} = i_{02}^* \frac{P_{12}}{P_0}$, the parity $\frac{E_0}{E_2} = \frac{i_{02}^*}{i_{02}}$ is also verified.

$\frac{(1-\alpha)\gamma C}{i^*_{24}} = 27$, which is equivalent to the value obtained by premature restructuring.[23] However,

the price level at date 2 is $P_{12} = \frac{M_0 + B_2}{\frac{\tau(I^*+e)}{1-\tau}[\alpha C + \frac{(1-\alpha)c}{i^*_{24}}]} = 1,157$ and the value of nominal financial

assets is $\frac{\tau(I^*+e)}{1-\tau}[\alpha C + \frac{(1-\alpha)c}{i^*_{24}}] = 17,286$. The bank's profit in terms of the value at date 2 is

$\frac{1}{2}[V(r_{24}, 1, P_{12}) - (\frac{E_2 D^*}{P^*} + d_0)] = 2,643$. According to the purchasing power parity, the exchange

rate at date 2 becomes less volatile and is $E_2 = \frac{P_{12}}{P^*_{12}} = 1,157$. As in the previous cases, the

solutions satisfy the uncovered interest rates parity (2.8).

Our example shows that when $i^*_{24} = \frac{\gamma C}{c}$, banks obtain the same value from late projects

regardless of their decision to continue or restructure. However, a mature project at date 4

generates $\frac{C}{i^*_{24}} = 0.75$ units of goods and a restructured project offers only $c = 0.6$ units of goods

at date 2. The price level is therefore lower in continuation than in restructuring, so the value of

nominal financial assets held by banks also becomes higher in the case of continuation.

Whatever the perspective of individual banking entrepreneurs, our examples reveal that the

continuation of immature projects always allows more products to be offered to the economy,

which reduces the volatility of the general price level and increases the profit of banks. It should

be noticed that there are a large number of identical banks – acting as 'price takers' – that ignore

the impact of their individual decisions on the price level, the market interest rate and the value

of nominal financial assets. Given the myopic behavior of individual banks, the intervention

of the authority to prevent inefficient restructuring is crucial. It helps to maintain the value of

the national currency and of the nominal financial assets, as well as keeping the stability of the

financial system.

2.4.2 Minimum capital ratio

According to maximization problem (2.11), the higher the minimum capital ratio is at the

initial date, the lower the amount of mature obligations will be at date 2. Funding through issuing

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[23] In numerical example 1, we focus on the different outcomes from banks' choice between restructuring and continuing immature projects, while neglecting the minimum capital ratio. We will examine the impact of the capital ratio in the next subsection.

equity shares can strengthen the stability of the banking system in this sense. However, raising the capital ratio during a liquidity shortage is not always favorable. Numerical example 2 examines the impact of the capital ratio on banks' liquidity position at date 2.

Numerical Example 2: We assume that the foreign investments, including equity shares and short-term debts, collected at the initial date are respectively K^* and $D^* = 20$, and the foreign gross interest rate of the second period is $i_{24}^* = 1, 2$. The weight of projects maturing at date 2 is $\alpha = 0.218$. Moreover, the central bank of the small country requires commercial banks to respect a minimum capital ratio $k = 0.08$ at date 2. All other parameters are the same as in example 1.

The total value of maturing obligations at date 2 is $i_{24}^*(d_0 + \frac{D_1}{P^*}) = 65$. The bank's income from early projects is $(K^* + D^* + e)\alpha\gamma C = 13, 08$. When $i_{24}^* = 1, 2 < \gamma C/c$, the bank prefers to continue rather than to restructure immature projects. However, the minimum capital ratio limits the value of new funds raised at date 2, which is a fraction $\frac{1}{(1+k)i_{24}^*}$ of the pledgeable assets maturing at date 4. With $k = 0.08$, the maximum value of new funds backed by immature projects is $(1 - \alpha)((K^* + D^* + e)\frac{\gamma C}{(1+k)i_{24}^*} = 36, 2$. If this new funding is sufficient relative to the liquidity gap, all projects will continue until their maturity at date 4. The value of nominal financial assets held by the bank at date 2 will be $\frac{M_0+B_2}{P_{12}} = \frac{\tau(K^*+D^*+e)}{1-\tau}[\alpha C + (1 - \alpha)\frac{c}{i_{24}^*}] = 14, 3$. We first assume that this is the case and then consider whether it is justified or not. The total assets of the bank at date 2 have a value of $(I^* + e)[\alpha\gamma C + \frac{(1-\alpha)\gamma C}{(1+k)i_{24}^*}] + \frac{M_0+B_2}{P_{12}} = 63, 58$, if all the projects are allowed to continue and mature at date 4. However, the available liquidity is inadequate relative to the maturing obligations, amounting to $i_{02}^*(d_0 + D^*) = 65$. That is to say, the bank cannot sustain the continuation of immature projects, since this will lead to insolvency. Consequently, the bank has to restructure some projects prematurely.

Note that, in this example, the inability of the bank to raise new funds is mainly caused by a relatively high minimum capital ratio (k) and the maturity mismatch between the income and the

obligations on the bank's balance sheet. However, the bank's investment projects are performing. If the immature projects can be continued, they will mature at date 4 and the late entrepreneurs will be able to fulfil their repayments to banks. In this case, maintaining $k = 0.08$ during the liquidity shortage will in fact exacerbate the liquidity crisis. By contrast, if the central bank lowers the capital ratio to a level equal to or less than $k = 0.04$, the banks' available assets on date 2 can be enough to repay the maturing liabilities. Thus, no project will be restructured prematurely and all the immature projects can continue.

This example shows that during a period of liquidity shortfall, raising the minimum capital ratio will be disruptive and contrary to the original intention of the central bank, aiming to stabilize the banking system. From expression (2.9), we find that the government should encourage banks to strengthen the capital structure (issuing more equity shares) in growing periods. Improving banks' capital structure through a preventive higher capital ratio has the effect of enhancing the resilience of the banks to shocks and avoiding or mitigating the liquidity crisis. However, during crisis times, raising or even maintaining the capital ratio can negatively affect the financial health of the bank system facing the liquidity shortage.

Basel III proposes a higher capital requirement and redefines the concept of 'banking capital'. Furthermore, it highlights the stabilizing effect of the common equity shares. In this chapter, the definition of capital ratio (interpreted as equity ratio) is consistent with the spirit of Basel III.[24] The inverse of the minimum capital ratio in the model is akin to a leverage ratio. Our analyses confirm the effect of the bank capital in alleviating the liquidity crisis and reveal the 'countercyclical' characteristic of the preventive capital regulation. However, the previous example shows that during the crisis, the central bank should be careful when increasing the capital ratio. The implementation of a more severe capital requirement for banks suffering a liquidity shortage

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[24] See Blundell-Wignall and Atkinson (2010) and http://www.bis.org/list/basel3/index.htm for more information on Basel III.

might not strengthen the banking system but deteriorate banks' liquidity position and aggravate the crisis.[25]

2.4.3 The impact of the informal sector and open market policy

The open market operation is efficient in stabilizing the nominal interest rates and in alleviating banks' debt burden in a closed economy (Diamond and Rajan, 2006). In this section, we examine the effect of such a policy in the context of a small open economy. Through the following example, we study first how the informal sector affects the volatility of the nominal interest rate.[26] Then, we analyze whether or not the open market policy can reduce or eliminate the volatility of the nominal interest rate and thus enhance banks' resilience to the shock from the informal sector.

Numerical Example 3: Now we assume that all the contracts signed with domestic agents are denominated in national currency. Different from example 1, we now measure banks' balance sheet in terms of national currency. All the other variables and parameters are equivalent to those in example 1.[27] We already know that banks' income from maturing projects is inadequate with respect to the liquidity demand. When banks finance through borrowing, the real value of financial assets held by banks at date 2 is 17.286 and the price level at date 2 is $P_{12} = 1,157$. Thus, the value of the money used for paying the tax is $\frac{M_0}{M_0+B_2} \left\{ \frac{\tau(eP_0+E_0(K^*+D_1^*))}{1-\tau} \left[\alpha C + \frac{(1-\alpha)c}{i_{24}^*} \right] \right\} = 12,9645$. However, with the same amount of money ($M_0 = 15$), consumers can now buy a quantity of informal goods equal to $q_1 = 14$. As the informal goods and formal products are perfect substitutes, the banks must adjust the nominal gross interest rate on deposits to $i_{02} = q_1/(M_0/P_{12}) = 1,0799$. According to the purchasing power parity, the nominal exchange rate on date 1 increases to $E_1 = P_{02}/P^* = (M_0/q_1)/P^* = 1,0714$,

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[25] The crisis studied in this chapter is mainly caused by the maturity mismatch between the assets and the liabilities of the bank and the liquidity crunch in the international financial market. In other words, this crisis is not caused by banks' non-performing loans. We refer to a crisis of the type studied in this model as a liquidity crisis other than a solvency crisis.

[26] Numerical example 3 describes the case in which a portion of banks' balance sheet is denominated in foreign currencies. We use the model of section 2.3.2 to study the currency mismatch.

[27] See numerical example 1 for the demand and aggregate supply of liquidity, the price level and the amount of new funds raised at date 2.

and the exchange rate at date 2 climbs upward to $E_2 = P_{12}/P^* = 1,157$. Given that

$E_1/E_2 = i^*_{02}/i_{02} \rightarrow 1,0714/1,157 = 1/1,0799$, these solutions satisfy the uncovered interest rate

parity (2.8). Banks' revenue from both early and late entrepreneurs measured in nominal terms

at date 2 equals $[P_0 e + E_0(K^* + D^*)][\alpha \gamma C + (1 - \alpha)\gamma C/i^*_{24}] = 63$ units of national currency.

Accordingly, the total value of banks' assets at date 2 is $63 + M_0 + B_2 = 83$ units of national

currency. On the liability side, the foreign short-term debt corresponds to 30 units of foreign

currency, or 34.71 units of national currency, and the national deposits are worth $i_{02} d_0 P_0 = 52,065$

units of national currency. Finally, the liabilities and assets of the banks at date 2 are respectively

86.775 and 83 units of national currency. According to condition (2.15), the banking system

becomes insolvent at date 2. It is necessary to notice that all the information is taken into account

by economic agents at date 0. Therefore, the bank run will take place immediately at date 0 and

all the projects will be prematurely restructured, including the early projects maturing at date 2.

This situation is socially inefficient since at least part of the restructuring is not necessary.

We study through the following example whether or not the open market operation can be an

effective tool to avoid the bankruptcy caused by the dynamics in the informal sector.

Continuous Numerical Example: If the amount of money available at date 0 increases by Δ

units following an open market operation, i.e., $M_0 + \Delta$ and $B_2 - \Delta$, the role of money as a

medium of transaction of informal goods will be weakened. Revisiting example 3, we find that if

the currency available at date 0 increases to 16.198 (the scale of the operation is thus $\Delta = 1.198$),

the value of the currency is no longer dominated by its role in the purchase of informal goods.

We have that $i_{02} = P_{12}/P_{02} = P_{12}/[(M_0 + \Delta)/q_1] = 1$. The increase in the nominal interest rate

is no longer necessary to ensure the market equilibrium. The nominal deposits are now worth

$i_{02} d_0 P_0 = 45$ units of national currency. The liabilities and assets of banks' balance sheet at

date 2 in such a case are respectively 79.713 and 83 units of national currency. Consequently,

the banking system regains solvency due to the open market operation. In our example, the open market operation reduces the price level to $P_{02} = P_{12} = 1,08$. Since the foreign price is constant and equal to $P^* = 1$, according to the purchasing power parity, the nominal exchange rate is $E_1 = E_2 = P_{12}/P^* = 1,157$. These solutions satisfy the uncovered interest rates parity, given that $E_1/E_2 = i_{02}^*/i_{02} \rightarrow 1,157/1,157 = 1/1$.

Through this example, we can conclude that the open market operation is effective in mitigating the negative effects of the informal sector. A loose monetary policy can alleviate the burden of nominal debts on the banking system by stabilizing the nominal interest rates. It should be noticed that the open market operation is carried out at date 0 when all the initial contracts have already been negotiated and signed. This ensures that the temporarily expansionary monetary policy will not change the other variables determined before date 0. Moreover, it does not affect the aggregate money supply and the value of the national currency at date 2. Our example shows that the exchange rate on date 2 remains unchanged following the open market operations.

Facing a liquidity shortage, the central bank can also take the role of the lender of last resort to increase the money supply in the case of a banking crisis. However, this policy will not have the same positive effects as the open market operation. Our model implies that a direct liquidity injection could relieve banks from the burden of nominal liabilities. However, the domestic price level will increase with the money supply, reducing the real value of banks' income contracted in national currency. Furthermore, the depreciation of national currency will lead directly to an increase in banks' foreign debts in terms of the national currency. Therefore, the effectiveness of this policy decreases with the amount of obligation denominated in foreign currencies and income in national currency.

2.5 Conclusion

We have examined in this chapter the mechanism of a financial crisis caused by the maturity and currency mismatches on banks' balance sheet, as well as the policy implications for stabilizing

the monetary condition for small economies like Iceland and CEE countries. In this open economy banking crisis model, we also studied the impacts of the informal sector and the foreign capital flows on the stabilization of the banking system.

We showed that the banking system of a small open economy is highly vulnerable to shocks from the international financial market. For a small economy, the 'unexpected' foreign capital reversal can induce a sharp credit crunch and even a sudden collapse of its banking system. The trouble of the banking sector can easily induce the depreciation of the national currency and contraction in the real sector. Thus, the 'sudden stop' of the foreign capital inflow could trigger a vicious circle between the weakened real sector, the deteriorated financial system and the depreciated national currency in small open economies.

In general, funding through issuing common shares improves the stability of the banking system, given that the equity capital can absorb banks' losses resulting from premature restructuring and thus lower the risk of a bank run. The minimum capital ratio studied in the model is close to the 'equity ratio' proposed by Basel III. Our analysis shows that a preventive capital reserve has the 'countercyclical' characteristic, especially when it is composed of common shares. However, the rise of the minimum capital ratio in crisis times should be conducted carefully to avoid aggravating banks' liquidity condition during a liquidity shortage. Contrariwise, preventively increasing the capital ratio during normal times will improve the stability of the banking system and enhance its resilience in crisis times.

In the model, when the banking system is facing an unexpected rise in foreign borrowing costs, the policy makers play an important role in ensuring its stability. This is true especially when banks are indifferent between continuing and not continuing their long-term investments. Banks, being the 'price takers', cannot take into account the influences of their individual actions on the aggregate supply of products or the general price level. Policy makers should encourage banks to

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continue their immature projects and thus avoid inefficient premature liquidation.

Regarding the impact of the informal sector, we have shown that growth in the informal economy can lead to a higher interest rate, the depreciation of the national currency and a decrease in the value of nominal financial assets. As a result, the balance sheet of the banking sector can deteriorate and the stability of the banking system can be weakened by the dynamics of the informal sector. We show that the open market operation to increase the quantity of money can reduce or even eliminate the negative impacts of the informal sector on the banking system.

Finally, a more rigorous prudential regulation practiced in normal times can improve the stability of the financial system of a small open economy. An appropriate policy in times of liquidity crisis should aim to reduce banks' debt burden and thus improve their liquidity position. A reform of the banking system, for example an increase in the minimum capital ratio, should be implemented during normal times. Moreover, the economic reform should not be limited to the financial system. Institutional regulation to reduce the scale of the informal sector will have a significant effect on improving the financial stability of small emerging or transitional countries.

Chapter 3   The banking crisis with interbank market freezes

3.1   Introduction

The recent global financial crisis has revealed the fragility of the banking system which is strongly reliant on the interbank market to alleviate the liquidity shortage and to reduce the funding liquidity risk. Following the collapse of Lehman Brothers and Bear Sterns in 2008 and the outbreak of the Greek sovereign debt crisis in late 2009, several episodes of severe turbulences have been observed in interbank markets along with systemic banking crises around the world. Central banks and fiscal authorities were forced to carry out massive liquidity injections in an attempt to restore the normal functioning of the banking system. In the Eurozone, national governments undertake the responsibility for supervising and bailing out domestic banks, while they are themselves subject to additional financial pressures given that they have abandoned monetary sovereignty to the European Central Bank.

The financial fragility can be characterized by interbank market freezes, fire sales, contagion and eventually insolvency and bailouts (Tirole, 2009). Before the eruption of the global financial crisis, banks extensively expanded their balance sheets, leading to a highly leveraged and less liquid banking system with heavy reliance on wholesale funding sources such as interbank loans (Adrian and Shin, 2008). In normal times, the interbank market, by allowing banks that respect the market discipline, to bridge temporary liquidity mismatches, permits them to keep fewer liquidity reserves. Banks' maturity transformation increased impressively in the pre-crisis period. However, in crisis times, the malfunctioning of the interbank market magnifies the illiquidity in the banking system that has developed a vulnerable balance sheet in euphoric period.

Given that safe types of assets are usually employed in the transaction, a complete interbank market is quite competitive and efficient in bridging short-term liquidity gaps and achieving the

optimal resource allocation of the banking system (Allen and Gale, 2000). However, financially fragile banks and the interbank market are extremely sensitive to sudden shocks. When the borrowing banks have a questionable solvency position, the lending banks may rationally suspend loans to them to avoid the counterparty risk. An aggregate liquidity shock can immediately give rise to the freezing of the funding market, either for the reason that lending banks suffer a liquidity shortage themselves or because they have concern about the solvency of the borrower.

The recent twin banking and sovereign debt crises in Eurozone countries have aroused broad attention among economists and policymakers (Lane, 2012; Moro, 2013). The elimination of national currencies attached the utmost importance to national fiscal policies as a tool for countercyclical macroeconomic policy (Wyplosz 1997; Gali and Monacelli, 2008). In particular, since banking regulation remained a national responsibility, individual governments had to bear the risks of a banking crisis and the direct and indirect costs associated with it. The fiscal bailouts undertaken by governments with unsustainable public debt cannot stop an unfolding banking crisis and will contrarily aggravate the panic among market participants. Consequently, the normal conditions of the interbank market will not be restored unless the government has a large enough fiscal cushion to provide sufficient scope for policy manipulation during crisis times (Attinasi et al., 2010).

The main purpose of this chapter is to identify the bright and dark sides of the interbank market, especially the impact of the market discipline on the stability of the banking sector in normal and in crisis times respectively. We are mostly interested in the crisis situation during the 2009-2012 Eurozone crises. Therefore, unlike earlier works on the financial crisis that concentrated on the effectiveness of the monetary policy response and the link between banking fragility and monetary vulnerability, we highlight the role of the fiscal crisis response from a government that has no monetary instrument and explore the close linkage between the banks' balance sheet and

the government's budget.

We develop a theoretical framework of banking crisis to study the impact of the interbank market by introducing a role for the market discipline. Through examining the balance sheet of banks in normal and crisis times respectively, we show that in normal times the interbank market allows banks to cope with idiosyncratic liquidity shocks through the redistribution of the fixed amount of reserves held within the banking system. Therefore, banks voluntarily respect the market discipline to profit from the interbank lending so as to ensure the continuation of investments, reduce their losses when facing the liquidity shock, and thus improve the return to their shareholders. Nevertheless, from a macro-prudential view, the market discipline cannot ensure banks the normal borrowing terms in crisis times. The interbank market can freeze when affected by unexpected liquidity shocks. We investigate three sources of liquidity risks with different implications for the role of the interbank market in spreading and amplifying the crisis in the banking system. First, a crisis could be triggered by a self-fulfilling bank-run in which depositors' attempt to withdrawal prematurely can lead to a bank failure (Diamond and Dybvig, 1983). Second, a liquidity shock can result from the revelation of asymmetric information about the balance sheet of non-performing banks (Chari and Jagannathan, 1988; Acharya et al., 2012). We characterize the asymmetric information by introducing a gambling asset that delivers extra profits to investors if the gambling is successful (Hellmann et al., 2000; Agliardi et al., 2009; Hasman et al., 2013). Third, banks' ex-ante safe assets could see their values suddenly depreciated. In practice, triple-A government bonds are held by banks as liquidity reserves and serve as the interbank market's liquidity pool, rendering the banking system vulnerable to a sovereign debt crisis (Bolton and Jeanne, 2011; Reinhart and Rogoff, 2011).

One major finding of this chapter is that the malfunctioning of the interbank market might not be avoided by banks' feasible risk reallocation, and it could be caused by unexpected shocks

stemming from within the banking system. This malfunctioning in crisis times could be associated with banks' ex-post inappropriate capital and reserve ratios, although the latter are consistent with the market discipline. The interbank market, which facilitates the liquidity transfer among banks to deal with idiosyncratic shocks in normal times, may impair the stability of the banking system in crisis times. Its freezing will further aggravate the financial position of banks in a liquidity shortage. Thereby, we argue that the market discipline imposed by the interbank market is not an efficient tool to ensure the stability of the banking system.

Another finding of the chapter is that the interbank market can be a channel of contagion in the sense that it may respond to external shocks with an immediate lending suspension and thus to magnify the liquidity shortage in domestic banking system. This situation is particularly manifested in Eurozone where banks keep a significant amount of overestimated sovereign bonds issued by the national government and by other member states to build their liquidity reserves and the liquidity pool of the interbank market.[28] Therefore, both banks and the interbank markets in Eurozone are highly vulnerable facing sovereign debt crises in either national or foreign countries. Without the direct monetary support from the ECB, the national government intervention becomes the most essential instrument to curb the banking crisis and its spreading. Notwithstanding, the national governments in the monetary union have limited capabilities in banking bailouts. Our model shows that the scope of the government's involvement in the crisis management depends largely on its budgetary positions. The government's bailout is credible if it does not lead to a risk of sovereign default. In other words, the inability of the government to save in good times to build a war chest for bad times has often resulted in gut-wrenching twin financial and sovereign-debt crises. Consequently, the reform of the banking regulation should be accompanied by fiscal reform.

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[28] Under EU Capital requirement Directives, the zero risk weight is granted to sovereign debts of all member states of the EMU.

In addition, our results underline the importance of enhancing banks' capital position so as to reinforce their resilience to shocks. However, the high opportunity cost of capital incites banks to keep their capital as low as possible. Our analysis thereby supports the regulatory reform with the target of imposing a higher capital ratio, as prescribed by Basel III. Nevertheless, a ceiling of the capital ratio exists, beyond which banks' capacity to raise deposits would be hampered. This is explained by the fact that risk-averse depositors have a threshold rate of return; a high capital ratio causes the return of deposits to plummet and leads them to withdraw their deposits from banks, forcing the latter to become pure 'equity banks'. In certain circumstances the banking regulation can eliminate the risk of banking crisis at the cost of depriving banks of their role as financial intermediaries. The risk of a banking crisis cannot be entirely ruled out by any forms of ex-ante regulation, implying that the government crisis responses are essential for avoiding turmoil in the banking system during a crisis.

The remainder of the chapter is organized as follows. The next section reviews the literature. Section 3 describes the basic model with an interbank market. Section 4 examines the functioning of the interbank market in the presence of liquidity risks due to a bank run, asymmetric information, and the depreciation of ex-ante risk-free assets. Section 5 studies the crisis management conducted by the fiscal authority and the relation between the fiscal bailout and the government's budget position. The last section concludes.

3.2 Related literature

Rochet and Tirole (1996), Freixas and Parigi (1998) and Aghion et al. (2000) underline that the banking sector and the interbank market, as the most important components of the financial system, can not only contribute to spreading shocks stemming from outside the local financial system, but can also be the original culprits in wide-spread crises. Diamond and Rajan (2005) show that due to the feed-back interactions through the interbank market, a liquidity mismatch

can induce insolvency while the latter will aggravate the liquidity shortage and lead to a bank run. Heider et al. (2008) highlight the effects of banks' asset risk on the functioning of the interbank market. They show that, depending on the level and the distribution of the risk in the banking sector, the liquidity trading may be smooth, impaired or dry up completely and massive liquidity injections by the central bank might not be sufficient to restore the interbank activity. Tirole (2011) characterizes the recent crisis by massive illiquidity whereby transactions were suspended in financial markets, leading financial institutions to struggle for liquidity through restructuring assets prematurely at fire sale prices and panicking investors to run on these financial institutions unless the authorities implemented a substantial and credible rescue package. In the spirit of these papers, we model the interactions between banks with a liquidity surplus and those enduring a liquidity shortage in the interbank market. A bank failure can result from the freezing of the interbank loans; likewise, the malfunctioning of the interbank lending can be the outcome of banks' vulnerable balance sheets.

Our chapter is most closely related to the seminal work of Allen et al., (2009). They show that, banks with low liquidity reserves can protect themselves against the liquidity mismatch induced by idiosyncratic liquidity shocks through trading long-term assets in the interbank market.

Our model is distinct from Allen et al., (2009) in three main aspects. First, rather than focusing uniquely on the uncertainty about deposit withdrawal, we also consider a shock arising from banks' ongoing projects. More precisely, banks are submitted to not only the risk of a self-fulfilling bank run, but also the risk of non-performing assets that require refunding at the intermediate date to avoid restructuring or fire sales. We show in our framework that these two risks could interact with each other. In this respect, our model is similar to Tirole (2011) in the sense that contagions arise from both the asset and the liability side of the balance sheet, but different from Chen (1999), Allen and Gale (2004) and Diamond and Rajan (2011), which focus

on the shocks stemming from the liability side of the balance sheet.

Second, regarding the role of the bank capital in improving the banking stability, our model is in line with Rochet and Tirole (1996), Aghion et al. (2000), and Allen and Gale (2000). Different from these earlier works, the banks in our setting may choose a capital level in accordance with their optimal resource allocation and with the market discipline imposed by the interbank market.

Third, we are interested in government crisis management to illustrate the euro-zone crisis during which assistances from the ECB was usually considered both deferred and insufficient, and the restoration of normal financial conditions largely depended on crisis managements conducted by national governments. In this respect, this chapter is close to the model of the sovereign debt crisis built by Bolton and Jeanne (2011) and Acharya et al. (2011). In contrast, most papers on financial contagion underline the crisis responses of the central bank (Freixas et al., 2000; Nier et al., 2007; Fahir and Tirole 2012).

3.3 The model

Our basic framework is built on Allen et al. (2009) who extend the classic banking crisis model of Diamond and Dybvig (1983) by including a complete interbank market where banks purchase and sell long-term assets to hedge against liquidity shocks. The main difference from Allen et al. (2009) is that we provide an explicit role for the market discipline (i.e., the capital and liquidity requirement imposed by the interbank lending market) and its effect in ensuring the performance of the banking system and the interbank market.

3.3.1 The environment

The small open economy is populated by a large number of ex-ante identical residents of mass one. The economic activities are carried out during two periods marked by three dates respectively denoted by t_0 as the initial date, t_1 as the intermediate date (or short-term) and t_2 as the final date (or long-term). There is a single, all-purpose good that can be used for consumption or investment. Each resident has an endowment of e units of the good at the planning date t_0.

Domestic residents consume either at the intermediate date t_1 or at the final date t_2 according to their type (i.e., impatient or patient consumers). The information about the type of residents is only revealed at t_1. At date t_0, they only know the probability of being impatient (λ) and being patient ($1 - \lambda$). Denoted by x and y the amount of good respectively consumed at t_1 and at t_2, the expected utility of domestic residents at t_0 is

$$\lambda u(x) + (1 - \lambda)u(y)$$

where $u(.)$ is a CRRA instantaneous utility function defined by $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, with $0 < \sigma < 1$. Since domestic residents do not consume at t_0, they will either invest their endowments by themselves or entrust them to banks depending on the rate of return offered respectively by these two options.

There are two types of investment vehicles in this economy: safe assets composed of 'risk-free' domestic and foreign government bonds identical in terms of risk and return, and a risky long-term production technology. Government bonds are accessible to all agents, while the investment in the long-term technology requires special human capital possessed exclusively by domestic banks to accompany the producer throughout the production processes to collect all the output.

The domestic government starts with a debt from previous periods and issues bonds in domestic and international financial markets at date t_0. These bonds are quasi-liquidity and can be sold whenever necessary in the secondary market. Maturing bonds will be redeemed at date t_2. For one unit of resources invested in this liquid asset at date t_0, investors can receive $1 + r_{01}$ if the bond is sold in the secondary market at date t_1, and $1 + r_{02}$ if bonds are held until date t_2, where r_{ij} denotes the interest rate on government bonds from date i to date j. For simplicity, we assume that in normal times both the short-term and the long-term interest rate attributed to these bonds, equal to the corresponding international interest rates, are respectively $r_{01} = 0$ and $r_{02} = r^*$. The domestic government raises a tax on banks' investment income at a tax rate τ and redeems

maturing bonds with fiscal revenues at the final date.

The long-term production technology is possessed by entrepreneurs with no endowment. To begin a project, each entrepreneur needs to borrow one unit of goods from one bank. A large number of entrepreneurs exist in the economy and only a fraction of projects can be funded by the resources available to banks. The insufficiency of long-term funding and the competition of entrepreneurs to finance their projects imply that banks can obtain all the outputs of the projects that they have financed at date t_0. Long-term projects are risky in the sense that with a probability π, a long-term asset will turn out to be non-performing at the intermediate date t_1 and need a refunding equal to $\phi \ll 1$ units of goods (fresh liquidity) so as to continue the production until its maturity at t_2. A maturing long-term asset yields $(1-\tau)R$ units of goods at t_2 after tax, regardless of its position at t_1. However, if a bank fails to raise enough funds to fill the small liquidity gap ϕ induced by the refunding at t_1, it yields nothing at t_2 and hence a large liquidity shock occurs. Banks with an urgent need for liquidity cannot sell their long-terms assets at a normal market price defined by the assets' present value that a bank with abundant liquidity could wait for, and they have to liquidate (or restructure) their immature projects at a lower price. For one unit of long-term assets liquidated through a fire sale or restructured at the intermediate date, banks can obtain less than one unit of goods. More precisely, the fire sale of a performing asset at t_1 delivers $(1-\tau)r_l^p$ units of goods after tax, while that of a non-performing asset yields $(1-\tau)r_l^{np}$ after tax, where

$$R > 1 > r_l^p > r_l^{np}. \tag{3.1}$$

Condition (3.1) indicates that the value from liquidating a performing asset is higher than that from a non-performing asset and the liquidation is costly for both types of banks. The relationship $r_l^p > r_l^{np}$ is explained by the fact that the continuation of a non-performing project requires refunding.

In spite of its riskiness, long-term assets are much more appealing than government bonds owing to its higher return. Even for a non-performing asset that requires the refunding of ϕ units of goods at t_1 besides the initial investment of one unit of goods at t_0, its return is still higher than that from government bonds, i.e.,

$$(1 - \tau)R - (1 + \phi) > r^*, \tag{3.2a}$$

meaning that government bonds are dominated by long-term assets in terms of their return. To maximize their utility, domestic residents will entrust all their endowments to banks that offer deposit contracts promising a fixed payment on the revelation of their type. In effect, the consumption of domestic residents is equal to the gross return of government bonds if they do not deposit their endowments in banks. Deposit contracts would be more attractive than direct investment to domestic investors for two reasons: first, long-term assets with a higher return are accessible only to banks; second, no resident knows his type before t_1, while for banks there is no aggregate uncertainty about the types of depositors according to the law of large numbers.

Commercial banks are identical at the planning date t_0. They maximize the welfare of domestic residents by optimally allocating the resources to safe government bonds and risky long-term assets. At the intermediate date t_1, based on the quality of their long-term assets, banks are divided into two types, i.e., 'good' banks and 'bad' banks. As long-term assets have a probability π of being non-performing at t_1, a proportion π of banks turn out to be 'bad', their assets needing reinvestment to deliver the normal return at t_2 and a proportion $1 - \pi$ of banks are 'good' in the sense that the return from their long-term investments is ensured at t_2 without requiring any new funding at the intermediate date.

The soundness of banks is public information and can be obtained by all agents without any cost at a time point just before t_1. In observing this information, 'good' banks make their decision about whether or not to extend interbank loans depending on their own liquidity position and on

their expectation about the solvency of 'bad' banks.

Following Allen and Carletti (2006, 2008) and Allen and Gale (2007), we consider another type of investor with risk neutral preferences called ordinary shareholders who have an initial endowment a at t_0 and do not receive any endowment in future dates. They either consume or buy common shares of banks at the planning date. Being bank shareholders at t_0, they can claim dividends after the payments to bank creditors.

Denote by d_t dividends paid to shareholders at date t, the utility function of shareholders is given by

$$u(d_0, d_1, d_2) = R(1 - \tau)d_0 + d_1 + d_2.$$

According to this linear utility function, shareholders can obtain a utility of $aR(1 - \tau)$ from the immediate consumption of their endowment at t_0, and they are indifferent between the consumption at t_1 and at t_2. Therefore, they have to be compensated by a gross return no less than $R(1 - \tau)$ for each unit of consumption that they renounced at the initial date t_0. Let $K(\leq a)$ be the bank capital, i.e., the investment of shareholders in banks; then $d_0 = a - K$ is the consumption of shareholders at t_0. The utility of an investor, provided that he buys common shares, is then $(a - K)R(1 - \tau) + d_1 + d_2$. For the investor to be a shareholder, the utility from future dividends should not be less than that from the immediate consumption of all his endowment, i.e., $(a - K)R(1 - \tau) + d_1 + d_2 \geq aR(1 - \tau)$. Thus, the incentive constraint for holding bank capital can be written as

$$d_1 + d_2 \geq (1 - \tau)RK$$

Given this incentive constraint, banks should hold enough maturing long-term assets.[29] Consequently, the dividend can be distributed only at t_2, and the above incentive constraint for shareholders can be rewritten as follows

$$d_2 \geq (1 - \tau)RK. \tag{3.3a}$$

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[29] Only the return from maturing projects at t_2 can sustain the dividends.

Even though domestic banks can sell common shares to both domestic and foreign investors, we assume for simplicity that, at the aggregate level, domestic investors' endowments are always large enough to meet banks' capital needs, i.e., $a > K$. When the dividend for shareholders satisfies condition (3.3a), banks can always raise capital through issuing stocks.

The cost of capital is apparently higher than the expected return from the risky long-term asset.[30] On the one hand, the bank capital harms the interest of depositors. The latter receive a fixed and non-negotiable payment conditional on the dates of deposit withdrawal, while shareholders' dividends are not insured by any mandatory contract. The remuneration for shareholders is state contingent, depending on the financial situation of banks. On the other hand, when a bank receives a negative shock, the bank capital works as a buffer to avoid or at least reduce the scale of the 'fire sale' of immature projects and shields the depositors from losses. Therefore, the high compensation of shareholders in 'normal circumstances' is reasonable as long as it does not impair banks' ability to absorb deposits.

In a deposit market characterized by perfect competition, banks compete with each other to provide the best deposit contract they can to absorb as many deposits from domestic residents as possible. The rate of return to shareholders being higher than that from the investment implies a subsidy from depositors to shareholders. Given that a higher capital level results in lower remuneration to depositors, banks competing with each other for deposits tend to keep the lowest possible capital stock.

3.3.2 Market discipline in the interbank lending market

A complete interbank market exists in our small economy in which banks with a liquidity surplus extend collateralized loans to banks with a liquidity shortage. Since the payments to depositors are non-negotiable, the projects financed by deposits cannot be used as collateral.

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[30] The average expected net return from a maturing long-term project is $(1 - \tau)R - [(1 - \pi) + \pi(1 + \phi)] = (1 - \tau)R - (1 + \pi\phi)$.

Consequently, the quantity of pledgeable assets is given by the amount of projects financed by shareholders and is equal to K. Provided that a refinanced project yields $(1 - \tau)R$ at t_2 and the international interest rate from t_1 to t_2 equals $1 + r^*$, in equilibrium, the size of an interbank loan per unit of collateral is given by $(1 - \tau)R/(1 + r^*)$. Let L be the amount of the interbank borrowing requested by a 'bad' bank, at the intermediate date t_1. Then the size of interbank loans limited by the value of available collateral should be:

$$L \leq \frac{(1 - \tau)R}{1 + r^*}K. \tag{3.4}$$

Investment in long-term assets is risky, yet this risk can be shared and thus reduced through a complete interbank market in 'normal times', if the interbank lending can fill the liquidity gap caused by non-performing production projects.

By using immature projects as collateral for interbank loans, the borrowing bank abandons the right to restructure them. If the borrowing bank remains solvent, it has to deliver the full return from a collateral $(1 - \tau)R$ at the final date t_2 to the lending bank to pay the loan made at t_1. In the event that the borrowing bank, after receiving the loan, becomes bankrupt, the lending bank takes over the collateral and collects $(1 - \tau)(R - \tau)$ units of goods per collateral at t_2, with $R > \delta > 0$, where δ represents the effort cost of the lending bank in supervising a long-term project that it starts monitoring from the intermediate date.[31] We assume that the payoff from taking over the collateral is low and hence unprofitable for lending banks. Thus, a bank with liquidity surplus will not extend the interbank loan if it expects the borrowing bank might go into bankruptcy; whereas, if the loan has already been granted, the lending bank does not fire sale the collateral either, since

$$(1 - \tau)r_l^{np} < (1 - \tau)(R - \delta) < 1 + r_{02}. \tag{3.5}$$

Condition (3.5) indicates that the return from the seized collateral $(1 - \tau)(R - \delta)$ is lower than

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[31] An alternative assumption is that a bank financing a project from the beginning can obtain $(1 - \tau)R$ units of goods at the final date t_2, since it has relatively complete information concerning the production process and the producer, while a lending bank starting to monitor the collateralized asset at the intermediate date has less information about the investment and thus a limited capacity to collect the return from it. Thereby, the maximum amount a lending bank can obtain is $(1 - \tau)(R - \delta)$.

that from the government bonds $(1 + r_{02})$, while it is higher than the fire-sale price $(1 - \tau)r_l^{np}$.

In 'normal times', there is no other risk besides the idiosyncratic shocks affecting the quality of banks' investments. Banks hold government bonds as liquidity reserves to pay for the early withdrawals of impatient depositors and the expected refinancing of non-performing long-term projects. 'Good' banks will not doubt the solvency of 'bad' banks if the optimal resource allocation is implemented. At the planning date t_0, bankers know that, with probability π, their bank will become a 'bad' one and will need the reinvestment of ϕ units of goods at t_1 for each troubled project. As banks are ex-ante identical, each bank has the same probability (π) of becoming a 'bad' one. Let A denote the investment in long-term assets. Without the interbank market, each bank should keep an amount of liquidity reserves for expected refinancing of non-preforming projects (hereafter called refinancing reserves) up to ϕA units of goods at t_1 to ensure the expected reinvestment, given that the fire sale of long-term assets at t_1 is too costly.

However, if a bank with a liquidity deficit can obtain an amount of interbank collateralized loan up to

$$L \equiv (1 - \pi)\phi A, \tag{3.6}$$

it needs a refinancing reserve of only $\pi\phi A$ to achieve the expected reinvestment.[32] The composite coefficient $\pi\phi$ is akin to a minimal refinancing reserve ratio that is required for a bank to be admitted to participate in the interbank market. Apparently, this refinancing reserve ratio is much lower than that required in a banking system without an interbank market. As each bank hoards a refinancing reserve $\pi\phi A$ for the expected reinvestment and 'good' banks account for a proportion $1 - \pi$ of all banks, the total liquidity surplus (or supply) in the interbank market at t_1 is $(1 - \pi)\pi\phi A$. Given that 'bad' banks stand for a proportion π of all banks, the total liquidity shortage (or demand) of 'bad' banks at t_1 in the interbank market is $\pi(1 - \pi)\phi A$. If the

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[32] When the risk of long-term assets is hedged through the competitive interbank market, the optimal allocation (i.e., the investment scale in long-term projects and the payments to depositors) at t_0 is identical to the first-best allocation implemented by a social planner.

interbank market functions well in reallocating the liquidity from surplus banks to shortage banks, the first-best risk reallocation can be implemented, hence allowing higher investment in more lucrative long-term projects.

Combining (3.4) and (3.6) leads to the interbank-market participation constraint, or the capital requirement imposed by market discipline:

$$(1-\pi)\phi A \leq \frac{(1-\tau)R}{1+r^*}K, \tag{3.7}$$

Constraint (3.7) implies that, even without governmental regulation, the interbank market can provide bank with an efficient incentive to keep their capital at a certain level. From (3.7) results a minimum capital ratio k for participating banks according to the market discipline:

$$k^i \equiv \frac{K}{A} = \frac{(1+r^*)(1-\pi)\phi}{(1-\tau)R}. \tag{3.8}$$

The minimal capital ratio k^i increases with the unit cost of refinancing a troubled project ϕ. When this capital ratio is not satisfied, 'bad' banks will experience the illiquidity caused by the reinvestment scale, which is excessively large relative to the available collateral.

According to (3.8), the capital ratio imposed by the market discipline is pro-cyclical in the sense that the interbank market demands a higher capital ratio k when the risk of assets π is lower and *vice versa*. When the risk is low, the supply of liquidity reserve and the refinancing reserve ratio $\pi\phi$ required for participation in the interbank market are small, and banks need to keep a higher capital ratio to be able to invest when they are hit by adverse idiosyncratic shocks and *vice versa*.

When the interbank market functions well and banks hit by adverse idiosyncratic shocks can borrow the amount defined by (3.6), the expected return to bank capital in normal times can be expressed as follows:

$$E[d_2] = (1-\tau)R\{\pi[K-\frac{(1+r^*)(1-\pi)\phi A}{(1-\tau)R}]+(1-\pi)[K+\frac{(1+r^*)\pi\phi A}{(1-\tau)R}]\} = (1-\tau)RK. \tag{3.9}$$

According to (3.9), for shareholders of 'bad' banks accounting for a proportion π of all banks, the

total amount of the dividend at t_2 is $(1-\tau)R[K - \frac{(1+r^*)(1-\pi)\phi A}{(1-\tau)R}]$, where the term $\frac{(1+r^*)(1-\pi)\phi A}{(1-\tau)R}$

stands for the return from long-term assets pledged to the repayment of interbank loans. For

shareholders of 'good' banks representing a proportion $1-\pi$ of all banks, the amount of the

dividend is equal to $(1-\tau)R[K + \frac{(1+r^*)\pi\phi A}{(1-\tau)R}]$, where $\frac{(1+r^*)\pi\phi A}{(1-\tau)R}$ corresponds to the interbank

loans lent by 'good' banks at t_1 that bring them $(1+r^*)\pi\phi A$ units of goods at t_2 if the 'bad'

banks are solvable. Therefore, the expected amount of the dividend for a risk-neutral investor is

$E[d_2]=(1-\tau)RK$, implying that the constraint (3.3a) is satisfied with equality.

It is straightforward to see that if banks do not respect the market discipline, the interbank

market cannot function to satisfy banks' liquidity need for refunding. The average expected

rate of return for shareholders can decrease to $(1-\pi)(1-\tau)RK$, given that, without the

interbank liquidity, bad banks can even default on debts. Therefore, banks will respect the capital

requirement voluntarily even it is not regulated by the government.

3.3.3   The maximization problem of banks

To pool the resources, banks compete for deposits by offering the highest return they can. The

optimization problem of a representative bank at the planning date is to maximize the payments to

impatient and patient depositors such as

$$maxE[\lambda u(x) + (1-\lambda)u(y)], \tag{3.10}$$

and subject to the following resource constraints:

$$K \geq k^i A, \tag{3.11}$$

$$\frac{B}{1+r_{02}} + A \leq e + K, \tag{3.12}$$

$$\lambda x + \pi\phi A \leq \frac{B}{1+r_{12}} + (1-\tau)r_l^{np}l, \tag{3.13}$$

$$(1-\lambda)y + (1-\tau)RK = (1+r_{12})[\frac{B}{1+r_{02}} + (1-\tau)r_l^{np}l - \lambda x - \pi\phi A] + (1-\tau)R(A-l). \tag{3.14}$$

Constraint (3.11) is the capital requirement imposed by the market discipline. Constraint (3.12)

is bank's resource constraint at the planning date t_0. It specifies that the bank's total investment including A units of long-term assets and B units of government bonds cannot exceed its available resources $e + K$ at t_0. Government bonds are issued at discount per value, thus $\frac{B}{1+r_{02}}$ in (3.12) represents the value of B units of government bonds at t_0.

Constraint (3.13) is the bank's feasibility or solvability condition at the intermediate date t_1. It indicates that the bank's liquidity available at t_1, through selling government bonds $\frac{B}{1+r_{12}}$ and liquidating $l (\leq A)$ units of long-terms assets $(1 - \tau) r_l^{np} l$, must be adequate relative to the scale of the withdrawal by impatient depositors λx and of its liquidity reserve $\pi \phi A$ imposed by the interbank market. The type of a bank will be revealed at a time point merely before t_1 and the interbank market provides only collateralized loans. All banks, facing the same uncertainty of holding non-performing projects, will set the fire-sale price at r_l^{np} instead of r_l^p, because the interbank market only providing collateral loans will not support bank to cover the gap between r_l^p and r_l^{np}. When (3.13) is satisfied, there will be no concern over the solvability of the bank in normal circumstances. Otherwise, the bank is insolvent, implying that it may need to liquidate its entire holding of long-term assets.

Finally, (3.14) is the bank's feasibility condition at t_2. At the final date, the liquidity available to banks should be sufficient to clear all the remaining claims by patient depositors, $(1 - \lambda) y$, and shareholders, $(1 - \tau) RK$. This constraint reflects the fact that, in a perfectly competitive deposit market, banks realize no profit after the payment to depositors and shareholders.

In this benchmark case, there is no shock affecting the aggregate liquidity. Banks in normal times consider only the idiosyncratic shock impacting the liquidity needs due to refinancing non-performing assets.

3.3.3.1   The solutions to the optimization problem

Provided that the return from the restructuring is so low that any level of restructuring will

lead to a loss for banking entrepreneurs, it is obvious that banks' optimal allocation planned at t_0 will correspond to the case with no restructuring, or $l = 0$. It is straightforward to see that at the optimum all inequality constraints are satisfied with equality to maximize the utility of domestic residents. Furthermore, the interest rates on riskless government bonds during normal times, r_{12} and r_{02}, are equal to the international interest rate, r^*. As a result, in equilibrium, all banks will choose a capital stock that satisfies condition (3.8) as follows:

$$\tilde{K} = k^i A, \tag{3.11}$$

where the tilde on top of K indicates the optimal solutions. A high opportunity cost of capital and an environment of perfect competition incite banks to keep the lowest possible capital level. However, imposing a ratio lower than k^i causes banks to be unable to obtain enough interbank loans to answer the potential risk and thus to suffer a liquidity shortage. Contrariwise, keeping a capital ratio higher than k^i makes a bank less competitive in the deposits market, if other banks keep a capital ratio k^i and thus are able to offer more appealing deposit contracts.

The optimal allocation between x and y should satisfy the following social transformation curve obtained with the binding constraints of banks' optimization problem:

$$\Phi \lambda x + (1 - \lambda)y \equiv \Phi e, \tag{3.12}$$

with $\Phi \equiv \frac{(1-k^i)(1-\tau)R}{1-k^i+\pi\phi} > 1$ representing the marginal rate of substitution between consumption at t_1 and that at t_2. More precisely, if impatient depositors renounce the consumption of λx at t_1, they can obtain consumption equal to $\Phi \lambda x$ in t_2. Φ can also be interpreted as the expected return from the deposits withdrawn at t_2. Thereby, the left-hand side of (3.12) stands for the total wealth for depositors at t_2 if all of them withdraw only at the final date. The right-hand side of (3.12) represents the expected value of total withdrawal when all depositors consume only at t_2.

As described previously, domestic residents will entrust their resources to a bank if its rate of

return is no smaller than that of government bonds. Consequently, the condition

$$\Phi \geq 1 + r^* \tag{3.13}$$

should be satisfied. (3.13) is the incentive constraint. If it is satisfied, depositors will entrust all endowments to banks. The fact that Φ decreases with k^i implies that the welfare of domestic depositors declines with the capital ratio. This justifies the capital level in equilibrium given by condition (3.11). Denoted by $\overline{k}$ the maximum value of k verifying condition (3.13), the minimal capital ratio k^i must be such that

$$k^i \leq \overline{k} \equiv \frac{(1-\tau)R - (1+\pi\phi)(1+r^*)}{(1-\tau)R - (1+r^*)}. \tag{3.14}$$

Given the value of k^i defined by (3.14), this condition is verified if the following condition is satisfied,

$$\phi \leq \frac{(1-\tau)R}{1+r^*} \left[1 - \frac{(\pi(1+r^*)}{(1-\tau)R - (1-\pi)(1+r^*)} \right]. \tag{3.15}$$

As both ϕ and π are structural parameters of the economy, we may alternatively describe (3.15) by $\pi \leq 1 - \frac{(1-\tau)R}{1+r^*\phi} \left[1 + \phi - \frac{(1-\tau)R}{1+r^*} \right]$. As a result, the interbank market grants protection only for banks holding investments within a certain scope of riskiness measured by $\pi\phi$. This implies that in normal times the interbank market discourages banks from taking too much risk. In the following, we focus on the case in which (3.15) holds.

Using the social transformation curve defined by (3.12) and the CRRA utility function of depositors, we easily obtain the following condition:

$$\left(\frac{x}{y}\right)^{-\sigma} = \Phi. \tag{3.16}$$

The verification of (3.13) means that $\Phi^{\frac{1}{\sigma}} \geq 1 + r^*$, which ensures $y > x(1+r^*)$ implying that patient depositors will report their type honestly, and withdraw and consume at date t_2 in normal times. Thereby, this banking system, with the help of an efficient interbank market, is able to design an efficient deposit contract for each type of residents to attract deposits.

Combining (3.12) with (3.16) yields the best plan for revenue distribution between impatient

and patient depositors as

$$\tilde{x} = \frac{\theta}{\lambda e}, \tag{3.17}$$

$$\tilde{y} = \frac{1-\theta}{1-\lambda}\Phi e, \tag{3.18}$$

where $\tilde{x}$ and $\tilde{y}$ stand for optimal payments to impatient and patient depositors respectively and $\theta = \left(1 + \frac{1-\lambda}{\lambda}\Phi^{\frac{1-\sigma}{\sigma}}\right)^{-1}$ taking its value within the unit interval is an important coefficient in determining the revenue distribution between impatient and patient depositors. The composite coefficient θ decreases with ϕ, meaning that the higher ϕ is, the smaller the return for the impatient residents will be. θ increases with σ, indicating that the higher is the degree of risk aversion (measured by σ), the lower will be the depositors' willingness to substitute consumption over time. An increase in σ induces a higher payment to impatient residents, implying that patient depositors will cross-subsidize impatient ones.

Substituting the solutions of $\tilde{x}$ and $\tilde{y}$ given by (3.17) and (3.18) into binding constraints (3.12)-(3.14), we obtain the bank's optimal investment in long-term projects $\tilde{A}$ and in government bonds $\tilde{B}$ as follows:

$$A = \frac{1-\theta}{1-k^i+\pi\phi}e, \tag{3.19}$$

$$B = \frac{(1+r^*)[\pi\phi+\theta(1-k^i)]}{1-k^i+\pi\phi}e. \tag{3.20}$$

According to (3.19)-(3.20), the optimal investment in risky long-term assets is negatively related to θ, and the inverse is true for the optimal holding of government bonds. The scale of investment in both assets increases with the endowment of domestic agents, e.

To put into evidence the role of the interbank market, we consider here a banking system with a perfect competitive deposit market without the interbank market. In this system, given that a minimal capital ratio is no longer imposed, banks competing for depositors will set the bank capital to zero to maximize the return for deposits. To deal with the expected refinancing of non-performing projects, they will keep a refinancing reserve up to ϕA. Accordingly, the social

transformation curve is $\frac{(1-\tau)R}{1+\phi}\lambda x + (1 - \tau)\lambda y = \Phi' e$, with $\Phi' \equiv \frac{(1-\tau)R}{1+\phi}$. Provided that $\phi < 1$, we have $\Phi > \Phi'$, i.e., the social wealth and hence the social welfare are higher in an economy with an efficient interbank market than in the one without it. In addition, the marginal rate of substitution is higher in the former than in the latter. This implies that an early withdrawal by patient depositors is more costly when there is an interbank market.

The complete interbank market, by allowing banks to cope efficiently with idiosyncratic liquidity shocks during normal times, makes it possible for banks to invest in a larger quantity of profitable long-term assets and thereby ensures a higher output level. In the meantime, it does not necessarily encourage excessive risk-taking in the banking sector. The interbank market is auto-regulated in the sense that banks must implement a minimal capital ratio imposed by the market discipline. By allowing the management of short-term liquidity gaps, interbank lending allows banks to reduce their liquidity reserve and permits a higher social welfare.

Nevertheless, a banking system that implements the optimal resources allocation constrained by the market discipline is not immune to potential bank runs. Having examined the bright side of the interbank market, in the following section we will investigate its dark side, especially, its role in amplifying and disseminating a banking crisis.

3.4   Crises in the interbank market

In this section, we consider the functioning of the interbank market when individual banks are confronted with a self-fulfilling run (confidence crisis), asymmetric information or sudden depreciation of ex-ante safe assets. Our investigation is carried out in a context whereby the establishment of the interbank market makes the banking system more vulnerable to shocks given that the perspective of interbank lending leads banks to reduce their liquidity reserve.

3.4.1 Pure confidence crisis

The interbank market allows banks that respect market discipline to cope with a liquidity mismatch with lower liquidity reserves, implying that fewer funds are available in the adverse state and the risk of a bank run becomes higher. Our framework allows examining bank runs localized respectively in two types of banks and their effects on the interbank market. It also explores that feedback or auto-reinforcement exists between the self-fulfilling run and the suspension of interbank lending.

In this subsection, there is no concern over the safety of government bonds. We consider the bank run as a rare event corresponding to an inefficient situation where the first-best allocation considered previously is not anymore feasible due to withdrawals by panicking depositors. In the present framework, a bank run is induced principally by a self-fulfilling loss of confidence.

With the revelation of the quality of long-term projects, banks are divided into 'good' and 'bad' banks. The confidence crisis could happen to both types of banks, while 'bad' banks burdened by non-performing assets are more vulnerable than 'good' banks. Furthermore, 'good' banks are subject only to the risk of premature withdrawal, whereas the solvency of 'bad' banks depends on the expectations of both depositors and good banks.

Accordingly, the condition of the existence of a run on 'good' banks is different from that on 'bad' ones. Thus, we consider these two types of run equilibrium separately in the following.

The run equilibrium for 'good' banks

The self-fulfilling crisis in a 'good' bank can occur if it cannot ensure synchronicity between the liquidity needs and the liquidity inflows. Thus, a run on a 'good' bank is possible if

$$z_p^+ \equiv \widetilde{x} - (1-\tau)r_l^p \widetilde{A} - \frac{\widetilde{B}}{1+r^*} > 0. \tag{3.21}$$

Condition (3.21) illustrates the situation in which a 'good' bank fails to honor withdrawals by panic depositors $\widetilde{x}$ in the event of a run even after having depleted all its liquidity reserves $\frac{\widetilde{B}}{1+r^*}$

and restructured all long-term asset $(1 - \tau) r_l^p \widetilde{A}$.[33]

Using conditions (3.17)-(3.20) and the definition of θ, we express condition (3.21) in terms of structural parameters as follows:

$$r_l^p < \frac{r_1^+}{1 - \tau}, \tag{3.22}$$

where $r_1^+ \equiv (1 - k^i + \pi\phi)\Phi^{(\sigma-1)/\sigma} - \pi\phi$ is a measure of illiquidity with a lower r_1^+ meaning less illiquidity.[34] The term $\frac{r_1^+}{1-\tau}$ defines the lowest liquidation price that the performing asset must attain to eliminate a bank run on 'good' banks.

The value of r_1^+ depends on the structural parameters of the economy. It is straightforward to show that $\frac{\partial r_1^+}{\partial \sigma} > 0$ and $\frac{\partial r_1^+}{\partial k^i} < 0$. This implies that banks are more vulnerable to a run if depositors have a high degree of risk aversion (σ) and when the capital ratio (k^i) is low. For a given r_1^+, the 'good' bank is solvent if the fire sale price of immature assets r_l^p is high enough to fill the liquidity gap.

The verification of (3.22) indicates the failure of the 'good' banks in a run equilibrium. This will result in the depletion of the interbank market's liquidity pool. Without adequate funds required for refinancing, 'bad' banks can no longer honor the payments to patient depositors at t_2. A run on 'bad' banks is thus immediately triggered. As a result, the failure of the interbank market has a "knock on" effect that spreads the crisis from one bank to others and thus induces a systemic collapse.

While a systemic confidence crisis is possible in our model, we are more interested in less severe situations to specify the conditions under which the interbank market is resilient during a self-fulfilling crisis. From now on, we focus on the case when there is no risk of a bank run on 'good' banks and the solvability condition of 'good' banks during a banking crisis is such that

$$z_p^+ \leq 0 \quad \text{or} \quad r_l^p \geq \frac{r_1^+}{1 - \tau}.$$

---

[33] The liquidity pool of the interbank market is composed of the liquidity surplus of 'good' banks. As a result, 'good' banks cannot obtain assistance from the interbank lending in a run.

[34] Provided that $0 < \sigma < 1$, the illiquidity measure is always smaller than 1, i.e., $r_1^+ < 1$.

This assumption is justified by the fact that a bank with a well-managed balance sheet (i.e. promisingly profitable assets and thus no need for external funding) is generally rather resilient to liquidity shocks.

The run equilibrium for 'bad' banks

For 'bad' banks, the condition for the existence of a confidence crisis depends simultaneously on the decision of their depositors and of lending banks. Thereby, to analyze the condition for the existence of a run on 'bad' banks, we need to distinguish two cases: the interbank market freezing and it functioning.

We first examine the case in which no interbank loan is granted. Proceeding as before, we obtain that a bank run on 'bad' banks is possible if the condition

$$
\begin{aligned}
z_{np}^+ &\equiv \widetilde{x} - (1-\tau)r_l^{np}\widetilde{A} - \frac{\widetilde{B}}{1+r^*} > 0 \\
&\equiv z_p^+ + (1-\tau)\widetilde{A}(r_l^p - r_l^{np}) > 0
\end{aligned}
\tag{3.23}
$$

is satisfied. Given that a non-performing asset is less valuable than a performing one ($r_l^p > r_l^{np}$), the condition for the existence of a run equilibrium is less restrictive for a 'bad' bank than for a 'good' one. It follows directly from (3.23) that $z_{np}^+ > z_p^+$. In terms of structural parameters, (3.23) can be expressed as:

$$
r_l^{np} < \frac{r_1^+}{1-\tau}.
\tag{3.24}
$$

Comparing (3.24) with (3.22), given that $r_l^{np} < r_l^p$ and for a given illiquidity measure r_1^+, 'good' banks have a greater chance of surviving during a confidence crisis than 'bad' banks.

However, the verification of (3.23) does not necessarily imply the failure of 'bad' banks that may survive if the interbank market is normally functioning. In effect, 'good' banks may offer loans to 'bad' banks even when (3.24) is satisfied since they know that new funding could improve the liquidity condition of 'bad' banks and hence protect the latter from insolvency. Interbank

loans will be granted if

$$z_i^+ \equiv \widetilde{x} - (1-\tau)r_l^{np}\widetilde{A}(1-k^i) - \frac{\widetilde{B}}{1+r^*} - \frac{(1-\tau)R}{1+r^*}k^i\widetilde{A} > 0 \qquad (3.25)$$

$$\equiv z_p^+ + (1-\tau)\widetilde{A}(r_l^p - r_l^{np}) - [\frac{(1-\tau)R}{1+r^*} - (1-\tau)r_l^{np}]k^i\widetilde{A} < 0$$

The term $[\frac{(1-\tau)R}{1+r^*} - (1-\tau)r_l^{np}]k^i\widetilde{A}$ in (3.25) represents the additional liquidity brought by interbank loans for $k^i\widetilde{A}$ units of pledgeable non-performing assets compared with the liquidity delivered by restructuring them.

Comparing conditions (3.21), (3.23) and (3.25), we can conclude that during a confidence crisis, 'bad' banks suffer larger liquidity pressures than 'good' ones and the liquidity condition of 'bad' banks deteriorates further when the interbank market is frozen, i.e., $z_p^+ < z_i^+ < z_{np}^+$.

The condition $z_p^+ < z_{np}^+$ shows that the liquidity position of 'bad' banks is vulnerable during a crisis time and hinges largely on the functioning of the interbank market. In the case when both (3.23) and (3.25) are satisfied, 'bad' banks survive in a run if the interbank lending is granted but fails if the latter is suspended. 'Good' banks will extend collateralized loans, if (3.25) is verified. Clearly, there is no counterparty risk for 'good' banks in such a case and the interbank market enhances the stability of the banking system by allowing the optimal risk reallocation among banks.

On the contrary, if condition (3.25) is not verified, the insolvency of 'bad' banks facing a run results, even though interbank loans are granted. In this case, the illiquidity of 'bad' banks is still measured as in (3.23). When expecting the prevalence of the run equilibrium at the intermediate date, 'good' banks decide at a time point slightly before t_1 to suspend loans to 'bad' banks. As we described in section 3, in a banking system without a role for the interbank market, each bank will keep a refinancing reserve up to ϕA. For a banking system with a complete interbank market, the liquidity reserves of a bank are only $\pi\phi A$ and the interbank market is expected to finance the gap equal to $(1-\pi)\phi A$. Consequently, when the interbank market fails, the liquidity position of

a troubled bank deteriorates compared to its position in a banking system without an interbank market.

The above analysis suggests that the failure of the interbank market plays an important role in triggering a self-fulfilling banking crisis. First, given that in normal times banks neglect the impact of premature liquidation, the interbank market could deteriorate the liquidity position of banks in a bank run if the fire sale price of immature projects is sufficiently low. Second, the interactions between depositors of 'bad' banks and lending banks could act as a catalyst for a confidence crisis if condition (3.25) is not verified. More precisely, lending banks make, at a time point slightly before t_1, their decision on interbank lending based on the expectations about the choice of borrowing banks' depositors at t_1. The interbank market thus functions as a selective device in the sense that its freezing due to the pessimistic expectations of lending banks will send a bad signal to borrowing banks' depositors and urge them to fulfill the expectations of a run immediately, although they may originally have wished to withhold their claims until t_2.

Proceeding as before, we can express (3.25) with structural parameters as follows:

$$r_l^{np} > \frac{r_2^+}{1 - \tau}, \tag{3.26}$$

where $r_2^+ \equiv \left[(1 - k^i + \pi\phi)\Phi^{(\sigma-1)/\sigma} - \phi\right](1 - k^i)^{-1} = \frac{r_1^+ - (1-\pi)\phi}{1-k^i}$. Given that $r_1^+ < 1$ and $k^i < (1 - \pi)\phi$, we obtain that $r_2^+ < r_1^+$ showing that 'bad' banks become less illiquid when the interbank market functions well. If $\frac{r_2^+}{1-\tau} < r_l^{np} < \frac{r_1^+}{1-\tau}$, 'bad' banks survive only when they can borrow from the interbank market. These results confirm our previous analysis.

The minimal capital ratio required for borrowing from the interbank market, k^i, substantially affects banks' solvency condition in a run. The negative sensitivity of r_1^+ and r_2^+ to an increase in k^i, means that the minimal liquidation price compatible with the absence of a run decreases with the minimal capital ratio and thus banks with a higher capital ratio are more resilient to a run. The capital ratio k^i, set at the planning date by only taking account of the risk of detaining

non performing projects π and the unit cost of refunding ϕ, may prove insufficient during a crisis such that $r_l^{np} < \frac{r_2^+}{1-\tau} < \frac{r_1^+}{1-\tau}$. Consequently, the run equilibrium could be entirely ruled out if the government imposes at t_0 a regulatory capital ratio, k^g, high enough for condition (3.26) to be verified. Since the right-hand side of (3.26) decreases with the capital ratio, we must have $k^g > k^i$. The minimal regulatory capital, eliminating a bank run, cannot be expressed explicitly in terms of structural parameters given the non-linearity in (3.26). For $\sigma = 0.5$, $\tau = 0.1$, $\phi = 0.2$, $r_l^{np} = 0.6$, $R = 2$ and various values (from 0.1 to 0.7) of π, numerical simulations show that k^g could be so high that the role of banks as financial intermediaries is ruled out at the run-free equilibrium (i.e., $k^g > \overline{k}$). Therefore, in our model the government cannot always set a practicable regulatory capital ratio to eliminate the risk of bank runs completely.

3.4.2 Foreign debt crisis and the domestic interbank market

In the above, domestic and foreign government bonds are assumed to be risk free in any circumstances. While this was the general perception among financial operators before the $2008 - 2009$ global financial crisis, such an assumption has been invalidated by the events in the recent Eurozone crisis. The latter reminded the financial operators that sovereign debts might be subject to a risk of default. In a monetary union without a banking union, a banking crisis could lead to a sovereign debt crisis and *vice versa*, given that the national government takes responsibility for supervision and bailout the domestic banking system while the domestic banks hold a significant quantity of national debts. Due to the high degree of financial integration, such twin crises could have destructive impacts on the banking systems of other member states.

We examine in this subsection the effects of a financial shock originating from outside the domestic country in a variant of the baseline model described in section 3 to illustrate the situation in some core-Euro countries like France or Germany, whose domestic banks suffer the contagion from Euro-periphery countries' sovereign debt crisis. We consider a case where the interest rate

on foreign government bonds rises at the intermediate date t_1, reflecting the sudden discovery of the risk of sovereign default by market operators, such that:

$$r_{12}^f = r^* + \rho,$$

where ρ is the risk premium.

The optimal allocation made by the banking system at t_0 is based on the assumption that all government bonds are risk-free, and that both domestic and foreign government bonds are indifferently held by banks as liquidity reserves. The rise in the foreign country's interest rate will affect the domestic banking system through the balance-sheet effect.

The composition of the portfolio of bonds at t_1 and just before the foreign financial shock is given by $B \equiv B^f + B^d$ with $B^f > 0$ referring to the amount of foreign bonds and $B^d > 0$ the amount of domestic bonds. Denote by $\eta \in (0, 1)$ the share of foreign bonds in the total bonds holdings, it follows that

$$B^d = (1 - \eta)B \qquad \text{and} \qquad B^f = \eta B. \tag{3.27}$$

The depreciation of foreign government bonds weakens domestic banks' liquidity position. Given constraints (3.13) and (3.27), we obtain the aggregate loss of domestic banks directly caused by the foreign sovereign debt crisis as

$$l(\rho) = \frac{\eta \rho \widetilde{B}}{(1 + r^* + \rho)(1 + r^*)}. \tag{3.28}$$

Disequilibrium results in the interbank market because such losses reduce the available liquidity reserves of all types of banks, thus decreasing the liquidity supply of banks with surplus reserves and increasing the liquidity demand of banks with a liquidity shortage.

When foreign bonds depreciate, 'good' banks will divert part of their liquidity reserves invested in government bonds, initially meant to be lent through the interbank market, to ensure the payments to impatient depositors. Therefore, the total liquidity available in the interbank market

is now

$$I^s = (1 - \pi)[\pi\phi\widetilde{A} - l(\rho)]. \tag{3.29}$$

Comparing (3.29) with (3.7), we directly obtain that $I^s < (1 - \pi)I$, implying a credit crunch in the domestic interbank market during a foreign sovereign debt crisis.

The aggregate liquidity supply, I^s, can be positive or negative. The case in which $I^s < 0$ corresponds to a systemic liquidity crisis in the sense that 'good' banks themselves suffering from a liquidity shortage are forced to carry out the premature liquidation of their long-term projects. Therefore, the interbank market is entirely frozen and 'bad' banks, due to the lack of funds for reinvestment, fail immediately at t_1, given that condition (3.23) is verified.

The freezing of the interbank market could coincide with a systematic banking crisis if the condition for the existence of the run equilibrium is verified even for 'good' banks, i.e.,

$$z_{pf}^+ \equiv z_p^+ + l(\rho) > 0. \tag{3.30}$$

To examine the role of the interbank market during a foreign debt crisis, we consider an intermediate case in which the initial measure of illiquidity z_p^+ is negative such that (3.30) does not hold and 'good' banks still have a liquidity surplus to lend in the interbank market, i.e., $I^s > 0$. Consequently, the interbank market could remain functioning but becomes very strained as the liquidity offer decreases by $(1 - \pi)l(\rho)$. The increase in 'bad' banks' liquidity needs caused by the depreciation of foreign bonds is equal to $\pi l(\rho)$. The liquidity shortage of 'bad' banks I^d cannot be satisfied by the liquidity supply from the interbank market I^s, i.e.,

$$I^d = \pi[(1 - \pi)\phi\widetilde{A} + l(\rho)] > I^s. \tag{3.31}$$

As a result, 'bad' banks are compelled to liquidate a certain amount of their long-term projects to meet their liquidity needs at t_1. Such liquidation implies, according to solvency constraint (3.14), that 'bad' banks will be insolvent at the final date t_2.

The equilibrium depends on the decisions of patient depositors who use the state of the

interbank market as a signal. This assumption reflects the behavior of most depositors during a bank run quite well given that they have less information than the financial institutions participating in the interbank market and form their expectation based on the reactions of financial institutions regarding their banks.

Assume that the foreign shock is such that, as long as the interbank market functions, a confidence crisis will not occur at t_1. In the case in which collateralized interbank loans are granted, a run on 'bad' banks would be avoided at t_1 but could still occur before t_2. If interbank loans are suspended, depositors immediately run on 'bad' banks at t_1.

It is straightforward to see that the bankruptcy of 'bad' banks before the debt collection at t_2 will reduce 'good' banks' return from interbank lending to $(1 - \tau)(R - \delta)$ according to (3.5), given the effort cost δ of supervising the collateralized projects. However, 'good' banks could have an interest in lending to these 'bad' banks if the latter are expected to fail only after having received payments from entrepreneurs of long-term projects.

After the arrival of foreign financial shocks, 'good' banks decide to lend by imposing less favorable terms on borrowing banks by lowering the price of a unit of collateral from $\frac{(1-\tau)R}{1+r^*}$ to $\frac{(1-\tau)(R-\delta)}{1+r^*}$, taking account of the effort cost. In fact, the drop in the collateral price implies extra revenue $\frac{(1-\tau)(R-\delta)}{1+r^*}$ for 'good' banks. The latter can thus compensate for their eventual effort cost when the insolvency of 'bad' bank is perceived by their depositors before t_2.[35] 'Bad' banks borrow with the reduced collateral price equal to $\frac{(1-\tau)(R-\delta)}{1+r^*}$ if the liquidity obtained from interbank lending is larger than that from premature liquidation, i.e., $\frac{(1-\tau)(R-\delta)}{1+r^*} > r_l^{np}$ and the maximal amount of borrowing that can be backed up by collateral is now reduced to $\mu \equiv \frac{\pi(1-\tau)(R-\delta)}{1+r^*} k^i \widetilde{A}$.

As a result, 'good' banks will grant collateralized loans to 'bad' banks if the condition for the existence of the run equilibrium at the intermediate date is not satisfied for 'bad'

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35   This situation is different from that in the last subsection whereby during a confidence crisis an immediate run definitely occurs on 'bad' banks at t_1 if (3.25) holds. Therefore, there is no additional profit left for 'good' banks.

banks:

$$Z_{npf}^+ = \begin{cases} Z_i^+ + l(\rho) + \frac{(1-\tau)\delta}{1+r^*}k^i \widetilde{A} < 0, & \text{if } I^s > \mu, \\ Z_i^+ + l(\rho) + \frac{1}{\pi}[(1-\pi)l(\rho)] - \frac{(\mu-I^s)(1+r^*)r_l^{np}}{R-\delta}, & \text{if } I^s \leq \mu. \end{cases} \quad (3.32)$$

When condition (3.32) is verified, an immediate run at t_1 on 'bad' banks can be avoided.[36] The liquidity position of 'bad' banks is deteriorated by the foreign crisis such that $Z_{npf}^+ > Z_i^+$.

Conditions (3.29) and (3.31) and the quantity of available collateral $k^i \widetilde{A}$ fixed at t_0 mean that the extra liquidity shortage caused directly by the depreciation of foreign government bonds held by 'bad' banks $\pi l(\rho)$ cannot be filled through the interbank market suffering a liquidity crunch equal to $(1-\pi)l(\rho)$, i.e., the depreciation of foreign bonds held by 'good' banks. In the meantime, the reduction of the collateral price implies that 'bad' banks' borrowing capacity is deteriorated. The two alternative cases represented in (3.32) imply that the amount of interbank loans is limited by either lending banks' liquidity surplus when $I^s > \mu$ or the total value of collateral held by borrowing banks when $I^s \leq \mu$. In the case in which $I^s > \mu$, the value of collateral μ cannot support a loan equal to I^s, and the total borrowing is equal to μ. The extra liquidity shortfall due to the depreciation of collateral is equal to $\frac{\delta k^i \widetilde{A}}{1+r^*}$ and the total additional liquidity gap of a 'bad' bank is thus $l(\rho) + \frac{(1-\tau)\delta}{1+r^*}k^i \widetilde{A}$.[37]

In the case in which $I^s \leq \mu$, the value of collateral, despite its depreciation, exceeds the amount required for obtaining a loan equal to I^s. 'Bad' banks will thus liquidate, at a fire-sale price $(1-\tau)r_l^{np}$, the assets that are no longer used as collateral, i.e., $\frac{(\mu-I^s)(1+r^*)}{(1-\tau)(R-\delta)}$, and obtain $\frac{(\mu-I^s)(1+r^*)r_l^{np}}{R-\delta}$.[38] Thus, for 'bad' banks, given that the liquidity shortage caused by the interbank market credit crunch is $(1-\pi)l(\rho)$, the extra liquidity gap is equal to $(1-\pi)l(\rho) - \frac{(\mu-I^s)(1+r^*)r_l^{np}}{R-\delta}$.

---

[36] Note that as the solvability condition at t_2 is not satisfied, there will be a run during the period after t_1 until t_2, if the depositors recognize that their banks are insolvent.

[37] The additional liquidity shortage is obtained by calculating the difference between the amount of interbank loans granted in normal times $(1-\pi)\phi A$ and that granted during a foreign debt crisis. The latter is defined by $\min(\mu, I^s)$. Therefore, this additional liquidity shortfall is $\frac{\delta k^i \widetilde{A}}{1+r^*}$ in the case in which $I^s > \mu$ and $\frac{1-\pi}{\pi}l(\rho)$ in the contrary case. Besides, the direct liquidity shortfall caused by the depreciation of foreign bonds for each banks 'good' or 'bad' is equal to $l(\rho)$.

[38] The term $\mu - I^s$ stands for the value of redundant collateral due to the credit crunch. As redundant collateral assets, $\mu - I^s$ is measured in terms of the actual price and it is divided by the actualized collateral price $\frac{(1-\tau)(R-\delta)}{1+r^*}$ to obtain the quantity of collateral to be liquidated at the fire sale price $(1-\tau)r_l^{np}$.

Thus, the extra liquidity gap for each bad bank is equal to $\frac{1}{\pi}[(1-\pi)l(\rho) - \frac{(\mu-I^s)(1+r^*)r_l^{np}}{R-\delta}$. Due to the credit crunch and the fall in the collateral price in response to the foreign sovereign debt crisis, the liquidity position of domestic banks deteriorates and this could compromise the stability of the interbank market.

Here, the bank-run after t_1 but before the achievement of long-term projects is not inefficient and is thus different from a self-fulfilling crisis at t_1 when the panic-induced run reduces the utility of both depositors and banks' shareholders. Such a delayed run results from the true insolvency of 'bad' banks, and it will reduce depositors' losses given that condition (3.32) holds but not constraint (3.14) compared with a self-fulfilling crisis. The insolvency of 'bad' banks may be avoided if they keep a capital level higher than that required by the interbank market and large enough to cover the direct and indirect losses caused by the foreign debt crisis. However, increasing the capital requirement is not always feasible. As in the previous subsections, a capital ratio that is efficient in eliminating the risks in the banking system could easily exceed the ceiling $\bar{k}$ and thus deprive banks of their role as financial intermediaries.

3.4.3 Asymmetric information and the interbank market

We now examine the impact of the interbank market on the stability of the banking system in a more complex and realistic environment characterized by asymmetric information between borrowing and lending banks at t_1 due to the appearance of a gambling asset. Such a problem is perceived by banks only at a time point just before the intermediate date t_1 and it is unknown by depositors so it does not directly lie at the root of a bank run. However, if banks gamble, the information will be revealed and obtained costlessly by all the other agents at the final date t_2. A bank run could be triggered when the depositors perceive the gambling behavior of their banks.

A gambling asset is suddenly available for investment at the intermediate date t_1. It yields $\psi R > R$ at the final date t_2 with the probability $\vartheta < 1$ for each unit of goods invested at t_1, and

0 otherwise. $(\psi - 1)R > 0$ is the unobservable excess return if the gambling asset succeeds. To capture the characteristics of a gambling asset, we assume that its probability of success is low (ϑ is quite small), its unobservable rate of return is high (ψ is large) and investing in this gambling asset is socially inefficient such that

$$\vartheta \psi R < R. \tag{3.33}$$

Condition (3.33) indicates that the average expected return from a gambling asset is lower than that from a long-term project. Therefore, any risk-averse or risk-neutral investors will not fund the gambling asset with their own endowments. However, for 'bad' banks subject to limited liability, purchasing the gambling asset could be a rational choice. More precisely, they have the incentive to divert funds from interbank loans and from the premature liquidation of long-term projects to invest in the gambling asset, if

$$\vartheta(1-\tau)R[\psi(1-\tau)(1-k^i)\widetilde{A}r_l^{np}+\psi\frac{(1-\tau)R}{1+r^*}k^i\widetilde{A}-k^i\widetilde{A}-\frac{(1-\lambda)y}{(1-\tau)R}] > (K-k^i\widetilde{A})(1-\tau)R. \tag{3.34}$$

The left hand side of (3.34) represents the expected gain for 'bad' banks' shareholders, if they divert the funds obtained from the liquidation of part of their long-term projects equal to $(1-\tau)(1-k^i)\widetilde{A}r_l^{np}$, and the interbank loans $\frac{(1-\tau)R}{1+r^*}k^i\widetilde{A}$ to purchase gambling assets, which are demanded by 'bad' banks according to (3.7). With the probability ϑ, 'bad' banks may repay their interbank loans $(1-\tau)Rk^i\widetilde{A}$ and patient depositors $(1-\lambda)y$, their shareholders take the remainder. The right hand side of the condition is the cost of investing in gambling assets. Given that banks must hold bank capital equal to $\widetilde{K} = k^i\widetilde{A}$, the right hand side of the condition is zero.

It is easy to see that condition (3.34) breaks easily. A 'bad' bank will have no incentive to gamble if (3.34) is not verified. In other words, it will not gamble if it keeps a capital ratio k^r imposed by the government's regulation higher than the minimum level imposed by the interbank

market, i.e.,[39]

$$k^r > k^i + \frac{\vartheta}{1-\vartheta}[\psi(1-\tau)(1-k^i)r_l^{np} + \psi(1-\pi)\phi - 1]$$ (3.35)

Therefore, the governmental capital requirement seems to be essential to avoid gambling behavior, as banks under perfect competition will not voluntarily adopt a capital ratio higher than the interbank market requires. However, given the fact that ψ is high and $\frac{\partial k^r}{\partial \psi} > 0$, k^r could exceed the ceiling $\overline{k}$ defined by (3.14). This means that when the unobservable excess profit is sufficiently high, an ex-ante higher capital ratio introduced to avoid gambling could be incompatible with the existence of the equilibrium with banks as financial intermediaries.

Using $\widetilde{A}$ given by (3.19) and $(1-\lambda)y = A(1-k)(1-\tau)R$ given by constraint (3.14), the constraint (3.34) is equivalent to

$$r_l^{np} > \frac{r_3^+}{1-\tau},$$ (3.36)

where $r_3^+ \equiv \frac{1-(1-\pi)\phi\psi}{(1-k^i)\psi} < 1$.[40] When condition (3.36) is satisfied, 'bad' banks will invest all their resources in the gambling asset since this is more profitable for their shareholders, even though it is socially inefficient. We obtain directly from the definition of r_3^+ that $\frac{\partial r_3^+}{\partial k^i} < 0$, implying that condition (3.36) is more easily verified when the minimal capital ratio is higher. This result does not contradict (3.35). Condition (3.35 indicates that bank capital that is higher than the minimal level $k^i\widetilde{A}$ required for obtaining interbank lending, increases the cost of premature liquidation (i.e., the term $(K - k^iA)(1-\tau)R$ on the right-hand side of (3.34), and thus incites 'bad' banks to give up their gambling behavior. The definition of r_3^+ implies that a higher minimal capital ratio imposed by the interbank market leads to more liquidity that can be raised through the interbank market, generating thus more (and hence cheaper) funds for investing in the gambling asset.

The information revealed by condition (3.36) is costless for all banks but not available to depositors at t_1. Thus, the arrival of the gambling asset will not induce the run in the first place.

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[39] (3.35) is obtained by inverting (3.34) while using (3.18)-(3.19) and the definition of Φ.
[40] Provided that $k^i = \frac{(1+r^*)(1-\pi)\phi}{(1-\tau)R}$, we directly obtain $k^i < (1-\pi)\phi$, which ensures that $r_3^+ < 1$.

'Good' banks cannot directly monitor 'bad' banks' gambling behavior. Their decision of lending depends on the verification or not of(3.36). If (3.36) does not hold, 'good' banks will extend the interbank loans and the situation of the banking system remains the same as in the section 3. The presence of gambling asset has no influence on the equilibrium. On the contrary, the gambling asset is more lucrative in terms of dividend than reinvestment for 'bad' banks' shareholders, and there are two options left for 'good' banks. They may either refuse granting interbank loans to avoid the counterparty risk caused by the gambling or demand a higher return from the loans so as to compensate the additional risk. Nevertheless, for risk neutral banks, the second option remains more appealing because it could yield higher dividends for their shareholders than the first option.

The initial safe return from the interbank loans is given by $(1 - \tau)Rk^i A$. With the presence of the gambling assets, lending banks may gamble with 'bad' banks by requiring a higher return from interbank loans equal to $\frac{1-\tau}{\vartheta}Rk^i A$ to compensate for the risk associated with the gambling behavior. Accordingly, 'bad' banks will still have the incentive to gamble, if the condition

$$\psi[(1 - \tau)(1 - k^i)Ar_l^{np} + \frac{(1 - \tau)R}{1 + r^*}k^i A] - \frac{k^i A}{\vartheta} - \frac{(1 - \lambda)y}{(1 - \tau)R} > 0 \qquad (3.37)$$

is satisfied. (3.37) represents the case whereby the investment in the gambling asset remains the better solution for 'bad' banks when the cost of borrowing rises. If an interbank loan is not granted, 'bad' banks fail immediately at t_1 and their shareholders receive no dividend. This consequence compels 'bad' banks to accept the less favorable loan terms if (3.37) holds. 'Bad' banks' shareholders may then partially recoup their investment with a probability ϑ while their depositors potentially suffer a huge loss if the gambling fails.

Condition (3.37) can be rewritten with the structural parameters as follows:

$$r_l^{np} > \frac{r_4^+}{1 - \tau}, \qquad (3.38)$$

where $r_4^+ \equiv \frac{\vartheta + k^i(1 - \vartheta) - \vartheta\psi(1 - \pi)\phi}{\vartheta\psi(1 - k^i)}$. If condition (3.38) holds, the interbank loans will be granted. Consequently, 'bad' banks will carry out the premature liquidation of $(1 - k^i)\widetilde{A}$ units of long-term

assets and invest the proceeds in the gambling asset.

A bank run on 'bad' banks happens if the interbank market freezes. This is possible if 'bad' banks cannot honor the repayment of the interbank loans borrowed at the risky rate $\frac{(1-\tau)R}{\vartheta}$. Given that $r_4^+ > r_3^+$, which follows immediately from comparing (3.36) with (3.38), a situation exists in which (3.36) holds but not (3.38). In such a situation, a bank run on 'bad' banks occurs immediately at t_1 since the depositors acquire the information that, due to a lack of refunding, their banks cannot ensure the payments at t_2. As a result, neither the refinancing of long-term projects nor the investment in the gambling asset will be implemented. Thus, the presence of asymmetric information increases the chance of failure of 'bad' banks.

The interbank market functions poorly in answering the unexpected shock to the banking system represented by the sudden appearance of the gambling asset at the intermediate date. Several observations could be made about the interplay between the interbank market and the gambling asset.

First, given the requirement of a minimal capital ratio to access the interbank market, the interbank loans, while ensuring optimal risk-sharing, could amplify the gambling activities of borrowers. As shown by (3.34) and (3.37), due to this minimal capital ratio, borrowing banks' shareholders bear no additional cost for the failure of the gambling activity while they may receive compensations if their banks win in the gambling. Consequently, such a minimal capital ratio is inefficient in the sense that it can neither ensure the liquidity transfer between banks nor prevent their excessive risk-taking when the economy is affected by asymmetric information about the unexpected shock.

Second, the operating principle of the interbank market becomes incompatible with the presence of asymmetric information. Comparing (3.26) with (3.38), we find that in normal circumstances, the interbank market protects banks with a relatively liquid balance sheet (i.e., a

higher r_l^{np}), whereas, in the presence of asymmetric information, the interbank market works if borrowing banks have a more illiquid balance sheet (i.e., a lower r_l^{np}). This paradoxical reaction of the interbank market to the unexpected shock destabilizes the banking system, particularly when banks have a relatively sound balance sheet with more liquid assets.

Third, the interbank market facing an unexpected shock may encourage the excessive risk-taking of the banking system. As shown by (3.36) and (3.38), lending banks could have an interest in permitting borrowing banks to gamble when the latter have a more liquid balance sheet. Their risk neutral shareholders prefer this risky activity, since it delivers an average expected return no less than that from the refunding of long-term projects. Nevertheless, risk-averse domestic depositors suffer huge losses, especially when the gambling banks fail. In this event, the production level falls sharply, since the borrowing banks have to liquidate their long-term projects prematurely.

To enhance the stability of the banking system and the interbank market in the presence of asymmetric information, the government might stipulate a capital regulation that requires banks to hold a level of capital higher than the minimal capital imposed by interbank lending. Nevertheless, as shown by condition (3.35), a regulation that is fully efficient in eliminating banking crises could imply a capital ratio exceeding the capital ratio ceiling $\overline{k}$, especially when the gambling is highly attractive (i.e., ϑ and ψ are relatively high). As a result, the government's ex-post crisis management plays a crucial role in stabilizing the banking system and in restoring the normal conditions of the interbank market during crisis times.

3.5   The government's crisis response

The banking sector and the interbank market are the most important components of the financial system. In normal times, the existence of the interbank market reinforces the liquidity position of banks and boosts the economic performance, whereas the dysfunction of the interbank

market could aggravate the instability of the banking system during a crisis. More restrictive regulations, which are usually costly in terms of social welfare, are not always feasible due to the constraints imposed by the structural parameters of the economy. Consequently, the government's crisis management is crucial to sustain the banking system and to restore the normal conditions of the interbank market during crisis times. This is confirmed by the experiences during recent banking crises across the world. However, the lessons from several euro-peripheral countries such as Spain, Portugal or Ireland have revealed that the government's ability to bail out banks is largely limited by the institutional constraints introduced with the creation of the euro zone. Due to these constraints, the government of a member state might not be able to implement a credible bailout program if the latter's execution impairs its budgetary position. Carrying out an infeasible bailout program could induce twin sovereign debt and banking crises.

The domestic government in our model starts with an amount of debt D_0, which is financed by issuing at t_0 a quantity of long-term government bonds with a face value of B_{02}^g maturing at the end of period 2. They are sold at a discount of the par value, such that $\frac{B_{02}^g}{1+r_{02}^g} = D_0$. During the period, the government collects taxes, T, to finance public spending, G. Without new bonds being issued after the initial date t_0, the amount of debt left at the end of t_2 is $D_2 = B_{02}^g + (G - T)$. The debt D_2 is refinanced by issuing new bonds in the international financial market after t_2. In practice, international investors would accept the refinancing of the debt up to a certain level. To reflect this fact, we assume that a ceiling exists for the ratio of debt over GDP, g_f, above which the government's risk of default on its debt in the future becomes significant, and that the cost of refinancing stays at normal levels if the ratio of debt over GDP does not exceed the exogenous ceiling g_f,[41] i.e.

$$\frac{D}{Y} \leq g_f \ . \tag{3.39}$$

[41] More information and justifications concerning the government budget and the public debt to GDP ratio are provided in the next chapter.

In normal times, the level of taxes and of government spending is such that the ratio of debt over GDP remains at a constant level g, i.e. $D_2 = D_0 = \overline{D}$, and all projects mature and the amount of taxes collected is therefore $\overline{T} = \tau R \widetilde{A} = \tau \overline{Y}$ with $\overline{Y}$ being the total production in normal times. The amount of government spending consistent with a constant level of debt is $\overline{G} = \tau R \widetilde{A} - r^* \overline{D}$. The government debt lies within the credible level and the debt to GDP ratio in the sense that g does not surpass the ceiling g_f, such that condition (3.39) holds.

If $g > g_f$, the government is exposed to the risk of sovereign default and will need to pay a risk premium ϱ^d increasing with the level of g for its borrowing. The present value of government bonds will plummet accordingly. In the following, we first consider the case without gambling asset (subsections 5.1 and 5.2) and then the case with it (subsection 5.3).

3.5.1 Bailout during a pure confidence crisis

To resolve a banking crisis resulting from a run by panicking depositors on 'bad' banks, the government can try to rule out this run equilibrium by deciding, at t_1, to conduct a bailout through injecting liquidity into these banks. As shown by (3.25), the run equilibrium can be eliminated and the normal functioning of the interbank market can be restored, if the liquidity gap z_i^+ is filled. Given that 'bad' banks accounts for π percent of all banks, the amount of liquidity injection required to eliminate the confidence crisis is $G_2^d = \pi z_i^+$. Without the seigniorage revenue, the government must issue new (short-term) bonds with a face value B_2^d sold at a discount of the par value. We take the case in which the government's solvency is not a concern, the interest rate applied to these bonds is $r_{12}^g = r^*$, so that:

$$G_2^d = \frac{B_2^d}{1 + r^*} = \pi z_i^+. \tag{3.40}$$

In the meantime, the revenue of the government declines when 'bad' banks liquidate their investments for an amount of $\Delta T^b = \overline{T} - (1 - \tau)(R - r_l^{np})\pi \widetilde{A}$, where the superscript 'b' denotes

the equilibrium with the run on 'bad' banks being avoided by the government bailout.

Assume that, in the crisis state, the government is able to commit to bailing out 'bad' banks in a run. Then the condition

$$g^b \equiv \frac{D^b}{Y^b} = \frac{\overline{D} + G_2^d + \Delta T^b}{\overline{Y} - (R - r_l^{np})\pi \widetilde{A}} \leq g_f,$$

(3.41)

should be satisfied. From condition (3.41), we have $g^b > \overline{g}$ indicating that, with taxes plummeting and public spending soaring, the fiscal bailout induced by a banking crisis endangers the sustainability of the government's debt. The level of g^b depends largely on the scale of the crisis, which could be measured by the proportion of 'bad' banks π, and the liquidity of the assets measured by the gap between r_2^+ and r_l^{np}.

In the case of $g^b > g_f$, the government suffers a sovereign debt crisis due to the unsustainable debt level resulting from its engagement in the unviable bailout. Given the existence of the risk of default, the government can no longer sell bonds without paying a risk premium over the international interest rate. This implies that the present value of domestic government bonds plummets at t_1. The liquidity gap of the domestic banks that hold these bonds substantially on their balance sheet becomes larger. In consequence, the government must borrow more funds at higher costs to fill banks' enlarged liquidity gap with the sensitivity of the liquidity gap to the risk premium given by $\frac{\partial Z_i^+}{\partial \varrho} \equiv \frac{-(1-\eta)\widetilde{B}}{(1+r^*+\rho)^2}$. In other words, if $g^b > g_f$, the bailout is infeasible and its implementation will induce twin banking and sovereign debt crises.

In the case whereby $g^b \leq g_f$, the confidence crisis can be easily ruled out once the government announces its bailout program G_2^b. The fact that a credible announcement is sufficient to eliminate a bank run implies that no new debts need to be issued given that the interbank market resumes its role in the liquidity transfer.

3.5.2   Bailout during a crisis resulting from a foreign debt crisis

We consider now the government intervention during a liquidity crisis stemming from the

contagion of a foreign sovereign debt crisis. There are two preeminent differences between a confidence crisis and a crisis originating from depreciating assets. In terms of crisis origins, the first is due to the liquidity mismatch in banks' balance sheet induced by premature withdrawals, while the second is caused by the insolvency of 'bad' banks as a result of the aggregate liquidity shortfall and the resulting plummeting collateral price. In terms of crisis management, the first could be ruled out with a mere announcement of a credible bailout package while the second must be dealt with by effective implementation of the bailout program destined to fill the liquidity gap.

To cope with a crisis induced by the depreciation of foreign sovereign bonds, the government should inject sufficient liquidity to fill the aggregate liquidity gap $l(\rho)$ to avoid a credit crunch and a drop in the collateral price in the interbank market, which could result in the failure of 'bad' banks. The total cost of the bailout package in this case is thus $G_2^s = l(\rho)$. A government without a monetary instrument should issue at t_1 an amount of short-term bonds equal to $\frac{B_{12}^s}{1+r^*} = G_2^s$, if its solvency is not the concern of market participants. Consequently, this bailout program is feasible under the condition that[42]

$$g^s \equiv \frac{D^s}{Y^s} = \frac{\overline{D} + G_2^s + \Delta T^b}{\overline{Y} - (R - r_l^{np})\pi\widetilde{A}} \leq g_f. \tag{3.42}$$

Condition (3.42) directly yields that $g^s > \overline{g}$, implying that the government's budgetary position could be largely deteriorated by the banking bailout. The value of g^s depends on the proportion of 'bad' banks (π) in the banking system and their degree of illiquidity measured by the gap between r_2^+ and r_l^{np}, as well as on the connectedness between the domestic banking system and the foreign country measured by η and the magnitude of the depreciation of foreign bonds ϱ. In the case where $g^s > g_f$, the government is unable to rescue the banking sector contaminated by the foreign sovereign debt crisis. The implementation of an incredible bailout policy, G_2^s, will induce twin banking and sovereign debt crises in the domestic economy. 'Good' banks could also be involved

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[42] In (3.42), we consider as in (3.41) the worst scenario where the run on 'bad' banks continues although 'good' banks survive with the intervention of the government. The bankruptcy of 'bad' banks decreases the tax revenue by an amount of ΔT^b and the production by a quantity of $\pi\widetilde{A}$.

in such crises if the depreciation of domestic and foreign government bonds is such that condition (3.30) is verified. To avoid such a scenario following the contagion of a foreign sovereign debt crisis, the domestic government should initially keep sufficient room for policy maneuver during crisis times such that $g^s < g_f$ holds even if the bailout package $l(\rho)$ is implemented.

3.5.3 Preventive policy to avoid a crisis due to gambling behavior

As described in subsection 4.2, the gambling behavior of 'bad' banks and the asymmetric information between banks at t_1 could induce the interbank market either to stop liquidity transfer from lending banks to borrowing banks or to encourage the over risk-taking of the entire banking system. The capital regulation could be too costly or infeasible to rule out the consequences of the sudden arrival of gambling asset at t_1 and the direct supervision over individual banks' balance sheet will not be practicable.

We assume that, while the domestic government does not receive more information about the soundness of banks' balance sheet than the financial markets' participants, it has the capacity to verify at date t_2 whether banks are gambling or not. To avoid the potential loss and destabilizing effects caused by the gambling behavior, the domestic government, as the banking regulator, can announce before t_1 that it will raise a penalty tax to be collected on the gambling income at t_2. Let τ^p denote the penalty tax rate. This preventive policy is efficient if it can effectively destroy banks' incentive to gamble such that

$$(1 - \tau - \tau^p)R[\psi(1 - \tau)(1 - k^i)\widetilde{A}r_l^{np} + \psi\frac{(1 - \tau)R}{1 + r^*}k^i\widetilde{A}] - [(1 - \tau)Rk^i\widetilde{A} - (1 - \lambda)y] < 0. \quad (3.43)$$

The left hand side of the above condition stands for 'bad' banks' gain from gambling, which is lower than that in condition (3.34) due to the presence of a penalty tax. The right hand side, identical to that in (3.34), represents 'bad' banks' revenue loss due to the abandonment of viable long-term projects. Arranging the terms of condition (3.43), we obtain that, to prevent gambling

behavior, the government should set a penalty tax rate verifying the following condition:

$$\tau^p > (1 - \tau)\{1 - \frac{1}{\psi[(1 - \tau)(1 - k^i)r_l^{np} + (1 - \pi)\phi]}\}.$$

When the preventive policy, defined by a penalty tax rate τ^p satisfying the above condition, is introduced, it is not in the interest of 'bad' banks to gamble as it yields a negative expected return. Therefore, at the final date t_2, no penalty tax will actually be collected.

Finally, the mere announcement of the credible preventive policy τ^p can completely eliminate the gambling incentive. Thus, the introduction of such a policy protects the banking system efficiently from the destabilizing effects of gambling assets.

3.6 Conclusion

The model presented in this chapter captures several features of recent banking crises characterized by the dysfunction of the interbank market. It is shown that, while the interbank market facilitates the liquidity transfer between banks and improves the social welfare during normal times, it could be a factor of instability by disseminating the effects of various shocks to the entire banking system during crisis times. We show that the interbank market could aggravate or induce the confidence crisis by making possible the self-reinforcing panic of both borrowing banks' depositors and lending banks. It could increase banks' risk-taking in the presence of gambling asset and aggravate the negative effects of the contagion from foreign sovereign debt crisis to domestic banking crisis.

Whether the interbank market functions well or not depends on the level of banks' capital. Without a capital regulation, the minimal capital ratio required by the interbank market to achieve optimal risk-sharing in the banking system during normal times could be too low to be efficient during crisis times. Therefore, the capital regulation stipulated by the government should be considered as an essential instrument to enhance banks' resilience during crises. However, too restrictive a regulation is impractical because, while stabilizing the banking system, it could

hamper the role of banks as financial intermediaries. To minimize the gambling behaviors of banks, the government should introduce a penalty tax conditioned on the ex-post discovery of such behaviors.

Given that a banking crisis cannot be entirely eliminated by reasonably strict government regulations, the government's crisis management becomes a key factor in stabilizing the banking sector during a crisis stemming from self-fulfilling bank runs, the contagion of a foreign sovereign debt crisis, and the gambling behaviors of banks. Notwithstanding, the government's capacity to restore the normal functioning of the banking system and the interbank market and to prevent the crisis contagion is constrained by its budgetary position. If its initial budgetary position makes the implementation of a bailout policy impossible in the sense that it increases the national public debt to an unsustainable level, its engagement in bailing out banks subject to run could result in twin banking and sovereign-debt crises, particularly when the government does not have any monetary sovereignty as is the case in the Eurozone.

Chapter 4   Banking and Sovereign Debt Crises in a Monetary Union Without Central Bank Intervention

4.1   Introduction

One remarkable unexpected consequence of the 2007-2009 financial crisis is that several countries in the Europeriphery (such as Ireland or Spain) whose governments had been prudent in the management of public finance before the crisis, are since then confronting a new kind of *twin crisis* affecting simultaneously the banking system and the market for sovereign debt.[43] As described by Lane (2012), before the crisis, the creation of the euro and the elimination of the currency risk allowed banks in europeriphery countries to substantially increase international short-term funding at significantly lower real interest rates, enabling them to sustain a strong domestic economic growth. Yet, the global financial crisis triggered a massive international reallocation of resources in a movement of flight to quality. Countries which relied the most on international funding were disproportionately more affected by this drying up of liquidity, and their banking system was put under extraordinary stress. As a result, Ireland, Portugal and Spain had to implement massive bailout programs to save their domestic banks. This, combined with the significant reductions in tax revenues incurred by the sharp economic contraction, led to strong increases in public debt-to-GDP ratios in these countries.

In October 2009, following the announcement by newly elected government in Greece of much larger deficits than previously reported, increasing concerns about the ability of europeriphery countries to honor their debt quickly emerged, leading to a dramatic increase in the yields on their government bonds (perhaps aggravated by excessive rating downgrades by credit rating agencies). This generated two main effects which contributed to the emergence of the twin-crisis: first, the cost of public debt in these countries was dramatically increased by a surge in risk

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[43]   The government debt/GDP ratio in 2008 was 36% for Spain, 25% for Ireland, and 68% for Portugal. In the first quarter of 2012, these ratio climbed to 72%, 108% and 112%, respectively.

premia, aggravating the debt sustainability concern. Second, the increased risk of sovereign defaults significantly deteriorated the balance sheet of domestic banks (which were often the main buyers of domestic debt), but also of many major banks in the core Eurozone which were holding significant amount of euro-country government bonds for regulatory purposes. The Eurozone found itself stuck in a situation where a potential collapse of the economy of several of its member states would spread over the entire area, while the status of the European Central Bank prevented it (or, at least, in the wake of the crisis, *were supposed to* prevent it) to provide direct financial support to private banks or to stabilize sovereign debt markets by playing the role, either explicitly or implicitly, of a lender-of-last-resort in the government bond market.[44] Fears of contagion of the crisis from periphery to core-euro countries, and the resulting endangering of the entire monetary union, became the predominant concern of policy-makers in the Eurozone and worldwide. As a result, the European Union and the IMF settled large joint bailout programs for Greece, Ireland, Portugal and Spain. Shortly after, in August 2012, the ECB implicitly changed its doctrine by announcing that it would purchase – upon request and subject to conditionality – unlimited amounts of government bonds of a distressed member state (the OMT program).[45] This announcement was followed by a significant and persistent drop in the interest rates on sovereign bonds of stressed countries, helping to stabilize the Eurozone and removing immediate threats of a potential Euro breakup.

There is by now a substantial academic literature that documents the course of these events and their main determinants. De Grauwe (2011), Lane (2012) and Shambaugh (2012) are prominent examples. These papers clearly ascribe a dominant role to the mutually enforcing interactions

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[44] Several "unconventional" monetary policy measures, such as Longer Term Refinancing Operations (LTROs) with a maturity of up to 36 months, had actually been undertaken by the ECB between 2008 and 2012. Yet, the fact that these measures were limited in amounts implied that they were not successful to stabilize sovereign rate spreads durably.

[45] The fact that the ECB implicitly changed its doctrine by announcing the OMT program has been widely recognized by commentators, and is actually the main reason for the legal dispute between the Bundesbank and the ECB – the Bundesbank arguing that the ECB overstepped its legal limits by committing to such a program.

between the banking crisis and the sovereign debt crisis — what Brunnermeier *et al.* (2011) have dubbed the "diabolical loop" — and emphasize the potential contagion effects of the crisis from the Europeriphery to the whole monetary union. They also analyze how these harmful interactions have been favored by the weak institutional design of the Eurozone.

Yet, from a theoretical point of view, very few models enabling to understand the links between the banking and the sovereign debt crises in an institutional framework broadly similar to that of the Eurozone exist in the literature (see the "related literature" section below). This chapter aims to make a step in this direction. We provide a theoretical framework enabling us to analyze the conditions of emergence of a twin banking and sovereign debt crisis affecting a subset of member states of a monetary union in which (i) member state economies are intimately intricate, in the sense that domestics banks in each country hold a significant amount of foreign debt of other member state countries (ii) government bonds issued by member states are denominated in local currency, (iii) the central bank is not allowed to provide direct financial support to distressed member states or to play the role of a lender-of-last-resort in government bond markets, and (iv) (as a consequence of (iii)) the burden of rescuing the banking system is entirely left to domestic governments (there is no banking union or similar insurance mechanisms at the supranational level). As a result, the main instrument available to domestic countries for fighting against large scale bank runs is the implementation of a *financial safety net*. We argue that these characteristics describe fairly well the institutional context of the Eurozone at the onset of the crisis, i.e. before the change in the ECB doctrine that occurred with the announcement of the OMT program.

We investigate these issues by introducing government and public debt concerns in the small open-economy banking crisis model of Chang and Velasco (2001). In this setup, the role of domestic banks is to pool resources collected from domestic residents and external investors and to invest them efficiently into short-term and long-term (illiquid) investment projects. As

in Diamond and Dybvig (1983), the maturity mismatch between assets and liabilities is usually associated with the existence of two equilibria in the laissez-faire economy: a "good" equilibrium in which agents do not run and which decentralizes the second-best resources allocation and a "bad" equilibrium in which agents run and force banks to liquidate long-run investment projects before going bankrupt.

In order to prevent the realization of such large scale bank runs, we assume that member states of the monetary union have implemented a *financial safety net*. The latter is based on two main pillars: first, there is a *liquidity regulation*, imposed at the supranational level, that forces banks to hold a fraction of their assets in the form of AAA-rated government bonds. Second, each government provides a *deposit guarantee*, implemented at the country level, associated with a commitment to raise any possible additional resources on financial markets in order to bailout banks with insufficient liquidity (and thus to cover the withdrawal requests of depositors). We show that, in the model, a larger intensity of liquidity regulation imposed *ex ante* reduces the financial burden of the bailout package *ex post* (if a large scale bank run were to materialize). Yet, it also decreases consumption and welfare in normal times, so that there is a trade-off involved.

We analyze the conditions under which the existence of this financial safety net is sufficient, or not, to prevent the occurrence of a nationwide bank run. It is at this stage, we argue, that the legal framework delimiting the role and functions of the central bank is of crucial importance. In particular, we show that if the central bank is not empowered to play the role of a lender-of-last-resort in government bond markets (and is not allowed to provide direct financial support to countries facing a major threat on their banking system), there are circumstances in which the financial safety net *aggravates*, instead of *improves*, the financial situation of domestic banks and of the government.[46] When this is the case, a mere banking crisis threat may translate

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[46] Our result in this regard can be viewed as a direct application of the analysis by Allen and Gale (2007), who show that poorly designed and implemented banking regulation can lead to an increase in systemic risk.

into a fully fledged twin banking and sovereign debt crisis. We show that such a crisis, triggered by self-fulfilling changes in investors' expectations, may occur even for countries with "decent" economic fundamentals.

The main economic mechanisms underlying this result can be described as follows. If, in the face of the government's commitment to rescue failing banks, investors remain confident about the sustainability of the public debt, they do not require a large risk premium on newly-issued government bonds and the bailout package is *credible*: its mere existence, combined with the liquidity regulation described above, is sufficient to eliminate the run equilibrium. If, by contrast, the commitment to bailout banks raises strong concerns about the creditworthiness of the government, the resulting increase in the risk premium on sovereign bonds generates two negative effects on the banking system and on public finance: first, it decreases the price of government bonds in the secondary market, thus reducing the liquidity buffer that banks can obtain by selling their government bond holdings and aggravating their liquidity shortfall. Second, it increases the cost of the bailout package for the government, since a larger amount of financial backstop must be financed through bond issuance at worst market conditions. When the surge in the risk premium on government bonds is such that the level of public debt if the bailout package was implemented is considered unsustainable, the government deposit guarantee becomes *non-credible,* and the lack of confidence of external investors triggers a self-fulfilling twin banking and sovereign debt crisis. We establish the coexistence of these two situations as equilibrium configurations in countries with soft (not overly weak or strong) economic fundamentals. Moreover, we show that countries with a larger reliance on external short-term funding are more exposed to a twin crisis equilibrium.

In the final section of the chapter, we illustrate how our framework can be used to analyze related policy issues that have emerged during the Eurozone crisis. In particular, we assess the proposition that Credit Rating Agencies (CRAs) have played a role in triggering the crisis by

downgrading countries by more than would have been justified by economic fundamentals. We show that while CRAs do not have any influence on the existence of a twin crisis equilibrium configuration, CRA ratings may favor the emergence of a twin crisis in the limited sense of playing the role of an exogenous coordination device. Moreover, such self-fulfilling rating downgrades would appear ex post as entirely justified by economic fundamentals. We also analyze the issue of contagion from stressed countries to other member states through the banking system, and discuss proposed policy options to avoid the resurgence of such crises, such as the creation of "Eurobonds".

Related literature   This chapter is related to a number of contributions in the literature. Most obviously, it brings together elements from the literature on banking crisis and from the literature on sovereign default. Regarding the banking crisis literature, the structure of our benchmark model is based on Chang and Velasco (2001), which transposes the seminal banking crisis model of Diamond and Dybvig (1983) into the context of a small open economy with heavy reliance on short term external funding (see also Diamond and Rajan, 2001). We introduce in the Chang and Velasco setup various additional features, such as the existence of a financial safety net (liquidity regulation and government deposit guarantee) and the presence of a government with public debt issues, to analyze the conditions of emergence of a twin crisis in a context more closely related to that of the Eurozone. Concerning the sovereign default literature, our model borrows from Eaton and Gersovitz (1981) the notion that the ability of a country to rely on external funding is limited by a ceiling on its public debt. Eaton and Gersovitz (1981) show that such a feature emerges endogenously in a context of potential debt repudiation. Another particularly relevant reference is Calvo (1988), who shows that when the government has the possibility to renege on its debt, government bond issuance can generate multiple perfect-foresight equilibria, with or without government default.

More recent papers closely related to our research also analyze the conditions of emergence of a sovereign debt crisis in the Eurozone context. Bolton and Jeanne (2011) analyze the contagious effects of the sovereign debt crisis through the banking system. Gennaioli *et al.* (2012) emphasize the interactions between a government's incentive to default and the fragility of its banking system. Acharya *et al.* (2013) study the interactions between the banking and the sovereign debt crises implied by government bailouts (and the associated increase in the risk premium on sovereign bonds). Unlike us, the analyses in these papers are entirely based on economic fundamentals, while we emphasis, beyond fundamentals, the possibility that the emergence of a twin banking and sovereign debt crisis can be triggered by self-fulfilling changes in investors' expectations.[47] As such, our analysis provides direct support to the empirical findings by De Grauwe and Ji (2013) that europeriphery countries with initially small debt-to-GDP ratio were more exposed to a sovereign debt crisis than standalone countries with monetary sovereignty and much larger initial levels of public debt (relatively to GDP). Finally, Corsetti and Dedola (2013) analyze the possibility for a central bank to eliminate "Calvo-style" self-fulfilling sovereign debt crises by intervening in the sovereign bond market. As such, Corsetti and Dedola (2013) more adequately describe the situation of the Eurozone after the change in ECB doctrine discussed above, while we focus on the earlier stages of the Eurozone crisis.

The remainder of this chapter is organized as follows. In the next section, we present the benchmark model. In section 3, we introduce the financial safety net and explore the conditions under which it eliminates the run equilibrium under normal financial market conditions. In section 4, we show how these results can be overturned under stressed financial conditions. Section 5

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[47] Our aim is obviously not to claim that economic fundamentals did not play a significant role in the trigger of a twin crisis in europeriphery countries. Actually, this chapter underlines the importance of crucial economic variables such as the initial debt-to-GDP ratio, the fire sale value of restructured assets, the degree of reliance of banks on short-term external funding, etc., for the existence of a twin crisis equilibrium. Yet, depending on the situation, investors may underreact or overreact to exogenous changes in the economic environment. Our paper shows that an abrupt change in investors' expectations can drive a country with "moderately strong" economic fundamentals into a twin banking and sovereign debt crisis, even though such a crisis would not occur under more positive expectations.

shows how our model can be used to discuss recent policy issues associated with the Eurozone crisis. Section 6 concludes.

4.2 A small economy model with a banking system

4.2.1 The environment

We consider a small open-economy populated by a large number of *ex ante* identical domestic residents of mass 1. Each period is divided by three stages indexed by $t = 0, 1, 2$, defined as the planning stage, the intermediate stage (short-term) and the final stage (long-term), respectively. To produce the unique good of the economy, which is freely traded in the world market and can be consumed and invested, domestic (and only domestic) residents have access to a short-term and a long-term constant-return-to-scale production technology. The long-term technology is illiquid and is highly productive, with a yield $R_h > 1$ if the investment is held until stage 2, but early liquidation in $t = 1$ will cause its yields to diminish to $R_l < 1$ per unit invested. The short-term technology yields, in the intermediate stage $t = 1$, R_s units of good per unit invested, with $1 < R_s < R_h$. There is also a world capital market in which each unit invested at $t = 0$ yields a unit return in $t = 1$, and a return $R^* = 1 + r^*$ in $t = 2$, where $r^* > 0$ is the world interest rate.[48] As in Chang and Velasco (2001), we assume that domestic agents can invest as much as they want in this international market, but can borrow a maximum of $f > 0$ units of good per period.[49] Finally, the government taxes entrepreneurs' projects at a rate τ per unit produced in order to finance public expenditures. We assume that τ is sufficiently small that after-tax returns satisfy:

$$(1 - \tau)R_l < 1 < R^* < (1 - \tau)R_s < (1 - \tau)R_h, \tag{4.1}$$

As explained below, because agents at the planning stage do not know whether they will be "patient" or "impatient" (and thus whether they will prefer to consume at stage 1 or stage 2), the best option for them, rather than investing directly into the available production technologies, is to

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[48] The assumption of a unit return between stages 0 and 1 is a simplifying assumption imposed without loss of generality.

[49] As discussed below when we introduce public debt, the existence of such a ceiling can be justified by many theories of international borrowing under credit market imperfections.

pool their resources and form a coalition. The obtained coalition, which is called a "commercial bank" for obvious reasons, can then use the law of large numbers to get rid of individual uncertainty and invest efficiently into the two types of investment projects.

In the following, we give a detailed description of the behaviors and constraints of domestic residents, commercial banks and the government.

Domestic residents   Domestic residents are of two types: *impatient* (type 1) or *patient* (type 2). An impatient agent derives utility only from consuming at the intermediate stage, $t = 1$, while a patient agent derives utility from consuming at the final stage $t = 2$. Each domestic resident is endowed with an amount $e > 0$ of a tradable good in period 0. Yet, information about agent types is private and is revealed only at $t = 1$. Thus, during the planning stage $t = 0$, domestic resident are uncertain about their type. They do know, however, the probability λ of being impatient, which is identical for all agents. Denoting by x the amount of good consumed at $t = 1$ and by y the amount of good consumed at $t = 2$, the expected utility of the representative domestic resident at $t = 0$ is:

$$\lambda U(x) + (1 - \lambda)U(y).$$

where $U(\cdot)$ is a CRRA instantaneous utility function defined by $U(c) = c^{1-\sigma}/(1 - \sigma)$ for $\sigma \neq 1$, and by $U(c) = \ln C$ for $\sigma = 1$, where $\sigma > 0$ is a positive relative risk aversion coefficient.

The government   The government starts the period with an amount of debt D_0 inherited from the past period. This debt is rolled over by issuing at $t = 0$ a quantity B_{02} of "long-term" (zero-coupon) government bond maturing at the end of stage 2. Each unit of bond promises to pay 1 unit of good in stage 2. The discount rate on these bonds is denoted by r_{02}^d, so that the issue price of each unit of bonds is $1/(1 + r_{02}^d)$. Thus, $D_0 = B_{02}/(1 + r_{02}^d)$.

During stages 1 and 2, the government collects taxes T raised on short-term, long term and restructured projects, and spends an exogenous amount G of government expenditures. It can

also issue an additional amount B_{12} of "short-term" government bonds in the intermediate stage ($t = 1$) if it needs extra liquidity. These bonds also mature at the end of stage 2, but the discount rate r_{12}^d applied on them depends on stage 1 market conditions.

The government budget constraint is thus:

$$
\begin{aligned}
D_2 &= B_{02} + B_{12} + G - T \\
&= D_0(1 + r_{02}^d) + B_{12} + G - T
\end{aligned}
$$

The debt level D_2 left at the end of stage 2 will be the initial debt level at the beginning of the next period and, again, this debt will have to be rolled over by issuing new long-term government bonds in international financial markets. However, as in the case of domestic resident, we assume that there exists a ceiling g_f for the ratio of public debt over potential GDP, $\widetilde{Y}$, above which international investors refuse to refinance the debt.[50]

Thus, refinancing will be done provided that the ratio of debt over potential GDP does not exceed the exogenous ceiling g_f, i.e. the constraint

$$
\frac{D_2}{\widetilde{Y}} \leq g_f
$$

is satisfied.[51] Otherwise, the government is considered insolvent.

Commercial banks   As intermediaries between depositors and firms, banks take advantage of the law of large numbers to predict more accurately future needs for (costly) liquidity. Banks thus collect agent deposits (equal to e at equilibrium) and use their capacity to borrow in the

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[50]   The assumption that such a ceiling indeed characterizes the situation of europeriphery countries is worth discussing. As is well known, a limit on the ability of a government to borrow in international financial markets arises endogenously in economies with potential debt repudiation when there is no possible backstop from the monetary authority (Eaton and Gersovitz, 1981). In the case of emerging countries, this is a natural assumption since government debt is usually denominated in foreign currency. In the Eurozone, however, a different logic applies since government bonds are typically denominated in euros. In this case, it is mostly the *institutional design* of the Eurozone (before september 2012) that actually made the situation of member states "as if" they were borrowing in a foreign currency, since the lack of monetary sovereignty at the coutry level and the inability of the ECB to play a role of lender-of-last–resort in government bond markets implied that each member state could actually default. This is particularly true when the borrowing cost of governments sharply increases due to a surge in risk premia, as was typically the case in europeriphery countries in the aftermath of the financial crisis. For more discussions of these issues and of the "fiscal limits" imposed on governments with or without central bank intervention, see Leeper (2013).

[51]   The formal expression for potential GDP $\widetilde{Y}$, defined as the level of GDP in "normal times", i.e. when there is no banking crisis threat, is derived below.

international financial market (up to $f > 0$ in each stage 0 and 1) to invest K and A units of good in the long-term and the short-term productive technologies, respectively. The deposit contract stipulates that depositors are allowed to withdraw, at their discretion, either x units of consumption in period 1 or y units of consumption in period 2. An agent of type 2 who withdraws x units of consumption in period 1 can invest them in the international market and consume $R^* x$ in period 2. The incentive compatibility constraint, implying that an agent of type 2 has no interest to misrepresent his type, then requires $R^* x < y$.

Banks' investment decisions are also restricted by two kinds of constraints. First, banks must obviously ensure that they have enough liquidity to meet the withdrawal requests of impatient agents, λx, at $t = 1$ under any circumstances. Second, as explained below, in order to limit the possibility of occurrence of a large-scale bank run, banks must comply with a financial regulation which imposes them to hold a minimum percentage $\alpha \in (0, \overline{\alpha})$ of their debt principal in the form of safe and liquid assets, the latter being uniquely composed, in the model, of AAA-rated government bonds issued by member states of the monetary union. The upper bound $\overline{\alpha}$ on the intensity of regulation will be endogenously derived below. Banks are required to hold such bonds (purchased at $t = 0$) until $t = 2$ unless a bank run occurs in the intermediary stage, in which case they can get extra-liquidity by selling them in the secondary market.[52]

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[52] This form of liquidity regulation actually reflects the spirit of the liquidity coverage ratio in Basel III. For others analyses emphasizing the interactions between the financial situation of commercial banks and the government budget constraint, see for instance Brutti (2011) and Bolton and Jeanne (2011).

The constraints faced by the representative commercial bank are thus the following:

$$A + K + \frac{B_{02}^d}{1 + r_{02}^d} + \frac{B_{02}^f}{1 + r_{02}^f} = e + f_0, \tag{2}$$

$$f_0 \leq f, \qquad f_1 \leq f, \tag{3}$$

$$\frac{B_{02}^d}{1 + r_{02}^d} + \frac{B_{02}^f}{1 + r_{02}^f} \geq \alpha(e + f_0), \tag{4}$$

$$\lambda x + f_0 \leq (1 - \tau)R_s A + f_1 + (1-\tau)R_l l + \mathbb{I}_c \left(\frac{B_{02}^d}{1 + r_{12}^d} + \frac{B_{02}^f}{1 + r_{12}^f} \right), \tag{5}$$

$$(1 - \lambda)y + R^* f_1 = (1 - \tau)R_h(K - l) + (1 - \mathbb{I}_c) \left(B_{02}^d + B_{02}^f \right), \tag{6}$$

where B_{02}^d and B_{02}^f are the face value of *domestic* and *foreign* governments bonds, respectively,[53] and r_{02}^d and r_{02}^f are the long-term discount rates on these bonds. Furthermore, f_0 and f_1 are net foreign borrowing in stages 0 and 1, respectively, l is the amount of long-term projects restructured in stage 1, and $\mathbb{I}_c$ is a dummy variable which is equal to 1 when a run occurs and to 0 otherwise (as government bond holdings are intended to provide extra liquidity in the case of bank run). The discount rates applied on these bonds, when they are sold in the secondary market in the intermediary stage, are r_{12}^d and r_{12}^f, respectively.

Condition (4.2) is the resource constraint at $t = 0$. Condition (4.3) captures the external credit constraints. Condition (4.4) is the liquidity regulation constraint. Conditions (4.5) and (4.6) are the bank's feasibility/solvability constraints for stages 1 and 2, respectively. As mentioned above, in stage 1, the bank has the option to restructure a chosen amount l of long-term projects, with $l \leq K$, but the return on these restructured projects is low: $R_l < 1$. In stage 2, maturing long-term projects must be enough to match the withdrawal requests of patient agents and to honor the repayment of debt to foreign investors.

4.2.2 The optimal allocation (normal times)

We can now describe the optimal allocation of this economy in which banks, viewed as a coalition of domestic depositors, act in those depositors' interest. This allocation, which

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[53] Without loss of generality, we assume that there exists only one "foreign country", and thus only one kind of "foreign" government bonds.

is obtained as the good Nash equilibrium of the demand deposit system described above, corresponds to a situation in which investors believe – correctly at equilibrium – that the solvency of governments is ensured at any stage, so that the discount rate applied on long-term government bonds is equal to the risk-free international interest rate: $r_{02}^d = r_{02}^f = r^*$. We refer to this situation as "normal times". Also, note that this allocation is optimal *conditional on the size of the government,* as measured by τ, *and on the intensity of liquidity regulation*, α, which are taken as given by individual agents.[54]

The optimal allocation is obtained when banks maximize the expected utility of depositors:

$$\lambda U(x) + (1 - \lambda)U(y), \tag{4.7}$$

subject to (4.2)–(4.6). It is easy to verify that all inequality constraints bind at the optimum: as long as long-term projects are more profitable than short-term projects and yield a higher return than the riskless interest rate in international markets, $R^* < (1 - \tau)R_s < (1 - \tau)R_h$, it is optimal for banks to borrow as much as they can at the planning stage so as to invest as many resources as possible in long-term projects. This debt is then rolled-over at $t = 1$. Likewise, since the return on government bonds is dominated by the return on investment projects, banks have interest to hold as little government bonds as possible, given the liquidity regulation constraint (4.4). Thus the resource constraint (4.2), the credit ceilings (4.3), the liquidity regulation constraint (4.4) and the feasibility condition (4.5) all bind at the optimum. Moreover, restructuring long-term projects

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[54] The level of the tax rate τ, set to maintain the level of public debt constant in normal times, is endogenously determined below.

prematurely is clearly suboptimal ex-ante, so that $\widetilde{l} = 0$.[55] We thus obtain:

$$\widetilde{A}(\alpha) + \widetilde{K}(\alpha) + \frac{\widetilde{B}^*(\alpha)}{R^*} = e + f \tag{4.8}$$

$$\widetilde{f}_0 = \widetilde{f}_1 = f \tag{4.9}$$

$$\frac{\widetilde{B}^*(\alpha)}{R^*} = \alpha(e + f) \tag{4.10}$$

$$\lambda \widetilde{x}(\alpha) = (1 - \tau)R_s \widetilde{A}(\alpha) \tag{4.11}$$

$$(1 - \lambda)\widetilde{y}(\alpha) = (1 - \tau)R_h \widetilde{K}(\alpha) + \widetilde{B}^*(\alpha) - R^* f \tag{4.12}$$

where $\widetilde{B}^*(\alpha) \equiv \widetilde{B}^d_{02} + \widetilde{B}^f_{02}$ is a basket composed of domestic and foreign government bonds.

Obviously, if these bonds have identical (*ex ante*) risk and return characteristics, the composition

of the bond portfolio should be indifferent to the bank. We simply assume here that domestic

banks choose to allocate a fraction $\gamma \in (0, 1)$ of their total bond purchases to the purchase of

domestic government bonds, so that $\widetilde{B}^d_{02} = \gamma \widetilde{B}^*(\alpha)$ and $\widetilde{B}^f_{02} = (1 - \gamma)\widetilde{B}^*(\alpha)$, and we will

consider some implications of this portfolio composition later when we analyze the issue of

contagion.[56]

From these optimality conditions, we can deduce that the optimal allocation between x and y

must satisfy the social transformation curve:

$$\frac{R_h}{R_s}\lambda \widetilde{x}(\alpha) + (1 - \lambda)\widetilde{y}(\alpha) = v_0 - \alpha(e + f)((1 - \tau)R_h - R^*) \equiv v(\alpha). \tag{4.13}$$

with $v_0 \equiv (1 - \tau)R_h(e + f) - R^* f$. Given the CRRA utility function, the maximization of (4.7)

subject to (4.13) implies that the following first-order condition

$$\frac{\widetilde{y}}{\widetilde{x}} = \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} \tag{4.14}$$

must hold. The truth-telling condition $R^* \widetilde{x} < \widetilde{y}$ then requires:

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55 Tildes are used to characterize the social optimum.

56 In practice, there exists subtle differences (such as a distortive domestic legislations) which imply that domestic and
    foreign bonds with equivalent risk and return characteristics are not perfectly substitutable from the viewpoint of
    domestic banks. The choice of γ would then be obtained as the result of an explicit portfolio optimization problem,
    given these constraints. We do not consider this distinction here, and take instead γ as given.

$$R^* < \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} \tag{4.15}$$

Using (B.2)–(B.8), we then obtain the banks' optimal investment strategy giving the best distribution of resources between patient and impatient depositors as:

$$\widetilde{A}(\alpha) = \frac{\theta}{(1-\tau)R_h} v(\alpha), \tag{4.16}$$

$$\widetilde{K}(\alpha) = (1-\alpha)(e+f) - \frac{\theta}{(1-\tau)R_h} v(\alpha), \tag{4.17}$$

$$\widetilde{x}(\alpha) = \frac{\theta}{\lambda}\frac{R_s}{R_h} v(\alpha), \tag{4.18}$$

$$\widetilde{y}(\alpha) = \frac{1-\theta}{1-\lambda} v(\alpha), \tag{4.19}$$

where $\theta \equiv \left[1 + (1-\lambda)/\lambda \, (R_h/R_s)^{(1-\sigma)/\sigma}\right]^{-1}$ is a coefficient in the unit interval.

Note that feasibility requires $\widetilde{K}(\alpha) \geq 0$, which effectively sets an upper bound $\overline{\alpha}$ on the intensity of liquidity regulation. In the technical appendix accompanying this chapter, we show that $\overline{\alpha}$ satisfies:

$$\overline{\alpha} = \frac{(1-\theta)(1-\tau)R_h(e+f) + \theta R^* f}{(1-\theta)(1-\tau)R_h(e+f) + \theta R^*(e+f)} \in (0,1) \tag{4.20}$$

Total output $\widetilde{Y}(\alpha)$ in normal times (which we also refer to as "potential output") is given by

$$\widetilde{Y}(\alpha) = R_s\widetilde{A}(\alpha) + R_h\widetilde{K}(\alpha),$$

and the amount of taxes collected by the government is:

$$\begin{aligned} \widetilde{T}(\alpha) &= \tau\left(R_s\widetilde{A}(\alpha) + R_h\widetilde{K}(\alpha)\right) \\ &= \tau\widetilde{Y}(\alpha). \end{aligned}$$

We can now describe a "quasi steady-state" for this economy, obtained when "normal times" periods follow one another. In normal times, the initial debt-to-GDP ratio inherited from the past period is sustainable: $g_0 \leq g_f$. At the beginning of the planning stage, the government rolls over its public debt D_0 by issuing a quantity B_{02} of long-term government bonds at current market conditions: $r_{02}^d = r_{02}^f = r^*$. In stages 1 and 2, short-term and long-term investment

projects mature, the government collects $\widetilde{T}(\alpha) = \tau\widetilde{Y}(\alpha)$ of taxes on these projects, and the amount of outstanding debt left at the end of stage 2 is $D_2 = D_0 R^* + G - \tau\widetilde{Y}(\alpha)$. In this "quasi steady-state", the tax rate τ is set so that the level of taxes collected in normal times is just sufficient to maintain the level of public debt constant, i.e. such that $D_2 = D_0 = \widetilde{D}$. This occurs when taxes collected on matured projects are just sufficient to finance government expenditures and to pay interest charges on public debt, i.e. when $\widetilde{T}(\alpha) = G + r^*\widetilde{D}$. The corresponding tax rate τ is thus: $\tau = \left(G + r^*\widetilde{D}\right)/\widetilde{Y}(\alpha)$.

Under these conditions, the debt-to-GDP ratio also remains constant and equal to $g_2 = g_0 = \widetilde{D}/\widetilde{Y}(\alpha) \equiv \widetilde{g} \leq g_f$, so that the next period starts in exactly the same environment as the current period. Consequently, as expected by domestic depositors and foreign investors, there is no concern about government solvency.

4.3 The financial safety net: regulatory measures and government deposit guarantee

Although the demand deposit contract can decentralize the optimum, it is well-known from the Diamond and Dybvig (1983) analysis that under plausible parameter configurations, the maturity mismatch between the short-term liabilities of banks (deposits) and their long-term assets (illiquid investment projects) implies that there also exists a bank run equilibrium triggered by a sudden lack of confidence of market operators in the banking system. This bad equilibrium occurs when all depositors run and attempt to withdraw their funds in stage 1 – expecting other depositors to do the same – and the bank fails to honor its obligations (and thus bankrupts). We illustrate this possibility within our model in section 3.1. To overcome this problem, many countries around the world have implemented a *financial safety net* built on two main pillars: bank regulation and government deposit guarantee. We then analyze the effectiveness of these two pillars in preventing a large scale banking crisis when there is no concern about the government solvency. The next section will illustrate why the possibility of a sovereign debt crisis critically changes the analysis.

4.3.1 The unregulated economy ($\alpha = 0$)

Before turning to the financial safety net, it is useful to consider as a starting point the benchmark economy without liquidity regulation: $\alpha = 0$. The economy is in this case very similar to the small open economy considered in Chang and Velasco (2001), and most of the results they obtain also apply here. As Chang and Velasco (2001) emphasize, the conditions of existence of a bank run equilibrium are quite sensitive to the assumption made about the behavior of foreign investors when a banking crisis threatens. If foreign investors agree to roll over banks' external debt in stage 1 at normal market conditions – for example because banks can credibly commit to repay their liabilities fR^* under any circumstances – the liquidity shortage is less severe. We will refer to this case as a "*no sudden stop situation*". If, by contrast, foreign investors abruptly decide not to roll over external debt in stage 1 when they fear that a banking crisis may materialize (so that $f_1 = 0$), the liquidity shortage becomes much more stringent, and we will speak in this case of a "*sudden stop situation*". As Lane (2012) and Shambaugh (2012) underline, domestic banks in europeriphery countries suffered from a major and long-lasting drying up of external funding shortly after the burst of the financial crisis. This contrasts with banks of core-Euro countries which did not face persistent refinancing difficulties. Considering these two polar cases is thus important for accounting for the potentially different implications of the financial crisis on the vulnerability of the banking sector in the core and in the periphery of the Eurozone.

No sudden stop situation. In the "no sudden stop situation", the commitment to repay external debt fR^* at stage 2 implies that the maximum amount of long-term projects that can be liquidated in stage 1 is $l_0^+ = \widetilde{K}_0 - R^* f / ((1 - \tau) R_h)$.[57] A run equilibrium then exists as soon as the bank's short-term obligations exceed its available resources after liquidation, *i.e.* when $\widetilde{x}_0 - (1 - \tau) \left(R_s \widetilde{A}_0 + R_l l_0^+ \right) > 0$. In the accompanying technical appendix, we show that this

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[57] Variables with "0" subscript are used to refer to the unregulated case obtained when $\alpha = 0$, i.e. for any variable X, $X_0 \equiv X(0)$.

condition can be rewritten as

$$z_1^+ \equiv \left(r_1^+ - R_l\right) \frac{(1-\theta)v_0}{R_h} > 0, \qquad (4.21)$$

where z_1^+ is a measure of banks' illiquidity in the unregulated economy, and $r_1^+ \equiv (R_h)^{\frac{\sigma-1}{\sigma}} (R_s)^{\frac{1}{\sigma}}$. A trivial equivalent condition is

$$R_l < r_1^+ \equiv (R_h)^{\frac{\sigma-1}{\sigma}} (R_s)^{\frac{1}{\sigma}}, \qquad (4.22)$$

i.e., a run exists as soon as the fire sale price of immature investment projects is lower than the threshold r_1^+.

Sudden stop situation. In the "*sudden stop situation*", there is no rollover of external debt (i.e. $f_1 = 0$) in stage 1, so that all long-term projects are subject to restructuring. It can easily be verified that the condition of existence of a run equilibrium, $\widetilde{x}_0 + f - (1-\tau)\left(R_s \widetilde{A}_0 + R_l \widetilde{K}_0\right) > 0$, is equivalent to

$$z_2^+ \equiv z_1^+ + \underbrace{\left(1 - \frac{R_l R^*}{R_h}\right) f}_{>0} > 0 \qquad (4.23)$$

with $z_2^+ > z_1^+$ (by (4.1)). We can again express this condition in terms of a a critical threshold for the fire-sale value of liquidated assets:

$$R_l < r_2^+ \equiv \frac{r_1^+ + \frac{R_h f}{(1-\theta)v_0}}{1 + \frac{R^* f}{(1-\theta)v_0}} \qquad (4.24)$$

with $r_2^+ > r_1^+$, given (B.9).

Conditions (4.22) and (4.24) help to understand why countries in the Europeriphery, like Ireland or Spain, have been the most exposed to a banking crisis. Like most international banks, banks in the Eurozone found themselves sharply exposed to the subprime crisis as they held substantial amounts of Mortgage Backed Securities and related dubious assets in their balance sheet. During the financial crisis, the strong depreciation in the value of these assets, as captured

by a decline in R_l, contributed to put those banks under significant stress. Yet, in countries like Ireland or Spain, these balance sheet losses were significantly aggravated by the collapse of their own domestic real estate market (since mortgage loans were granted in large proportion by domestic banks). Moreover, while banks in core-Euro countries were quickly able to go back to financial markets and raise funds, countries in the Europeriphery faced a major and persistent drying up of external funding (putting them in the "sudden stop situation" described above). Overall, banks in these countries experienced a much more significant decrease in the fire-sale value R^l of their assets compared to banks in the core, while the "sudden stop" of external funding increased disproportionately more their exposure to a liquidity shortage ($r_2^+ > r_1^+$). Both factors contributed to weaken their banking system more than in the core of the Eurozone. Note finally that the threshold r_2^+ is increasing in f, so that among countries that experience a drying up of external funding, the model predicts that those with the larger reliance on foreign investment should be the most exposed to the threat of a collapse of their banking system.

4.3.2 Liquidity regulation : $\alpha > 0$

The unregulated economy considered so far helps to uncover the important forces undermining the stability of the banking system, but it does not fully describe the situation of Eurozone countries at the onset of the crisis, since most governments had implemented a financial safety net precisely aimed at preventing the occurrence of large scale bank runs. We now use our model to describe how the two main pillars of these financial safety nets – bank regulation and government deposit guarantee – can achieve this objective in normal circumstances.

Consider first the effects of a liquidity regulation that forces banks to hold a fraction $\alpha > 0$ of their assets in the form of AAA-rated government bonds. A straightforward consequence, underlined by $v'(\alpha) < 0$, is that such regulation reduces agents' consumption in normal times (as well as investment in short-term and long-term projects), as it implies a suboptimal allocation of resources. The benefit is that banks, facing the threat of a bank run, now have the option to sell

their government bonds in the secondary market at the intermediary stage and get extra liquidity to cover the liquidity requests of depositors. In the absence of concern about domestic or foreign government solvency, the discount rates applied on these bonds are equal to the risk-free rate, $r_{12}^f = r_{12}^d = r^*$, so that the extra liquidity that can be obtained from these sales is $\widetilde{B}^*(\alpha)/R^*$.

No sudden stop situation. We can now describe how the liquidity regulation works in practice. Consider first the "no sudden stop situation". In this configuration, the maximum amount of long-term project that can be liquidated in stage 1 is $l_1^+(\alpha) = \widetilde{K}_1(\alpha) - R^*f/((1-\tau)R_h)$, and the condition for existence of a bank run equilibrium, $\widetilde{x}(\alpha) - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l l_1^+(\alpha)\right) - \widetilde{B}^*(\alpha)/R^* > 0$, becomes

$$\overline{z}_1^+(\alpha, R^*) = z_1^+ - \underbrace{(r_1^+ - R_l)\frac{(1-\theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e+f)\left(1 - \frac{R_l R^*}{R_h}\right)}_{>0} > 0, \qquad (4.25)$$

so that $\overline{z}_1^+(\alpha, R^*) < z_1^+$ for any $\alpha > 0$. We can again express this condition in terms of a critical threshold for the liquidation value of restructured projects:

$$R_l < r_1^+(\alpha, R^*) \equiv \frac{r^+ - \Theta_1(\alpha)R_h}{1 - \Theta_1(\alpha)R^*}, \qquad \alpha \in (0, \widetilde{\alpha}),$$

with $\Theta_1(\alpha) \equiv \alpha(e+f)/\left((1-\theta)v(\alpha)\right)$.

Sudden stop situation. In the "sudden stop situation", we similarly obtain that the new condition for existence of a bank run equilibrium, $\widetilde{x}_0 + f - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l\widetilde{K}(\alpha)\right) - \widetilde{B}^*(\alpha)/R^* > 0$, can be expressed as

$$\overline{z}_2^+(\alpha, R^*) = z_2^+ - \underbrace{(r_1^+ - R_l)\frac{(1-\theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e+f)\left(1 - \frac{R_l R^*}{R_h}\right)}_{>0} > 0, \qquad (4.26)$$

implying $\overline{z}_2^+(\alpha, R^*) < z_2^+$ for any $\alpha > 0$. Expressed in terms of the liquidation value R_l of restructured projects, the conditions is:

$$R_l < r_2^+(\alpha, R^*) \equiv \frac{r^+ - \Theta_2(\alpha)R_h}{1 - \Theta_2(\alpha)R^*}, \qquad \alpha \in (0, \widetilde{\alpha}),$$

with $\Theta_2(\alpha) \equiv (\alpha(e+f) - f)/(1-\theta)v(\alpha)$.

Denoting by $i \in (1, 2)$ the "no sudden stop" and the "sudden stop" situations, respectively, we show in the technical appendix that, in both cases:

$$sign\left(\frac{\partial \overline{r}_i^+(\alpha, R^*)}{\partial \alpha}\right) = sign\left(R^* - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right) < 0 \qquad (4.27)$$

where negativity is implied by (B.9). Thus, an increase in the intensity of regulation α reduces the range of values for R_l below which a run equilibrium exists (and thus decreases the likelihood of existence of a run equilibrium). We also show that there exists an $\widetilde{\alpha}_i$ in $(0, \overline{\alpha})$ such that $\overline{z}_i^+(\widetilde{\alpha}_i, R^*) = 0$. Thus, any intensity of regulation $\alpha \in (\widetilde{\alpha}_i, \overline{\alpha})$ completely destroys the run equilibrium.

We summarize these results in the following proposition:

Proposition 1. Effectiveness of liquidity regulation

In the absence of sovereign debt concerns, a liquidity regulation imposing banks to hold a fraction α of their assets in the form of AAA-rated government bonds:
- *decreases production and welfare in normal times,*
- *reduces the likelihood of existence of a run equilibrium,*
- *destroys the run equilibrium for any $\alpha \in (\widetilde{\alpha}_i, \overline{\alpha})$, where $\widetilde{\alpha}_i$ solves $\overline{z}_i^+(\widetilde{\alpha}_i, R^*) = 0$.*

From Proposition 1, it is clearly never optimal to set a regulation intensity greater than $\alpha = \widetilde{\alpha}_i$ since liquidity regulation also has a cost in terms of production and welfare. But even setting $\alpha = \widetilde{\alpha}_i$ is not necessarily optimal since the benefits from eliminating infrequent bank runs through a large α may be more than offset by the welfare losses incurred in normal times from reduced consumption. For this reason, an alternative (and arguably better) strategy, typically pursued in industrialized countries, has been to combine a *moderate* intensity of liquidity regulation, $\alpha < \widetilde{\alpha}_i$, with a government deposit guarantee. We turn to this issue in the next subsection.

4.3.3 Government deposit guarantee

We now explore the effect of adding a government deposit guarantee in our benchmark economy, seen as a commitment by the government to raise any possible additional resources

in financial markets in order to bail out banks with insufficient liquidity (and thus to cover the liquidity requests of depositors).[58] To conform with the initial institutional design of the Eurozone, we assume that the central bank is not allowed either to participate to this bailout plan through some form of monetization (thus providing the government with additional seigniorage revenue) or to contribute itself to the deposit guarantee by playing the role of a lender-of-last-resort. Likewise, we also assume that there does not exist any form of "banking union" which would lead to collectively handle, at the supranational level, the problems raised by the potential collapse of the banking system in one member state. Thus, the government must carry itself the burden of bailing out failing banks if the run actually occurs. In order to do so, it issues a quantity $B_{i,12}$ of additional (short-term) government bonds, $i \in (1,2)$, sold at a discount of the par value. The discount rate applied on these bonds, r_{12}^d, depends on the current (intermediary stage) market conditions. In particular, it depends on investors' expectations about the creditworthiness of the government if the bailout package was implemented.

The deposit guarantee provided by the government can now be described as follows: if the government is expected to be able to borrow, at current market conditions, the required funds necessary to fill the liquidity gap of banks, then the government deposit guarantee is said to be *credible.* In the opposite case, the deposit guarantee is non-credible. Formally:

Definition 1. Credible deposit guarantee

Let $g_i(\alpha, R_{12}^d)$, be the level of government debt-per-GDP if a bailout package is implemented at current market conditions, i.e. when the discount rate on newly-issued government bonds is $r_{12}^d = R_{12}^d - 1$, where $i \in (1,2)$ stands for the "no sudden stop" and the "sudden stop" situations, respectively. The deposit guarantee is credible if the government remains solvent after

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[58] In practice, the government guarantee is often limited to a certain amount (€100,000 in most EZ countries) and to certain types of depositors (households and some SMEs). We abstract from these specificities as they would not change the substance of our analysis.

the implementation of the bailout package: $g_i(\alpha, R_{12}^d) \leq g^f$.

Clearly, the difference between a credible and a non-credible deposit guarantee, given an intensity of regulation α, is that only the former is able to prevent the occurrence of a bank run. Indeed, under a non-credible government guarantee, depositors anticipate that the government will not be able to raise sufficient resources on financial markets to honor the totality of withdrawal requests of depositors, so that each of them has an interest to run and to attempt to withdraw before the bank bankrupts.

We can now characterize the conditions under which a credible government deposit guarantee exists in "normal times", i.e., when investors remain confident – correctly at equilibrium – that the government solvency is not endangered by its commitment to rescue banks.[59]

To do so, observe first that if a large scale bank run materializes, the minimal amount of government liquidity injection required to refund depositors is $G_i(\alpha, R^*) = \overline{z}_i^+(\alpha, R^*)$, $i \in (1, 2)$. Raising these funds requires to issue new bonds $B_{i,12}(\alpha)$ sold at the price $1/R^*$ (if investors do not fear government insolvency, the discount rate on these newly-issued government bonds is $r_{12}^d = r^*$), so that the required additional amount of public spending is:

$$G_i(\alpha, R^*) = \frac{B_{i,12}(\alpha)}{R^*} = \overline{z}_i^+(\alpha, R^*).$$

The amount $T_i^+(\alpha)$ of taxes collected by the government is also smaller, as the return on liquidated projects is smaller than the return on matured projects. In the no "sudden stop situation" ($i = 1$), we easily derive

$$
\begin{aligned}
T_1^+(\alpha) &= \tau(R_s \widetilde{A}(\alpha) + R_l l_1^+(\alpha) + R_h(\widetilde{K}(\alpha) - l_1^+(\alpha))) \\
&= \widetilde{T}(\alpha) - \underbrace{\tau(R_h - R_l)l_1^+(\alpha)}_{>0},
\end{aligned}
\tag{4.28}
$$

implying $T_1^+(\alpha) < \widetilde{T}(\alpha)$, where $\widetilde{T}(\alpha)$ is the amount of taxes collected in normal times.

In the "sudden stop" situation ($i = 2$), all long-run projects are restructured in the event of a

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[59] We devote the analysis of a global confidence crisis to the next section.

run, and we get

$$
\begin{aligned}
T_2^+(\alpha) &= \tau(R_s \widetilde{A}(\alpha) + R_l \widetilde{K}(\alpha)) \\
&= \widetilde{T}(\alpha) - \underbrace{\tau(R_h - R_l)\widetilde{K}(\alpha)}_{>0},
\end{aligned}
\tag{4.29}
$$

implying $T_2^+(\alpha) < T_1^+(\alpha) < \widetilde{T}(\alpha)$.

Thus, the level of debt at the end of period 2 after the implementation of the bailout package is

$$
\begin{aligned}
D_i(\alpha, R^*) &= D_0 R^* + G + B_{i,12}(\alpha, R^*) - T_i^+(\alpha) \\
&= \widetilde{D} + \overline{z}_i^+(\alpha, R^*)R^* + (\widetilde{T}(\alpha) - T_i^+(\alpha)).
\end{aligned}
$$

Dividing the LHS and the RHS by $\widetilde{Y}(\alpha)$, and defining by $\widetilde{z}_i^+(\alpha, R^*) = \overline{z}_i^+(\alpha, R^*)/\widetilde{Y}(\alpha)$ and $\Delta T_i(\alpha) \equiv (\widetilde{T}(\alpha) - T_i^+(\alpha))/\widetilde{Y}(\alpha)$ the illiquidity index and the tax-revenue losses per unit of potential GDP, we obtain

$$
g_i(\alpha, R^*) = \widetilde{g} + \widetilde{z}_i^+(\alpha, R^*)R^* + \Delta T_i(\alpha), \quad i \in (1, 2)
$$

with $g_2(\alpha, R^*) > g_1(\alpha, R^*) > \widetilde{g}$.

Clearly, if $g_i(\alpha, R^*) > g^f$, depositors understand that the limited ability of the government to raise funds at the prevailing interest rate r^* is insufficient to fully honor the withdrawal requests of depositors, so that the guarantee is *non-credible*. If a large scale bank run materializes, the reimbursement of depositors is implemented until the public debt ratio increases to the ceiling g^f above which the government is considered insolvent. If, on the contrary, $g_i(\alpha, R^*) \leq g^f$, the government solvency would not be endangered even if the bailout was implemented. But in this case patient households no longer have any interest to withdraw their funds in the intermediary stage, and the run equilibrium is destroyed. Since, at equilibrium, no bailout is implemented, the debt-to-GDP ratio remains constant and equal to $\widetilde{g}$. This justifies in turn that the market interest rate on government bonds remains equal to $r_{12}^d = r^*$.

Let $i \in (1, 2)$ stands for the "no sudden stop" situation" and the "sudden stop" situations, respectively. Define by

$$g_i(\alpha, R^*) = \widetilde{g} + \widetilde{z}_i^+(\alpha, R^*)R^* + \Delta T_i(\alpha) \ , \ \ i = 1, 2$$

the debt-to-GDP ratio obtained if a bailout package is implemented at normal market conditions

(i.e., when the discount rate on government bonds is equal to the international interest rate r^*).

The illiquidity indices $\widetilde{z}_i^+(\alpha, R^*)$ and the tax revenue losses per unit of GDP, $\Delta T_i(\alpha)$, are defined

as above. We can summarize these results in the following proposition:

Proposition 2. Existence of a credible deposit guarantee

- $2(a) : g_i(\alpha, R^*) \leq g^f$: *the government guarantee is credible and sufficient to prevent the occurrence of a run,*
- $2(b) : g_i(\alpha, R^*) > g^f$: *the government guarantee is non-credible and does not eliminate the run equilibrium.*

Proposition 2 underlines the important role of economic fundamentals for the existence of an

effective financial safety net. The existence of a credible government guarantee requires:
  - a sufficiently low initial debt-to-GDP ratio $\widetilde{g}$
  - sufficiently capitalized domestic banks (i.e., banks with a sufficiently low illiquidity index $\widetilde{z}_i^+(\alpha, R^*)$, influenced by the intensity of regulation α)
  - low tax revenue losses in the event of a crisis, (in particular, a not too low liquidation value R_l of restructured assets)

Moreover, a clear corollary from Proposition 2 is that liquidity regulation and government

deposit guarantee are *complementary instruments* in the prevention of banking crises (since

$\partial g_i(\alpha, R^*)/\partial \alpha < 0$). Countries with a higher intensity of regulation α have a lower illiquidity

index $\widetilde{z}_i^+(\alpha, R^*)$ and thus require less government backing to prevent a bank run. Conversely,

"healthy" countries with an initially low level of public debt, or for which the liquidation value R_l

of restructured assets is relatively high, are able to provide a credible deposit guarantee without

imposing a large intensity of regulation.

4.4 The financial safety net in a sovereign debt crisis

The analysis undertaken so far has shown that for countries with strong or "decent" economic

fundamentals, the existence of a financial safety net should be able to deter the occurrence of a

large scale bank run provided that government bonds are truly considered as "*safe assets*", i.e. are immune from a sharp revaluation in their risk component by foreign investors. Yet, the recent Eurozone crisis has shown that in a monetary union where the central bank is not allowed to provide substantial backing to distressed member states, this "safe asset" assumption is not a relevant one. As reflected in the surge in sovereign CDS spreads between core and peripheral Eurozone countries between 2009 and 2012, documented in numerous studies, investors' expectations about a country's solvency may abruptly change in the face of an ongoing financial crisis.

In this section, we take account of this fact and assume that investors now truly question the creditworthiness of a government once the latter is confronted to its commitment to rescue failing domestic banks. We consistently assume that as investors have more and more doubts about the government solvency, the risk premium they require on newly-issued sovereign bonds also continuously increases until the public debt-to-GDP ratio reaches its ceiling g_f. How does such feature influence our analysis above?

4.4.1 Role of investors' expectations

To capture the sensitivity of risk premia to changes in investors' expectations, we follow Schmitt-Grohe and Uribe (2003) and assume that the yields on government bonds includes a risk premium which is increasing in the expected debt-to-GDP ratio at the end of period 2, denoted by g_2^a:

$$R_{12}^d(g_2^a) = R^* + \rho(g_2^a), \tag{4.30}$$

with $\rho(\widetilde{g}) = 0$ and $\rho'(g_2^a) > 0$ for $g_2^a > \widetilde{g}$. This notion of a "debt-elastic interest rate" has become increasingly popular in the literature for its empirical relevance.[60]

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[60] See, among others, Uribe (2007), Garcia-Cicco et al. (2010), Justiniano and Preston (2010) and Fahri et al. (2011) for recent references. The main difference with these previous papers is that, in (4.30), we are assuming that the interest rate is sensitive to the *expected,* instead of the *current,* debt-to-GDP ratio. This assumption, which we see as more realistic (what matters for investors is whether the government will be solvent at the maturity date of the bonds, and not at their issue date), also leaves the room for investors' expectations to significantly affect the dynamics of the economy, as we establish in propositions 3 to 5 below.

Clearly, the shape of the function $\rho(\cdot)$ – in particular its degree of convexity – is likely to be strongly dependent on the institutional design that characterizes the monetary union. In particular, for reasons emphasized above, the sensitivity of the risk premium to a change in the level of public debt is likely to be less acute in standalone countries with monetary sovereignty or in a monetary union where the central bank plays the role of a lender-of-last-resort in sovereign debt markets than in a monetary union in which the statutes of the central bank prevents it from doing so.

4.4.2 Twin banking and sovereign debt crisis

We now introduce our main differing assumption compared to the previous section by assuming that investors now believe that the solvency of the government would be truly endangered if the banking crisis threat were to materialize. These means that they believe that if the government was forced to borrow additional funds in order to bail out banks and to implement the deposit guarantee, the level of public debt would quickly reach the ceiling g_f above which the government is prevented from making further borrowing. As a result of (4.30), the yields on newly-issued government bonds jumps to $R_{12}^d(g_f) = R^* + \rho(g_f) \equiv R_{12}^{g_f}$. Can such a negative shift in investors' "sentiment" be justified under the assumption of rational expectations?

To answer this question, observe that the impact of an increase in the risk premium on government bonds has two negative effects on the solidity of the banking system and on public finance. First, it decreases the market price of government bonds in the secondary market (from $1/R^*$ to $1/R_{12}^{g_f}$), which in turn reduces the liquidity buffer $\widetilde{B}^*(\alpha)/R_{12}^{g_f}$ that banks can be obtained from selling their government bond holdings (and thus aggravates their solvency situation).[61] This is synthesized by the illiquidity index obtained when $R_{12}^d(g_2^a) = R_{12}^{g_f}$, which jumps to

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$$\overline{z}_i^+(\alpha, R_{12}^{g_f}) = \overline{z}_i^+(\alpha, R^*) + \underbrace{\alpha\,(e + f)\left(1 - \frac{R^*}{R_{12}^{g_f}}\right)}_{>0}, \quad i = 1, 2,$$

implying $\overline{z}_i^+(\alpha, R_{12}^{g_f}) > \overline{z}_i^+(\alpha, R^*)$.

Second, the increase in the risk premium on government bonds burdens the cost of the bailout package for the government, which must now issue new bonds at significantly deteriorated financial conditions. Using the same reasoning as above, we can easily compute the level of public debt if the bailout package was implemented as

$$g_i\left(\alpha, R_{12}^{g_f}\right) \equiv \widetilde{g} + z_i^+\left(\alpha, R_{12}^{g_f}\right) R_{12}^{g_f} + \Delta T_i(\alpha) \ , \ \ i = 1, 2, \tag{4.31}$$

implying $g_i\left(\alpha, R_{12}^{g_f}\right) > g_i\left(\alpha, R^*\right)$. Note that the level of public debt is actually negatively affected *twice*, since a larger amount of financial backstop, $z_i^+\left(\alpha, R_{12}^{g_f}\right) > \overline{z}_i^+(\alpha, R^*)$, must be financed by issuing new government bonds at a larger borrowing cost, $R_{12}^{g_f} > R^*$.

Clearly, if $g_i\left(\alpha, R_{12}^{g_f}\right) > g_f$, the high interest rate $R_{12}^{g_f}$ required on government bonds is consistent with rational expectations, since at the prevailing borrowing rate the government is unable to obtain sufficient liquidity on financial markets to fully compensate depositors: the deposit guarantee is in this case *non-credible*. The government's obligations imply that the compensation of depositors will be made until the public debt ratio reaches the ceiling g_f. Yet, depositors understand that they will not all be able to obtain the government compensation and run to withdraw their funds: a twin banking and sovereign debt crisis materializes.

Define by

$$g_i\left(\alpha, R_{12}^{g_f}\right) \equiv \widetilde{g} + \widetilde{z}_i^+\left(\alpha, R_{12}^{g_f}\right) R_{12}^{g_f} + \Delta T_i(\alpha) \ , \ \ i = 1, 2$$

the debt-to-GDP ratio obtained if a large-scale bailout package is implemented under stressed financial market conditions (the current discount factor on government bonds is equal to $R_{12}^{g_f} = R^* + \rho(g_f)$). The illiquidity indices $\widetilde{z}_i^+\left(\alpha, R_{12}^{g_f}\right)$ and the tax revenue losses per unit of

GDP, $\Delta T_i(\alpha)$ $(i = 1, 2)$, are defined as above. We thus Summarize the results by the following proposition:

Proposition 3. Existence of a twin crisis equilibrium

We have:
- $3(a) : g_i\left(\alpha, R_{12}^{g_f}\right) > g^f$: *a twin crisis equilibrium exists despite the government deposit guarantee,*
- $3(b) : g_i\left(\alpha, R_{12}^{g_f}\right) \leq g^f$: *no twin crisis equilibrium exists.*

Combining Propositions 2 and 3, we immediately obtain the following corollary:

Corollary 4. Multiplicity of equilibria

If $g_i\left(\alpha, R^*\right) < g^f < g_i\left(\alpha, R_{12}^{g_f}\right)$*, the government deposit guarantee is* credible *in "normal times", and* non-credible *under stressed financial market conditions. The existence of a financial safety net either completely eliminates the bank run equilibrium or triggers a twin banking and sovereign debt crisis.*

Although controversial, we believe that Corollary 4 may very well have characterized the situation of europeriphery countries at the onset of the financial crisis. As emphasized above, countries like Ireland, Spain and, to a lesser extent, Portugal, had a very low initial debt-to-GDP ratio. In these countries, while the burst of the housing bubble significantly reduced the value of immature assets R_l – putting their banking sector under stress – the decision to bail out failing banks and to increase the amounts covered by the deposit guarantees did not prove useful to stabilize the crisis. On the contrary, growing suspicions by foreign investors as to whether such countries would be able to honor their debt in the future generated sharp increases in the risk premium on their sovereign bonds, at levels never observed before. But such high levels of borrowing rates indeed implied that these countries were virtually excluded from financial markets, thus making their debt effectively unsustainable and triggering a twin banking and

sovereign debt crisis.

What Corollary 4 shows, in any case, is that the possibility of multiple equilibria affects countries with "soft" (neither overly weak or strong) economic fundamentals: countries for which $g_i(\alpha, R^*) > g_f$ will collapse independently of whether there exists a government deposit guarantee or not, and countries for which $g_i(\alpha, R_{12}^{g_f}) < g_f$ are immune to a twin-crisis equilibrium under any circumstances.

4.4.3 Potentially perverse effects of regulation

The inability of a monetary union to prevent the occurrence of a twin banking and sovereign debt crisis affecting a subset of its member states obviously raises questions about its whole institutional architecture. Actually, using our model, a simple question can be raised as to whether the liquidity regulation really improved, or actually worsened, the financial situation of banks during the crisis. To understand why this is an issue, observe that once a sovereign debt crisis materializes and banks are forced to sell their government bonds in the secondary market, the *ex-post* return on these bonds is *strongly negative* (bonds were purchased at unit price $1/R^*$ while their are sold at the price $1/R_{12}^{g_f} < 1/R^*$). When the increase in the risk premium $\rho(R_{12}^{g_f})$ is very large, the opportunity cost of selling government bonds in such poor market conditions may turn out to be greater than the opportunity cost of restructuring immature long-term projects. In this case, the regulatory requirements imposed *ex ante* actually *worsens* the liquidity situation of banks *ex post*.

To establish this point formally, we rewrite as $R_l < r_1^+(\alpha, R_{12}^{g_f})$ the condition $\bar{z}_i^+(\alpha, R_{12}^{g_f}) > 0$ required for the existence of a run equilibrium in the no-sudden stop situation when the discount rate on government bonds jumps to $R_{12}^{g_f}$ in the intermediary stage. In the technical appendix, we show that:

$$sign\left(\frac{\partial \bar{r}_1^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign\left(R_{12}^{gf} - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right) \tag{4.32}$$

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with $R_{12}^{g_f} = R^* + \rho(R_{12}^{g_f})$. Thus, as soon as the risk premium on domestic sovereign debt, $\rho(R_{12}^{g_f})$, exceeds $(R_h/R_s)^{\frac{1}{\sigma}} - R^*$, an increase in the intensity of regulation α *worsens* the liquidity situation of banks in stressed financial market conditions.[62]

In the "sudden stop" situation, the same logic applies, but the situation can be even much worse. In the technical appendix, we show that we have is this case

$$sign\left(\frac{\partial \overline{r}_2^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign\left(R_{12}^{g_f} - \left[(1-\xi)\left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} + \xi R^*\right]\right), \qquad (4.33)$$

where

$$\xi \equiv \left[1 + \frac{(1-\theta)(1-\tau)R^* r^+}{(1-\theta)(1-\tau)R^h + \theta R^*}\frac{e}{f}\right]^{-1} \qquad (4.34)$$

is a coefficient in the unit interval, which depends on the country's reliance on foreign funding (a larger dependence on foreign investment implies a smaller e/f and a coefficient ξ closer to 1). Thus, condition (4.33) shows that, in a sovereign debt crisis, an increase in the intensity of regulation α now weakens the liquidity situation of banks as soon as $\rho(R_{12}^{g_f})$ exceeds $(1-\xi)\left((R_h/R_s)^{(1/\sigma)} - R^*\right)$. This condition is significantly weaker than (4.32) above, especially when $1 - \xi$ is small, i.e. when the reliance of domestic banks on foreign funding is large. Summarizing:

Proposition 5. Potentially perverse effects of liquidity regulation

Assume that the risk premium on newly-issued government bonds satisfies $\rho(R_{12}^{g_f}) > (R_h/R_s)^{(1/\sigma)} - R^*$ in the "no sudden stop" situation, and $\rho(R_{12}^{g_f}) > (1-\xi)\left[(R_h/R_s)^{(1/\sigma)} - R^*\right]$ in the "sudden stop" situation, where ξ is defined by (B.33). Then, in a sovereign debt crisis

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[62] To understand the logic behind (4.32), consider the effects of the liquidity regulation when a banking crisis threat materializes without and with a sovereign debt crisis. Without sovereign debt crisis, each unit of government bonds sold in the secondary market provides $1/R^*$ units of extra liquidity in stage 1, instead of 1 unit in stage 2. Likewise, each unit of restructured projects enables to obtain R_l units of liquidity in stage 1, compared to R_h units in stage 2. The regulatory measure improves the liquidity situation of banks when the relative return of selling government bonds is greater than the one obtained from restructuring long-term projects: $1/R^* > R_l/R_h$, or $R^* < R_h/R_l$. Since the existence of a run equilibrium in the uregulated economy requires $R_l < r_1^+ \equiv (R_h)^{\frac{\sigma-1}{\sigma}}(R_s)^{\frac{1}{\sigma}}$, we can equivalently express this condition as $R^* < (R_h/R_s)^{1/\sigma}$, a condition which is automatically satisfied given (B.9). When a sovereign debt crisis occurs, the surge in the risk premium on government bonds implies that the market value of these bonds is now $1/R_{12}^{gf}$. Using the same reasonning as above but substituting R_{12}^{gf} to R^*, we obtain that the liquidity regulation improves the liquidity situation of banks when $R_{12}^{gf} < (R_h/R_s)^{1/\sigma}$, and worsens it otherwise.

situation, an increase in the intensity of regulation α *aggravates, instead of mitigates, the*
exposition of domestic banks to runs.

Again, the implications of Proposition 5 are worth clarifying. The proposition *does not* per
se imply that a liquidity regulation is harmful to the economy under any circumstances. On the
contrary, in section 2, we proved that such a regulation, alone or combined with a government
deposit guarantee, is a useful tool to eliminate the bank run equilibrium in normal circumstances.
The proposition rather suggests that a liquidity regulation may have perverse effects when the
assets required to be held by banks for liquidity purposes do not have the "safe asset" property they
were supposed to have. In the case of the Eurozone, the lack of this property is best understood
as a consequence of the inability for the central bank to play the role of a lender-of-last-resort in
sovereign debt markets when an abrupt change in investors' expectations threaten to drive one of
the member states into a self-fulfilling twin banking and sovereign debt crisis.[63]

4.5   Policy issues

In this last section, we show how our framework can be used to discuss – rather informally –
several of the policy issues that have emerged during the Eurozone crisis. Our aim here is not to
address these complex issues in details – which would be far beyond the scope of this chapter
– but rather to shed some insights on their main underpinnings and/or implications. We first
consider the role played by credit rating agencies in the crisis and assess the proposition that they
have contributed to aggravate the crisis. Then, we discuss the issue of contagion from stressed
to other member states through the banking system. Finally, we briefly address some questions
raised by the creation of "Eurobonds".

4.5.1   Role of credit rating agencies

At the onset of the European sovereign debt crisis, many commentators and political leaders

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[63]   As shown by Corsetti and Dedola (2012), the ability by a central banks to issue nominal liabilities whose demand is
not undermined by fears of default can indeed eliminate the risk of a sovereign debt crisis triggered by self-fulfilling
changes in investors' expectations. Likewise, in the canonical Calvo (1988) model, the central bank's ability to put a
ceiling on government bond interest rates is sufficient to eliminate a self-fulfilling sovereign debt crisis.

have expressed concerns that Credit Rating Agencies (CRAs) have contributed to aggravate the crisis by downgrading countries by much more than implied by fundamentals. According to them, these decisions contributed to spread panic among investors (aggravating the sudden stop of capital inflows) and to induce an unsustainable sovereign debt burden due to the climb of yield spreads. Thus, voices calling for regulation and control of CRAs have emerged.

Our model can be used to explore the meaningfulness of these arguments and to assess their domain of validity. Assume that, because information is costly to acquire, investors delegate the task of assessing the creditworthiness of the government to a specialized entity, called a "credit rating agency". The CRA is completely independent of any political entity and aims to provide the most accurate evaluation of the government situation at the end of the period. The results of its analysis are reflected by a rating decision on a discrete scale assumed to include only two ratings, "$\mathbb{A}$" and "$\mathbb{B}$". Denote by g_{cra}^a the CRA forecast for the level of the public debt ratio at the end of stage 2. It is publicly known that the CRA rating will be $\mathbb{A}$ if the CRA expects that the government will be able to honor its debt under any circumstances (i.e., if $g_{cra}^a < g_f$), and that its rating will be $\mathbb{B}$ otherwise.

If investors give strong credence to the CRA's forecast, the interest rate r_{12}^d on newly-issued government bonds will be a direct function of the CRA rating: $r_{12}^d(\mathbb{A}) = r^* + \rho(\mathbb{A}) = r^*$, and $r_{12}^d(\mathbb{B}) = r^* + \rho(\mathbb{B}) = r_{12}^{g_f}$. We can then state the following proposition, obtained as a direct implication of propositions 2 and 3 when investors' expectations are influenced by CRA ratings:

Proposition 6:. Self-fulfilling credit ratings

Assume that Credit Rating Agencies set their rating as described above, and the discount rate required by investors on newly-issued government debt is based on the CRA ratings: $r_{12}^d(\mathbb{A}) = r^*$ and $r_{12}^d(\mathbb{B}) = r_{12}^{g_f}$. We have:
- *6(a): $g_i\left(\alpha, R_{12}^{g_f}\right) < g_f$, the only consistent (perfect-foresight) rating is $\mathbb{A}$,*
- *6(b): $g_i(\alpha, R^*) \geq g_f$, the only consistent (perfect-foresight) rating is $\mathbb{B}$,*

- *6(c): $g_i(\alpha, R^*) < g_f \leq g_i\left(\alpha, R_{12}^{g_f}\right)$, there are two consistent (perfect-foresight) ratings: $\mathbb{A}$ and $\mathbb{B}$. In addition, the rating decision act as a self-fulfilling prophecy.*

Proposition 6 gives both support and qualifications to the claims that rating downgrades of europeriphery countries may have acted as a self-fulfilling prophecy. A first obvious qualification is that investors' expectations must be significantly influenced by the CRA ratings. As is often argued, this is most likely the case for countries for which the size of capital inflows is moderate on a worldwide scale or for which information is more difficult to collect. A second qualification is that there are situations for which economic fundamentals determine *a unique consistent rating*: countries with a high initial public debt ratio and/or an extremely fragile banking system (case (b) of Proposition 6) would collapse whatever their rating, while countries with very robust economic fundamentals (case (a) of proposition 6) would not collapse whatever their rating even if they had to implement a bailout package.

Finally, in case (c) of proposition 6, the decision to downgrade or not a country may indeed act as a self-fulfilling prophecy. Note that case (c) corresponds to our "featured" situation analyzed above, where a good equilibrium in which the financial safety net prevents the occurrence of a bank run coexists with a bad equilibrium in which a twin banking and sovereign debt crisis arises. In this case, a rating downgrade by a CRA may indeed favor the trigger of the twin crisis by playing the role of an exogenous selection device, coordinating investors' expectations on the bad equilibrium. It is worth noting that in this case, the rating decision by the CRA will appear ex-post as *perfectly justified by economic fundamentals*, since the situation that will materialize will actually be influenced by the rating decision.

4.5.2 Contagion

A major concern in the European sovereign debt crisis has been the issue of contagion from stressed countries to other member states. Peripheral countries such as Greece, Ireland or Portugal only account for a small share of the total GDP of the Eurozone, so that this fear of a contagion did

not stem from the negative impact on exports and imports implied by the economic contraction in these countries. Rather, fears arose from the potential domino effect that a global collapse of one country (public debt default and large-scale bankruptcy of the domestic banking system) would have on the banking system of the others.

In this subsection, we show how our model can be used to take into account this contagion effect via the banking system. In particular, we analyze how a relatively "healthy" country of the monetary union can be affected by the degradation of the economic situation in an other member state. Assume for that matter that, for some exogenous reason (bad economic fundamentals and/or negative self-fulfilling expectations of investors), the other country participating to the monetary union (the "foreign" country) is involved in a twin banking and sovereign debt crisis, so that the risk premium on its sovereign bonds jumps to $R_{12}^{g_f} > R^*$ in the intermediary stage.

This risk premium increase has two negative effects on the economic situation of the healthy country. First, it decreases the liquidity buffer that domestic banks can obtain by selling their foreign government bonds in the secondary market, thus weakening the liquidity situation of these banks: this is a *direct effect*. Second, the stressed economic environment – in particular the more fragile banking system – may lead investors to reassess their evaluation of the creditworthiness of the *domestic* government, which is now more likely to have to intervene in order to rescue domestic banks: this is an *indirect effect*. These two negative effects can potentially reinforce each other, an increase in the risk premium on domestic government bonds would not only further deteriorate the liquidity situation of (domestic and foreign) banks, but also further increase the cost of a potential bailout for the government.

More formally, denote as above by $R_{12}^d(g_2^a)$ the discount factor on domestic government bonds in the intermediary stage, as determined by (4.30). If investors, taking into account the increased vulnerability of the banking system, remain confident in the solvency of the domestic government,

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the discount rate on newly-issued government bonds remains equal to $R_{12}^d = R^*$. If, by contrast, investors become concerned about the government solvency in this new economic situation, the discount rate jumps to $R_{12}^d = R_{12}^{g_f} > R^*$.

Using our assumption that domestic banks in the healthy country allocated a fraction $1 - \gamma$ and γ of their total government bond purchases to the purchase of foreign and domestic sovereign bonds, respectively, their illiquidity index after the risk premium increase on foreign sovereign bonds is

$$
\begin{aligned}
\overline{z}_1^+\left(\alpha, R_{12}^d(g_2^a), R_{12}^{g_f}\right) &= \widetilde{x}(\alpha) - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l l_1^+(\alpha)\right) - \widetilde{B}_{02}^f/R_{12}^{g_f} - \widetilde{B}_{02}^d/R_{12}^d \\
&= \overline{z}_1^+(\alpha, R^*) + \underbrace{(1-\gamma)\alpha(e+f)\left(1 - \frac{R^*}{R_{12}^{g_f}}\right)}_{>0} \quad \text{(direct effect)} \\
&\quad + \underbrace{\gamma\alpha(e+f)\left(1 - \frac{R^*}{R_{12}^d(g_2^a)}\right)}_{\substack{= 0 \text{ if } R_{12}^d(g_2^a) = R^* \\ > 0 \text{ if } R_{12}^d(g_2^a) = R_{12}^{g_f}}} \quad \text{(indirect effect)},
\end{aligned}
$$

$$(4.35)$$

with $\overline{z}_1^+\left(\alpha, R_{12}^{g_f}, R_{12}^{g_f}\right) > \overline{z}_1^+\left(\alpha, R^*, R_{12}^{g_f}\right) > \overline{z}_1^+(\alpha, R^*)$.

As (4.35) shows, the liquidity buffer of domestic banks is immediately reduced after the increase in the risk premium on foreign sovereign bonds, by an extent which depends on $1 - \gamma$, the share of foreign in total bond holdings, and on $R_{12}^{g_f}/R^*$, the yield spread between "safe" and "risky" sovereign bonds (this is the direct effect). The indirect effect, on the other hand, only occurs if investors change their evaluation about the creditworthiness of the "healthy" government (so that $R_{12}^d(g_2^a) = R_{12}^{g_f} > R^*$). In this case, the liquidity situation of banks is further deteriorated by the decrease in the value of domestic government bonds that occurs in this new economic environment.

For similar reasons, the indirect effect also increases the cost of a potential bailout for the government, since a larger amount of funds must be raised on financial market by issuing

more government bonds at a higher interest rate, $R_{12}^{g_f}$. Denoting by $g_i\left(\alpha, R_{12}^d, R_{12}^{g_f}\right) \equiv$ $\widetilde{g} + \overline{z}_1^+\left(\alpha, R_{12}^d, R_{12}^{g_f}\right) R_{12}^d + \Delta T_i(\alpha)$ the expected debt-to-GDP ratio if the more expensive government bailout package was implemented (and financed) at current market conditions R_{12}^d, we see that as soon as

$$g_i\left(\alpha, R^*, R_{12}^{g_f}\right) < g^f < g_i\left(\alpha, R_{12}^{g_f}, R_{12}^{g_f}\right),$$

both types of investors' expectations (pessimistic or optimistic) are consistent with rational expectations.

This result emphasizes the potentially devastating domino effects that a twin banking and sovereign debt crisis affecting one or several member states may have over the entire monetary union. When, for some exogenous reason, the foreign country is hit by a twin banking and sovereign debt crisis, the domestic country may be driven into a similar crisis mainly because the weakening situation of banks changes investors' expectations about the solvency of the government.

In the Eurozone, the climb in sovereign yields in peripheral Euro countries put banks in countries like France and Germany (which were holding significant amounts of sovereign debt and of bonds issued by banks in stressed countries) under increasing stress. Fears of contagion became a predominant concern for the Eurozone and worldwide, leading the IMF to urge domestic governments to take mandatory actions to force banks to recapitalize (and even to consider contributing themselves to such recapitalization).[64]

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[64] In a famous and controversial statement, Christine Lagarde, head of the IMF, declared at the onset of the European sovereign debt crisis: "[European] banks need urgent recapitalization. They must be strong enough to withstand the risks of sovereigns and weak growth. This is key to cutting the chains of contagion. If it is not addressed, we could easily see the further spread of economic weakness to core countries, or even a debilitating liquidity crisis. The most efficient solution would be mandatory substantial recapitalization—seeking private resources first, but using public funds if necessary." [Christine Lagarde: "Global Risks Are Rising, But There Is a Path to Recovery", speech at the Jackson Hole Conference, August 27, 2011].

4.5.3 Eurobonds

The potential domino effects of a twin banking and sovereign debt crisis in a monetary union has stimulated a number of proposals by economists and policymakers to avoid the resurgence of such crises. One of the most discussed proposals has been the creation of Eurobonds, i.e. common sovereign debt securities pooling the risks of all Eurozone countries.

Proponents of the Eurobond proposal (see e.g. Brunnermeier *et al.*, 2011) argue that issuing such bonds would be an effective solution to restore the market confidence and to reduce the pressure on refinancing of Eurozone member states in crisis. Opponents to the proposal emphasize that pooling public debts may create a serious moral hazard problem, since fiscally imprudent governments would be encouraged to not sufficiently control their budgetary deficits, undermining the stability of the whole Monetary Union while eventually increasing risks and associated costs for all member states in the future.

Without addressing this debate, our framework is at least useful to evaluate the conditions under which "Eurobonds"would be an effective way of fighting against twin banking and sovereign debt crisis. Assume that, instead of holding a proportion γ and $(1 - \gamma)$ of domestic and foreign bonds, respectively, banks now have access to "Eurobonds" issued at the monetary union level. This means that, instead of

$$A + K + \left(\frac{B_{02}^d}{1 + r_{02}^d} + \frac{B_{02}^f}{1 + r_{02}^f} \right) = e + f_0$$

constraint (4.2) would become:

$$A + K + \left(\frac{B^{euro}}{1 + r_{02}^{euro}} \right) = e + f_0$$

where B^{euro} is the face value of Eurobonds held by the bank. In the planning stage, without crisis threat, the discount rates on domestic, foreign and Euro-bonds are $r_{02}^d = r_{02}^f = r_{02}^{euro} = r^*$. However, at the intermediary stage, concerns about the solvency of *some* member states imply an

increase in the risk premium associated to their sovereign bonds and to newly-issued Eurobonds. Assume for example that the stressed country is the "foreign country" (so that the discount factors on newly-issued government bonds are $1 + r_{12}^d = R^*$ and $1 + r_{12}^f = R_{12}^{g_f}$, respectively, in the intermediary stage) and denote by $1 + r^H \equiv \left(\gamma/R^* + (1 - \gamma)/R_{12}^{g_f}\right)^{-1}$ the weighted harmonic mean of R^* and $R_{12}^{g_f}$ (with weights given by the shares of government bond holdings issued by the domestic and the foreign country in the representative bank portfolio). Our analysis suggest that if the interest rate on Eurobonds, r_{12}^{euro}, is smaller than the implicit discount rate r^H on the weighted basket of government bonds, the creation of Eurobonds would improve the liquidity situation of banks in crisis time (and would worsen it otherwise).

Proponents of the Eurobonds proposal argue that this would typically be the case. Clearly, as they underline, the way these bonds would be structured and guaranteed is crucial for that matter. For example, would the guarantee be joint or several ? A joint guarantee would likely make the Eurobond discount rate smaller than the average discount rate r^H on a representative bank's government bond holdings in the event of a crisis. But such bonds are difficult to implement for political reasons. On the other hand, if Eurobonds were structured as a several guarantee, their ability to decrease r_{12}^{euro} below r^H in the event of a crisis would be far from warranted.

For example, assume as above that investors adjust their expectation according to CRA ratings. In a widely quoted September 2011 declaration, Standard and Poor's warned that if Eurobonds were structured such that each member state guarantees only a fixed share of the debt (several guarantee), it would rate these bonds using the "weakest-link approach", i.e. it would get the weakest member's rating.[65] Thus, we would have in this case $r_{12}^{euro} = r^* + \rho(\mathbb{B}) > r^H$ and the liquidity situation of banks would be aggravated, and not improved, by the presence of Eurobonds structured in that way.

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[65] In particular, the managing director of Standard & Poor's European sovereign ratings, Moritz Kraemer, declared: "If the euro bond is structured like this (...), then the answer is very simple. If we have a euro bond where Germany guarantees 27 percent, France 20 and Greece 2 percent then the rating of the euro bond would be CC, which is the rating of Greece." [Moritz Kraemer, declaration at the European Forum Alpbach, Austria, september 2011].

4.6   Conclusion

We developed a simple open-economy model with a large banking system and a strong reliance on external funding to examine the conditions of emergence of a twin banking and sovereign debt crisis in a monetary union with a broadly similar institutional framework as that of the Eurozone when it entered the 2007-2009 financial crisis. Our analysis shows that when the central bank is unwilling, in any circumstances, to play the role of a lender of last resort and to back the government debt of stressed member states, the main instrument to fight against systemic banking crisis — the financial safety net – may not be able to prevent the occurrence of large scale bank runs. The banking system and the government may either survive a negative financial shock or fail together, depending on investors' expectations. Under extreme circumstances – yet circumstances that have been observed during the Eurozone crisis – the climb in the risk premia on stressed sovereign bonds can even imply that the regulatory framework imposed to banks exacerbate, instead of mitigate, the risk of emergence of a twin banking and sovereign debt crisis. We also used our framework to assess the potentially destabilizing role played by credit rating agencies in such crises, to analyze potential contagion effects through the banking system, and to discuss some policy options that have emerged to avoid the resurgence of such crises, in particular the creation of Eurobond.

Chapter 5 Banking Crisis, Moral Hazard and Fiscal Policy Responses

5.1   Introduction

We studied, in the last chapter, the interconnection between banking fragility, activity contraction and budgetary vulnerability and the resulting twin banking and sovereign debt crises in a member state of a monetary union. Our model showed that the absence of monetary policy tools could undermine the credibility of the ex post fiscal bailout and thus induce a 'diabolic' loop between the banking and the sovereign crisis. In this chapter, we investigate the influence of a committed fiscal policy prior to the onset of the crisis, especially the effectiveness of an ex ante fiscal bailout plan, on stabilizing the banking sector of the member states of a monetary union. The introduction of a specific form of financial transaction tax in a framework of banking fragility is in line with the proposals to introduce a new tax on financial institutions published by the European Commission over the past three years, since 28 September 2011.

One salient feature of the recent financial crises occurring since 2007 is, besides the wide-scale maturity mismatch in banks' balance sheet, the significant role of discretionary fiscal policies in banking bailouts (IMF, 2013). The weakness in the regulatory framework and in banks' risk management has been clearly revealed. Banking regulations (from Basel I to Basel II) have generally focused on incremental rules, notably by strengthening banks' capital and liquidity position. While more exigent regulations on banks' capital requirement and liquidity reserves might strengthen an individual bank's resilience to adverse idiosyncratic shocks, they do not eliminate the risk of banking crisis and could even increase the systemic risk by being pro-cyclical.

The debate over the effectiveness of the taxation on financial institutions as a prudential policy has been aroused amongst industrial countries since the deepening of the global financial crisis in 2008 following successive waves of large-scale banking rescues (Claessens et al., 2010;

Llewellyn, 2010, 2012; Beck and Huizinga, 2011; Matheson, 2011; Mullineux, 2013). In Europe, several proposals to introduce a new financial transaction tax have been published by the European Commission over the past three years, since 28 September 2011. In a perfect Pigouvian world, taxation and regulation would be equivalent. Thus, in a banking system without all kinds of imperfections, taxation could be complementary to banking regulation. There are three rationales for imposing specific taxation on banks: first, it allows the government to recoup the costs of past bailouts and interventions; second, the tax revenue is a counterpart of the expected subsidy received by banks that are too big and/or connected to fail during possible future bailouts; and, finally, such taxation could create incentives for banks to improve their funding structures, to avoid over-borrowing and perhaps even not to become too big/connected.

In this chapter, we advance the idea that the regulatory reform needs to be strategic rather than incremental (i.e., capital or liquidity ratios). A strategic regulation implies enhancing the resilience of banks and lowering the cost of their failures. In contrast, incremental regulations focus on reducing the probability of bank failures while overlooking the issue of the costs of banking crises. We show that an appropriate fiscal measure embodying clearly defined crisis resolution arrangements can achieve these goals, in particular for the EMU's member states, which have renounced the autonomy of the monetary policy. The pre-committed fiscal policy has incentive effects that prevent the moral hazard problem caused by the expectations of banking rescues and could significantly reduce the total costs of intervention. Moreover, when the strategic regulation is properly implemented, the objectives of the incremental regulation could be achieved.

The costs of a systemic banking crisis are so tremendous that the government can rarely just stand by idly during a crisis. Nevertheless, prior to the eruption of such crises, most countries do not possess a priori well-designed bailout policy, leading to uncertainty about the crisis resolution arrangements and thus inducing moral hazard in the banking sector. This encourages banks to

make excessive irreversible investments. If the banking sector with a risky balance sheet fails, the policy makers might find themselves incapable of implementing a large and credible bailout package. The eurozone crisis has clearly demonstrated this. Countries such as Spain or Ireland were drawn into the twin banking and sovereign debt crises following the implementation of an unsustainable bailout policy in an attempt to rescue aggressive risk-taking banks.[66] Honohan and Klingebiel (2003), using a cross-country econometric database, show that accommodative policies (i.e., liquidity support, recapitalization, debtor bailouts) increase the fiscal costs of banking bailouts substantially. During the crisis of the Eurozone, the fiscal position of several member states turned out to be critical in the absence of national monetary sovereignty once their engagement in huge bailouts became evident. Some economists and policy makers consider the monetary union as an inherently flawed system characterized by a lack of coordination between fiscal and monetary policies, in which both the banking sector and the national budget become more vulnerable (Lane, 2012).

We show in this chapter that, given a relatively stable monetary policy ensured by the European Monetary Union, a pre-committed fiscal policy including a well-defined bailout program can function efficiently as a prudential instrument to stabilize the banking sector and to reduce the loss of social welfare in the event of a banking crisis. We consider two types of bailout: one is conducted through tax reduction, which is in effect akin to a direct liquidity injection, and the other is carried out through public lending. Banks may adopt a risky balance sheet in anticipation that the government is 'bailout-prone'. This could result in a systemic liquidity shortage during crisis times. On average, risky activity can be profitable for banks even in an adverse state if the government intervenes. In the light of our results, we may consider that the banking crisis in the Eurozone is a result of the discretionary and 'bailout-prone' fiscal policy that tends to protect banks in the event of a crisis. What the Eurozone needs might be a time-consistent and

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[66] See Serrano (2010) for the case of Spain and Dellepiane et al. (2010) for that of Ireland.

well-conceived fiscal policy and a credibly pre-committed fiscal bailout policy in the absence of an autonomous national monetary policy.

5.1.1 Relationship to the literature

The objective of this chapter is to evaluate the effects of a time-consistent fiscal policy, including a pre-committed fiscal bailout program, on the investment decision of the banking sector and on avoiding the replay of the Eurozone crisis in the future. As explored in two previous chapters, the 'doom loop' involves banking and sovereign debt crises that reinforce each other in Euro-periphery countries that cannot deploy a credible fiscal guarantee given their high risk of sovereign default. To assess, henceforward in the Eurozone crisis, the effectiveness of the fiscal policy with ex ante bailout plans for preventing the emergence of a banking crisis, we consider in this chapter a prudential fiscal authority that has not been tangled with debt inherited from previous periods.

Our model is related to several studies about banking crises and the taxation of financial activity. The fragility of the banking sector, in particular the issue of maturity mismatch, has been emphasized by a line of research following the seminal contribution of Diamond and Dybvig (1983), i.e., Rodrick and Velasco (1999), Chang and Velasco (2000), Radelet and Sachs (2000) and Allen and Gale (2009). These authors stress the connection between banking crises and macroeconomic policies. Nevertheless, their interest in the latter is restricted to monetary and exchange rate policies. In contrast, we focus on the situation of member states with the responsibility for supervising and rescuing the national banking system in a monetary union that limits the role of the central bank as the lender of last resort. Given that the common monetary policy could be used to deal with the financial difficulty at the national level during a banking crisis, the existence of such a union could be put into question even though the risk of an exchange rate crisis is generally perceived as null. To avoid this scenario, the impact of the fiscal policy on the stability of the banking system must be taken into account seriously from the beginning of its

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conception. This is the principal concern of the model in this chapter.

The current empirical studies on the taxation of banking activity mainly examine its effects on the profitability of banks and show that it could also have a certain impact on the stability of the banking system. According to Albertazzi and Gambacorta (2010), the taxation of banks' profit is equivalent to the taxation of loans and as such it exerts a substantial impact on the composition of banking sector revenues. Chiorazzo and Milani (2011) show that if banks are able to shift their tax burden forward, the taxation of banking activities could affect the loss provisions, with negative implications for the stability of the banking system.

A strand of literature considers that taxation could be superior to regulation in coping with the systemic risk externality in the financial sector (Keynes, 1936; Stiglitz, 1989; Cooley et al., 2009; Adrian and Brunnermeier, 2011; Goodhart, 2011; Acharya et al., 2012; Masciandaro and Passarelli, 2013). Reflecting the agents' marginal costs of reducing risk, a well-designed non-linear tax scheme could yield any desired progressive impact. This type of tax solves the Mirrlees problem, whereby the government cannot detect these costs. A tax works best in an environment in which information about agents' preferences is costly or impossible to gather (Claessens et al., 2010; Jeanne and Korinek, 2010).

Our model contributes to the literature on the taxation of financial activity by evaluating the effect of financial transaction taxes on the investment decision and risk-taking of the banking sector. Several financial transaction taxes could be directly or indirectly related to the banking sector.[67] Recently, a number of G-20 countries, including France and Germany, have imposed different forms of financial transaction tax to enhance the stability of the financial system (Matheson, 2011). We consider a particular financial transaction tax in our theoretical model by assuming that the government sets tax rates on banks' risky investments. Such taxes could reduce

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[67] Such as securities transaction tax, currency transaction tax, capital levy tax, bank transaction tax, real estate transaction tax, etc.

the level of risky investment and might thus improve the stability of the banking sector.

The active role of the government in financial crisis management has been explored by several theoretical and empirical studies (Reinhart and Rogoff, 2008, 2010; Bolton and Jeanne, 2011; Laeven and Valencia, 2012; Kollman et al., 2013). Focusing on the impact of fiscal bailouts on the stability of the banking sector, they do not consider how these bailouts could be optimally designed prior to the crisis.

Associating the literature on taxation with that on the banking crisis, our study analyzes the effect of the fiscal policy on the risk-taking of the banking sector. Our framework is close in spirit to that of Hasman and Samartín (2011), in which the government may raise a lump sum tax on financial transactions to provide public services, and the effectiveness of different ex post fiscal bailout policies is considered. Following them, the government in this chapter has no other revenue than the tax on banks' investment (i.e., it does not issue sovereign debt). Therefore, the cost of a banking bailout is reflected in the supply of public services to domestic agents. The case of a sovereign debt crisis is beyond the scope of this chapter, although it can be easily characterized in our model by considering the situation in which the costs of the bailout exceed the disposable fiscal revenues of the government. Different from Hasman and Samartín (2011), in our setting the government may choose the tax rate under commitment or discretion to maximize the social welfare and to discourage the excessive risk-taking of banks. The time-consistency problem of fiscal bailouts and the resulting moral hazard are considered. From this perspective, our model is related to Pastén (2011), who suggests that the tax on borrowing reinforces the time-inconsistency problem of bailouts if it decreases households' tax burden. Focusing on the optimal fiscal policy design and fiscal bailout, our study is complementary to Farhi and Tirole (2012), who analyzes the impact of the central bank's put through the interest rate policy on the risk-taking behavior of financial institutions and show that an interest rate policy under

commitment could avoid the moral hazard and reduce the leverage choice of banks when the risky asset is not extremely attractive.

We build our framework on the model of Farhi and Tirole (2012). Considering that the fiscal bailout policy could be either discretionary or pre-committed, we study the effects on banks' activity and the social welfare of a small country within a monetary union. Our model shows that, in a monetary union, national fiscal authorities can favorably influence the leverage choice and thus the risk-taking of the banking sector by adopting appropriate fiscal and bailout policies with commitment, even in the case in which banks' risky project is highly lucrative. The government is confronted with a trade-off between the benefits obtained from using fiscal resources in the production of public services and the reduction of social welfare loss caused by the banking crisis, during which such resources are used for bailing out distressed financial institutions.

The remainder of this chapter is organized as follows. In section 2, we develop the basic framework and show the effectiveness of taxation in reducing banks' risk-taking. Section 3 examines the government's choice of tax rates while ignoring the banking bailout in crisis times. Section 4 considers a potential fiscal bailout through a tax reduction under commitment and discretion, respectively. In section 5, we study the interplay between the fiscal policy and the moral hazard in the banking sector. Section 6 concludes.

5.2 Basic framework

The government of a small country, having abandoned monetary sovereignty by joining a monetary union, has only a certain degree of fiscal autonomy. To identify the effects of the fiscal policy, we assume that the monetary policy is stable and the gross interest rate R is equal to 1 in each period. There are three dates, denoted respectively by t_0, t_1 and t_2.

For simplicity, we assume that all banks are identical. The risk-neutral banking entrepreneurs are subject to limited liability and have a capital stock K in the initial stage t_0. They have access to a constant returns-to-scale production technology that yields a safe cash flow $\gamma(<1)$ at t_1 for

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each unit invested at t_0 independently of the states of the economy. The project is risky, since the safe return γ is not enough to cover the investment cost. The shocks impacting on the projects of different banks are assumed to be perfectly correlated. With the probability α, the project is performing (i.e., the good state) such that a unit of investment delivers at the intermediate stage t_1 a pay-off of ρ_1 in addition to γ; with the probability $1 - \alpha$, the project is non-performing (i.e., the adverse state) such that a unit of investment yields no pay-off at t_1 except for γ. The non-performing project can yield ρ_1 at t_2, if one unit of fresh resources is invested at t_1. If the refinancing is not in place, the non-performing asset will be liquidated at t_1. For simplicity, we assume that the liquidation yields no revenue.

For each maturing project, only part of return ρ_0 ($\rho_1 < 1 < \rho_1$) is pledgeable to investors. Consequently, $\rho_1 - \rho_0$ is the rate of profit for banking entrepreneurs when risky projects succeed. The assumption $\rho_0 < 1$ is imposed to avoid the case in which banks will not have a liquidity shortage in the adverse state.[68]

Let I denote the bank's total investment in the risky asset determined in the initial period t_0 and J the scale of continuation investment at t_1 in the adverse state. We assume that no new investment can be initiated at the intermediate date t_1, hence the scale of continuation cannot exceed the scale of initial investments (i.e., $J \leq I$). In the normal state, there is no concern about the continuation. However, in the adverse state, carrying on a non-performing project requires refinancing equal to one unit of fresh liquidity; thereby, J depends preliminarily on the bank's liquidity availability at date t_1.

The government sets the tax rates on banks' risky investments and collects taxes at t_0 and t_1 to invest in short-term public projects.[69] Public projects initiated at t_0 deliver public services to

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[68] The reinvestment demands one unit of a fresh resource for each troubled project. Thus, for the case in which $\rho_0 \geq 1$, banks can always obtain enough collateralized loans backed by their future revenue to ensure full-scale continuation. We do not analyze this case, because $\rho_0 \geq 1$ implies the situation in which banks' balance sheet is riskless, which is not the concern of this article.

[69] We concentrate our attention on the impact of the fiscal policy on banks' investment decision and the time-consistency problem of such a policy. Thereby, our interest is limited to the flat tax rate on banks' investment. An income tax

consumers at t_1 and those started at t_1 provide public services at t_2. Let τ_t indicate the tax rate at date t, and, without loss of generality, we assume that the tax rates in the two periods are constant in the normal state, such that $\tau_1 = \tau_2$. The government raises the tax to affect banks' investment decision and to provide public services. Given that the gross interest rate is $R = 1$, setting a constant tax rate τ_t at each date is equivalent to setting an overall rate $\tau = \tau_1 + \tau_2$ on either date t_0 or date t_1. Consequently, a tax rate reduction at t_1 that implies a reduction in the provision of public services could be substituted by an alternative solution whereby the government raises all taxes at t_0 and bails out banks with a liquidity injection at t_1.

The risky projects should be attractive enough for the banks to use all their endowment (K) to invest in as many projects as possible. We therefore establish the following assumption:

Assumption 1: $\rho_1 > 1 + \frac{(1+\alpha)(\gamma+\alpha-1)}{1-\alpha}$.

There are a large number of risk-neutral consumers who have an endowment at the initial date and are indifferent to the dates of consumption. At t_0, they can invest their endowment by purchasing safe assets and by investing in banks. We assume that this endowment is large enough to support banks' investment at both dates (t_0 and t_1). The gross rate of return from a safe asset is given by the gross interest rate $R = 1$. The risk-neutral consumers invest (part of) their money in banks, if the average gross rate of return from rendering the liquidity to banks is no less than that from holding a safe asset.

Taking into account the taxes, to effectuate an investment of scale I, the bank needs to raise $(1 + \tau_1)I - K$ from consumers at t_0 through issuing state-contingent debt. In the good state (with the probability α), the bank returns $(\rho_0 + \gamma - \tau_2)I$ to consumers and only δI with $\delta \leq \gamma - \tau_2$ in the bad state (with the probability $1 - \alpha$). The higher the payment to investors in the adverse state δ, the higher the amount of short-term debt the bank can accumulate at the initial date. Provided

would not be appropriate in our model for two reasons: first, an income tax imposed on risk-neutral consumers is uninteresting from the viewpoint of policy analysis, as in this simple model consumers obtain an average gross rate of return equal to 1 both from state-contingent deposits and from the safe asset; second, a tax on banks' income depending on the realization of an aggregate shock therefore hampers the analysis of the time-consistency problem.

that the average expected rate of return to the bank deposit is 1, the borrowing capacity of banks at t_0 is limited by the expected present value of future returns that is pledgeable to risk-neutral consumers. In equilibrium, we have

$$(1 + \tau_1)I - K = \alpha(\rho_0 + \gamma - \tau_2)I + (1 - \alpha)\gamma I. \tag{5.1}$$

When condition (5.1) holds, the bank's borrowing reaches the ceiling and any additional debt will be unsustainable. This condition also indicates that the bank's borrowing capacity increases when it invests more (when I is larger). To ensure that the bank's investment is finite, we therefore establish the following assumption:

Assumption 2: $1 - \alpha\rho_0 - \gamma > 0.$

This assumption implies that the maximum pledgeable return to consumers from a unit of risky projects is always smaller than the cost of the initial investment. Therefore, assumption 2 guarantees that the bank's borrowing capacity is bounded by the investment scale, which is itself limited and proportional to the bank's capital stock.

We can rewrite (5.1) to obtain the scale of investment in the risky project as follows:

$$I = \frac{K}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta}, \tag{5.2}$$

where $\tau \equiv \tau_1 + \tau_2$ is the sum of the tax rates for the two periods and $\eta \equiv \gamma - \tau_2 - \delta$ is the liquidity reserve ratio chosen by the bank.[70] The value of η is jointly defined with δ. For a given τ_2, a higher payment to consumers δ implies a lower η. Equation (5.2) shows that the investment scale is proportional to the capital stock of banks and increases with the probability of success, but decreases with the liquidity reserve ratio and the taxation. Clearly, a higher η reinforces banks' liquidity position in the adverse state, but implies a lower δ and hence a lower investment scale. Thereby, the bank may choose a liquidity reserve ratio as low as possible to increase the investment at t_0. Let $\beta(\eta) \equiv (1 - \alpha\rho_0 - \gamma) + (1 - \alpha)\eta$ measure the riskiness or the illiquidity of

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[70] As the interest rates remain constant and equal to 1, the expression $\tau \equiv \tau_1 + \tau_2$ represents the total tax charges on banking entrepreneurs' investment.

the project: a larger $\beta(\eta)$ refers to a larger expected liquidity gap and thus a higher degree of risk. Provided that assumption 2 holds, we can easily determine that $\beta(\eta) > 0$ in any circumstances. Consequently, we can rewrite condition (5.2) as follows:

$$\frac{I}{K} = l \equiv [\beta(\eta) + \tau]^{-1}. \tag{5.3}$$

From condition (5.3), it is straightforward to see that l is the financial leverage ratio and is defined by the riskiness of banks' investment and the tax rate on these investments.

Moreover, the tax rate is the key factor that affects η and l simultaneously. Therefore, without a clearly defined tax rate policy, the leverage and the liquidity ratios cannot be defined credibly.

The scale of continuation J is determined by the total liquidity available for the bank at t_1. In crisis times, the bank has two sources of funds for refinancing troubled projects: it can use its liquidity reserves ηI and can issue new debt against the future pledgeable income $\rho_0 J$ from the projects refinanced at t_1 and maturing at t_2. Consequently, $J \in [0, I]$ must satisfy the following condition:

$$J \leq \eta I + \rho_0 J. \tag{5.4}$$

Provided that $\rho_0 < 1$, the resource from issuing new short-term debt $\rho_0 J$ is not enough to cover the cost of full-scale continuation ($J = I$). Therefore, in order to implement full-scale continuation, the amount of banks' liquidity reserves is a key factor. It is straightforward to see that a higher η leads to a lower investment scale, but ensures a more comfortable liquidity condition for banks in crisis times.

Using the definition of the liquidity ratio $\eta \equiv \gamma - t_2 - \delta$, we can rewrite condition (5.4) as follows:

$$J = \min\{\frac{\gamma - \tau_2 - \delta}{1 - \rho_0}, 1\}I. \tag{5.5}$$

From condition (5.5), we can capture the fact that a lower tax rate in the second period τ_2 increases the continuation scale of banks in the bad state. We assume that banking entrepreneurs have no

alternative use for the unneeded liquidity and will keep the minimal liquidity reserve required in the adverse state. Accordingly, they will never choose to have excess liquidity; the interval for the liquidity reserve ratio is then $\eta \in [0, 1 - \rho_0]$. Full-scale reinvestment can be implemented when the liquidity ratio is such that $\eta = 1 - \rho_0$.

Banking entrepreneurs will choose a safe balance sheet by limiting the quantity of short-term debt and keeping a sufficient liquidity reserve (i.e., $\eta = 1 - \rho_0$), if doing so delivers a higher profit than taking on a risky balance sheet. Using (5.2) and (5.5), we can write banks' objective function as follows:

$$\pi(\eta) = (\rho_1 - \rho_0)[\alpha I + (1 - \alpha)J] = (\rho_1 - \rho_0) \left(\frac{\alpha + (1 - \alpha)\frac{\eta}{1 - \rho_0}}{1 - \alpha\rho_0 - \gamma + \tau + (1 - \alpha)\eta} \right) K. \quad (5.6)$$

From (5.6), it is straightforward to show that banks' profits π rise with the liquidity reserve ratio η if $1 + \tau - \gamma - \alpha > 0$ and decrease in the contrary case. Thereby, when the condition

$$1 + \tau > \gamma + \alpha \quad (5.7)$$

is satisfied, the first-order condition of banks' optimization problem implies that the balance sheet chosen by them will be the safe one corresponding to $\eta = 1 - \rho_0$, and there will be no aggregate liquidity shortage in the adverse state.

From condition (5.7), we have two possible scenarios: one with $\gamma + \alpha < 1$ and the other with $\gamma + \alpha > 1$. It is noticeable that, in the absence of taxation, banks will keep a sufficient liquidity reserve only if the risky projects have a moderate expected return (Farhi and Tirole, 2012). Since they analyze the effect of monetary policy on banks' risk-taking, the only case that they can consider is that in which $\gamma + \alpha < 1$. In contrast, our setting permits us to deal with both cases. In practice, banking entrepreneurs are more prone to adopt a risky balance sheet when the risky project is highly profitable. This leaves the banking sector extremely vulnerable during crisis times.

It is easy to verify that when $\gamma + \alpha < 1$, the effect of the fiscal policy in stabilizing the banking

system is modest in the sense that the condition is always verified regardless of the level of taxation, implying that the latter does not affect banks' choice of liquidity reserve ratio. However, a higher level of taxation could reduce the financial leverage of banks according to (5.3). In fact, $\gamma + \alpha < 1$ stands for the case in which the yield from the project is relatively low with respect to its riskiness. Therefore, banking entrepreneurs will not over-accumulate the short-term debts but will always keep enough liquidity reserves to be able to continue full-scale reinvestment in the adverse state.

However, the second scenario, $\gamma + \alpha > 1$, implies that the high return from the project overwhelms its riskiness. Accordingly, banking entrepreneurs have a strong incentive to adopt a risky balance sheet in setting $\eta = 0$ and loading up as much short-term debt as possible to invest more in risky but highly profitable projects. In this situation, if the tax rate set by the government satisfies condition (5.7), or equivalently,

$$\tau \geq \tau_{\min} \equiv \gamma + \alpha - 1, \tag{5.8}$$

the banking entrepreneurs will abandon their risky balance sheet and choose a safe one. This is because, in the absence of taxes, $\gamma + \alpha > 1$, risky projects are appealing, but the taxes could reduce their attractiveness since we could have $\gamma + \alpha - \tau < 1$. Thus, an appropriate fiscal policy can be an efficient prudential instrument that could be used to impel banks to keep enough liquidity reserve even in the case in which the risky project is exceedingly lucrative ($\gamma + \alpha > 1$). We are primarily interested in the second scenario, and from now on, we concentrate on the case in which the condition $\gamma + \alpha > 1$ holds.

One limit for the tax rate policy is that the government cannot set a tax rate higher than

$$\tau_{\max} \equiv \rho_1 - (1 - \gamma + 1 - \alpha).$$

If $\tau > \tau_{\max}$, any investment will yield a loss for banking entrepreneurs, i.e. $\pi(\tau) - K < 0$. In addition, assumption 1 ensures that $\tau_{\max}$ is non-negative for $\gamma + \alpha > 1$.

In a nutshell, the tax rate policy plays an important role in stabilizing the banking system and for this reason can be considered as an efficient instrument of strategic regulation. Given that the liquidity reserve ratio (η) and the leverage ratio (l) adopted by banking entrepreneurs depend on τ, the financial regulation concerning these ratios could be inefficient and reduced to soft budgetary constraints, if the tax rates (τ) are not credibly set by the government. In the absence of a credibly pre-committed tax rate policy, the regulatory requirement for liquidity reserves and capital ratios might have insignificant effects on the stability of the banking system.

5.3 Fiscal policy ignoring the potential bailout

We start our analysis with the simplest case in which the tax rates for the two periods are constant and non-state-contingent. More precisely, when the government makes the taxation decision, it takes into account the probability of the adverse state while disregarding crisis resolution arrangements. The fiscal policy of the small economy aims to stabilize the banking sector and maximize the social welfare. Since in this section we only consider the government's initial decisions about the tax rates, we do not distinguish the policy regimes under commitment and discretion.

The utility of investors (consumers) depends on the consumption of private goods and public services. C stands for the utility from the consumption of private goods. The utility from the consumption of public services is a linear function of their cost and is equal to $\theta \tau I$, with $\theta > 0$.

Given assumption 2, we can easily verify that the investment $I(\tau)$ is inelastic with respect to the tax rate τ such that a reduction in the tax rate will induce a decrease in the fiscal revenue $\tau I(\tau)$ and thus the supply of public services.[71] There is a minimum demand for public services, implying a corresponding threshold tax rate $\widehat{\tau}$. When the tax rate is below $\widehat{\tau}$, the consumer will

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[71] The investment is inelastic with respect to the tax rate when the measure of projects' illiquidity satisfies $\beta > 0$. Provided assumption 2, we can easily find that $\beta > 0$ holds in any circumstances.

suffer a deadweight utility loss of $\zeta > 0$. This is justified if the public services are subject to the economy of scale and a reduction of the tax revenue will induce an insufficient supply of public services. Lowering the public services to a level below their minimum demand impairs the consumption structure of consumers and results in a dead loss ζ.[72] The threshold tax rate $\widehat{\tau}$ is country-specific and can vary greatly across countries. We assume henceforth that $\widehat{\tau} > \tau_{\min}$.[73] Under this assumption, the prudential tax rate policy ($\tau_{\min}$) imposes a constraint to be taken into account by the policy makers when setting the fiscal policy, but it does not necessarily impair the output of the economy. To avoid the case in which the threshold tax rate is sky-high, such that the taxation is impractical, we introduce the following assumption:

Assumption3: $\frac{1}{2}\widehat{\tau} < \frac{\alpha+\gamma-1}{1-\alpha}$.

Assumption 3 ensures that the exogenous threshold tax rate $\widehat{\tau}$ is compatible with the profitability of banking entrepreneurs' investment and that the government has enough tax revenue to fill the liquidity gap in the event of a crisis. Assumption 1 ensures that $\widehat{\tau} < \tau_{\max}$.

Risk-neutral consumers are indifferent to the dates of consumption and their utility is given by[74]

$$U(\zeta, \tau) = \begin{cases} C + \theta\tau I(\tau), & \text{if } \tau \geq \widehat{\tau} \\ C + \theta\tau I(\tau) - \zeta, & \text{if } \tau < \widehat{\tau} \end{cases} \qquad (5.9)$$

The utility function given by (A.7) specifies that consumers' utility increases with the tax rate, despite the investment scale decreasing with the tax rate τ as shown by condition (5.2).[75]

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[72] More precisely, some public services cannot be (entirely) substituted by private goods. When the supply of public services fails to cover the minimum demand, consumers will suffer a utility loss.

[73] In fact, if $\widehat{\tau} < \tau_{\min}$, the prudential tax rate policy ($\tau > \tau_{\min}$) becomes very costly in terms of social welfare. The government is in an either-or situation: it chooses either the safety of the banking system or a higher level of social welfare.

[74] Given that the natural rate of interest is $R = 1$, the date of consumption does not impact on the utility of risk-neutral consumers. For investors (consumers), the expected return from a risky project is the same as that from the saving technology; hence, the consumption of private goods C is not affected by the investment scale I.

[75] The formulation of consumers' utility function is similar to the one in Hasman and Samartín (2011). They introduce a threshold for the consumption of private goods, while we consider a minimum demand for public services. Further, this utility function is also close to that in Fahir and Tirole (2012). They measure consumers' utility loss directly when the government bails out the banking sector, while we compare the consumers' utility in the case in which the bailout is implemented with the one in which no bailout is in place.

The objective of the policy maker at the initial date is to set an 'optimal' tax rate for the two periods to maximize the social welfare and stabilize the banking system. The government's optimization problem is

$$\max_{\tau} W \;=\; U(\zeta, \tau) + \phi J(\tau), \tag{5.10}$$

$$\text{s.t.} \quad \tau \;>\; \tau_{\min}$$

where $\phi(\leq 1)$ is the relative weight associated with banks' continuation scale J. As a country-specific parameter, ϕ measures the size or the influence of the banking sector in the whole economy. In the normal state, we have $J = I$ as there is no requirement for refunding; in the adverse state, $J \leq I$, depending on the bank's liquidity availability. The objective function (5.10) is a weighted average W of consumers' consumption $U(\zeta, \tau)$ and banks' continuation investment scale J. The introduction of the term $\phi J(\tau)$ into the social welfare function (5.10) is extensively justified by Farhi and Tirole (2012) by suggesting that a higher reinvestment scale improves the utility of banking entrepreneurs, lenders and workers. Given that $U(\zeta, \tau)$ increases while $\phi J(\tau)$ decreases with τ, the social welfare (5.10) captures well the conflict of interest between consumers and banks induced by the taxation of risky investment.

Considering the dual objective of the government, i.e., improving the social welfare and stabilizing the banking system, the constraint $\tau > \tau_{\min}$ implied by condition (5.8) should be verified in all circumstances. The satisfaction of this constraint implies that the government's fiscal policy could discourage banks from excessive risk-taking.

The social welfare function W is a step function depending on τ. For $\tau \in [\tau_{\min}, \widehat{\tau}]$, $W \mid_{\tau_{\min} \leq \tau < \widehat{\tau}} = C + \theta \tau I(\tau) - \zeta + \phi J(\tau)$, and for $\tau \geq \widehat{\tau}$, $W \mid_{\tau \geq \widehat{\tau}} = C + \theta \tau I(\tau) + \phi J(\tau)$. The optimal fiscal policy (i.e., 'optimal' tax rate) is set over two distinct intervals of τ, i.e., $\tau \in [\tau_{\min}, \widehat{\tau}]$ and $\tau \geq \widehat{\tau}$, by evaluating the value of W for τ in these two intervals. If condition (5.8) is verified, i.e., $\tau \geq \tau_{\min}$, banks will keep a sufficient liquidity reserve ratio such that

$\eta = 1 - \rho_0$ in the adverse state. Consequently, full-scale refunding (i.e., $J(\tau) = I(\tau)$) is ensured for both intervals of τ. Using the definition of $I(\tau)$ and $\beta \equiv 1 - \alpha\rho_0 - \gamma + (1-\alpha)\eta$, we can rewrite $W \mid_{\tau \geq \widehat{\tau}}$ and $W \mid_{\tau_{\min} \leq \tau < \widehat{\tau}}$, respectively, as

$$W \mid_{\tau \geq \widehat{\tau}} = C + \frac{(\phi + \theta\tau)K}{\beta + \tau} \quad \text{and} \quad W \mid_{\tau_{\min} \leq \tau < \widehat{\tau}} = C - \zeta + \frac{(\phi + \theta\tau)K}{\beta + \tau}.$$

We have that $\frac{\partial W \mid_{\tau \geq \widehat{\tau}}}{\partial \tau} < 0$ and $\frac{\partial W \mid_{\tau_{\min} \leq \tau < \widehat{\tau}}}{\partial \tau} < 0$, if

$$\phi > \theta\beta \tag{5.11}$$

Condition (5.11) implies that the government is more prone to set the tax rate at a moderate level if there is a relatively large banking sector in the economy, i.e., ϕ is relatively large. Condition (5.11) is more easily verified when the investment is less risky (β is lower), the productivity of the public sector (θ) is lower and the utility of the banking sector represents a greater weight in the social welfare function (ϕ is higher). Under condition (5.11), only corner solutions of τ exist (see Figure 1). If condition (5.11) is not satisfied, two cases need to be distinguished. For $\phi < \theta\beta$, i.e., the size of the banking sector is small, the government should set a maximum tax rate corresponding to ceiling $\tau_{\max}$. For $\phi = \theta\beta$, there are infinite optimal solutions of τ. Hereafter, we assume that condition (5.11) is always verified.

Given the verification of (5.11), the social welfare decreases within both intervals of τ. Therefore, it is straightforward to see that $\tau = \tau_{\min}$ to maximize $W \mid_{\tau_{\min} \leq \tau < \widehat{\tau}}$ in the interval $\tau \in [\tau_{\min}, \widehat{\tau}]$ and $\tau = \widehat{\tau}$ maximizes $W \mid_{\tau \geq \widehat{\tau}}$ in the interval $\tau \geq \widehat{\tau}$.

To determine the optimal overall tax rate for the two periods, we now compare the social welfare obtained respectively in the two intervals of τ studied above. It is easy to see that the policy maker sets the 'optimal' tax rate at $\tau^* = \widehat{\tau}$ if $\Delta W \equiv W \mid_{\tau = \widehat{\tau}} - W \mid_{\tau = \tau_{\min}} > 0$. Let $\Delta_1 = \widehat{\tau} - \tau_{\min}$; the condition $\Delta W > 0$ is equivalent to

$$\phi < \theta\beta + \frac{\zeta(\beta + \widehat{\tau})(1 - \rho_0)}{\Delta_1 K} \equiv \Phi_1. \tag{5.12}$$

From the definition of ΔW, we observe that the welfare gap depends negatively on Δ_1 and ϕ. The

social welfare is highest at $\tau = \widehat{\tau}$ if the weight of the banking sector is such that $\phi \in [\theta\beta, \Phi_1]$. In this interval of ϕ, the social welfare is a decreasing function of the tax rate in two intervals, i.e., $\tau \in [\tau_{\min}, \widehat{\tau}]$ and $\tau \in [\widehat{\tau}, \tau_{\max}]$. Due to the deadweight utility loss of consumers induced by insufficient provision of public services when the tax rate is lower than $\widehat{\tau}$, the welfare obtained for $\tau = \widehat{\tau}$ is higher than when setting $\tau = \tau_{\min}$, i.e. the welfare gain for consumers from setting a higher tax rate overcompensates for the loss of stakeholders of the banking sector. It is noticeable that for $\phi > \Phi_1$, it is optimal for the government to set $\widehat{\tau} - \tau_{\min}$ since the gain from a higher investment scale attributed to a reduction in the tax rate always dominates the utility loss of consumers of public services.

When condition (5.12) is satisfied, the policy maker will set $\tau^* = \widehat{\tau}$ as the optimal overall tax rate for the two periods. Given that the government is assumed to maintain a constant tax rate in the two periods, the 'optimal' tax rate for each period is $\tau_1 = \tau_1 = \frac{1}{2}\widehat{\tau}$ when the government does not consider the potential banking bailout in the event of a crisis. It is identical to the tax rate in the case of no fiscal bailout. The social welfare when $\tau^* = \widehat{\tau}$ is given by:

$$W \mid_{\tau = \widehat{\tau}} = C + \frac{(\theta\widehat{\tau} + \phi)K}{1 + \widehat{\tau} - \alpha\rho_0 - \gamma + (1 - \alpha)\eta} \tag{5.13}$$

A lower tax rate, such as $\tau^* = \tau_{\min}$, will improve the social welfare when condition (5.12) is not satisfied. It is easy to see that this condition is more difficult to hold when the continuation investment scale has a larger weight (i.e., ϕ is higher) in the social welfare function (5.10), the banking sector is less vulnerable (i.e., with a high capital stock, K), projects are less risky (β is smaller), consumers' deadweight utility loss caused by a reduction in public services when $\tau^* < \widehat{\tau}$ is smaller (i.e., ζ is lower) and their utility gain from the consumption of public goods is lower (i.e., θ is smaller).

In short, the government chooses $\tau = \widehat{\tau}$ as the overall tax rate for the two periods when conditions (5.11) and (5.12) hold and the bailout is not taken into account. From now on, we focus

on the case in which both condition (5.11) and condition (5.12) always hold, or $\phi \in [\theta\beta, \Phi_1]$, while the government takes account of the potential fiscal bailout.

5.4 Fiscal response to the crisis

Banking regulation, failing to eliminate crises fully, has usually been focused on lowering their likelihood. When a banking crisis is inevitable, policy makers generally react in urgency and do not make much effort to conceive a well-defined bailout policy both for stabilizing the banking sector and for reducing the social cost of the crisis. In this respect, the study of the role of fiscal bailouts in pre-committed crisis resolutions is particularly interesting.

In the last section, the non-state-contingent tax rates fixed at t_0 are $\tau_1 = \tau_2 = \frac{1}{2}\widehat{\tau}$, when the government considers only the probability of the adverse state while ignoring the possibility of implementing a fiscal bailout. In practice, this type of tax rate policy may be referred to as untrustworthy if the implementation of a bailout improves the social welfare.

In this section, we examine the case in which the government takes into account the potential bailout of the banking sector in the adverse state. The government may modify the tax rate in the second period in the adverse state if such a bailout attenuates the effect of negative shocks during crisis times and improves the social welfare. This bailout program is akin to a bailout through a direct liquidity injection. We may alternatively assume that the government collects taxes at a constant tax rate in any circumstance and transfers the tax revenue to banks in the adverse state. The government's fiscal policy is such that the tax rate at t_0 is $\tau_1 = \frac{1}{2}\widehat{\tau}$, with the taxes being perceived before the realization of the state of the economy, and the tax rate at t_1 is $\tau_2 = \frac{1}{2}\widehat{\tau}$ in the normal state.[76] However, the government may reduce the tax rate of the second period in the event of a crisis. We study two fiscal policy regimes associated with the pre-committed and discretionary fiscal bailout, respectively.

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[76] In the previous section, the 'optimal' tax rate that ignores the need for a bailout is $\widehat{\tau}/2$ in each period. Departing from this solution, we may consider an alternative crisis arrangement whereby policy makers increase the tax rate over $\widehat{\tau}/2$ in the normal state and reduce it under $\widehat{\tau}/2$ in the adverse state to obtain an average expected overall tax rate $\widehat{\tau}$. However, it is easy to verify that this policy does not improve the expected social welfare and is therefore superfluous.

5.4.1 Commitment

Given the likelihood of a crisis at t_1, the government sets at t_0 the tax rate in the second period by distinguishing the adverse state from the normal state. The government will not alter the second-period tax rate in normal times, whereas it is committed to carrying out the fiscal bailout by reducing the tax rate in the adverse state at t_1.

Let Δ_2 ($\equiv \frac{1}{2}\hat{\tau} - \tau_2^c$) denote the deviation of the tax rate under commitment in the adverse state, τ_2^c, from its value in the normal state $\frac{1}{2}\hat{\tau}$. The government will never allow the expected overall tax rate to drop below $\tau_{\min}$; therefore, the scope of the tax rate reduction is given by $\Delta_2 \in [0, \frac{\Delta_1}{1-\alpha}]$.[77] Given assumption 3 and the definition of Δ_2, we have $\tau_2^c \geq 0$ for $\Delta_2 \in [0, \frac{\Delta_1}{1-\alpha}]$, implying that the bailout package can be entirely funded and fulfilled through a reduction of the tax rate in the second period.[78] It is equivalent to consider a tax rate set independently of the state of nature combined with a fiscal bailout in the form of a liquidity injection to banks in the adverse state.

The maximization problem of the government under commitment is

$$\max_{\Delta_2} W^c(\hat{\tau}, \Delta_2) = C + \alpha[U_1(\eta, \tau) + \phi I(\hat{\tau}, \Delta_2)] + (1 - \alpha)[U_2(\eta, \tau) + \phi J(\hat{\tau}, \Delta_2)$$

$$\text{s.t.} \quad \frac{1}{2}\hat{\tau} + [\frac{1}{2}\hat{\tau} - (1-\alpha)\Delta_2] \geq \tau_{\min} ,$$

where $U_1(\eta, \tau) \equiv \theta\hat{\tau}I(\hat{\tau}, \Delta_2)$ and $U_2(\eta, \tau) \equiv \theta(\hat{\tau} - \Delta_2)I(\hat{\tau}, \Delta_2) - \zeta$ represent the utility of consumers in the normal and adverse state, respectively.[79] Note that consumers sign a state-contingent contract with banks at t_0, which ensures a fixed average expected return equal to 1. Consequently, the fiscal policy influences the consumers' consumption of public services while not affecting their consumption of private goods.

The liquidity position of banks will be improved if the government reduces the tax rate τ_2^c

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[77] It is easy to verify that $\Delta_2 > \frac{\Delta_1}{1-\alpha}$ implies $\tau_1 + \tau_2 < \tau_{\min}$. This induces the excessive risk-taking in the banking system according to condition (5.7). Therefore, the government limits Δ_2 within the interval $[0, \frac{\Delta_1}{1-\alpha}]$.

[78] In other words, the government has no need to liquidate any public services produced with the tax revenue collected in the initial stage to fund the bailout in the intermediate stage.

[79] The investment is inelastic with respect to the tax rate such that $\theta(\hat{\tau} - \Delta_2)I(\hat{\tau}, \Delta_2) < \theta\hat{\tau}I(\hat{\tau}, \Delta_2)$. Therefore, consumers will suffer a utility loss $\frac{\zeta\Delta_2}{\hat{\tau}}$ when the tax rate is reduced in crisis times.

below the threshold level ($\frac{1}{2}\hat{\tau}$) in the event of a crisis. Such a tax reduction is akin to a welfare transfer from consumers to banks. Banks benefits from an increase in the investment following a reduction in the tax rate below the threshold level, while such a decision directly results in a deadweight utility loss ζ for consumers in the adverse state.

If condition (5.8) is verified, banks will choose a safe balance sheet such that $\eta = 1 - \rho_0$ when the constraint $\frac{1}{2}\hat{\tau} + [\frac{1}{2}\hat{\tau} - (1 - \alpha)\Delta_2] \geq \tau_{\min}$ holds. This implies that $J(\hat{\tau}, \Delta_2) = I(\hat{\tau}, \Delta_2)$ in the adverse state. Thereby, we can rewrite the social welfare function under commitment as

$$W^c(\hat{\tau}, \Delta_2) = C + \alpha U_1(\eta, \tau) + (1 - \alpha)U_2(\eta, \tau) + \phi I(\hat{\tau}, \Delta_2).$$

The government will not alter the tax rate in the event of a crisis if doing so fails to enhance the social welfare, i.e., $W^c(\hat{\tau}, \Delta_2) < W \mid_{\tau=\hat{\tau}}$. Using the definitions of $I(\tau)$ and ζ, we can easily obtain that this condition is equivalent to

$$\phi < \theta\beta + \frac{\zeta(\beta + \hat{\tau})[\beta + \hat{\tau} - (1 - \alpha)\Delta_2]}{\Delta_2 K} \equiv \Phi_2. \tag{5.14}$$

As the right-hand side of (5.14) decreases with Δ_2, if (5.14) holds for $\Delta_2 = \frac{\Delta_1}{1-\alpha}$, it will hold for all $\Delta_2 \in [0, \frac{\Delta_1}{1-\alpha}]$. The government's choice of tax rates depends on structural parameters (i.e., ζ, K, θ and β, ϕ), in particular the weight of the banking sector ϕ. The commitment to bailing out the banking sector in the event of a crisis will not be optimal if the banking sector is not sufficiently important, i.e., $\phi \in [\beta, \Phi_2]$.

Using the definition of β and Δ_1 and substituting Δ_2 with $\frac{\Delta_1}{1-\alpha}$ in (5.14) leads to

$$\phi < \theta\beta + \frac{\zeta(1 - \alpha)(\beta + \hat{\tau})(1 - \rho_0)}{\Delta_1 K} \equiv \Phi_2 \mid_{\Delta_2 = \frac{\Delta_1}{1-\alpha}}. \tag{5.15}$$

When (5.15) is verified, any tax rate reduction $\Delta_2 \in [0, \frac{\Delta_1}{1-\alpha}]$ could decrease the social welfare. Thus, the tax rate policy under commitment is given by $\tau_1 = \tau_2 = \frac{1}{2}\hat{\tau}$, as in the last section when the bailout policy is neglected.

In the contrary case, i.e., if condition (5.15) does not hold, the constant tax rate policy may be sub-optimal in terms of social welfare. Given that condition (5.15) is more restrictive than (5.12),

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we might have a situation in which condition (5.15) breaks while (5.12) holds, i.e., $\phi \in [\Phi_2, \Phi_1]$. For ϕ lying within this interval, the banking sector is too big to fail, leading the government to announce at t_0 a predetermined bailout package for the adverse state at t_1. If the government insists on a constant tax rate policy corresponding to the one verifying (5.12), the moral hazard problem will arise and will trigger an ex post bailout in the adverse state. In the presence of an important banking sector, the implementation of the bailout policy lowers the costs of a crisis and improves the social welfare. However, the non-state-contingent fiscal policy given by $\tau_1 = \tau_2 = \frac{1}{2}\hat{\tau}$ could be suboptimal in such circumstances.

In a nutshell, the government will insist on a fiscal policy without a bailout described by $\tau_1 = \tau_2 = \frac{1}{2}\hat{\tau}$ whe condition (5.15) holds. Otherwise, a social-welfare-improving fiscal policy with a bailout should be implemented.

5.4.2 Discretion

Under discretion, the government sets the tax rate for the second period only at t_1. The tax rate in the second period is at its equilibrium level $\frac{1}{2}\hat{\tau}$ if no crisis occurs and could be reduced in the event of a crisis. At t_0, banking entrepreneurs form expectations about the tax rate at the intermediate date $\tau^a \leq \frac{1}{2}\hat{\tau}$ that the policy maker would set in the adverse state. Based on these expectations, the representative bank invests at scale $I(\tau^a)$ and holds just enough liquidity reserves $\eta^a I(\tau^a)$ to achieve the full-scale continuation investment in the event of a crisis. All the agents know that the government, with the objective of stabilizing the banking sector, will never accept an overall tax rate lower than $\tau_{\min}$ according to condition (5.8). Consequently, the expected scale of the tax rate reduction will not exceed $\frac{\Delta_1}{1-\alpha}$.

At t_1, the policy maker is not bound by any previous commitment and is free to set the tax rate to maximize the welfare. The tax rate at t_1 is $\frac{1}{2}\hat{\tau}$ in the normal state and may be altered during a crisis. The tax rate set by the government for the second period in the case of crisis in the

non-commitment solution is denoted by τ^{nc}. The policy maker will never set the rate below τ^{a}.[80]

For $\tau^{nc} > \tau^{a}$, banks cannot continue with full-scale refunding in crisis times. Thereby, τ^{nc} takes its value within the interval $[\tau^{a}, \frac{1}{2}\widehat{\tau}]$ and Δ_{3}, the gap between τ^{nc} and τ^{a}, takes its value within the interval $[0, \frac{\Delta_{1}}{1-\alpha}]$.

According to condition (5.5), we can define the reinvestment scale under the discretionary fiscal policy as follows:

$$J(\tau^{a}) = \frac{\gamma - \tau^{nc} - \delta}{\gamma - \tau^{a} - \delta} I(\tau^{a}). \tag{5.16}$$

Condition (5.16) shows that given the expected tax rate τ^{a}, the banking entrepreneur sets the payment to investors in the adverse state equal to $\delta = \gamma - \tau^{a} - \eta$ with $\eta = 1 - \rho_{0}$ to realize the full-scale continuation investment. The latter will be achieved if the government sets $\tau^{nc} = \tau^{a}$ in crisis times. For any $\tau^{nc} > \tau^{a}$, the liquidity reserves for the crisis will not be adequate since $\gamma - \tau^{nc} - \delta = \eta < 1 - \rho_{0}$, meaning that the full-scale continuation investment cannot be implemented. In fact, condition (5.5) shows that without a credible pre-committed fiscal policy, the regulatory rules regarding the liquidity reserves as well as the capital requirement, if they are imposed, could be ineffective in dealing with the excessive risk-taking of banking entrepreneurs.

Given the tax rate expected by private agents τ^{a} and condition (5.16), we can then compute the ex post social welfare $W^{nc}(\tau^{a}, \tau^{nc})$ in the event of a crisis, when the tax rate set by the government is $\tau^{nc} \geq \tau^{a}$ as follows:

$$\max_{\tau^{nc}} W^{nc}(\tau^{a}, \tau^{nc}) = U(\zeta, \tau) + \phi J(\tau^{a}). \tag{17}$$

$$\text{s.t. } \frac{1}{2}\widehat{\tau} + \alpha\frac{1}{2}\widehat{\tau} + (1-\alpha)\tau^{nc} \geq \tau_{\min}.$$

Condition (5.17) is observable for both the banking entrepreneur and the government. Under the discretionary fiscal policy, the banking entrepreneur forms, on the initial date t_{0}, the expected tax rate, τ^{a}, for the adverse state based on condition (5.17), while the government sets τ^{nc} in line with

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[80] The policy makers have no incentive to set a tax rate below τ^{a}, as that will not have any other effect than inducing the utility loss of consumers.

this condition only when the adverse state is realized at date t_1.

In the event of a crisis occurring at t_1, the policy maker sets $\tau^{nc} \in [\tau^a, \frac{1}{2}\widehat{\tau}]$ to maximize $W^{nc}(\tau^a, \tau^{nc})$. Given the expectations of banking entrepreneurs, the policy maker will reduce the tax rate if a tax reduction realizing banks' expectations enhances the social welfare, i.e. $W^{nc}|_{\tau^{nc}=\tau^a} > W^{nc}|_{\tau^{nc}=\frac{1}{2}\widehat{\tau}}$. We can easily show that $W^{nc}|_{\tau^{nc}=\tau^a} > W^{nc}|_{\tau^{nc}=\frac{1}{2}\widehat{\tau}}$ is equivalent to

$$\phi > \theta\beta + \theta\tau_{\min} + \frac{\zeta[\beta + \widehat{\tau} - (1-\alpha)\Delta_3](1-\rho_0)}{\Delta_3 K} \equiv \Phi_3. \qquad (5.18)$$

In consequence, when condition (5.18) is satisfied, a set of non-commitment equilibria exists, parameterized by the reduction of the tax rate by the government in the event of a crisis. This tax rate depends on the expectations of banking entrepreneurs $\tau^a = \tau^{nc}$ formed at t_0. Consequently, the moral hazard problem is triggered when (5.18) holds and the government sets a constant tax rate policy based on the verification of (5.12).

Under commitment, the pre-committed bailout is justified if (5.15) is not verified, i.e., $\phi > \Phi_2$. The latter condition and condition (5.18) show that under both fiscal policy regimes, the government has more incentive to bail out banks when the banking sector is large (large ϕ).

The right-hand side of equation (5.18) decreases with Δ_3, implying that the government is more tempted to bail out banks if the illiquidity crisis is more severe.[81] Provided that banks' profits increase with the investment scale and the latter decreases with the expected overall tax rate, the satisfaction of (5.18) implies that banks will expect a tax rate reduction corresponding to $\Delta_3 = \frac{\Delta_1}{1-\alpha}$ and the government under discretion will be obliged to set the second period's tax rate equal to $\tau^{nc} = \frac{1}{2}\widehat{\tau} - \frac{\Delta_1}{1-\alpha}$ at t_1 in the adverse state.

Using the definition of β and Δ_1, and substituting Δ_3 by $\frac{\Delta_1}{1-\alpha}$, (5.18) could be rewritten as

$$\phi > \theta\beta + \theta\tau_{\min} + \frac{(1-\alpha)\zeta[\beta + \widehat{\tau} - \Delta_1](1-\rho_0)}{\Delta_1 K} \equiv \Phi_3. \qquad (5.19)$$

Comparing conditions Φ_2 and Φ_3, we find that ϕ could satisfy both condition (5.15) and condition

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[81] Provided that the scale of the continuation investment is determined by (5.16), the severity of the liquidity shortfall under discretion could be measured indirectly by $\tau^{nc} - \tau^a \equiv \Delta_3$.

(5.19), i.e., $\phi \in [\Phi_3, \Phi_2]$, when the inequality

$$K > \frac{(1-\alpha)\zeta[\beta + \widehat{\tau} - \Delta_1]}{\theta} \tag{5.20}$$

holds. Condition (5.20) represents the situation of an economy in which the level of bank capital K is sufficiently high that there will be a bailout through decreasing the tax rate under discretion, whereas no bailout will be implemented under commitment. Banks' investment scale given by (5.2) depends positively on the bank capital. For a given size of the banking sector ϕ, a higher K increases the share of the banking system in the social welfare function. Therefore, the government would have less freedom to manipulate the fiscal policy at t_1 under discretion if an overwhelmingly large banking sector adopted a risky balance sheet at t_0.

Consequently, when condition (5.20) is satisfied, the government is more prone to bail out the banking sector in the adverse state under discretion than under commitment. As shown by this condition, the relative weight of the banking sector in the social welfare function ϕ is determinant. When ϕ is high enough for condition (5.20) to hold, the fiscal policy largely depends on the expectations of banking entrepreneurs.

The verification of conditions (5.14), (5.18) and (5.20) implies that the government's crisis management could be affected by the choice of tax rate policy regime. The average expected social welfare is higher under commitment than under discretion. More precisely, the discretionary bailout, which is ex post preferred in the adverse state, is socially inefficient, because when (5.14) holds, the expected social welfare taking into account all the states of the economy is higher in the case of no bailout than in the case of a bailout. Therefore, it is optimal for the government to adopt the commitment fiscal policy regime, especially when there is a relatively 'big' banking sector.

The government's fiscal policy decisions under discretion and commitment examined in sections 3 and 4 are summarized in Figure 2.

Ignoring the moral hazard problems, the government sets the fiscal policy independently of

the banking sector's expectations. If $\phi < \beta\theta$, the government sets the tax rate at $\tau_{\max}$. For $\phi \in [\theta\beta, \Phi_1]$, the government sets the tax rate at $\widehat{\tau}$ For $\phi \geq \Phi_1$, the government entirely caters to the interests of banks given that the latter have too great an impact on the government's fiscal decisions. These decisions will not be affected by the consideration of moral hazard problems either for $\phi < \theta\beta$ or for $\phi \geq \Phi_1$. For $\phi < \theta\beta$, the weight of the banking sector is too small to affect the fiscal decisions, while for $\phi \geq \Phi_1$, the government keeps the tax rate at the minimal level and will have no fiscal room for maneuver in the event of a crisis. This incites rational banking entrepreneurs not to adopt an over-risky balance sheet, thus eliminating moral hazard problems.

Taking account of moral hazard problems at t_0, the impact of the weight of the banking sector depends on the policy regimes. The government will bail out the banking sector if $\phi > \Phi_3$ under discretion, while the condition for ensuring a social-welfare-improving bailout becomes $\phi > \Phi_2$ under commitment. A discretionary fiscal policy reinforces the influence of the banking sector on the government and is suboptimal in terms of social welfare compared with a commitment fiscal policy. Furthermore, compared with the discretionary solution, a commitment fiscal policy, by increasing the threshold for the weight of the banking sector (from Φ_3 to Φ_2) over which the government will bail out, contributes to reducing the excessive risk-taking and hence the moral hazard problems in the banking sector.

5.5   Crisis resolution through public lending

In our model, banks make their investment decision following the announcement of the fiscal policy and thus have the incentive to take too much risk in the hope that the government will come to their rescue in the event of a crisis. In the previous sections, such moral hazard problems are not taken into account when considering the interactions between the government and the banking entrepreneurs under commitment.

The moral hazard becomes a potential problem when banks do not behave as followers in the strategic game between banks and the government and expect that leeway exists for the alteration

of the announced fiscal policy. To avoid potential moral hazard problems, the government should take the latter into account when setting pre-committed tax rates and bailout schema.

In certain cases, the moral hazard could improve social welfare and its occurrence could be a rational response to an inadequate fiscal policy. Consider a situation in which the structural parameters of the economy verify condition (5.12) but not condition (5.14). In such a situation, a fiscal bailout in the adverse state is preferred in terms of social welfare. Considering that condition (delw) is verified while ignoring the moral hazard problems, the government sets, under commitment, constant tax rates, i.e., $\tau_1 = \tau_2 = \frac{1}{2}\widehat{\tau}$ (see section 3).

The moral hazard problems could happen notably if condition (5.14) is not verified, meaning that banking entrepreneurs are incited to ignore the announced fiscal policy without a tax rate reduction and to adopt a more risky balance sheet.[82] The government will be obliged to implement the bailout in the adverse state, although doing so means discarding its original promise. Due to moral hazard problems, the fiscal policy without a bailout is time-inconsistent given that the bailout is welfare-improving by attenuating the negative effects of the crisis and achieving a higher output level as long as condition (5.14) does not hold.

From now on, we consider the situation of an economy with a big banking sector such that the parameter K is high enough to satisfy condition (5.20). The government sets the fiscal policy based on the verification of condition (5.14) to maximize the social welfare. As shown in section 4, the commitment to maintaining a constant tax rate policy is socially optimal if there are no moral hazard problems. However, if condition (5.20) is satisfied, a moral hazard could occur, leading banking entrepreneurs to ignore the government's commitment and adopt more risky investment decisions. Thus, without a fiscal bailout, the scale of the continuation investment is determined as under discretion and is given by equation (5.16) with $\tau^{nc} = \frac{1}{2}\widehat{\tau}$.

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[82] The banking entrepreneurs will expect a tax reduction in the adverse state $\Delta_2 \in [0, \frac{\Delta}{1-\alpha}]$ and set the leverage ratio and liquidity ratio according to this expectation.

Without preventing moral hazard problems, the government is obliged to rescue banks adopting a risky balance sheet in the adverse state if condition (5.18) is satisfied, implying that the commitment to no-bailout through the tax rate reduction could be incredible at the initial date. Even though the moral hazard problem could be potentially resolved by an appropriate regulation of banking activities, such a regulation could be not only laborious and costly but also ineffective in dealing with such problems given that banks could develop new financial techniques to circumvent the regulatory rules. This justifies the government's trimming down of the moral hazard incentive in the first place when conceiving the fiscal policy.

To ensure the sustainability of the committed fiscal policy, the government should take into account how the potential moral hazard affects banks' balance sheet and investment decisions when setting the tax rates at t_0. Banking entrepreneurs have an incentive to adopt a risky balance sheet if they are sure that the government will bail them out in the adverse state and their expected profits will be higher if such a rescue happens.

Given equations (5.2) and (5.6), it is straightforward to show that banks' profits are higher with the accommodative tax rate that the government adopts once it abandons its previous commitment to the constant tax rate policy.[83] Under (5.2) and (5.6) and the verification of condition (5.20), there is potential moral hazard in the banking sector since banks have a strong incentive to adopt a risky balance sheet. Accordingly, the government's commitment made at t_0 cannot be fulfilled and the fiscal policy at t_1 will be ultimately modified according to the investment project of the bank.

Given that the government cannot influence condition (5.20), it should focus on influencing the level of investment and profitability of the banking sector given respectively by (5.2) and (5.6) in the presence of moral hazard. Aiming to eliminate the moral hazard incentive, policy makers can design a credible predetermined bailout to affect banks' expected profit. This will incite

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[83] Condition (5.2) shows that the investment scale is higher for a lower overall tax rate and condition (5.6) indicates that banks' profits are proportional to the investment scale.

banks to choose financial leverage and a liquidity ratio complying with the no-bailout fiscal policy announced by the government.

In the previous section, banking entrepreneurs adopting a risky balance sheet receive without counterpart the welfare transfer from consumers through a tax reduction during a crisis, if condition (5.20) holds. This case is close to the situation occurring during 2010–2012 in some Eurozone countries, where illiquid excessive risk-taking banks obtained massive cost-free liquidity support from national governments that could not endure the costs due to the collapse of their overwhelmingly big banking sector. The experience of some Eurozone member states supports the idea that a bailout through a 'government put' after the eruption of the crisis is socially inefficient (just as in the case of the 'central bank put') by inducing moral hazard problems in the banking sector.

We argue that an efficient bailout should be conceived to eliminate banks' incentive to engage in excessive risk-taking, thus preventing the government from being forced to execute it. More precisely, we consider the case in which banks have to bear the costs of the bailouts caused by the moral hazard.

The government can announce at t_0 that if banks do not set their investment plan to correspond to the commitment to no tax reduction in the adverse state and for this reason are affected by a liquidity crisis, the government will bail them out at t_1 through public lending rather than tax reduction.

The amount of lending Υ should be sufficient to cover the liquidity gap in the crisis, i.e.,

$$\Upsilon = (\frac{1}{2}\widehat{\tau} - \tau^a)I(\tau^a).$$

Since the government has no other income than the tax revenue, the loan Υ at t_1 implies a decline in the supply of public services, which results in a utility loss equal to $\theta\Upsilon$ for consumers at t_1. Denoting by $R^p(> 1)$ the gross interest rate on this loan, the bank should repay $R^p\Upsilon$ to the

government at t_1 when the investment is mature. The government can transfer the pay-off $R^p\Upsilon$ resulting from the public lending to consumers with a unitary gain of utility equal to $\lambda < 1$. Therefore, consumers' utility increases by $\lambda R^p\Upsilon$ at t_2.

The public lending will not induce a utility loss if $\theta\widehat{\tau}I(\tau^a) - \theta\Upsilon + R^p\lambda\Upsilon \geq \theta\widehat{\tau}I(\tau^a)$. The LHS of the latter condition indicates the total public services received by consumers when banks repay the loan and its RHS represents the threshold level of public services. Using definitions of $I(\tau)$ and Υ, the previous condition is equivalent to

$$R^p \geq \frac{\theta}{\lambda}\frac{\beta + \alpha\widehat{\tau}}{\beta + \widehat{\tau}}. \tag{5.21}$$

Consequently, when the interest rate on public lending satisfies condition (5.21), consumers do not pay for the banking bailout. If (5.21) is not satisfied, they will suffer a utility loss of $(\theta - \lambda R^p)\Upsilon + \zeta$.

The costs of public lending reduce the profit of banking entrepreneurs. Banking entrepreneurs will not wish to borrow from the government if carrying a risky balance sheet reduces the average expected profits compared with a safe balance sheet. In particular, if the condition

$$(\rho_1 - \rho_0)I(\tau^a) - (1 - \alpha)R^p\Upsilon < (\rho_1 - \rho_0)I(\widehat{\tau}) \tag{5.22}$$

holds, the bank will adopt a safe balance sheet, complying with the pre-committed fiscal policy to avoid costly borrowing in crisis times. Using the fact that $\gamma - \tau^a - \delta = 1 - \rho_0$ implied by condition (5.16) and the definition of $I(\widehat{\tau})$, we find that condition (5.22) is equivalent to

$$R^p > \frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}. \tag{5.23}$$

When the interest rate on public lending satisfies condition (5.23), the banking entrepreneurs will not disregard the commitment to no tax reduction and will be incited to adopt a safe balance sheet. According to (5.3), $1/(\beta + \widehat{\tau})(\equiv 1/l)$ represents the leverage ratio. Thus, $\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}$ corresponds to the expected rate of profits that banking entrepreneurs could realize by adopting a safe balance sheet. Condition (5.23) implies that the interest rate on public lending should be higher than the expected

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rate of profit under constant tax rates. Setting an interest rate higher than $\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}$ is equivalent to imposing a penalty on banks. Such a penalty, if practicable, can eliminate the moral hazard.

However, to ensure the credibility of such a bailout programme, the interest rate on the public lending must not exceed a ceiling over which banks will not borrow in the event of a crisis. It is straightforward to see that banking entrepreneurs will take into account the costs of public lending in the design of their investment plan on the initial date t_0 if the following condition is satisfied:

$$(\rho_1 - \rho_0)I(\tau^a) - R^p \Upsilon > (\rho_1 - \rho_0)J(\tau^a). \tag{5.24}$$

The left-hand side of (5.24) represents banks' profits in the adverse state when public loans are accepted and thus full-scale continuation (τ^a) is carried out. The right-hand side of (5.24) stands for banks' profits in the adverse state when public lending is refused and only a fraction of projects are refunded, i.e., $J(\tau^a) < I(\tau^a)$.

As the government maintains a constant tax rate, i.e., $\tau_2 = \frac{1}{2}\widehat{\tau}$, a liquidity gap exists on banks' balance sheet measured by $\frac{1}{2}\widehat{\tau} - \tau^a$, which makes full-scale continuation infeasible. As a result, the continuation scale is equal to $J(\tau^a)$, determined by (5.16). For banks to have an incentive to accept public loans, (5.24) must be verified. When (5.24) does not hold, banks engaging in excessive risk-taking will not have any incentives to refund projects with the public lending. Given the importance of the banking sector and the horrendous losses for the whole economy that a banking crisis can induce, the government cannot just stand by idly in the case in which banks do not accept the public lending imposing a large penalty. To avoid massive premature liquidation, the government will thus be obliged to modify the bailout programme at t_1 by decreasing either the tax rate in the second period or the interest rate on public lending. Consequently, the time-consistency problem of the fiscal policy remains unresolved and banks' excessive risk-taking is not prevented. The result that public lending with an exceedingly high interest rate will be ineffective in dealing with the banking crisis is consistent with the empirical

observations that extremely severe penalties are rarely implemented for morally hazardous banks.

Using (5.2), (5.16) and the definition of Υ, condition (5.24) allows the determination of the above-mentioned interest ceiling such that:

$$R^p < \frac{\rho_1 - \rho_0}{1 - \rho_0}. \tag{5.25}$$

When (5.25) holds, banking entrepreneurs adopting a risky balance sheet will have an incentive to borrow from the government in the adverse state. Given the definition of β, we can easily verify that $1 - \rho_0 < \beta + \widehat{\tau}$, implying that $\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}} < \frac{\rho_1 - \rho_0}{1 - \rho_0}$, where the left-hand side is taken from (5.23) representing the minimum to be imposed to discourage the appearance of moral hazard in the banking sector. Therefore, for any interest rate on public lending in the interval $i \in [\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}, \frac{\rho_1 - \rho_0}{1 - \rho_0}]$, banking entrepreneurs will accept the public lending and bear a cost for the bailout since their profits will otherwise be lower.

By eliminating the moral hazard incentive, a bailout through public lending with a gross interest rate such that $R^p \in [\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}, \frac{\rho_1 - \rho_0}{1 - \rho_0}]$ ensures the credibility of the pre-committed fiscal policy and reduces the costs of crisis management. In fact, observing the gross interest rate corresponding to $R^p \in [\frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}, \frac{\rho_1 - \rho_0}{1 - \rho_0}]$, banks will abandon the risky balance sheet in the first place. Thereby, the announced fiscal policy can be credibly implemented and public lending will not even be required. Under these conditions, public lending can be an efficient instrument to resolve both the moral hazard problem of banks and the time-consistency problem of the fiscal policy.

Two aspects of the public lending policy need to be emphasized: the timing and the social costs. First, the government should pre-commit to this bailout programme on the initial date t_0. Apparently, if the government does not decide on a bailout policy in advance (at t_0) but only at t_1 in the adverse state, the impact of this policy could be largely different from the one with commitment. When the interest rate on public loans satisfies condition (5.23), public lending is unprofitable for banking entrepreneurs. If this interest rate is announced at t_0, banking

entrepreneurs are incited to adopt a safe balance sheet to avoid this costly borrowing. Thus, there will be no liquidity shortage at t_1 even in the adverse state. However, if the bailout policy is announced only at t_1, banks do not have the occasion to modify their irreversible investments initiated at t_0. Consequently, a liquidity shortage becomes inevitable in the adverse state. In short, the pre-committed bailout package can avoid its implementation, whereas a discretionary one implies actual execution that could be costly in terms of both banks' profit and social welfare.

Second, the implementation of the pre-committed bailout policy does not necessarily need to be costly for consumers. We consider the case in which the condition

$$\theta < \frac{\rho_1 - \rho_0}{\beta + \alpha\widehat{\tau}} \lambda \qquad (5.26)$$

holds,[84] meaning that consumers' utility loss due to the transfer implied by the bailout is relatively small compared with the potential utility gain resulting from the success of public lending. Through setting the interest rate of public lending, the government could easily restrain the risk-taking of the banking sector. A government attaching more importance to social welfare could impose an gross interest rate at an intermediate level, i.e., $R^p \in [\frac{\theta}{\lambda}\frac{\beta+\alpha\widehat{\tau}}{\beta+\widehat{\tau}}, \frac{\rho_1-\rho_0}{\beta+\widehat{\tau}}.]$, and bail banks out through public lending in the adverse state. Unlike a bailout through the tax reduction forced by banks' irreversible risky investment due to the moral hazard, the public lending will be carried out when it is social-welfare-improving.[85] Furthermore, the decrease in the tax rate implies a pure welfare transfer from consumers to banks and thus a utility loss for consumers, while the cost of the public lending can be borne by banks and will not necessarily induce a social loss if condition (5.26) is verified.

Given a well-defined bailout policy with commitment, whether banks adopt a risky balance sheet or not depends on the interest rate on public loans set by the policy maker at t_0. The credibility of the pre-committed fiscal policy is no longer subject to the investment plans of banks.

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[84] Condition (5.26) is yielded by comparing the right-hand sides of (5.21) and (5.23) such that $\frac{\theta}{\lambda}\frac{\beta+\alpha\widehat{\tau}}{\beta+\widehat{\tau}} < \frac{\rho_1-\rho_0}{\beta+\widehat{\tau}}$.

[85] This is the case in which both condition (5.14) and condition (5.18) hold and the government sets a constant tax rate policy to maximize the social welfare

To ensure the stabilization of the banking sector and to lower the cost of a banking crisis, this interest rate should be high enough to eliminate the moral hazard incentive but moderate enough to ensure the feasibility of the bailout program.

The bailout through public lending analyzed above can be considered as an efficient regulatory instrument supplementary to the tax rate policy. Given a pre-committed constant tax rate policy, it can efficiently encourage banks to renounce the adoption of a risky balance sheet caused by the moral hazard that is present when conditions (5.14) and (5.20) hold while ensuring that no bailout through a tax reduction is necessary.

In some circumstances, decreasing the tax rate is superior to public lending. Notably, when condition (5.14) is not verified, a pre-committed bailout through reducing the tax rate in the adverse state is social-welfare-improving, while the one through public lending with an interest rate in the interval $R^p \in [\frac{\rho_1 - \rho_0}{\beta + \hat{\tau}}, \frac{\rho_1 - \rho_0}{1 - \rho_0}]$ will depress the investment to an inefficient scale and hence the social welfare to a lower level.[86] As a result, a bailout through public lending cannot replace the role of a fiscal bailout through tax reduction. However, it remains an effective tool for fighting the banking crisis and can be used to avoid the time-consistency problem of the pre-committed tax rate policy caused by the moral hazard in the banking sector.

5.6 Conclusion

In this chapter, we have studied several issues related to fiscal policy responses to banking crises in a country without monetary sovereignty, such as a member state of the Eurozone. Such fiscal responses could be conceived as a strategic regulation, which might be more efficient in stabilizing the banking sector than incremental regulation rules (i.e., leverage and liquidity ratios). This is because the latter concentrate on lowering the likelihood of bank failures but fail to take account of their own impact on social welfare.

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[86] When (C2) is not satisfied, we have $W^c(\hat{\tau}, \Delta_2) > W \mid_{\tau = \hat{\tau}}$. The public lending with $R^p \in [\frac{\rho_1 - \rho_0}{\beta + \hat{\tau}}, \frac{\rho_1 - \rho_0}{1 - \rho_0}]$ means that banks will set the leverage ratio corresponding to $\tau = \hat{\tau}$. Consequently, the social welfare realized under the committed tax rate reduction is $W^c(\hat{\tau}, \Delta_2)$, which is higher than the welfare under the committed public lending $W \mid_{\tau = \hat{\tau}}$.

When the fiscal (including bailout) policy is discretionary, incremental regulatory rules become problematic since they are reduced to 'soft' constraints on banks' balance sheet. The credibility and efficiency of these rules depend largely on the expectations of banking entrepreneurs about the government's crisis resolution arrangements. A bank keeping a high liquidity reserve ratio in the normal state could suffer a large liquidity shortage in the adverse state if the government does not carry out the large fiscal bailout expected by banking entrepreneurs subject to moral hazard. Contrariwise, given that the taxation can affect banks' choices of leverage and liquidity ratios simultaneously, an appropriately conceived pre-committed fiscal policy can restrain the riskiness of banks' balance sheet and minimize the social cost of a banking crisis. This kind of strategic regulation creates incentives for banking entrepreneurs to adopt a safe balance sheet to reduce the likelihood of insolvency, a goal that incremental rules also seek to achieve.

The optimal design of the fiscal policy depends on the structural parameters of the economy, in particular the weight of the banking sector. The optimal fiscal policy, by reinforcing the influence of the banking sector on the government's bailout decisions, induces lower social welfare under discretion than under commitment. Moreover, under commitment, the fiscal policy increases the threshold for the weight of the banking sector over which the government will conduct a bailout and thus contributes to reducing the excessive risk-taking and hence the moral hazard problems in the banking sector compared with the discretionary solution.

To deal with the potential moral hazard problems, we suggest that a pre-committed tax rate policy should be associated with a pre-committed bailout through public lending. The latter is complementary to the time-consistent tax rate policy and is destined to avoid the inefficient tax rate reduction caused by the moral hazard in the banking sector. Considering that the interest rate on public lending should be set in such a way as to improve the social welfare, we have shown that it must not be exceedingly high. Otherwise, public lending will be ineffective in dealing with

the banking crisis.

Our results imply that a credibly pre-committed fiscal policy embodying appropriately defined crisis resolution arrangements (including pre-committed fiscal bailouts and public lending) could be an efficient macro-prudential instrument in the sense that it discourages the moral hazard and the excessive risk-taking of the banking sector. It could lower the social cost of a banking crisis, even when risky assets are highly attractive. Using the fiscal policy as a strategic regulation tool could help to avoid the repetition of the Eurozone crisis, and as such its member states should reconsider the conception of their fiscal policies in relation to the micro- and macro-prudential financial regulation following the introduction of Basle III. A new fiscal policy conceived along the line discussed in this chapter could remediate the lacunae of these financial regulations by reinforcing the latter's capability to fight excessive risk-taking in the banking sector subject to moral hazard problems.

Chapter 6 Conclusion

This Ph. D. thesis has been written during the evolution of the persistent Eurozone crisis, and has focused on the deployment of fiscal policy management by national governments without monetary policy tools. The four theoretical models developed in this thesis permit a deep understanding of the genesis and the long-lasting of the twin banking and sovereign debt crises that were 'unexpected' by the policymakers when envisioning and constructing the monetary union. Chapter 2 depicted the financial crisis which occurred in 2008 in small European economies outside the EMU in order to highlight the distinctive features of the Eurozone crisis by making a tangible comparison. Chapters 3, 4 and 5 underlined the interlock between banking fragility, activity contraction and budgetary vulnerability as well as the role of the national government in supervising and guaranteeing its banking system.

6.1   Summary

The main results of this thesis can be summarized as follows:

(i) The financial crises prevailing in small economies outside the monetary union underline the connection between banking and currency crises. Howbeit, crises spreading in member states of a monetary union highlight the inherent link between banking fragility and budgetary vulnerability.

(ii) While having practiced financial institutions and stable macro-environment relative to that of emerging economies, Eurozone countries have experienced severe dysfunctions in their financial markets during the recent global crisis. Our analysis, through examining the functioning of the interbank market, shows that market discipline is more appropriate for covering the predictable idiosyncratic risk confronted by individual banks than for alleviating the aggregate risk encountered by the banking sector as a whole. The financial market, while strengthening the link between banks in normal times, can be a channel of contagion and induce a systemic crisis in

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difficult times.

(iii) Implementing more restrictive prudential regulations than market discipline could generally improve banks' resilience to shocks, although it could hamper the effectiveness of banks as financial intermediaries. Also, the cross border holdings of overestimated sovereign debts by banks in the Eurozone could offset the positive effect of preventive regulations, while aggravating instead of mitigating banks' liquidity condition, following the onset of twin crises. We suggest that, given the absence of ECBs' lender of last resort obligation, a credible crisis response by the fiscal authority would be an indispensable measure in maintaining confidence among market participants and normal conditions in the financial system.

(iv) Through exploring the link between the banking sector, the real economy and government budgets, we show that the banking crisis decreases fiscal revenue, and the depreciation of government bonds weakens banks' balance sheets and worsens banks' borrowing terms due to the tarnished reputation of national governments Therefore, a fiscal bailout can be efficient if the rescue package is adequate relative to the scale of crisis and if there is no concern about sovereign default while the government loads on more debt during its intervention. Otherwise, the upward expectation of sovereign default not only undermines banks' balance sheets, but also burdens the cost of the bailout package considerably. In addition, our model shows that successive waves of sovereign downgrade by credit rating agencies can contribute to the crystallization of self-fulfilling sovereign debt crisis as bonds yields surge when a sovereign default is anticipated.

(v) Our models show that the integration of the Eurozone financial system, characterized by banking sectors' massive intra-zone cross border bond holdings, magnifies the risk of contagion between member states. This is the major concern of policymakers in the fear of the exposure of core-Euro countries to Greek and other peripheral crisis-countries and the resulting threat to the entire monetary union. Our analysis indicates that the financial-fiscal interconnection associated

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with a lack of monetary policy tools can make the national banking regulation and guarantee virtually worthless. Therefore we consider crisis responses at a supranational level as essential measures for curbing a twin crisis in a member state and for preventing further contagion.

(vi) A bailout upon failure can give rise to moral hazard incentives for excessive risk-taking throughout banks' life-span. Through investigating the role of fiscal policy associated with an ex ante defined bailout plan, we suggest that such a time-consistent prudential policy can incite banks to voluntarily keep a safer balance sheet, and reduce the frequency and the cost of a crisis. We advance that a well-conceived committed fiscal policy, when affiliated with previously conceived bailout plan, can contribute to preventing the recurrence of twin banking and sovereign debt crises, particularly for the member states of a monetary union.

6.2   Extensions

The EMU's initial architecture encouraged banks to flourish in an increasingly integrated financial system while leaving the crisis response to independent fiscal authorities. This inherent flaw has been revealed following the intertwining of sovereign debt and banking crises in the Euro-periphery countries. The sheer size of the Eurozone economy and the duration of the turbulence within it have made the Eurozone crisis the biggest threat to the global economy. Amid tremendous criticism of its lack of indispensable supranational intervention, the European Union adopted EU emergency measures (including EFSF initiated in 2010 and EFSM in 2011) and the ECB took several 'unconventional' monetary policy measures, such as LTROs and SMP in 2010. However, these measures were limited in time and scale failed to restore confidence and normal conditions in financial markets. It was not until September 2012 that the EU approved the establishment of a permanent bailout fund (ESM) and the ECB announced conditional but unlimited support (OMTs) for all member states involved in sovereign debt distress. The mitigation of the crisis since then has justified the criticism on EMU's original architecture.

To break the 'diabolic' loop between banks and sovereign crises in the Eurozone, and to

improve resilience to the recurrence of twin crises, several proposals, such as the taxation of financial institutions, the introduction of Euro-bonds, the implementation of a single supervisory mechanism or the establishment of a banking union, have been made. We consider the Eurozone crisis as the outcome of reckless government budget, fragile banking systems and the lack of supranational support. We argue that, for any fiscal coordination to be effective to break the existing pattern of financial-fiscal interaction in the monetary union, all member states should confirm the Excessive Deficits Procedure (EDP) prior to the buildup of a more centralized fiscal capacity. Only can the regulation by a responsible authority be credible and efficient in banking supervision and guarantees. Except for the last framework that investigates the positive effect of the financial transaction tax imposed by a budgetary prudential government, this thesis mainly focuses on the Eurozone crisis before 2012. The frameworks of chapters 3 and 4 could be extended to evaluate the potential effects of the above proposals and the evolution of the crisis after 2012. In addition, the models developed in this Ph. D thesis have examined the financial crisis and its contagious effects through the balance sheets of private banks within one country. Extending them into two-country models permits a better understanding of crisis situations in a monetary union having great heterogeneity amongst its member states.

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Appendix A Appendix of Chapter 3

A.1 Social transformation curve

Assume that all constraints bind and $l = 0$ at optimal, we have

$$K = \kappa A \tag{A.1}$$

$$\frac{B}{1 + r_{02}} + A = e + K \tag{A.2}$$

$$\lambda x + \pi\phi A = \frac{B}{1 + r_{12}} \tag{A.3}$$

$$(1 - \lambda)y + (1 - \tau)RK = (1 - \tau)RA \tag{A.4}$$

Using (A.2) and (A.3) to eliminate $\frac{B}{1+r_{02}}$ and using (A.1), we get

$$A = \frac{e - \lambda x}{1 - \kappa + \pi\phi} \tag{A.5}$$

Substituting $K = \kappa A$ and A defined by (A.5) into (A.4) and rearranging the terms yields the social transformation curve:

$$\frac{(1 - \kappa)(1 - \tau)R}{1 - \kappa + \pi\phi}\lambda x + (1 - \lambda)y = \frac{(1 - \kappa)(1 - \tau)R}{1 - \kappa + \pi\phi}e \equiv \Phi e \tag{A.6}$$

A.2 Optimal allocation of the representative bank

Given the capital stock is such that $K = \kappa A$, the maximization problem of the bank in the planning stage is:

$$Max\{E[\lambda u(x) + (1 - \lambda)u(y)]\} \tag{A.7}$$

Subject to

$$\frac{B}{1+r_{02}} + A = e + \kappa A \tag{A.8}$$

$$\lambda x + \pi \phi A \leq \frac{B}{1+r_{12}} + r_l^{np} l \tag{A.9}$$

$$(1-\lambda)y + (1-\tau)RK = (1-\tau)R(A-l) + (1+r_{12})\left(\frac{B}{1+r_{12}} + r_l^{np}l - \lambda x - \pi\phi A\right) \tag{A.10}$$

The lagrangian of this problem is:

$$
\begin{aligned}
L = \ & \lambda u(x) + (1-\lambda)u(y)] - \mu_1\left(\frac{B}{1+r_{02}} + A - e - \kappa A\right) - \mu_2\left(\lambda x + \pi\phi A - \frac{B}{1+r_{12}} - r_l^{np}l\right) \\
& - \mu_4\left[(1-\lambda)y + (1-\tau)RK - (1-\tau)R(A-l) - (1+r_{12})\left(\frac{B}{1+r_{12}} + r_l^{np}l - \lambda x - \pi\phi A\right)\right]
\end{aligned}
$$

The first-order conditions are:

$$\frac{\partial L}{\partial x} = 0 \implies \lambda u\prime(x) - \mu_4\lambda(1+r_{02}) - \mu_2\lambda = 0, \tag{A.11}$$

$$\frac{\partial L}{\partial y} = 0 \implies (1-\lambda)u\prime(y) - \mu_4(1-\lambda) = 0, \tag{A.12}$$

$$\frac{\partial L}{\partial A} = 0 \implies -\mu_1(1-\kappa) - \mu_2\pi\phi - \mu_4[(1-\tau)R\kappa + \pi\phi(1+r_{02}) - (1-\tau)R] = 0 \tag{A.13}$$

$$\frac{\partial L}{\partial B} = 0 \implies -\mu_1(1/(1+r_{02})) - \mu_2(-1/(1+r_{02}) + \mu_4 = 0, \tag{A.14}$$

$$\frac{\partial L}{\partial l} = \mu_2 r_l^{np} + \mu_4(1+r_{02})r_l^{np} - \mu_4(1-\tau)R < 0, \tag{A.15}$$

From (A.11) we obtain

$$u\prime(x) = \mu_2 + \mu_4(1+r_{02}) \tag{A.16}$$

From (A.12), we have:

$$\mu_4 = u\prime(y) \tag{A.17}$$

Substituting μ_4 given by (A.17) into (A.13) and (A.14), we have:

$$-\mu_1(1-\kappa) - \mu_2\pi\phi - u\prime(y)[(1-\tau)R\kappa + \pi\phi(1+r_{02}) - (1-\tau)R] = 0, \tag{A.18}$$

$$\mu_2 = \mu_1 - (1+r_{02})u\prime(y) \tag{A.19}$$

Substituting μ_2 given by (A.19) into (A.18) yields:

$$\mu_1 = -\frac{u'(y)(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi} \tag{A.20}$$

Using this result into (A.19)

$$\mu_2 = \frac{u'(y)(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi} - (1+r_{02})u\prime(y), \tag{A.21}$$

Using (A.21) and (A.17) yields

$$\frac{\partial L}{\partial l} = u'(y)(1-\tau)R\left(\frac{1-\kappa}{1-\kappa+\pi\phi}r_l^{np} - 1\right) < 0$$

Therefore, the value of l should be set to zero. Using (A.17) into (A.16), we obtain

$$\frac{u'(x)}{u'(y)} = \frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi} \tag{A.22}$$

Given the CRRA utility function and the condition (A.22), we can easily obtain the optimal

allocation between the patient and impatient depositors:

$$\widetilde{y} = \widetilde{x}\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right]^{\frac{1}{\sigma}} \tag{A.23}$$

$$\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\lambda\widetilde{x} + (1-\lambda)\widetilde{x}\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right]^{\frac{1}{\sigma}} = \Phi e \implies$$

$$\widetilde{x}\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\lambda + (1-\lambda)\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right]^{\frac{1}{\sigma}}\right] = \Phi e \implies$$

$$\lambda\widetilde{x} = \frac{\Phi e}{\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi} + \frac{(1-\lambda)}{\lambda}\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right]^{\frac{1}{\sigma}}\right]} \implies$$

$$\lambda\widetilde{x} = \frac{\Phi e}{\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\left[1 + \frac{(1-\lambda)}{\lambda}\left[\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right]^{\frac{1-\sigma}{\sigma}}\right]} \implies$$

$$\lambda\widetilde{x} = \theta e \tag{A.24}$$

where $\theta = \left[1 + \frac{(1-\lambda)}{\lambda}\Phi^{\frac{1-\sigma}{\sigma}}\right]$ .Using (A.24) into (A.6), we obtain

$$(1-\lambda)\widetilde{y} = (1-\theta)\Phi e \tag{A.25}$$

Substituting the solution of $\widetilde{x}$ given by (A.24) and B determined by (A.8) into (A.9) yield:

$$\theta e + \pi\phi A = e + \kappa A - A \implies$$

$$\tilde{A} = \frac{(1-\theta)e}{1-\kappa+\pi\phi}$$

Replace A by its optimal value into the condition (A.8), we obtain the optimal holding of the government bonds as

$$\frac{\widetilde{B}}{1+r_{12}} = e\frac{\pi\phi + \theta(1-\kappa)}{1-\kappa+\pi\phi}$$

A.3 The proofs showing that $\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi} > 1$ and that the capital ratio imposed by the IBM does not deprive banks' role as efficient financial intermediaries

A.3.1 Checking that $\frac{(1-\tau)R(1-\kappa^i)}{1-\kappa^i+\pi\phi} > 1$

The condition $(1-\tau)R - (1+\phi) > r_{02}$ shows that $(1-\tau)R - 1 > \phi$. we can verify if the following fraction if bigger than unit

$$\frac{(1-\tau)R(1-\kappa^i)}{1-\kappa^i+\pi\phi} > \frac{(1-\kappa^i)(1+\phi)}{1-\kappa^i+\pi\phi} = \frac{(1-\kappa^i)+\pi\phi-\pi\phi+(1-\kappa^i)\phi}{1-\kappa^i+\pi\phi} = 1 + \frac{1-\kappa^i+\pi}{1-\kappa^i+\pi\phi}\phi$$

Using the definition of capital ratio demanded by interbank market $\kappa^i = (1 - \pi)\phi$, it follows that $1 - \kappa^i + \pi = (1 - \pi)(1 - \phi) > 0$ and $1 - \kappa^i + \pi\phi$, we have thus

$$\frac{(1 - \tau)R(1 - \kappa^i)}{1 - \kappa^i + \pi\phi} > 1$$

This ensures the holding of the incentive constraint for the patient depositors $x < y$.

A.3.2   Checking conditions (3.13) and (3.14)

The domestic agents will agree to entrust resources to banks if the return from the deposit is no smaller than that from buying government bonds, i.e., the following condition must be satisfied

$$\frac{(1 - \tau)R(1 - \kappa^i)}{1 - \kappa^i + \pi\phi} \geq 1 + r_{02} \Longrightarrow$$

$$(1 - \tau)R(1 - \kappa^i) \geq 1 - \kappa^i + \pi\phi \Longrightarrow$$

$$(1 - \tau)R - \kappa^i(1 - \tau)R \leq (1 + \pi\phi)(1 + r_{02}) - \kappa^i(1 + r_{02}) \Longrightarrow$$

$$\kappa^i \leq \frac{(1 - \tau)R - (1 + \pi\phi)(1 + r_{02})}{(1 - \tau)R - (1 + r_{02})} \tag{A.26}$$

This leads to condition (3.14) in the main text.

The condition (3.14) gives the ceiling of the capital ratio beyond which banks can no longer absorb deposits.

We find the up-limit for ϕ such that (3.14) is verified. We assume that the minimal ratio applied by the interbank market, i.e., $\kappa^i = \frac{(1-\pi)\phi(1+r_{02})}{(1-\tau)R}$, satisfies the condition (3.14):

$$\frac{(1 + \pi)\phi(1 + r_{02})}{(1 - \tau)R} \leq \frac{(1 - \tau)R - (1 + \pi\phi)(1 + r_{02})}{(1 - \tau)R - (1 + r_{02})}$$

This is equivalent to

$$\phi \leq \frac{(1 - \tau)R}{(1 + r_{02})} \frac{(1 - \tau)R - (1 + r_{02})}{(1 - \tau)R - (1 + r_{02})(1 - \pi)}$$

$$\phi \le \frac{(1-\tau)R}{(1+r_{02})}\left[1 - \frac{\pi(1+r_{02})}{(1-\tau)R - (1+r_{02})(1-\pi)}\right]$$

This is the condition (3.15) in the main text.

A.4 Expressing the conditions for the existence of the bank run in terms of structural parameters

A.4.1 The condition for existence of run equilibrium for good banks

$$z_p^+ \equiv \widetilde{x} - \frac{\widetilde{B}}{1+r^*} - (1-\tau)r_l^p A > 0 \tag{A.27}$$

could be rearranged by using $\widetilde{x} = \frac{\theta e}{\lambda}$, $\tilde{A} = \frac{(1-\theta)e}{1-\kappa+\pi\phi}$ and $\widetilde{B} = \frac{(1+r^*)(\pi\phi+\theta(1-\kappa^i))e}{1-\kappa^i+\pi\phi}$ as follows:

$$
\begin{aligned}
z_p^+ &\equiv \frac{\theta e}{\lambda} - (1-\tau)r_l^p\frac{(1-\theta)e}{1-\kappa+\pi\phi} - \frac{(\pi\phi+\theta(1-\kappa^i))e}{1-\kappa^i+\pi\phi} > 0 \Longrightarrow & \text{(A.28)}\\
r_l^p &< \frac{\theta}{\lambda}\frac{1-\kappa^i+\pi\phi}{(1-\tau)(1-\theta)} - \frac{\pi\phi+\theta(1-\kappa^i)}{(1-\tau)(1-\theta)} \Longrightarrow \\
r_l^p &< \frac{(1-\lambda)\theta(1-\kappa^i+\pi\phi)}{\lambda(1-\tau)(1-\theta)} + \frac{\theta(1-\kappa^i+\pi\phi)}{(1-\tau)(1-\theta)} - \frac{\pi\phi+\theta(1-\kappa^i)}{(1-\tau)(1-\theta)} \Longrightarrow \\
r_l^p &< \frac{(1-\lambda)\theta(1-\kappa^i+\pi\phi)}{\lambda(1-\tau)(1-\theta)} + \frac{\theta(1-\kappa^i+\pi\phi) - \pi\phi - \theta(1-\kappa^i)}{(1-\tau)(1-\theta)} \Longrightarrow \\
r_l^p &< \frac{(1-\lambda)\theta(1-\kappa^i+\pi\phi)}{\lambda(1-\tau)(1-\theta)} - \frac{\pi\phi}{1-\tau} & \text{(A.29)}
\end{aligned}
$$

Using the distribution between $\widetilde{x}$ and $\widetilde{y}$, we obtain

$$
\begin{aligned}
\frac{\widetilde{x}}{\widetilde{y}} &= \Phi^{-\frac{1}{\sigma}} \Longrightarrow \\
\frac{\frac{\theta}{\lambda}e}{\frac{1-\theta}{1-\lambda}e} &= \Phi^{-\frac{1}{\sigma}} \Longrightarrow \\
\frac{1-\lambda}{\lambda} &= \frac{1-\theta}{\theta}\Phi^{\frac{\sigma-1}{\sigma}}
\end{aligned}
$$

Using this result into (A.29), we obtain

$$r_l^p < \frac{r_1^+}{1-\tau}$$

where $r_1^+ \equiv (1 - \kappa^i + \pi\phi)\Phi^{\frac{\sigma-1}{\sigma}} - \pi\phi$. This is the condition (3.22) in the main text.

We now verify if the condition $r_1^+ < 1$ is satisfied

$$(1 - \kappa^i + \pi\phi)\Phi^{\frac{\sigma-1}{\sigma}} - \pi\phi \quad < \quad 1 \Longrightarrow$$

$$\Phi^{\frac{\sigma-1}{\sigma}} \quad < \quad \frac{(1-\tau)R(1+\pi\phi)}{(1-\tau)R(1+\pi\phi) - (1+r^*)(1-\pi)}$$

Given that σ is within the unity and $\Phi^{\frac{\sigma-1}{\sigma}} < 1$, the above inequality is verified.

A.4.2 The condition for existence of run equilibrium for bad banks when loans is granted

$$z_i^+ \equiv \widetilde{x} - (1-\tau)r_l^{np}\widetilde{A}(1-k^i) - \frac{\widetilde{B}}{1+r^*} - \frac{(1-\tau)R}{1+r^*}k^i\widetilde{A} > 0$$

Proceeding as before, above condition is equivalent to

$$\frac{\theta e}{\lambda} - (1-\tau)r_l^{np}\frac{(1-\theta)e}{1-k^i+\pi\phi}(1-k^i) - e\frac{\pi\phi + \theta(1-k^i)}{1-k^i+\pi\phi} - \frac{(1-\tau)R}{1+r^*}k^i\frac{(1-\theta)e}{1-k^i+\pi\phi} \quad > \quad 0 \Longrightarrow$$

$$\frac{\theta}{\lambda}(1-k^i+\pi\phi) - \pi\phi - \theta(1-k^i) - (1-\tau)r_l^{np}(1-k^i)(1-\theta) - \frac{(1-\theta)(1-\tau)R}{1+r^*}k^i \quad > \quad 0 \Longrightarrow$$

$$(1-\tau)r_l^{np} < \frac{\frac{(1-\lambda)\theta}{\lambda}(1-k^i+\pi\phi) + \theta(1-k^i+\pi\phi) - [(1-k^i)\theta + \pi\phi] - \frac{(1-\theta)(1-\tau)R}{1+r^*}k^i}{(1-k^i)(1-\theta)}$$

Using $\frac{1-\lambda}{\lambda} = \frac{1-\theta}{\theta}\Phi^{\frac{\sigma-1}{\sigma}}$ into the above condition, we obtain

$$(1-\tau)r_l^{np} < \frac{(1-\theta)\Phi^{\frac{\sigma-1}{\sigma}}(1-k^i+\pi\phi) + \theta - \theta k^i + \theta\pi\phi - \pi\phi - \theta + \theta k^i - \frac{(1-\theta)(1-\tau)R}{1+r^*}k^i}{(1-k^i)(1-\theta)} \Longrightarrow$$

$$(1-\tau)r_l^{np} < \frac{\Phi^{\frac{\sigma-1}{\sigma}}(1-k^i+\pi\phi) - \pi\phi - \frac{(1-\tau)R}{1+r^*}k^i}{(1-k^i)}$$

Replacing κ^i by $\frac{(1+\pi)\phi(1+r^*)}{(1-\tau)R}$ into the last term of the numerator the above inequality, we have

$$r_l^{np} < \frac{r_2^+}{(1-\tau)}$$

where $r_2^+ \equiv \frac{\Phi^{\frac{\sigma-1}{\sigma}}(1-k^i+\pi\phi)-\phi}{(1-k^i)(1-\tau)}$.

Given that $r_1^+ \equiv (1 - \kappa^i + \pi\phi)\Phi^{\frac{\sigma-1}{\sigma}} - \pi\phi$, we can rewrite r_2^+ as follows

$$r_2^+ \equiv \frac{r_1^+ - \frac{(1-\tau)R}{1+r^*}\kappa^i}{(1-k^i)}$$

Replace κ^i by $\frac{(1+\pi)\phi(1+r^*)}{(1-\tau)R}$ into the numerator, the above equality is equal to

$$r_2^+ \equiv \frac{r_1^+ - (1-\pi)\phi}{(1-k^i)}$$

Since r_l^p and r_l^{np} are bound by unity and we must have $r_1^+ < 1$ and $\kappa^i < (1-\pi)\phi$, we have

$$r_1^+ > r_2^+$$

A.4.3 The capital ratio eliminating the run equilibrium for 'bad' banks

To obtain the capital ratio eliminating the run equilibrium for 'bad' banks, using (znpi-1) and the definition of r_2^+, we obtain:

$$r_l^{np} > \frac{1}{(1-k^i)(1-\tau)}\left[\Phi^{\frac{\sigma-1}{\sigma}}(1 - k^i + \pi\phi) - \phi\right] \tag{A.30}$$

Using $\Phi \equiv \frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}$ into the above inequality, we obtain

$$(1 - \kappa^i)(1-\tau)r_l^{np} > \left(\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right)^{\frac{\sigma-1}{\sigma}}(1 - k^i + \pi\phi) - \phi \implies$$

Solving

$$\Theta(\kappa) = (1-\kappa)(1-\tau)r_l^{np} - \left(\frac{(1-\tau)R(1-\kappa)}{1-\kappa+\pi\phi}\right)^{\frac{\sigma-1}{\sigma}}(1 - k^i + \pi\phi) + \phi \tag{A.31}$$

allows to determine the minimal capital sufficient to eliminate the run equilibrium.

Using (A.31) to find numerically the solution of κ^g and compared it with the value of $\overline{\kappa}$, we obtain the following table

We have for these parameters values $\kappa^g > \overline{\kappa}$.

A.5 Banks' loss from the depreciation of foreign bonds

$$l(\varrho) = \frac{\eta \widetilde{B}}{1+r^*} - \frac{\eta \widetilde{B}}{(1+r^*+\varrho)} \Rightarrow$$

$$l(\varrho) = \frac{\varrho \eta \widetilde{B}}{(1+r^*+\varrho)(1+r^*)}$$

A.5.1 Condition for the existence of run equilibrium for 'bad' banks in the foreign sovereign debt crisis

The liquidity position of 'bad' banks is certainly deteriorated by the depreciation of foreign bonds. The condition for the existence of the run equilibrium should take into account the direct and the indirect losses due to the foreign debt crisis. It is straightforward to see that the direct loss is induced by the depreciation of foreign bonds held by 'bad' banks taking a proportion π of all banks such as $\pi l(\varrho)$. And the indirect loss is made though the interbank market and is distinguished by two cases, i.e., $I^s > \mu$ and $I^s < \mu$. Clearly, $I^s > \mu$ means that the amount of the interbank loans is constrained by the value of collateral μ which implies that the liquidity gap is enlarged by $\pi \kappa^i \widetilde{A} \frac{(1-\tau)\delta}{1+r^*}$. Therefore, the condition of the existence of the run on 'bad' banks in such case is given by $\pi Z_{npf}^+ = \pi[Z_i^+ + l(\varrho) + \kappa^i \widetilde{A} \frac{(1-\tau)\delta}{1+r^*}] > 0 \implies Z_{npf}^+ = Z_i^+ + l(\varrho) + \kappa^i \widetilde{A} \frac{(1-\tau)\delta}{1+r^*} > 0$. For $I^s < \mu$, the indirect loss is driven by the scale of liquidity crunch in the interbank market and the amount of the interbank loans is decreased by $(1-\pi)l(\varrho)$. This implies that a part of assets initially designed to support the interbank lending is not anymore useful as collateral and the quantity of these assets is such that $\frac{(\mu-I^s)(1+r^*)}{(1-\tau)(R-\delta)}$. Note that the term $\mu - I^s$ stands for the value of redundant collateral due to the credit crunch. As $\mu - I^s$ is measured in terms of actualized price, it is divided by the collateral price $\frac{(1-\tau)(R-\delta)}{(1+r^*)}$ to obtain the quantity of excess collateral. 'Bad' banks will thus liquidate these assets at the fire sale price $(1-\tau)r_l^{np}$ and obtain $\frac{(\mu-I^s)(1+r^*)(1-\tau)r_l^{np}}{(1-\tau)(R-\delta)}$. Consequently, the condition for the existence of a run on 'bad' banks when $I^s < \mu$ can be written

as

$$\pi Z_{npf}^+ = \pi Z_i^+ + \pi l(\varrho) + (1-\pi)l(\varrho) - \frac{(\mu - I^s)(1+r^*)(1-\tau)r_l^{np}}{(1-\tau)(R-\delta)} > 0 \implies$$

$$Z_{npf}^+ = Z_i^+ + \frac{1}{\pi}[l(\varrho) - \frac{(\mu - I^s)(1+r^*)(1-\tau)r_l^{np}}{(1-\tau)(R-\delta)}] > 0$$

A.6   Gambling asset

$$\vartheta(1-\tau)R[(1-\tau)(1-\kappa^i)\psi A r_l^{np} + \psi \frac{(1-\tau)R\kappa^i A}{(1+r^*)} - \kappa^i A - \frac{(1-\lambda)y}{(1-\tau)R}] > (K-\kappa^i A)(1-\tau)R \quad \text{(A.32)}$$

Using $(1-\lambda)y = A(1-\tau)(1-\kappa^i)R$ and $\kappa^i = \frac{(1-\pi)\phi(1+r^*)}{(1-\tau)R}$ and the fact that $K - \kappa^i A = 0$,

(A.32) is equivalent to

$$\psi(1-\tau)(1-\kappa^i)r_l^{np} + \psi \frac{(1-\tau)R\kappa^i A}{(1+r^*)} - 1 > 0 \implies$$

$$r_l^{np} > \frac{1 - \psi \frac{(1-\tau)R\kappa^i A}{(1+r^*)}}{\psi(1-\tau)(1-\kappa^i)}$$

$$r_l^{np} > \frac{r_3^+}{(1-\tau)}$$

where $r_3^+ \equiv \frac{1-(1-\pi)\phi\psi}{\psi(1-\kappa^i)}$. Provided the definition of κ^i, we obtain directly $\kappa^i < (1-\pi)\phi$, which

ensures that $r_3^+ < 1$.

A.7   Demonstration of r_4^+

$$\vartheta(1-\tau)R[(1-\tau)(1-\kappa^i)\psi A r_l^{np} + \psi \frac{(1-\tau)R\kappa^i A}{(1+r^*)} - \frac{\kappa^i A}{\vartheta} - \frac{(1-\lambda)y}{(1-\tau)R}] > 0 \implies$$

$$r_l^{np} > \frac{\kappa^i + (\vartheta - \vartheta\kappa^i) - \vartheta\psi(1-\pi)\phi}{\vartheta\psi(1-\tau)(1-\kappa^i)} \implies$$

$$r_l^{np} > \frac{\vartheta + \kappa^i(1-\vartheta) - \vartheta\psi(1-\pi)\phi}{\vartheta\psi(1-\tau)(1-\kappa^i)} \equiv r_4^+$$

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A.7.1 Comparing r_4^+ with r_3^+

$$\frac{\vartheta + \kappa^i(1-\vartheta) - \vartheta\psi(1-\pi)\phi}{\vartheta\psi(1-\tau)(1-\kappa^i)} \; > \; 1 - \psi(1-\pi)\phi \implies$$

$$1 - \psi(1-\pi)\phi + \frac{1-\vartheta}{\vartheta}\kappa^i \; > \; 1 - \psi(1-\pi)\phi$$

Consequently, the condition $r_4^+ > r_3^+$ is verified.

A.8 Prevention of gambling behaviors by a penalty tax

Taking account of a penalty tax at the rate τ^p, the gain of 'bad' banks from the gambling asset given at the left-hand side of (A.32) is modified , with $K - \kappa^i A = 0$, as:

$$\vartheta(1-\tau-\tau^p)R[(1-\tau)(1-\kappa^i)\psi Ar_l^{np} + \psi\frac{(1-\tau)R\kappa^i A}{(1+r^*)}] - \vartheta[(1-\tau)R\kappa^i A - (1-\lambda)y] < 0 \quad \text{(A.33)}$$

Using $(1-\lambda)y = A(1-\tau)(1-\kappa^i)R$ and $\kappa^i = \frac{(1-\pi)\phi(1+r^*)}{(1-\tau)R}$, (A.33) is equivalent to

$$(1-\tau-\tau^p)R\psi[(1-\tau)(1-\kappa^i)r_l^{np} + \frac{(1-\tau)R\kappa^i}{(1+r^*)}] - (1-\tau)R < 0$$

Replacing $\frac{(1-\tau)R\kappa^i}{(1+r^*)}$ by $(1-\pi)\phi$, we can rewrite the above inequality as

$$\tau^p \; > \; \frac{(1-\tau)R[\psi[(1-\tau)(1-\kappa^i)r_l^{np} + \psi(1-\pi)\phi - 1]}{\psi[(1-\tau)(1-\kappa^i)r_l^{np} + \psi(1-\pi)\phi} \implies$$

$$\tau^p \; > \; (1-\tau)[1 - \frac{1}{\psi[(1-\tau)(1-\kappa^i)r_l^{np} + \psi(1-\pi)\phi}]$$

Appendix B Appendix of chapter 4

Expected utility:

$$\lambda U(x) + (1 - \lambda)U(y) \tag{B.1}$$

with $U(c) = c^{1-\sigma}/(1-\sigma)$

Constraints:

$$A + K + \frac{B_{02}^d}{1 + r_{02}^d} + \frac{B_{02}^f}{1 + r_{02}^f} = e + f_0,$$

$$f_0 \leq f, \qquad f_1 \leq f,$$

$$\frac{B_{02}^d}{1 + r_{02}^d} + \frac{B_{02}^f}{1 + r_{02}^f} \geq \alpha(e + f_0),$$

$$\lambda x + \mathbb{I}_c(1 - \lambda)x + f_0 \leq (1 - \tau)R_s A + f_1 + (1 - \tau)R_l l + \mathbb{I}_c \left(\frac{B_{02}^d}{1 + r_{12}^d} + \frac{B_{02}^f}{1 + r_{12}^f} \right),$$

$$(1 - \mathbb{I}_c)(1 - \lambda)y + R^* f_1 = (1 - \tau)R_h(K - l) + (1 - \mathbb{I}_c) \left(B_{02}^d + B_{02}^f \right).$$

B.1 Optimum

The optimum allocation is obtained when there is no bank run in stage 1 ($\mathbb{I}_c = 0$). The discount rates on government bonds at the planning stage are equal to the international interest rate: $r_{02}^d = r_{02}^f = r^*$. Moreover, without banking crisis threat, no long-run investment projects are restructured, $\widetilde{l}(\alpha) = 0$, and all inequality constraints bind. We obtain:

$$\widetilde{A}(\alpha) + \widetilde{K}(\alpha) + \frac{\widetilde{B}^*(\alpha)}{R^*} = e + f, \tag{B.2}$$

$$\widetilde{f}_0 = \widetilde{f}_1 = f, \tag{B.3}$$

$$\frac{\widetilde{B}^*(\alpha)}{R^*} = \alpha(e + f), \tag{B.4}$$

$$\lambda \widetilde{x}(\alpha) = (1 - \tau)R_s \widetilde{A}(\alpha), \tag{B.5}$$

$$(1 - \lambda)\widetilde{y}(\alpha) = (1 - \tau)R_h \widetilde{K}(\alpha) + \widetilde{B}^*(\alpha) - R^* f, \tag{B.6}$$

from which we can deduce:

$$\frac{R_h}{R_s}\lambda\widetilde{x}(\alpha) + (1-\lambda)\widetilde{y}(\alpha) = (1-\tau)R_h\left(\widetilde{A}(\alpha) + \widetilde{K}(\alpha)\right) - R^*f$$

$$= (1-\tau)R_h\,(e+f) - R^*f - \alpha\,(e+f)\,((1-\tau)R_h - R^*)$$

$$\equiv v_0 - \alpha\,(e+f)\,((1-\tau)R_h - R^*) \equiv v(\alpha). \tag{B.7}$$

where $v_0 \equiv (1-\tau)R_h\,(e+f) - R^*f$.

The maximization of (B.1) subject to $(B.7)$ leads to

$$\frac{\widetilde{y}}{\widetilde{x}} = \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} \tag{B.8}$$

The truth-telling condition $R^*\widetilde{x} < \widetilde{y}$ then requires:

$$R^* < \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} \tag{B.9}$$

Combining $(B.7)$ and $(B.8)$, we obtain:

$$\lambda\widetilde{x}\,(\alpha) = \theta\frac{R_s}{R_h}v\,(\alpha), \tag{B.10}$$

$$(1-\lambda)\widetilde{y}\,(\alpha) = (1-\theta)v\,(\alpha), \tag{B.11}$$

where $\theta \equiv \left[1 + (1-\lambda)/\lambda\,(R_h/R_s)^{(1-\sigma)/\sigma}\right]^{-1}$ is a coefficient in the unit interval. Using $(B.2)$, $(B.5)$ and $(B.6)$, we also obtain:

$$\widetilde{B}^*(\alpha) = \alpha(e+f)R^*, \tag{B.12}$$

$$\widetilde{A}\,(\alpha) = \frac{\lambda\widetilde{x}(\alpha)}{(1-\tau)R_s}$$

$$= \frac{\theta}{(1-\tau)R_h}v\,(\alpha), \tag{B.13}$$

$$\widetilde{K}\,(\alpha) = e+f - \widetilde{A}(\alpha) - \frac{\widetilde{B}^*(\alpha)}{R^*}$$

$$= (1-\alpha)\,(e+f) - \frac{\theta}{(1-\tau)R_h}v\,(\alpha). \tag{B.14}$$

The constraint $\widetilde{K}\,(\alpha) \geq 0$ implies a maximal intensity of liquidity regulation $\overline{\alpha}$, obtained when

$\widetilde{K}(\overline{\alpha}) = 0$, i.e., when

$$
\begin{aligned}
(1-\overline{\alpha})(e+f) &= \frac{\theta}{(1-\tau)R_h}v(\overline{\alpha}) \\
&= \frac{\theta}{(1-\tau)R_h}\left[\begin{array}{c} (1-\tau)R_h(e+f) - R^*f \\ -\overline{\alpha}(e+f)((1-\tau)R_h - R^*) \end{array} \right].
\end{aligned}
\tag{B.15}
$$

Factorizing the terms in $\overline{\alpha}$ and simplifying, we obtain:

$$
\overline{\alpha} = \frac{(1-\theta)(1-\tau)R_h(e+f) + \theta R^*f}{(1-\theta)(1-\tau)R_h(e+f) + \theta R^*(e+f)} \in (0,1).
\tag{B.16}
$$

B.2 Bank run equilibrium and liquidity regulation: no sovereign debt crisis

Observe from (B.8) and (B.11) that

$$
(1-\lambda)\widetilde{y}(\alpha) = \frac{R_h}{r^+}(1-\lambda)\widetilde{x}(\alpha) = (1-\theta)v(\alpha),
\tag{B.17}
$$

where

$$
r^+ \equiv (R_h)^{\frac{\sigma-1}{\sigma}}(R_s)^{\frac{1}{\sigma}} = \frac{R_h}{\left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}}.
\tag{B.18}
$$

B.2.1 Bank run equilibrium: no sudden-stop situation

When banks can credibly commit to repay their external debt R^*f under any circumstances, the maximum amount of liquidated projects consistent with repayment of international debt is (using (B.4), (B.6) and (B.11)):

$$
\begin{aligned}
l_1^+(\alpha) &= \widetilde{K}(\alpha) - \frac{R^*f}{(1-\tau)R_h} \\
&= \frac{(1-\lambda)\widetilde{y}(\alpha) - \alpha(e+f)R^* + R^*f}{(1-\tau)R_h} - \frac{R^*f}{(1-\tau)R_h} \\
&= \frac{(1-\theta)v(\alpha) - \alpha(e+f)R^*}{(1-\tau)R_h}.
\end{aligned}
\tag{B.19}
$$

A run equilibrium ($\mathbb{I}_c = 1$) with rollover of external debt ($f_1 = f$) exists as soon as

$z_1^+(\alpha, R^*) > 0$, where (using (B.4)–(B.5), (B.17) and (B.19)):

$$
\begin{aligned}
z_1^+(\alpha, R^*) &\equiv \widetilde{x}(\alpha) - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l l_1^+(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R^*} \\
&= (1-\lambda)\widetilde{x}(\alpha) - (1-\tau)R_l l_1^+(\alpha) - \alpha(e+f) \\
&= (1-\lambda)\widetilde{x}(\alpha) - \frac{R_l}{R_h}\left[(1-\theta)v(\alpha) - \alpha(e+f)R^*\right] - \alpha(e+f) \\
&= (r^+ - R_l)\frac{(1-\theta)v(\alpha)}{R_h} - \alpha(e+f)\left(1 - \frac{R^*R_l}{R_h}\right).
\end{aligned}
\tag{B.20}
$$

The unregulated economy is obtained by setting $\alpha = 0$:

$$
z_1^+ = (r^+ - R_l)\frac{(1-\theta)v_0}{R_h},
\tag{B.21}
$$

so that

$$
z_1^+ > 0 \quad \Leftrightarrow \quad R_l < r^+.
\tag{B.22}
$$

Note that the truth-telling condition (B.9) implies an upper bound on the threshold r^+:

$$
R^* < \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} \Rightarrow r^+ < R^h/R^*.
\tag{B.23}
$$

In the regulated economy, combining (B.20) and (B.21), we obtain:

$$
z_1^+(\alpha, R^*) = z_1^+ - \underbrace{(r^+ - R_l)\frac{(1-\theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e+f)\left(1 - \frac{R^*R_l}{R_h}\right)}_{>0},
\tag{B.24}
$$

where $v_0 - v(\alpha) > 0$, showing that $z_1^+(\alpha, R^*) < z_1^+$ for any $\alpha > 0$.[87]

Moreover, the condition of existence of a run equilibrium, $z_1^+(\alpha, R^*) > 0$, can be expressed, using (B.20), as:

$$
r^+(1-\theta)v(\alpha) - \alpha(e+f)R_h > R_l\left[(1-\theta)v(\alpha) - \alpha(e+f)R^*\right]
$$

$$
\Leftrightarrow R_l < \frac{r^+ - \Theta_1(\alpha)R_h}{1 - \Theta_1(\alpha)R^*} \equiv r_1^+(\alpha, R^*),
\tag{B.25}
$$

where $\Theta_1(\alpha) \equiv \alpha(e+f)/\left((1-\theta)v(\alpha)\right)$.

---

[87] We are obviously assuming here that $R_l < r^+$. If $R_l > r^+$, there is no banking crisis equilibrium and thus no need for a liquidity regulation.

Note that:

$$\Theta_1'(\alpha) = \frac{(e+f)\left[v(\alpha) - \alpha v'(\alpha)\right]}{(1-\theta)v(\alpha)^2}$$
$$= \frac{(e+f)v_0}{(1-\theta)v(\alpha)^2} > 0.$$

Thus:

$$sign\left(\frac{\partial \overline{r}_1^+(\alpha, R^*)}{\partial \alpha}\right) = sign\left(\begin{array}{c} -\left(1 - \Theta_1(\alpha)R^*\right)\Theta_1'(\alpha)R_h \\ +\left(r^+ - \Theta_1(\alpha)R_h\right)\Theta_1'(\alpha)R^* \end{array}\right)$$
$$= sign\left(-\Theta_1'(\alpha)R_h + r^+\Theta_1'(\alpha)R^*\right)$$
$$= sign\left(r^+R^* - R_h\right)$$
$$= sign\left(R^*\left(\frac{R_h}{R_s}\right)^{-\frac{1}{\sigma}} - 1\right)$$
$$= sign\left(R^* - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right) < 0.$$

Finally, we can prove that there exists an $\widetilde{\alpha}_1 \in (0, \overline{\alpha})$ such that $z_1^+(\alpha_1, R^*) < 0$ for any $\alpha \in (\widetilde{\alpha}_1, \overline{\alpha})$. Since $\partial \overline{r}_1^+(\alpha, R^*)/\partial \alpha > 0$, it is sufficient to prove that $z_1^+(\overline{\alpha}, R^*) < 0$. Remind from (B.23) that the truth-telling condition (B.9) implies $r^+ < R^h/R^*$. The worst possible situation is obtained when the threshold r^+ is the *largest*, i.e. when $r^+ \to R^h/R^*$. We now prove that $\lim_{r^+ \to R^h/R^*} z_1^+(\overline{\alpha}, R^*) < 0$.

Using (B.20), we derive:

$$\lim_{r^+ \to \frac{R^h}{R^*}} z_1^+(\overline{\alpha}, R^*) = \left(\frac{R^h}{R^*} - R_l\right)\frac{(1-\theta)v(\overline{\alpha})}{R_h} - \overline{\alpha}(e+f)\left(1 - \frac{R^*R_l}{R_h}\right)$$
$$= \left(\frac{R^h - R_lR^*}{R^*R_h}\right)\left((1-\theta)v(\overline{\alpha}) - \overline{\alpha}(e+f)R^*\right).$$

Since $v(\overline{\alpha}) = (1-\tau)R_h(1-\overline{\alpha})(e+f)/\theta$ (see (B.15)), we get:

$$sign\left(\lim_{r^+ \to \frac{R^h}{R^*}} z_1^+(\overline{\alpha}, R^*)\right) = sign\left((1-\theta)(1-\tau)R_h(1-\overline{\alpha}) - \overline{\alpha}\theta R^*\right)$$
$$= sign\left(\begin{array}{c}(1-\theta)(1-\tau)R_h \\ -\overline{\alpha}\left((1-\theta)(1-\tau)R_h + \theta R^*\right)\end{array}\right).$$

Using the formal expression for $\overline{\alpha}$ derived in (B.16), we get:

$$sign\left(\lim_{r^+ \to \frac{R^h}{R^*}^*} z_1^+(\overline{\alpha}, R^*)\right) = sign\left(-\frac{(1-\theta)(1-\tau)R_h}{\frac{(1-\theta)(1-\tau)R_h(e+f)+\theta R^* f}{(e+f)}}\right)$$

$$= sign\left(-\theta R^* f\right) < 0.$$

$$(QED)$$

B.2.2 Bank run equilibrium: sudden stop situation

When foreign debt is not rolled over, all long terms investment projects are liquidated $l_2^+(\alpha) = \widetilde{K}(\alpha)$. The maximum amount of liquidated projects consistent with repayment of international debt is (using (B.4), (B.6) and (B.11)):

$$l_2^+(\alpha) = \widetilde{K}(\alpha)$$

$$= \frac{(1-\lambda)\widetilde{y}(\alpha) - \alpha(e+f)R^* + R^*f}{(1-\tau)R_h}$$

$$= \frac{(1-\theta)\upsilon(\alpha) - \alpha(e+f)R^* + R^*f}{(1-\tau)R_h}. \tag{B.26}$$

A run equilibrium($\mathbb{I}_c = 1$) *without* rollover of external debt ($f_1 = 0$) exists as soon as $z_2^+(\alpha, R^*) > 0$, where (using (B.4)–(B.5), (B.17) and (B.26))

$$z_2^+(\alpha, R^*) \equiv \widetilde{x}(\alpha) + f - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l\widetilde{K}(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R^*}$$

$$= (1-\lambda)\widetilde{x}(\alpha) - (1-\tau)R_l\widetilde{K}(\alpha) - \alpha(e+f)$$

$$= (1-\lambda)\widetilde{x}(\alpha) - \frac{R_l}{R_h}[(1-\theta)\upsilon(\alpha) - \alpha(e+f)R^* + R^*f] - \alpha(e+f)$$

$$= (r^+ - R_l)\frac{(1-\theta)\upsilon(\alpha)}{R_h} + \left(1 - \frac{R^*R_l}{R_h}\right)f - \alpha(e+f)\left(1 - \frac{R^*R_l}{R_h}\right)$$

$$= z_1^+(\alpha, R^*) + \left(1 - \frac{R^*R_l}{R_h}\right)f, \tag{B.27}$$

showing that $z_2^+(\alpha, R^*) > z_1^+(\alpha, R^*)$.

The unregulated economy is obtained by setting $\alpha = 0$:

$$z_2^+ = (r^+ - R_l)\frac{(1-\theta)\upsilon_0}{R_h} + \left(1 - \frac{R^*R_l}{R_h}\right)f$$

$$= z_1^+ + \left(1 - \frac{R^*R_l}{R_h}\right)f. \tag{B.28}$$

and a run equilibrium exists as soon as $z_2^+ > 0$.

In the regulated economy, combining (B.27) and (B.28), we obtain:

$$z_2^+(\alpha, R^*) = z_2^+ - \underbrace{(r^+ - R_l)\frac{(1-\theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e+f)\left(1 - \frac{R^* R_l}{R_h}\right)}_{>0}, \tag{B.29}$$

where $v_0 - v(\alpha) > 0$, showing that $z_2^+(\alpha, R^*) < z_2^+$ for any $\alpha > 0$.

Moreover, the condition of existence of a run equilibrium, $z_2^+(\alpha, R^*) > 0$, can be expressed, using (B.27), as:

$$r^+(1-\theta)v(\alpha) + R_h f - \alpha(e+f)R_h > R_l\left[(1-\theta)v(\alpha) + R^* f - \alpha(e+f)R^*\right]$$

$$\Leftrightarrow R_l < \frac{r^+ - \Theta_2(\alpha)R_h}{1 - \Theta_2(\alpha)R^*} \equiv r_2^+(\alpha, R^*). \tag{B.30}$$

with $\Theta_2(\alpha) \equiv (\alpha(e+f) - f)/(1-\theta)v(\alpha)$.

Note that:

$$
\begin{aligned}
\Theta_2'(\alpha) &= \frac{(e+f)\left[v(\alpha) - \alpha v'(\alpha)\right] + f v'(\alpha)}{(1-\theta)v(\alpha)^2} \\
&= \frac{(e+f)v_0 - (e+f)\left((1-\tau)R_h - R^*\right)f}{(1-\theta)v(\alpha)^2} \\
&= \frac{(e+f)\left[(1-\tau)R_h(e+f) - R^* f - \left((1-\tau)R_h - R^*\right)f\right]}{(1-\theta)v(\alpha)^2} \\
&= \frac{(e+f)(1-\tau)R_h e}{(1-\theta)v(\alpha)^2} > 0.
\end{aligned}
$$

Thus:

$$
\begin{aligned}
sign\left(\frac{\partial \bar{r}_2^+(\alpha, R^*)}{\partial \alpha}\right) &= sign\left(\begin{array}{c} -(1 - \Theta_2(\alpha)R^*)\Theta_2'(\alpha)R_h \\ + (r^+ - \Theta_2(\alpha)R_h)\Theta_2'(\alpha)R^* \end{array}\right) \\
&= sign\left(-\Theta_2'(\alpha)R_h + r^+\Theta_2'(\alpha)R^*\right) \\
&= sign\left(r^+ R^* - R_h\right) \\
&= sign\left(R^*\left(\frac{R_h}{R_s}\right)^{-\frac{1}{\sigma}} - 1\right) \\
&= sign\left(R^* - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right) < 0.
\end{aligned}
$$

As in the no-sudden stop situation, we can now prove that there exists an $\widetilde{\alpha}_2 \in (0, \overline{\alpha})$ such that $z_2^+(\alpha_2, R^*) < 0$ for any $\alpha \in (\widetilde{\alpha}_2, \overline{\alpha})$. Since $\partial \bar{r}_2^+(\alpha, R^*)/\partial \alpha > 0$, it is sufficient to

prove that $z_2^+(\overline{\alpha}, R^*) < 0$. Remind from (B.23) that the truth-telling condition (B.9) implies $r^+ < R^h/R^*$. The worst possible situation is obtained when the threshold r^+ is the largest, i.e. when $r^+ \to R^h/R^*$. We actually prove that $\lim_{r^+ \to R^h/R^*} z_2^+(\overline{\alpha}, R^*) = 0$ in this worst-case scenario.

Using (B.27), we derive:

$$
\begin{aligned}
\lim_{r^+ \to \frac{R^h}{R^*}} z_2^+(\overline{\alpha}, R^*) &= \left(\frac{R^h}{R^*} - R_l\right) \frac{(1-\theta)v(\overline{\alpha})}{R_h} + \left(1 - \frac{R^* R_l}{R_h}\right) f \\
&\quad -\overline{\alpha}(e+f)\left(1 - \frac{R^* R_l}{R_h}\right) \\
&= \left(\frac{R^h - R_l R^*}{R^* R_h}\right)\left((1-\theta)v(\overline{\alpha}) + fR^* - \overline{\alpha}(e+f)R^*\right).
\end{aligned}
$$

Since $v(\overline{\alpha}) = (1-\tau)R_h(1-\overline{\alpha})(e+f)/\theta$ (see (B.15)), we get:

$$
\begin{aligned}
sign\left(\lim_{r^+ \to \frac{R^h}{R^*}} z_2^+(\overline{\alpha}, R^*)\right) &= sign\left(\begin{array}{c} (1-\theta)(1-\tau)R_h(1-\overline{\alpha})(e+f) \\ +\theta fR^* - \overline{\alpha}(e+f)\theta R^* \end{array}\right) \\
&= sign\left(\begin{array}{c} (1-\theta)(1-\tau)R_h(e+f) + \theta fR^* \\ -\overline{\alpha}\left((1-\theta)(1-\tau)R_h(e+f) + \theta R^*(e+f)\right) \end{array}\right).
\end{aligned}
$$

Using the formal expression for $\overline{\alpha}$ derived in (B.16), we get:

$$
\begin{aligned}
sign\left(\lim_{r^+ \to \frac{R^h}{R^*}} z_2^+(\overline{\alpha}, R^*)\right) &= sign\left(\begin{array}{c} (1-\theta)(1-\tau)R_h(e+f) + \theta fR^* \\ -\left((1-\theta)(1-\tau)R_h(e+f) + \theta fR^*\right) \end{array}\right) \\
&= 0.
\end{aligned}
$$

$$(QED)$$

B.3 Twin banking and sovereign debt crisis

B.3.1 No sudden stop situation

When the discount factor on sovereign bonds jumps to $R_{12}^{g_f} > R^*$, the illiquidity index is:

$$
\begin{aligned}
z_1^+(\alpha, R_{12}^{g_f}) &\equiv \widetilde{x}(\alpha) - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l l_1^+(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R_{12}^{g_f}} \\
&= \underbrace{\widetilde{x}(\alpha) - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l l_1^+(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R^*}}_{=z_1^+(\alpha, R^*)} + \frac{\widetilde{B}(\alpha)}{R^*} - \frac{\widetilde{B}(\alpha)}{R_{12}^{g_f}} \\
&= z_1^+(\alpha, R^*) + \underbrace{\alpha(e+f)\left(1 - \frac{R^*}{R_{12}^{g_f}}\right)}_{>0}, \quad\quad (B.31)
\end{aligned}
$$

showing that $z_1^+(\alpha, R_{12}^{g_f}) > z_1^+(\alpha, R^*)$.

The condition of existence of a run equilibrium, $z_1^+(\alpha, R_{12}^{g_f}) > 0$, can be expressed, using (B.20), as:

$$r^+(1-\theta)\upsilon(\alpha) - \alpha(e+f)R_h + \alpha(e+f)R_h\left(1 - \frac{R^*}{R_{12}^{g_f}}\right) > R_l\left[(1-\theta)\upsilon(\alpha) - \alpha(e+f)R^*\right]$$

$$\Leftrightarrow R_l < \frac{r^+ - \Theta_1(\alpha)\left(\frac{R_h R^*}{R_{12}^{g_f}}\right)}{1 - \Theta_1(\alpha)R^*} \equiv r_1^+(\alpha, R_{12}^{g_f}),$$

where $\Theta_1(\alpha) \equiv \alpha(e+f)/\left((1-\theta)\upsilon(\alpha)\right)$ and $\Theta_1'(\alpha) > 0$ (as shown above).

Using the same calculation as above, but replacing R_h with $R_h R^*/R_{12}^{g_f}$, we obtain:

$$sign\left(\frac{\partial \overline{r}_1^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign\left(r^+ R^* - \frac{R_h R^*}{R_{12}^{g_f}}\right)$$

$$= sign\left(\left(\frac{R_h}{R_s}\right)^{-\frac{1}{\sigma}} - \frac{1}{R_{12}^{g_f}}\right)$$

$$= sign\left(R_{12}^{g_f} - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right).$$

B.3.2   Sudden stop situation

When the discount factor on sovereign bonds jumps to $R_{12}^{g_f} > R^*$, the illiquidity index in the sudden stop situation is:

$$z_2^+(\alpha, R_{12}^{g_f}) \equiv \widetilde{x}(\alpha) + f - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l\widetilde{K}(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R_{12}^{g_f}}$$

$$= \underbrace{\widetilde{x}(\alpha) + f - (1-\tau)\left(R_s\widetilde{A}(\alpha) + R_l\widetilde{K}(\alpha)\right) - \frac{\widetilde{B}(\alpha)}{R^*}}_{=z_2^+(\alpha, R^*)} + \frac{\widetilde{B}(\alpha)}{R^*} - \frac{\widetilde{B}(\alpha)}{R_{12}^{g_f}}$$

$$= z_2^+(\alpha, R^*) + \underbrace{\alpha(e+f)\left(1 - \frac{R^*}{R_{12}^{g_f}}\right)}_{>0}, \tag{B.32}$$

showing that $z_2^+(\alpha, R_{12}^{g_f}) > z_2^+(\alpha, R^*)$.

The condition of existence of a run equilibrium $z_2^+(\alpha, R_{12}^{g_f}) > 0$ can be expressed as:

$R_l < r_2^+(\alpha, R_{12}^{g_f})$, where $r_2^+(\alpha, R_{12}^{g_f})$ satisfies (using (B.27)):

$$r_2^+(\alpha, R_{12}^{g_f}) = \frac{r^+(1-\theta)\upsilon(\alpha) + R_h f - \alpha(e+f)\frac{R_h R^*}{R_{12}^{g_f}}}{(1-\theta)\upsilon(\alpha) + R^* f - \alpha(e+f)R^*}.$$

Deriving the sign of $\partial \bar{r}_2^+(\alpha, R_{12}^{g_f})/\partial \alpha$ is a little more tricky in this case. We have:

$$sign\left(\frac{\partial \bar{r}_2^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign \left(\begin{array}{c} [(1-\theta)v(\alpha) + R^*f - \alpha(e+f)R^*] \\ * \left[r^+(1-\theta)v'(\alpha) - (e+f)\frac{R_h R^*}{R_{12}^{g_f}}\right] \\ - \left[r^+(1-\theta)v(\alpha) + R_h f - \alpha(e+f)\frac{R_h R^*}{R_{12}^{g_f}}\right] \\ * [(1-\theta)v'(\alpha) - (e+f)R^*] \end{array} \right)$$

$$= sign \left(\begin{array}{c} (1-\theta)\left[v(\alpha) - \alpha v'(\alpha)\right](e+f)\left[r^+R^* - \frac{R_h R^*}{R_{12}^{g_f}}\right] \\ +(1-\theta)v'(\alpha)f\left[r^+R^* - R_h\right] \\ +R_h R^* f(e+f)\left(1 - \frac{R^*}{R_{12}^{g_f}}\right) \end{array} \right).$$

Observing that $v(\alpha) - \alpha v'(\alpha) = v_0$, $v'(\alpha) = -(e+f)\left((1-\tau)R_h - R^*\right)$ and $r^+ R^* - R_h R^*/R_{12}^{g_f} = (r^+R^* - R_h) + R_h(1 - R^*/R_{12}^{g_f})$, we obtain, after factorizing:

$$sign\left(\frac{\partial \bar{r}_2^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign \left(\begin{array}{c} [(1-\theta)v_0 + R^*f]\left(R_{12}^{g_f} - R^*\right) \\ +(1-\theta)(1-\tau)eR_{12}^{g_f}\left(r^+R^* - R_h\right) \end{array} \right)$$

$$= sign \left(\begin{array}{c} [(1-\theta)v_0 + R^*f]\left(R_{12}^{g_f} - R^*\right) \\ +(1-\theta)(1-\tau)e\left(r^+R^*R_{12}^{g_f} - R_hR^* - R_h\left(R_{12}^{g_f} - R^*\right)\right) \end{array} \right)$$

$$= sign \left(\begin{array}{c} [(1-\theta)v_0 + R^*f - (1-\theta)(1-\tau)eR_h]\left(R_{12}^{g_f} - R^*\right) \\ +(1-\theta)(1-\tau)eR^*\left(r^+R_{12}^{g_f} - R_h\right) \end{array} \right)$$

$$= sign \left(\begin{array}{c} \underbrace{[(1-\theta)(1-\tau)R_h f + \theta R^*f]}_{\equiv \xi_1 > 0}\left(R_{12}^{g_f} - R^*\right) \\ +\underbrace{(1-\theta)(1-\tau)eR^*r^+}_{\equiv \xi_2 > 0}\left(R_{12}^{g_f} - \left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}}\right) \end{array} \right)$$

Thus

$$sign\left(\frac{\partial \bar{r}_2^+(\alpha, R_{12}^{g_f})}{\partial \alpha}\right) = sign \left(R_{12}^{g_f} - \left[(1-\xi)\left(\frac{R_h}{R_s}\right)^{\frac{1}{\sigma}} + \xi R^*\right] \right)$$

where

$$\xi \equiv \frac{\xi_1}{\xi_1 + \xi_2}$$

$$= \frac{[(1-\theta)(1-\tau)R_h + \theta R^*]f}{[(1-\theta)(1-\tau)R_h + \theta R^*]f + (1-\theta)(1-\tau)R^*r^+e} \in (0,1).$$

For compactness, we rewrite ξ as:

$$\xi \equiv \left[1 + \frac{(1-\theta)(1-\tau)R^* r^+}{(1-\theta)(1-\tau)R^h + \theta R^*} \frac{e}{f}\right]^{-1} \in (0,1). \qquad \text{(B.33)}$$

Appendix C Appendix of chapter 5

C.1   The determination of the investment scale I

The borrowing capacity of banks at t_0 is given by

$$(1 + \tau_1)I - K = \alpha[\rho_0 + \gamma - \tau_2]I + (1 - \alpha)\delta I$$

From the above condition, we obtain the investment scale I

$$[1 + \tau_1 - \alpha\rho_0 - \alpha\gamma + \alpha\tau_2 - (1 - \alpha)\delta]I = K$$

Using $\eta \equiv \gamma - \tau_2 - \delta$, we replace δ by $\gamma - \tau_2 - \eta$ and have

$$[1 + \tau_1 - \alpha\rho_0 - \alpha\gamma + \alpha\tau_2 - (1 - \alpha)(\gamma - \tau_2 - \eta)]I \;\; = \;\; K \Longrightarrow$$

$$[1 + \tau_1 - \alpha\rho_0 - \gamma + \tau_2 + (1 - \alpha)\eta]I \;\; = \;\; K$$

Arranging the last equation, we obtain the definition of the investment scale as follows:

$$I = \frac{K}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta}, \tag{C.1}$$

where $\tau = \tau_1 + \tau_2$ is the overall tax rate for two periods. The above equation corresponds to the condition (5.2) in the main text.

C.2   The scale of continuation J

The condition $J \leq \eta I + \rho_0 J$, can be rewritten as :

$$J \leq \frac{\eta}{1 - \rho_0} I$$

Replacing η by $\gamma - \tau_2 - \delta$ into the above condition and taking into account that no new investment will be initiated in the intermediate date such that $J \leq I$, we can write the condition

for the scale of the continuation J as

$$J = \min\{\frac{\gamma - \tau_2 - \delta}{1 - \rho_0}, 1\}I$$

The above equation is the condition (5.5) in the main text.

C.3 Tax rate policy as prudential instrument

Bank's profit is given by

$$\pi(\eta) = (\rho_1 - \rho_0)[\alpha I + (1 - \alpha)J] = (\rho_1 - \rho_0)\frac{\alpha + (1 - \alpha)\frac{\eta}{1-\rho_0}}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta}K$$

To verified the effect of liquidity reserves η on banks' profit π, we derive π with respect to η as

follows:

$$
\begin{aligned}
\frac{\partial \pi}{\partial \eta} &= \frac{(\rho_1 - \rho_0)\partial \frac{\alpha + (1-\alpha)\frac{\eta}{1-\rho_0}}{1+\tau-\alpha\rho_0-\gamma-(1-\alpha)\eta}K}{\partial \eta} \Rightarrow \\
&= (\rho_1 - \rho_0)\frac{\frac{1-\alpha}{1-\rho_0}(1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta) - (1 - \alpha)[\alpha + (1 - \alpha)\frac{\eta}{1-\rho_0}]}{(1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta)^2} \Longrightarrow \\
&= \frac{(\rho_1 - \rho_0)\frac{1-\alpha}{1-\rho_0}((1 + \tau - \alpha - \gamma)}{(1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta)^2}
\end{aligned}
$$

It is straightforward to see that banks' profit increases with the liquidity reserves: i.e., $\frac{\partial \pi}{\partial \eta}$ if

$$1 + \tau - \alpha - \gamma > 0 \tag{C.2}$$

Therefore, the profit increases with the liquidity reserves when $1 + \tau - \alpha - \gamma > 0$. The

condition (C.2) is the condition (5.7) in the main text.

We can also verify if the gross return to capital is no smaller than shareholders' initial

investment, i.e., $\pi|_{\eta=1-\rho_0} \geq K$, when the liquidity ratio is $\eta = 1 - \rho_0$, we have

$$\pi|_{\eta=1-\rho_0} = \frac{\rho_1 - \rho_0}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)(1 - \rho_0)}K \Longrightarrow$$

The maximum tax rate: For given structural parameters, the maximum tax rate that the

government can set is determined by solving $\pi(\tau_{\max}) - K = 0$. For any $\tau > \tau_{\max}$, banks will

not invest in any project, since the profit cannot even cover the costs K. $\pi(\tau_{\max}) - K = 0$ is

equivalent to

$$
\begin{aligned}
\frac{\rho_1 - \rho_0}{1 + \tau_{\max} - \alpha\rho_0 - \gamma + (1 - \alpha)(1 - \rho_0)} &= 1 \Longrightarrow \\
1 + \tau_{\max} - \alpha\rho_0 - \gamma + (1 - \alpha)(1 - \rho_0) &= \rho_1 - \rho_0 \Longrightarrow \\
\tau_{\max} &= \rho_1 - (1 - \gamma + 1 - \alpha)
\end{aligned}
$$

The sensitivity of the tax revenue to the tax rate

From condition (C.1), we have directly that the investment decrease with the tax rate. To verify

the effect of adjusting tax rate on the tax revenue $\tau I(\tau)$, we calculate the elasticity as follows:

$$
\begin{aligned}
I(\tau) + \frac{\partial I}{\partial \tau} &> 0 \Longrightarrow \\
\frac{\tau}{I(\tau)} \frac{\partial I}{\partial \tau} &> -1 \Longrightarrow \\
\frac{\tau}{I(\tau)} \frac{\partial I}{\partial \tau} &= \frac{-K}{(1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta)^2} \frac{\tau}{\frac{-K}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta}} > -1
\end{aligned}
$$

Consequently, the tax revenue $\tau I(\tau)$ increases with the tax rate if

$$
\begin{aligned}
\frac{\tau}{1 + \tau - \alpha\rho_0 - \gamma + (1 - \alpha)\eta} &< 1 \Longrightarrow \\
1 - \rho_0 - \gamma + (1 - \alpha)\eta &> 0
\end{aligned}
$$

Let $\beta(\eta) \equiv 1 - \alpha\rho_0 - \gamma + (1 - \alpha)\eta$ measures the degree of illiquidity of the investment. Note

that when $\eta = 1 - \rho_0$, $\beta|_{\eta=1-\rho_0} = 1 - \alpha - \gamma + 1 - \rho_0$.

The assumption 2 in the main text ensures that $\beta > 0$ and hence $\frac{\tau}{I(\tau)} \frac{\partial I}{\partial \tau} > -1$, implying that

the tax revenue $\tau I(\tau)$ decreases when the government reduces the tax rate τ.

C.4   The determination of the 'optimal' tax rate ignoring the fiscal bailout

The social welfare function for $\tau_{\min} \leq \tau < \widehat{\tau}$ is given by

$$W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}= C + \theta\tau I(\tau) - \zeta + \phi J(\tau).$$

Using (C.1) and the fact that $I = J$ at optimal, the above function becomes

$$W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}= C + \frac{\theta\tau K}{1+\tau-\alpha\rho_0-\gamma+(1-\alpha)\eta} - \zeta + \frac{\phi K}{1+\tau-\alpha\rho_0-\gamma+(1-\alpha)\eta}$$

Substituting $1 - \alpha\rho_0 - \gamma + (1-\alpha)\eta$ by β, we obtain

$$W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}= C - \xi + \frac{(\phi+\theta\tau)K}{\beta+\tau}.$$

To verify the effect of the taxation on the social welfare, we derive the social welfare function

with respect to τ:

$$\frac{\partial W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}}{\partial\tau} = \frac{\theta K(\beta+\tau)-(\phi+\theta\tau)K}{(\beta+\tau)^2} = \frac{K(\theta\beta-\phi)}{(\beta+\tau)^2}$$

We have that $\frac{\partial W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}}{\partial\tau} < 0$, if

$$\phi - \theta\beta > 0.$$

The above inequality is the condition (5.11) in the main text. The same condition is true for

ensuring that $\frac{\partial W\mid_{\tau\geq\widehat{\tau}}}{\partial\tau} < 0$ for $\tau \geq \widehat{\tau}$.

Since the welfare is strictly increasing within each of the two intervals of τ, the optimal tax rate

is a corner solution.

For $\tau \geq \tau_{\min}$, the optimal tax rate is $\tau = \widehat{\tau}$. To obtain this result, we compare $W\mid_{\tau\geq\widehat{\tau}}$ and

$W\mid_{\tau_{\min}\leq\tau<\widehat{\tau}}$, given that the welfare function jumps at the point $\widehat{\tau}$. We can show that

$$W\mid_{\tau=\tau_{\min}} < W\mid_{\tau=\widehat{\tau}} \Longrightarrow$$

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$$C - \zeta + \frac{\theta \tau_{\min} K}{1 + \tau_{\min} - \alpha \rho_0 - \gamma + (1 - \alpha)\eta} + \frac{\phi K}{1 + \tau_{\min} - \alpha \rho_0 - \gamma + (1 - \alpha)\eta}$$

$$< C + \frac{\theta \widehat{\tau} K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1 - \alpha)\eta} + \frac{\phi K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1 - \alpha)\eta}$$

Using $\beta|_{\eta = 1 - \rho_0} = 1 - \alpha - \gamma + 1 - \rho_0 > 0$ to simplify the above expression, we have

$$
\begin{aligned}
\zeta + \frac{\theta \tau_{\min} K}{\beta + \tau_{\min}} + \frac{\phi K}{\beta + \tau_{\min}} \ &< \ \frac{\theta \widehat{\tau} K}{\beta + \widehat{\tau}} + \frac{\phi K}{\beta + \widehat{\tau}} \implies \\
\zeta \ &> \ K \frac{(\theta \tau_{\min} + \phi)(\beta + \widehat{\tau}) - (\theta \widehat{\tau} + \phi)(\beta + \tau_{\min})}{(\beta + \tau_{\min})(\beta + \widehat{\tau})} \implies \\
\zeta \ &> \ K \frac{\theta \beta (\tau_{\min} - \widehat{\tau}) - \phi(\tau_{\min} - \widehat{\tau})}{(\beta + \tau_{\min})(\beta + \widehat{\tau})} \implies \\
\zeta \ &> \ \frac{(\phi - \theta \beta)(\widehat{\tau} - \tau_{\min})K}{(\beta + \tau_{\min})(\beta + \widehat{\tau})} \quad\quad\quad\quad\quad (C.3)
\end{aligned}
$$

Given the definition of β and $\tau_{\min}$, we obtain that $\beta + \tau_{\min} = 1 - \rho_0$. Replace $\beta + \tau_{\min}$ by $1 - \rho_0$

and $\widehat{\tau} - \tau_{\min}$ by Δ_1, the condition (ss) is equivalent to:

$$
\begin{aligned}
\zeta \ &> \ \frac{(\phi - \theta\beta)\Delta_1 K}{(1 - \rho_0 + \Delta_1)(1 - \rho_0)} \implies \\
\phi \ &< \ \theta\beta + \frac{\zeta(1 - \rho_0 + \Delta_1)(1 - \rho_0)}{\Delta_1 K}.
\end{aligned}
$$

The above condition is the condition (5.12) in the main text.

C.5   Fiscal policy under commitment taking account of the fiscal bailout

The welfare function taking account of the fiscal bailout is:

$$
\begin{aligned}
W^c(\widehat{\tau}, \Delta_2) \ &= \ C + \alpha[U_1(\eta, \tau) + \phi I(\widehat{\tau}, \Delta_2)] \\
&\quad + (1 - \alpha)[U_2(\eta, \tau) + \phi J(\widehat{\tau}, \Delta_2)]
\end{aligned}
$$

We have that $\eta = 1 - \rho_0$, when the constraint $\frac{1}{2}\widehat{\tau} + [\frac{1}{2}\widehat{\tau} - (1 - \alpha)\Delta_2] \geq \tau_{\min}$ holds. This

implies that $J(\widehat{\tau}, \Delta_2) = I(\widehat{\tau}, \Delta_2)$ in the adverse state. Thereby, using (C.1), we have

$$W^c(\widehat{\tau}, \Delta_2) = C + \alpha \Big[\frac{\theta \widehat{\tau} K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2} \Big]$$
$$+ (1-\alpha) \Big[\frac{\theta(\widehat{\tau} - \Delta_2) K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2} - \zeta \Big]$$
$$+ \frac{\phi K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2}$$

As the investment is relatively inelastic with respect to the tax rate, we have that $(\widehat{\tau} - \Delta_2)\theta I(\widehat{\tau}, \Delta_2) < \widehat{\tau}\theta I(\widehat{\tau})$. Consequently, consumers will suffer a utility loss ξ when the tax rate is reduced in the crisis times.

The government will promise to keep the tax rate unchanged in the event of a crisis if

$$W^c(\widehat{\tau}, \Delta_2) < W \mid_{\tau = \widehat{\tau}} .$$

We develop the above inequality as follows

$$\alpha \Big[\frac{\theta \widehat{\tau} K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2} \Big]$$
$$+ (1-\alpha) \Big[\frac{\theta(\widehat{\tau} - \Delta_2) K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2} - \zeta \Big]$$
$$+ \frac{\phi K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta - (1-\alpha)\Delta_2}$$
$$< \frac{(\theta \widehat{\tau} + \phi) K}{1 + \widehat{\tau} - \alpha \rho_0 - \gamma + (1-\alpha)\eta}$$

Using $\beta|_{\eta = 1 - \rho_0} = 1 - \alpha - \gamma + 1 - \rho_0 > 0$ to simplify the above expression, we have

$$\frac{\alpha \theta \widehat{\tau} K}{\beta + \widehat{\tau} - (1-\alpha)\Delta_2} + \frac{\alpha \theta(\widehat{\tau} - \Delta_2) K}{\beta + \widehat{\tau} - (1-\alpha)\Delta_2} - (1-\alpha)\xi + \frac{\phi K}{\beta + \widehat{\tau} - (1-\alpha)\Delta_2}$$
$$< \frac{(\theta \widehat{\tau} + \phi) K}{\beta + \widehat{\tau}} \implies \tag{4}$$

$$\frac{K(\theta\widehat{\tau} + \phi - (1-\alpha)\theta\Delta_2)(\beta + \widehat{\tau})}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})}$$
$$- \frac{(1-\alpha)\xi(\beta + \widehat{\tau})(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})} <$$
$$\frac{K(\theta\widehat{\tau} + \phi)(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})} \Longrightarrow$$

$$\frac{K(\theta\widehat{\tau} + \phi - (1-\alpha)\theta\Delta_2)(\beta + \widehat{\tau}) - K(\theta\widehat{\tau} + \phi)(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})} <$$
$$\frac{(1-\alpha)\xi(\beta + \widehat{\tau})(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})} \Longrightarrow$$

$$K(\theta\widehat{\tau} + \phi - (1-\alpha)\theta\Delta_2)(\beta + \widehat{\tau}) - K(\theta\widehat{\tau} + \phi)(\beta + \widehat{\tau} - (1-\alpha)\Delta_2) <$$
$$(1-\alpha)\xi(\beta + \widehat{\tau})(\beta + \widehat{\tau} - (1-\alpha)\Delta_2) \Longrightarrow$$

$$K\Delta_2(\phi - \theta\beta) < \xi(\beta + \widehat{\tau})(\beta + \widehat{\tau} - (1-\alpha)\Delta_2) \Longrightarrow .$$

$$\phi < \theta\beta + \frac{\xi(\beta + \widehat{\tau})(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)}{\Delta_2 K}$$

The above inequality is the condition (5.14) in the main text.

When this condition satisfies, we have $W^c(\widehat{\tau}, \Delta_2) < W\mid_{\tau=\widehat{\tau}}$ such that the fiscal bailout will induce a welfare loss and the government will insist on the constant tax rate policy in optimal even in the adverse state.

As $\frac{\partial \frac{\Delta_2(\phi - \theta\beta)}{(\beta + \widehat{\tau} - (1-\alpha)\Delta_2)(\beta + \widehat{\tau})}}{\partial \Delta_2} > 0$, if condition (5.14) in the main text is satisfied for $\Delta_2 = \frac{\Delta_1}{1-\alpha}$, it will hold for all $\Delta_2 \in [0, \frac{\Delta_1}{1-\alpha}]$. We replace therefore Δ_2 by $\frac{\Delta_1}{1-\alpha}$ into the condition (5.14) and have

$$\phi < \theta\beta + \frac{\xi(1-\alpha)(\beta + \widehat{\tau})(\beta + \widehat{\tau} - \Delta_1)}{\Delta_1 K}$$

Using the definitions of β and of Δ_1, the above condition is equivalent to

$$\phi < \theta\beta + \frac{\xi(1-\alpha)(\beta+\widehat{\tau})(1-\rho_0)}{\Delta_1 K}$$

The above inequality is the condition (5.15) in the main text.

C.6 Fiscal policy under discretion taking account of the fiscal bailout

We set $\Delta_3 = \frac{1}{2}\widehat{\tau} - \tau^a$. The policymakers will not reduce the tax rate in accordance with the expectations of banking entrepreneurs if

$$W^{nc}|_{\tau^{nc}>\tau^a} > W^{nc}|_{\tau^{nc}=\tau^a}$$

Substituting $W^{nc}|_{\tau^{nc}>\tau^a}$ and $W^{nc}|_{\tau^{nc}=\tau^a}$ by their definitions yields:

$$\frac{\theta\widehat{\tau}K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}$$
$$+\frac{\gamma-\frac{1}{2}\widehat{\tau}-\delta}{\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3}\frac{\phi K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}$$
$$>-\xi+\frac{(\widehat{\tau}-\Delta_3)K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}+\frac{\phi K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3} \Longrightarrow$$

$$\xi > \frac{-\Delta_3\theta K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}$$
$$-\frac{\phi K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}\frac{\Delta_3}{\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3} \Longrightarrow$$

$$\frac{\xi}{K} > \frac{-\Delta_3\left[\phi-\theta\left(\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3\right)\right]}{\left[1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3\right]\left(\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3\right)} \Longrightarrow$$
$$\frac{\xi}{K} > \frac{-\Delta_3\left[\phi-\theta\left(\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3\right)\right]}{\left[\beta+\widehat{\tau}-(1-\alpha)\Delta_3\right]\left(\gamma-\frac{1}{2}\widehat{\tau}-\delta+\Delta_3\right)}.$$

As shown in the main text, the banking entrepreneur sets the payment to investors in the adverse state is equal to $\delta = \gamma - \tau^a - \eta$ with $\eta = 1-\rho_0$. Using this result and $\Delta_3 = \frac{1}{2}\widehat{\tau} - \tau^a$, we obtain $\gamma - \frac{1}{2}\widehat{\tau} - \delta + \Delta_3 = 1-\rho_0$. Substituting $\gamma - \frac{1}{2}\widehat{\tau} - \delta + \Delta_3$ by $1-\rho_0$ into the above

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inequality leads to

$$\phi < \theta\beta + \theta\tau_{\min} + \frac{\xi\left[\beta + \widehat{\tau} - (1-\alpha)\Delta_3\right](1-\rho_0)}{\Delta_3 K}.$$

The above inequality gives condition (5.18) in the main text.

To obtain the condition (5.20), we compare the right-hand sides of conditions (5.14) and (5.18). We get:

$$\theta\beta + \frac{\xi(\beta + \widehat{\tau})\left(\beta + \widehat{\tau} - (1-\alpha)\Delta_2\right)}{\Delta_2 K} < \theta\beta + \theta\tau_{\min} + \frac{\xi\left[\beta + \widehat{\tau} - (1-\alpha)\Delta_3\right](1-\rho_0)}{\Delta_3 K}$$

Given that both Δ_2 and Δ_3 take their value within the interval $[0, \frac{\Delta_1}{1-\alpha}]$, we can simplify the above condition by replacing Δ_2 by Δ_3 so as to compare the effects of change the same scale of tax rate in two regimes as follows

$$\xi(\beta + \widehat{\tau})\left(\beta + \widehat{\tau} - (1-\alpha)\Delta_3\right) < \xi\left[\beta + \widehat{\tau} - (1-\alpha)\Delta_3\right](1-\rho_0) + \theta\tau_{\min}\Delta_3 K$$

Replacing $1 - \rho_0$ by $\beta + \widehat{\tau} - \Delta_1$ yields

$$\xi[\beta + \widehat{\tau} - (1-\alpha)\Delta_3]\Delta_1 < \Delta_3 K \theta\tau_{\min}$$

Substituting Δ_3 by $\frac{\Delta_1}{1-\alpha}$, the above inequality becomes

$$K > \frac{(1-\alpha)\xi\left[\beta + \widehat{\tau} - \Delta_1\right]}{\theta}$$

The above inequality is the condition (5.20) in the main text.

C.7 The utility of consumers when the bailout is carried out through public lending

The consumer will not suffer a utility loss if the interest rate on public lending satisfies

$$\theta\widehat{\tau}I(\tau^a) - \theta\Upsilon + R^p\lambda\Upsilon - \theta\widehat{\tau}I(\widehat{\tau}) > 0.$$

Using the definition of I associating with corresponding tax rates, the above inequality

becomes:

$$\theta\left[\frac{\widehat{\tau}K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}-\frac{(\frac{1}{2}\widehat{\tau}-\tau^a)K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}\right]$$

$$+\lambda R^p\frac{(\frac{1}{2}\widehat{\tau}-\tau^a)K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}-\frac{\theta\widehat{\tau}K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta}>0\Longrightarrow$$

$$\frac{\theta\left[\widehat{\tau}-(\frac{1}{2}\widehat{\tau}-\tau^a)\right]+R^p\lambda(\frac{1}{2}\widehat{\tau}-\tau^a)}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}>\frac{\theta\widehat{\tau}}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta}.$$

Using $\Delta_3\equiv\frac{1}{2}\widehat{\tau}-\tau^a=1-\rho_0$ and the fact $\gamma-\tau^a-\delta=1-\rho_0$, the above inequality could be

rewritten as:

$$\frac{\theta\widehat{\tau}-\theta(1-\rho_0)+\lambda R^p(1-\rho_0)}{1+\widehat{\tau}-\alpha\rho_0-\gamma}>\frac{\theta\widehat{\tau}}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta}\Longrightarrow$$

$$\lambda R^p(\beta+\alpha\widehat{\tau})>\theta\left[(\beta+\alpha\widehat{\tau})-\widehat{\tau}(1-\alpha)\right]\Longrightarrow$$

$$R^p>\frac{\theta}{\lambda}\left(\frac{\beta+\alpha\widehat{\tau}}{\beta+\widehat{\tau}}\right).$$

The above condition is the condition (5.21) in the main text.

C.8   Interest rate on public lending

The bank will not over-load in short-term debt if the interest rate on public lending satisfies the

condition

$$(\rho_1-\rho_0)I(\tau^a)-(1-\alpha)R^p\Upsilon<(\rho_1-\rho_0)I(\widehat{\tau})$$

Substituting $I(\tau^a)$ and Υ by their definitions into above condition yields

$$[(\rho_1-\rho_0)-(1-\alpha)R^p]\frac{K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta-(1-\alpha)\Delta_3}$$

$$<(\rho_1-\rho_0)\frac{K}{1+\widehat{\tau}-\alpha\rho_0-\gamma+(1-\alpha)\eta}$$

Using $\Delta_3\equiv\frac{1}{2}\widehat{\tau}-\tau^a=1-\rho_0$ and $\gamma-\tau^a-\delta=1-\rho_0$, we obtain

$$\frac{(\rho_1 - \rho_0) - (1-\alpha)R^p\Delta_3}{1 + \widehat{\tau} - \alpha\rho_0 - \gamma - (1-\alpha)\Delta_3 + 1 - \rho_0} < \frac{(\rho_1 - \rho_0)}{1 + \widehat{\tau} - \alpha - \gamma + 1 - \rho_0} \implies$$

$$(1-\alpha)R^p\Delta_3(1 + \widehat{\tau} - \alpha - \gamma + 1 - \rho_0) > (1-\alpha)\Delta_3(\rho_1 - \rho_0 \implies$$

$$R^p > \frac{(\rho_1 - \rho_0)}{1 + \widehat{\tau} - \alpha - \gamma + 1 - \rho_0} \implies$$

$$R^p > \frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}.$$

The above inequality is the condition (5.23) in the main text.

The bailout policy satisfying $R^p > \frac{\rho_1 - \rho_0}{\beta + \widehat{\tau}}$ is viable if over risk-taking banks have incentive to borrow in the adverse state. We establish then the following condition, when it is verified banks will accept the public lending proposed by the government and thus bear some costs due to the bailout.

$$(\rho_1 - \rho_0)I(\tau^a) - R^p\Upsilon < (\rho_1 - \rho_0)J(\tau^a)$$

Using condition (5.16) in the main text for $\tau^{nc} = \frac{1}{2}\widehat{\tau}$ (given that the government will not bail out through the tax rate reduction) and the definition of Υ, the above condition is equivalent to

$$\left[(\rho_1 - \rho_0) - R^p(\frac{1}{2}\widehat{\tau} - \tau^a)\right]I(\tau^a) > (\rho_1 - \rho_0)\frac{\gamma - \tau^{nc} - \delta}{\gamma - \tau^a - \delta + \Delta_3}I(\tau^a),$$

Using $\gamma - \tau^a - \delta = 1 - \rho_0$, and $\tau^{nc} - \tau^a = \frac{1}{2}\widehat{\tau} - \tau^a = \Delta_3$, the above inequality can be rewrite as follows

$$\rho_1 - \rho_0 - R^p\Delta_3 > (\rho_1 - \rho_0)\frac{1 - \rho_0 - \Delta_3}{1 - \rho_0} \implies$$

$$\frac{1 - \rho_0 - \Delta_3}{1 - \rho_0} > R^p\Delta_3 \implies$$

$$R^p < \frac{\rho_1 - \rho_0}{1 - \rho_0}.$$

The above inequality corresponds to the condition (5.25) in the main text.

RESUME EN ANGLAIS: In this Ph. D. thesis, we analyze the conditions for the emergence and the aggravation of the recent crisis in Europe from 2008 to 2012. The major objective of this Ph. D. thesis is to develop theoretical models which will be effective in investigating the twin banking and sovereign debt crises in a monetary union with a broadly similar institutional design to the EMU before 2012. Different from 'traditional' financial crisis models that shed light on the role of the central bank in crisis policy response, the models developed in this thesis investigate and underline the importance of fiscal crisis management. While accentuating financial vulnerability, we explore the relationship between the banking sector, the real economy and the public budget in the context of a monetary union. This thesis consists of four theoretical models of the banking crisis, with the first framework depicting the financial crisis which burst in 2008 in small European economies outside the EMU and the next three models elucidating the crisis situation in the Eurozone from early 2009 until August 2012.

RESUME EN FRANCAIS: Depuis son eruption en septembre 2009, la crise de la zone euro a été au centre de l'attention des éonomistes et des décideurs politiques. L'objectif principal de cette thèse est de développer des modèles thériques pertinents afin d'analyser les facteurs à l'origine de la crise jumelle des banques et de la dette souveraine dans une union monétaire avec une architecture institutionnelle globalement similaire de l'Union économique et monétaire avant 2012. Tout en mettant l'accent sur la vulnéabilité financière, nous explorons la relation entre le secteur bancaire, l'économie réelle et le budget du gouvernement dans le contexte d'une union monétaire. Cette thèse se compose de quatre modèles théoriques de la crise bancaire, avec le premier illustrant la crise financière qui avait éclaté en 2008 dans les petites éonomies européennes en dehors de l'UEM et les trois modèles suivants élucidant la situation de crise dans la zone euro en 2009 jusqu'en 2012.