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Jin Cheng, Meixing Dai and Frédéric Dufourt[†]

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Abstract

We analyze the conditions of emergence of a twin banking and sovereign debt crisis within a monetary union in which: (i) the central bank is not allowed to provide direct financial support to stressed member states or to play the role of lender of last resort in sovereign bond markets, and (ii) the responsibility of fighting against large scale bank runs, ascribed to domestic governments, is ensured through the implementation of a *financial safety net* (banking regulation and government deposit guarantee). We show that this broad institutional architecture, typical of the Eurozone at the onset of the financial crisis, is not always able to prevent the occurrence of a twin banking and sovereign debt crisis triggered by pessimistic investors' expectations. Without significant backstop by the central bank, the financial safety net may actually *aggravate*, instead of improve, the financial situation of banks and of the government.

Keywords: banking crisis, sovereign debt crisis, bank runs, financial safety net, liquidity regulation, government deposit guarantee, self-fulfilling prophecies.

JEL Classification Numbers: E32, E44, F3, F4, G01, G28.

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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.¹ 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 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, either explicitly or implicitly, the role of lender of last resort in the government bond market.² Fears of contagion of the crisis from periphery to

¹The government debt/GDP ratio in 2008 was 36% for Spain, 25% for Ireland, and 68% for Portugal. In the first quarter of 2012, these ratios climbed to 72%, 108% and 112%, respectively.

²Several "unconventional" monetary policy measures, such as Longer Term Refinancing Operations

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).³ 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 (EZ) 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 reinforcing interactions 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 in the literature allow to explain how a twin banking and sovereign debt crisis may emerge within a monetary union with an institutional architecture broadly similar to that of the Eurozone when it entered the financial crisis. The aim of this paper is to make a contribution in this direction. We provide a theoretical framework enabling us to analyze the conditions of emergence of a twin banking and sovereign debt crisis within a monetary union characterized by the following distinctive features: (i) member state economies are strongly interrelated, in the sense that domestic 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, to "monetize" debt, or to play the role of lender of last resort in government bond markets, and (iv) (partly as a consequence of (iii)) the burden of rescuing the banking system if a large scale bank run materializes is entirely left to domestic governments (there is no banking union or similar insurance

(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.

³The 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.

mechanisms at the supranational level). In this latter respect, member states of the monetary union have implemented a *financial safety net* (banking regulation and government deposit guarantee). We argue that these characteristics, which significantly differ from those of emerging countries to which the traditional literature on banking crises and/or on sovereign default has applied, describe fairly well the institutional context of the EZ at the onset of the crisis, i.e. before the ECB changed its doctrine by announcing the OMT program.

We investigate these issues by introducing government and public debt concerns in a small open-economy banking crisis model inspired by 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. As in Chang and Velasco (2001), the potentiality of a major collapse of the banking system is reinforced when a "sudden-stop" of short term capital inflows occurs.

In order to prevent the realization of such large scale bank runs, member states of the monetary union have implemented a *financial safety net* based on two 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 high-grade 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 bail out banks with insufficient liquidity (and thus to cover the withdrawal requests of depositors). We show that, in the model, a greater 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 following a negative shock on economic fundamentals. 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 lender of last resort in government bond markets (and is not allowed to provide direct financial support to countries facing a major threat to their banking system), there are circum-

stances in which the financial safety net *aggravates*, instead of *improves*, the financial situation of domestic banks and of the government.⁴ When this is the case, a mere banking crisis threat may translate into a fully fledged twin banking and sovereign debt crisis. We show that such a crisis, partly 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 bail out 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 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 paper, we illustrate how our framework can be adapted to analyze several related policy issues that have emerged during the EZ 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

⁴Our 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.

justified by economic fundamentals. We also analyze the issue of contagion from stressed countries to other member states of the monetary union through the banking system, and we discuss proposed policy options to avoid the resurgence of such crises such as the creation of "Eurobonds".

To sum up, the contributions of our paper are twofold. First, our paper aims to provide a *framework* suitable for the analysis of the main determinants of the EZ crisis and its consequences. Being cast into the specific institutional design of the EZ (see above), this framework differs in several respects from those of "emerging economies" to which the traditional literature on banking crisis and/or sovereign default has applied (see the discussion of related literature in section 2 below). Second, using this framework, we highlight several features that, in our view, had a significant role in the emergence of the EZ crisis. Beyond the traditional influence of key macroeconomic variables (such as the initial debt-to-GDP ratio, the degree of reliance on external debt, the fire sale price of depreciated assets, etc.), we emphasize the importance of investors' *sentiments* as an important catalyst to the crisis, and we explain why the financial safety net has not fulfilled its role of containing the financial crisis in the face of negative investors' expectations. More generally, we analyze why the poor institutional design of the EZ did not help to stabilize the crisis. Finally, the discussion of various additional issues relevant to the EZ crisis provided in the end of the paper illustrates the flexibility of our framework and its ability to accommodate extensions.

The remainder of the paper is organized as follows. The next section briefly discusses the related literature. In section 3, we present the benchmark model. In section 4, we analyze the functioning of the financial safety net and explore the conditions under which it eliminates the run equilibrium under normal financial market conditions. In section 5, we show how these results can be overturned under stressed financial conditions. Section 6 shows how our model can be used to discuss recent policy issues associated with the EZ crisis, and section 7 concludes. Analytical calculations used to derive our main propositions and results are explicitly provided in an accompanying technical appendix.

2 Related literature

Our paper 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 in a unified framework. 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.⁵ Other particularly relevant references include the "self-fulfilling debt crisis" literature pioneered by Calvo (1988) and Cole and Kehoe (2000). Calvo (1988) 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. Cole and Kehoe (2000) demonstrate the possibility of self-fulfilling sovereign debt crises triggered by a lack of confidence of international investors who refuse to roll over government debt.

More recent papers related to our research also analyze the conditions of emergence of a sovereign debt crisis in the EZ context. In particular, Bolton and Jeanne (2011) analyze the contagious effects of the sovereign debt crisis through the banking system (see also Arellano and Bai, 2013). Gennaioli *et al.* (2012) emphasize the interactions between a government's incentive to default and the fragility of its banking system. Acharya *et al.* (2011) 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). Many determinants emphasized in these papers are also key ingredients in our analysis. Yet, the analyses in these papers are entirely based on economic fundamentals, while we emphasize, beyond fundamentals, the possibility that the emergence of a twin banking and sovereign debt crisis be triggered by self-fulfilling changes in investors' expectations.⁶ As such, our analysis provides direct support to the empirical findings

⁵The "sovereign default" literature that followed the seminal paper by Eaton and Gersovitz is too vast to be surveyed here (see Aguiar and Gopinath (2006), Arellano (2008) and Mendoza and Yue (2012) for important recent contributions). Note that our framework differs from that literature in that we treat the possibility of a government default more as a *constraint* on government intervention rather than as a strategic decision weighing the costs and benefits of default compared to other policy options. In our view, this last assumption is particularly relevant to describe the situation of europaeriphery countries, whose unwillingness to default on their public debt has been illustrated by the (repeated) commitment to undertake drastic austerity measures, despite the huge economic and political costs associated to such measures.

⁶Our aim is obviously not to claim that economic fundamentals did not play a significant role in the trigger of a twin crisis in europaeriphery countries. As mentioned above, our paper actually underlines the

by De Grauwe and Ji (2013) that europa countries with initially small debt-to-GDP ratio were more exposed to a sovereign debt crisis than standalone countries with monetary sovereignty (and much higher initial levels of public debt ratios). Related contributions on this issue include Corsetti and Dedola (2013) and Aguiar *et al.* (2013). Both papers explore the extent to which a central bank can eliminate "Calvo-style" self-fulfilling sovereign debt crises by intervening in the sovereign bond market (Corsetti and Dedola, 2013) or by creating inflation (Aguiar *et al.*, 2013). As such, these papers 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 EZ crisis.

3 A small economy model with a banking system

3.1 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 into 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.⁷ 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.⁸ Finally, the government taxes entrepreneurs' projects at a rate τ per unit produced in order to finance public expenditures. We assume that

importance of crucial economic variables 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.

⁷The assumption of a unit return between stages 0 and 1 is a simplifying assumption imposed without loss of generality.

⁸As 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.

τ is sufficiently small that after-tax returns satisfy:

$$(1 - \tau)R_l < 1 < R^* < (1 - \tau)R_s < (1 - \tau)R_h, \quad (1)$$

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 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 residents 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, \tilde{Y} , above which international investors refuse to refinance the debt.⁹

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

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

is satisfied.¹⁰ 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)

⁹The assumption that such a ceiling indeed characterizes the situation of europa-periphery 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 country 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 europa-periphery 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).

¹⁰The formal expression for potential GDP \tilde{Y} , defined as the level of GDP in "normal times", i.e. when there is no banking crisis threat, is derived below.

liquidity. Banks thus collect agent deposits (equal to e at equilibrium) and use their capacity to borrow in the 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 $\alpha \in (0, \bar{\alpha})$ of their debt principal in the form of safe and liquid assets, the latter being uniquely composed of AAA-rated government bonds issued by member states of the monetary union.¹¹ The upper bound $\bar{\alpha}$ 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.¹²

¹¹As is well known, holding (supposedly safe and liquid) high-grade government bonds was a convenient way to comply with the Capital Adequacy Ratio (CAR) in Basel II accords, since for a given amount of core capital, the CAR enabled to assign 0% risk weighting to AAA-rated government bonds (thereby reducing the value of total assets in the calculation of the ratio). This form of liquidity regulation has actually been reinforced by the Liquidity Coverage Ratio implemented in Basel III accords, whose aim is "to promote the short term resilience of the liquidity risk profile of banks [...] by ensuring that banks have an adequate stock of unencumbered high-quality liquid assets (HQLA) that can be converted easily and immediately in private markets into cash to meet their liquidity needs" during stressed episodes (Bank for International Settlements, 2013).

¹²Banking regulation was not of course the only reason why EZ banks held peripheral government bonds. As emphasized by Bolton and Jeanne (2011), another reason is that high-grade government bonds can be used as collateral for interbank loans or for lending from the central bank. Likewise, as stressed by Acharya and Steffen (2013), EZ banks also actively embraced a "carry trade" behavior, using funds collected on short-term wholesale markets to buy peripheral sovereign bonds and attempting to benefit from differences between the costs and returns of these investments. While we do not model explicitly this behavior, its ex-post impact on the fragility of the banking system is similar to the one we emphasize in the remaining of the paper, since what matters for the result is that banks hold a significant share of their assets in the form of peripheral and core EZ government bonds. For others analyses emphasizing the role of government bonds as a source of liquidity and the links between the sovereign and liquidity crises, see for instance Brutti (2011) and Gennaioli *et al.* (2012). The seminal analysis of government bonds as a source of liquidity for firms and banks is Holmström and Tirole (1998).

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

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

$$f_0 \leq f, \quad f_1 \leq f, \quad (3)$$

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

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

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

where B_{02}^d and B_{02}^f are the face value of *domestic* and *foreign* governments bonds, respectively,¹³ 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 (2) is the resource constraint at $t = 0$. Condition (3) captures the external credit constraints. Condition (4) is the liquidity regulation constraint. Conditions (5) and (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.

3.2 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 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

¹³Without loss of generality, we assume that there exists only one "foreign country", and thus only one kind of "foreign" government bonds.

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.¹⁴

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

$$\lambda U(x) + (1 - \lambda)U(y), \quad (7)$$

subject to (2)–(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). Thus the resource constraint (2), the credit ceilings (3), the liquidity regulation constraint (4) and the feasibility condition (5) all bind at the optimum. Moreover, restructuring long-term projects prematurely is clearly suboptimal ex-ante, so that $\tilde{l} = 0$.¹⁵ We thus obtain:

$$\tilde{A}(\alpha) + \tilde{K}(\alpha) + \frac{\tilde{B}^*(\alpha)}{R^*} = e + f \quad (8)$$

$$\tilde{f}_0 = \tilde{f}_1 = f \quad (9)$$

$$\frac{\tilde{B}^*(\alpha)}{R^*} = \alpha(e + f) \quad (10)$$

$$\lambda \tilde{x}(\alpha) = (1 - \tau)R_s \tilde{A}(\alpha) \quad (11)$$

$$(1 - \lambda)\tilde{y}(\alpha) = (1 - \tau)R_h \tilde{K}(\alpha) + \tilde{B}^*(\alpha) - R^* f \quad (12)$$

where $\tilde{B}^*(\alpha) \equiv \tilde{B}_{02}^d + \tilde{B}_{02}^f$ 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 $\tilde{B}_{02}^d = \gamma \tilde{B}^*(\alpha)$ and $\tilde{B}_{02}^f = (1 - \gamma)\tilde{B}^*(\alpha)$, and we will consider some implications of this portfolio composition

¹⁴The level of the tax rate τ , set to maintain the level of public debt constant in normal times, is endogenously determined below.

¹⁵Tildes are used to characterize the social optimum.

later when we analyze the issue of contagion.¹⁶

From these optimality conditions, we can deduce that the optimal allocation between x and y must satisfy the social transformation curve:

$$\frac{R_h}{R_s} \lambda \tilde{x}(\alpha) + (1 - \lambda) \tilde{y}(\alpha) = v_0 - \alpha(e + f) ((1 - \tau)R_h - R^*) \equiv v(\alpha). \quad (13)$$

with $v_0 \equiv (1 - \tau)R_h(e + f) - R^*f$. Given the CRRA utility function, the maximization of (7) subject to (13) implies that the following first-order condition

$$\frac{\tilde{y}}{\tilde{x}} = \left(\frac{R_h}{R_s} \right)^{\frac{1}{\sigma}} \quad (14)$$

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

$$R^* < \left(\frac{R_h}{R_s} \right)^{\frac{1}{\sigma}} \quad (15)$$

Using (8)–(14), we then obtain the banks' optimal investment strategy giving the best distribution of resources between patient and impatient depositors as:

$$\tilde{A}(\alpha) = \frac{\theta}{(1 - \tau)R_h} v(\alpha), \quad (16)$$

$$\tilde{K}(\alpha) = (1 - \alpha)(e + f) - \frac{\theta}{(1 - \tau)R_h} v(\alpha), \quad (17)$$

$$\tilde{x}(\alpha) = \frac{\theta R_s}{\lambda R_h} v(\alpha), \quad (18)$$

$$\tilde{y}(\alpha) = \frac{1 - \theta}{1 - \lambda} v(\alpha), \quad (19)$$

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 $\tilde{K}(\alpha) \geq 0$, which effectively sets an upper bound $\bar{\alpha}$ on the intensity of liquidity regulation. In the technical appendix accompanying this paper, we show that $\bar{\alpha}$ satisfies:

$$\bar{\alpha} = \frac{(1 - \theta)(1 - \tau)R_h(e + f) + \theta R^* f}{(1 - \theta)(1 - \tau)R_h(e + f) + \theta R^*(e + f)} \in (0, 1) \quad (20)$$

¹⁶In 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 explicitly consider this issue here and simply take γ as given.

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

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

and the amount of taxes collected by the government is:

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

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 $\tilde{T}(\alpha) = \tau \tilde{Y}(\alpha)$ of taxes on these projects, and the amount of outstanding debt left at the end of stage 2 is $D_2 = D_0 R^* + G - \tau \tilde{Y}(\alpha)$. 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 $D_2 = D_0 = \tilde{D}$. 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 $\tilde{T}(\alpha) = G + r^* \tilde{D}$. The corresponding tax rate τ is thus: $\tau = (G + r^* \tilde{D}) / \tilde{Y}(\alpha)$.

Under these conditions, the debt-to-GDP ratio also remains constant and equal to $g_2 = g_0 = \tilde{D} / \tilde{Y}(\alpha) \equiv \tilde{g} \leq g_f$, 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 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.

4.1 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 europaeriphery 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 $l_0^+ = \tilde{K}_0 - R^*f / ((1 - \tau)R_h)$.¹⁷ A run equilibrium then exists as soon as the bank's short-term obligations exceed its available resources

¹⁷Variables with "0" subscript are used to refer to the unregulated case obtained when $\alpha = 0$, i.e. for any variable X , $X_0 \equiv X(0)$.

after liquidation, *i.e.* when $\tilde{x}_0 - (1 - \tau) (R_s \tilde{A}_0 + R_l l_0^+) > 0$. In the accompanying technical appendix, we show that this condition can be rewritten as

$$z_1^+ \equiv (r_1^+ - R_l) \frac{(1 - \theta)v_0}{R_h} > 0, \quad (21)$$

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

$$R_l < r_1^+ \equiv (R_h)^{\frac{\sigma-1}{\sigma}} (R_s)^{\frac{1}{\sigma}}, \quad (22)$$

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, $\tilde{x}_0 + f - (1 - \tau) (R_s \tilde{A}_0 + R_l \tilde{K}_0) > 0$, is equivalent to

$$z_2^+ \equiv z_1^+ + \underbrace{\left(1 - \frac{R_l R^*}{R_h}\right) f}_{>0} > 0 \quad (23)$$

with $z_2^+ > z_1^+$ (by (1)). We can again express this condition in terms of a critical threshold for the fire-sale value of liquidated assets:

$$R_l < r_2^+ \equiv \frac{r_1^+ + \frac{R_h f}{(1-\theta)v_0}}{1 + \frac{R^* f}{(1-\theta)v_0}} \quad (24)$$

with $r_2^+ > r_1^+$, given (15).

Conditions (22) and (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.

4.2 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 EZ 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 $\tilde{B}^*(\alpha)/R^*$.

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 $l_1^+(\alpha) =$

$\tilde{K}_1(\alpha) - R^* f / ((1 - \tau)R_h)$, and the condition for existence of a bank run equilibrium, $\tilde{x}(\alpha) - (1 - \tau) \left(R_s \tilde{A}(\alpha) + R_l l_1^+(\alpha) \right) - \tilde{B}^*(\alpha) / R^* > 0$, becomes

$$\bar{z}_1^+(\alpha, R^*) = z_1^+ - \underbrace{(r_1^+ - R_l) \frac{(1 - \theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e + f) \left(1 - \frac{R_l R^*}{R_h} \right)}_{>0} > 0, \quad (25)$$

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

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

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

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

$$\bar{z}_2^+(\alpha, R^*) = z_2^+ - \underbrace{(r_1^+ - R_l) \frac{(1 - \theta)(v_0 - v(\alpha))}{R_h}}_{>0} - \underbrace{\alpha(e + f) \left(1 - \frac{R_l R^*}{R_h} \right)}_{>0} > 0, \quad (26)$$

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

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

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:

$$\text{sign} \left(\frac{\partial \bar{r}_i^+(\alpha, R^*)}{\partial \alpha} \right) = \text{sign} \left(R^* - \left(\frac{R_h}{R_s} \right)^{\frac{1}{\sigma}} \right) < 0 \quad (27)$$

where negativity is implied by (15). 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 $\tilde{\alpha}_i$ in $(0, \bar{\alpha})$ such that $\bar{z}_i^+(\tilde{\alpha}_i, R^*) = 0$. Thus, any intensity of regulation $\alpha \in (\tilde{\alpha}_i, \bar{\alpha})$ 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 $\alpha \in (\tilde{\alpha}_i, \bar{\alpha})$, where $\tilde{\alpha}_i$ solves $\bar{z}_i^+(\tilde{\alpha}_i, R^*) = 0$.*

From Proposition 1, it is clearly never optimal to set a regulation intensity greater than $\alpha = \tilde{\alpha}_i$ since liquidity regulation also has a cost in terms of production and welfare. But even setting $\alpha = \tilde{\alpha}_i$ 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, $\alpha < \tilde{\alpha}_i$, with a government deposit guarantee. We turn to this issue in the next subsection.

4.3 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).¹⁸ 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 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

¹⁸In 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 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 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.¹⁹

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 $G_i(\alpha, R^*) = \bar{z}_i^+(\alpha, R^*)$, $i \in (1, 2)$. 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

¹⁹We defer the analysis of a global confidence crisis to the next section.

spending is:

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

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

$$\begin{aligned} T_1^+(\alpha) &= \tau(R_s \tilde{A}(\alpha) + R_l l_1^+(\alpha) + R_h(\tilde{K}(\alpha) - l_1^+(\alpha))) \\ &= \tilde{T}(\alpha) - \underbrace{\tau(R_h - R_l)l_1^+(\alpha)}_{>0}, \end{aligned} \quad (28)$$

implying $T_1^+(\alpha) < \tilde{T}(\alpha)$, where $\tilde{T}(\alpha)$ 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 run, and we get

$$\begin{aligned} T_2^+(\alpha) &= \tau(R_s \tilde{A}(\alpha) + R_l \tilde{K}(\alpha)) \\ &= \tilde{T}(\alpha) - \underbrace{\tau(R_h - R_l)\tilde{K}(\alpha)}_{>0}, \end{aligned} \quad (29)$$

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

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

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

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

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

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

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 \tilde{g} . This justifies in turn that the market interest rate on government bonds remains equal to $r_{12}^d = r^*$.

We can summarize these results in the following proposition:

Proposition 2. Existence of a credible deposit guarantee

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

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

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 $\tilde{z}_i^+(\alpha, R^*)$ and the tax revenue losses per unit of GDP, $\Delta T_i(\alpha)$, are defined as above. We have:*

- *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 \tilde{g} ,
- sufficiently capitalized domestic banks (i.e., banks with a sufficiently low illiquidity index $\tilde{z}_i^+(\alpha, R^*)$, 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 $\bar{z}_i^+(\alpha, R^*)$ 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 high intensity of regulation.

5 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 EZ 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 EZ 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?

5.1 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 :

$$R_{12}^d(g_2^a) = R^* + \rho(g_2^a), \quad (30)$$

with $\rho(\tilde{g}) = 0$ and $\rho'(g_2^a) > 0$ for $g_2^a > \tilde{g}$. This notion of a "debt-elastic interest rate" has become increasingly popular in the literature for its empirical relevance.²⁰

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 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.

5.2 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. This 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 (30), the yields on newly-issued government bonds jumps to $R_{12}^d(g_f) = R^* + \rho(g_f) \equiv R_{12}^{gf}$. 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 $1/R_{12}^{gf}$), which in turn reduces the liquidity buffer $\tilde{B}^*(\alpha)/R_{12}^{gf}$ that banks can obtain from selling their government bond holdings (and thus aggravates their solvency situation).²¹ This is synthesized by the illiquidity index

²⁰See, 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 (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.

²¹For simplicity of exposition, we assume in this section that the portfolio of domestic banks is only composed of government bonds issued by their own government, i.e. $\gamma = 1$. We relax this assumption below when we analyze the issue of contagion.

obtained when $R_{12}^d(g_2^a) = R_{12}^{gf}$, which jumps to

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

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

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

$$g_i(\alpha, R_{12}^{gf}) \equiv \tilde{g} + z_i^+(\alpha, R_{12}^{gf}) R_{12}^{gf} + \Delta T_i(\alpha) \quad , \quad i = 1, 2, \quad (31)$$

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

Clearly, if $g_i(\alpha, R_{12}^{gf}) > g_f$, the high interest rate R_{12}^{gf} 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. Summarizing:

Proposition 3. Existence of a twin crisis equilibrium

Define by

$$g_i(\alpha, R_{12}^{gf}) \equiv \tilde{g} + \tilde{z}_i^+(\alpha, R_{12}^{gf}) R_{12}^{gf} + \Delta T_i(\alpha) \quad , \quad i = 1, 2$$

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 $R_{12}^{gf} = R^* + \rho(g_f)$). The illiquidity indices $\tilde{z}_i^+(\alpha, R_{12}^{gf})$ and the tax revenue losses per unit of GDP, $\Delta T_i(\alpha)$ ($i = 1, 2$), are defined as above. We have:

- 3(a) : $g_i(\alpha, R_{12}^{gf}) > g^f$: a twin crisis equilibrium exists despite the government deposit guarantee,

- 3(b) : $g_i(\alpha, R_{12}^{g_f}) \leq g^f$: no twin crisis equilibrium exists.

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

Corollary 4. Multiplicity of equilibria

If $g_i(\alpha, R^) < g^f < g_i(\alpha, R_{12}^{g_f})$, 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.

5.3 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 they are sold at the price $1/R_{12}^{gf} < 1/R^*$). When the increase in the risk premium $\rho(R_{12}^{gf})$ 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 $R_l < r_1^+(\alpha, R_{12}^{gf})$ the condition $\bar{z}_i^+(\alpha, R_{12}^{gf}) > 0$ 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}^{gf} in the intermediary stage. In the technical appendix, we show that:

$$\text{sign} \left(\frac{\partial \bar{r}_1^+(\alpha, R_{12}^{gf})}{\partial \alpha} \right) = \text{sign} \left(R_{12}^{gf} - \left(\frac{R_h}{R_s} \right)^{\frac{1}{\sigma}} \right) \quad (32)$$

with $R_{12}^{gf} = R^* + \rho(R_{12}^{gf})$. Thus, as soon as the risk premium on domestic sovereign debt, $\rho(R_{12}^{gf})$, 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.²²

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 in this case

$$\text{sign} \left(\frac{\partial \bar{r}_2^+(\alpha, R_{12}^{gf})}{\partial \alpha} \right) = \text{sign} \left(R_{12}^{gf} - \left[(1 - \xi) \left(\frac{R_h}{R_s} \right)^{\frac{1}{\sigma}} + \xi R^* \right] \right), \quad (33)$$

where

$$\xi \equiv \left[1 + \frac{(1 - \theta)(1 - \tau)R^*r^+}{(1 - \theta)(1 - \tau)R^h + \theta R^*f} \frac{e}{f} \right]^{-1} \quad (34)$$

²²To understand the logic behind (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 unregulated 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 (15). 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 reasoning 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.

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 (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 $\rho(R_{12}^{gf})$ exceeds $(1 - \xi) \left((R_h/R_s)^{(1/\sigma)} - R^* \right)$. This condition is significantly weaker than (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 $\rho(R_{12}^{gf}) > (R_h/R_s)^{(1/\sigma)} - R^$ in the "no sudden stop" situation, and $\rho(R_{12}^{gf}) > (1 - \xi) \left[(R_h/R_s)^{(1/\sigma)} - R^* \right]$ in the "sudden stop" situation, where ξ is defined by (34). Then, in a sovereign debt crisis 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, this lack of "safe asset" property is best understood as a consequence of the inability for the central bank to play the role of lender of last resort in sovereign debt markets when an abrupt change in investors' expectations threatens to drive one or several member states into a self-fulfilling twin banking and sovereign debt crisis.²³

6 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

²³As shown by Corsetti and Dedola (2013), 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.

is not to address these complex issues in details – which would be far beyond the scope of this paper – 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".

6.1 Role of credit rating agencies

At the onset of the European sovereign debt crisis, many commentators and political leaders 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, "A" and "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 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 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 $r_{12}^d(\mathbb{B}) = r^* + \rho(\mathbb{B}) = r_{12}^{gf}$. 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 $r_{12}^d(\mathbb{B}) = r_{12}^{gf}$. We have:*

- $\delta(a)$: $g_i(\alpha, R_{12}^{gf}) < g_f$, the only consistent (perfect-foresight) rating is \mathbb{A} ,
- $\delta(b)$: $g_i(\alpha, R^*) \geq g_f$, the only consistent (perfect-foresight) rating is \mathbb{B} ,
- $\delta(c)$: $g_i(\alpha, R^*) < g_f \leq g_i(\alpha, R_{12}^{gf})$, there are two consistent (perfect-foresight) ratings: \mathbb{A} and \mathbb{B} . In addition, the rating decision acts as a self-fulfilling prophecy.

Proposition 6 gives both support and qualifications to the claims that rating downgrades of europaeriphery 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.

6.2 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 $R_{12}^{gf} > R^*$ 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 (30). If investors, taking into account the increased vulnerability of the banking system, remain confident in the solvency of the domestic government, 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 $R_{12}^d = R_{12}^{gf} > R^*$.

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

$$\begin{aligned}
\bar{z}_1^+ \left(\alpha, R_{12}^d(g_2^a), R_{12}^{gf} \right) &= \tilde{x}(\alpha) - (1 - \tau) \left(R_s \tilde{A}(\alpha) + R_l l_1^+(\alpha) \right) - \tilde{B}_{02}^f / R_{12}^{gf} - \tilde{B}_{02}^d / R_{12}^d \\
&= \underbrace{\bar{z}_1^+(\alpha, R^*) + (1 - \gamma)\alpha(e + f) \left(1 - \frac{R^*}{R_{12}^{gf}} \right)}_{\substack{>0 \\ \text{(direct effect)}}} \\
&\quad + \underbrace{\gamma\alpha(e + f) \left(1 - \frac{R^*}{R_{12}^d(g_2^a)} \right)}_{\substack{= 0 \text{ if } R_{12}^d(g_2^a) = R^* \\ > 0 \text{ if } R_{12}^d(g_2^a) = R_{12}^{gf} \\ \text{(indirect effect)}}}, \tag{35}
\end{aligned}$$

with $\bar{z}_1^+(\alpha, R_{12}^{gf}, R_{12}^{gf}) > \bar{z}_1^+(\alpha, R^*, R_{12}^{gf}) > \bar{z}_1^+(\alpha, R^*)$.

As (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}^{gf}/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 $R_{12}^d(g_2^a) = R_{12}^{gf} > R^*$). 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 in financial markets by issuing more government bonds at a higher interest rate, R_{12}^{gf} . Denoting by $g_i(\alpha, R_{12}^d, R_{12}^{gf}) \equiv \tilde{g} + \bar{z}_1^+(\alpha, R_{12}^d, R_{12}^{gf}) R_{12}^d + \Delta T_i(\alpha)$ 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

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

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).²⁴

6.3 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,²⁵ 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 "Euro-

²⁴In 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].

²⁵A thorough assessment of the potential costs and benefits of Eurobonds within a more general analysis of various (*ex post* and *ex ante*) solidarity schemes is provided by Tirole (2014).

bonds" 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 (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 $1 + r_{12}^f = R_{12}^{gf}$, respectively, in the intermediary stage. If domestic banks had invested in domestic and foreign government bonds (in proportion γ and $(1 - \gamma)$, respectively), the liquidity buffer obtained by selling these bonds in a stressed situation is $\tilde{B}_{02}^d/R^* + \tilde{B}_{02}^f/R_{12}^{gf} = \gamma\alpha(e + f)/R^* + (1 - \gamma)\alpha(e + f)/R_{12}^{gf}$. If instead they had invested in Eurobonds, the liquidity buffer would be $B^{euro}/(1 + r_{12}^{euro}) = \alpha(e + f)/(1 + r_{12}^{euro})$.

Denoting by $1 + r^H \equiv (\gamma/R^* + (1 - \gamma)/R_{12}^{gf})^{-1}$ the weighted harmonic mean of R^* and R_{12}^{gf} (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 suggests that if, in crisis time, the interest rate on Eurobonds r_{12}^{euro} would be smaller than the implicit discount rate r^H , 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.²⁶ 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.

7 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 an institutional architecture broadly similar to 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 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 EZ 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 Eurobonds.

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²⁶In 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].

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