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Abstract

Data show that sovereign risk reduces liquidity, increases funding cost and risk of banks highly exposed to it. A feedback loop exists between sovereign and bank risk. I build a model that rationalizes those links. Banks act as delegated monitors and invest in risky projects and in risky sovereign bonds. As investors hear rumors of increased sovereign risk, they run the bank (via global games). Banks could rollover liquidity in repo market using government bonds as collateral, but as sovereign risk raises collateral values shrink. Overall banks' liquidity falls (its cost increases) and so does banks' credit. In this context noisy news (announcements with signal extraction) of consolidation policy are recessionary in the short run, as they contribute to investors and banks pessimism, and mildly expansionary in the medium run. The banks liquidity channel plays a major role in the fiscal transmission.

JEL Classification: E5, G3, E6

Keywords: liquidity risk, sovereign risk, feedback loops, banks' funding costs, repo freezes.

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1 Introduction

The euro are crisis has shown that sovereign risk can have a significant impact on banks' funding composition and cost, hence on their fragility. Prior to the 2009 banks in most euro area countries were highly exposed to sovereign bonds and their exposure is still high by today. As risk spreads on several national bonds soared starting in 2009-2010, banks' funding costs and liquidity increased. A BIS[11] report shows that the impact of sovereign risk on banks' funding costs in the euro area materialized through three main channels. First, an *asset-liquidity risk* channel: as sovereign risk raised, overall banks' asset risk raised too and this induced many investors of short term liability to run, thereby making liquidity scarce. Second, a *collateral channel*: as bonds' haircuts increased, the collateral value of bonds in the repo market decreased, thereby impairing banks' ability to rollover liquidity. Third, latent factors determine a positive correlation between sovereign and banks' risk, which in turn increases banks' spreads. The first two channels generate endogenous feedback loops and account for the bulk of the transmission between sovereign and banks' risk. In this paper I build a model that can account for the first two first channels. I use the model to assess the impact of sovereign risk on the real economy and on banks' fragility. Since the model proves capable of replicating salient stylized facts I also use it as a laboratory economy to examine the anticipatory effects of fiscal policy adjustment.

Banks in my model hold short term liabilities and equity capital and invest in risky firms' loans and risky government bonds[1]. Increases in asset risk, triggered for instance by increases in sovereign risk, impair banks' funding for two reasons. First, short term liabilities are subject to liquidity risk since investors run when receiving information signals on non-performing banks' asset[2]. Investors receive individual signals regarding the bank in which they have invested loans. The bank run is then modelled through an global game among investors. Second, banks can insure against liquidity shocks by borrowing in collateralized repo markers. Government bonds serve as collateral, hence when bond prices fall (due to increased sovereign risk) borrowing capacity shrinks. Banks' asset in the model are risky. Loans are risky since firms might exert low effort and impair the projects success probability, hence inducing moral hazard between firms and banks. Overall

[1]Banks invest in sovereign bonds for several reasons. My paper focuses on the consequences of sovereign risk for banks rather than on the motives for holding it.

[2]See Morris and Shin [29] and Carlsson and van Damme among others.

a dual moral hazard problem emerge between firms and banks on one side and between banks and investors on the other, which is formalized through a dynamic contractual agreement[3]. The contract results among other things in a bank capital ratio which acts as a discipline devise and co-moves with loans' and sovereign risk. Bonds' trading is also risky. Government bonds embed a risk term premium, modelled based on the approach of the debt limits[4]. Aggregate news shocks allow me to account for anticipatory effects of fiscal policy announcements[5]. Finally to account for non-neutrality of news shocks and of monetary policy the model includes nominal rigidities.

In the model a raise in sovereign risk increases banks' asset risk and induces investors reached by those news to coordinate and run the bank. In turn the supply of banks' funding falls; its cost increases. Also an increase in sovereign risks impairs the collateral value of bonds in repo markets, thereby reducing banks' ability to rollover liquidity and to insure unexpected short-falls. The transmission of sovereign risk also results in a credit crunch. This is so for two reasons. First, lower banks' funding induce the bank to shrink assets, particularly firms' loans. Second, the increased asset risk reduces banks' balance sheet values and forces them to increase optimal equity ratios, which serve as discipline device against moral hazard incentives. The increase in equity capital crowds out banks' funds availability for credit.

I assess the quantitative significance of the above channels through two main set of experiments. First, I simulate the model under standard macro (productivity, monetary and fiscal) and by comparing the case with risk-free versus the case with risky government bonds. The model can account well for several stylized facts characterizing the euro area sovereign crisis (highlighted in section 2). In presence of sovereign risk the economy's response to adverse shocks is exacerbated. The ratio of volatilities (in the models with and without sovereign risk) for all macro and banking variables are in line with the ratios observed for distressed countries (Greece, Ireland and Portugal) vis-a-vis non-distressed ones (Germany). The model can also reproduce the positive correlation observed in the data between banks' liquidity spreads and sovereign spreads. Second, I examine the role of sovereign shocks. They are contractionary, shift banks' funding composition away from short term liability, increase banks' equity ratios and banks' spreads and induce a credit crunch.

[3] The contract is an inter-temporal extension, albeit in a conext with anonimity, of Holmstrom and Tirole [23].

[4] See Corsetti, Kuester, Meier and Mueller [17] and Bi[10].

[5] See Mertens and Ravn[28].

Increases in sovereign spreads are often anticipated through rating agencies announcements. It has been argued that those announcements might sharpen contractions in distressed countries even beyond what implied by fundamentals[6]. For this reasons I introduce anticipatory effects through aggregate (equal to all investors) news shocks on sovereign risk. The model confirms the conjectures. News of sovereign distress deepen and prolong the recession. Investors become pessimistic about banks' profitability and withdraw banks' deposits. This in turn triggers the liquidity channel outlined above.

At last, I assess the role of consolidation policies (through tax increases) in the model with sovereign risk[7]. It is worth noticing that in most cases the implementation of consolidation packages is largely perceived as uncertain and announcements are often endangered by Parliamentary discussions and votes. For this reason I introduce noisy signal extraction[8] into the parameters of the tax rules. Reducing debt has some beneficial effects. Sovereign risk is reduced, and this makes investors and banks feel wealthier. Moreover agents expect lower taxes in the future. However the beneficial effects only materialize at medium horizon, while consolidation announcements are strongly recessionary at short horizons. Agents expect imminent tax hikes, hence reduce consumption. The ensuing fall in output (due to sticky prices) shrinks investment demand, which in turn reduces firms' loans demand and induces banks to increase bank equity ratios. As banks profitability falls (in this case due to lower firms' project profitability) investors run the bank and deposits fall. Banks' profits from bond trading also fall, mainly since investors and bank reduce demand, which in turn reduce bonds' prices. The recessionary effects as well as the liquidity flight associated with announcement of fiscal consolidations is well in line with the episodes characterizing the Greek economy in the summer 2015. The announcement of further austerity measures coupled with the institutional uncertainty surrounding it brought the economy into recession[9] and produced a deposit flight[10].

The rest of paper is organized as follows. Section 2 presents stylized facts on the link between sovereign risk on the one side and banks' funding costs and fragility on the other. Section 3 describes

[6] See Orphanides[30] for the effects of stress tests announcements.

[7] Darraq-Paries, Faia and Palenzuela[18] assess the ECB full allotment policy using a similar model.

[8] See Blanchard, L'Huillier and Lorenzoni[9].

[9] The growth rate registered for July 2015 was -1.7 against a 1.3 registered in the spring of the same year.

[10] Between January 2015 and July 2015 corporate and household deposits fell from 164 billions to 122. Several emergency liquidity assistance interventions from the ECB had to be advanced during the same period.

the model and some analytics highlighting the sovereign/bank links. Section 4 shows quantitative properties of the model. Section 5 concludes. Appendices, figures and tables follow.

2 Stylized Facts and Literature Review

This paper is related to a recent strand of the literature studying the effects of sovereign risk in macro models with and without financial frictions (see Bi[10] and also Corsetti, Kuester, Meier and Mueller [17] for a model with borrowing constraints). None of the previous models however considered banks' moral hazard and bank runs. To fully assess the impact of sovereign shocks I also considered anticipated news shocks along the lines Mertens and Ravn [28] and Leeper, Walker and Yang [25].

The nexus between banks and sovereign risk had been assessed in other models[11] which focused on the impact of sovereign risk on banks' balance sheets values and consequently on the extensibility of banks' credit. While my paper does contain the banks' asset channel of sovereign risk, it also explores further dimensions hinging on the nexus between sovereign exposure and liquidity shortfalls, a channel widely supported by the data. Although bonds in my model are held to increase banks' asset yields and for repo collateral purposes, I do not specifically assess the determinants of banks' demand for bonds, but rather focus on the impact that banks' exposure to them have on banks' funding and risk. At last my model is related to paper assessing the role of global games for bank runs[12] and to some of the recent paper introducing banking into macro and more specifically to model with banks' moral hazard[13] and to models introducing banks' runs[14].

The euro area sovereign crisis directed much of the policy maker attention toward the sovereign-bank risk nexus. Empirical evidence showed in particular that sovereign risk impaired banks' liquidity and re-financing ability and increased banks' funding costs. This in turn induced a credit crunch. A BIS[11] report on this topic concludes that the main channels behind the sovereign/bank liquidity risk nexus are the *asset-liquidity risk* and the *repo collateral*. For banks highly exposed to government bonds a fall in their price (due to increased risk) reduces profits and increases asset

[11] See Gennaioli et al. [21] and Pancrazi et. al.[31].
[12] See Morris and Shin [29], [16] Carlsson and van Damme or more recently Anand et. al. [4].
[13] See Meh and Moran[27], Faia [19] among others.
[14] See also Angeloni and Faia[2] which introduces fundamental banks' runs, while here I introduce information coordination games.

risks: as investors are reached by news of deteriorated banks' asset returns they liquidate short-term liabilities. Second, as bonds' haircuts raise, the collateral value of bonds in the repo market decreases, severing banks' liquidity rollover.

In this section I re-examine those channels using some more updated data. I start by assessing the link between sovereign risk (measured by CDS spreads) and banks' short term liabilities. Data for aggregate short term liabilities over the period 2009Q1-2015Q4 were obtained from the IMF-Financial Statistics Indicators, data for 5 years sovereign CDS from Datastream. The figure 1 below shows the data and the fitted regressions for a sample of selected countries. The selection of countries was based primarily on the longest possible span of available data[15], something which also delivers the highest R^2 and the highest significance of the regressions.

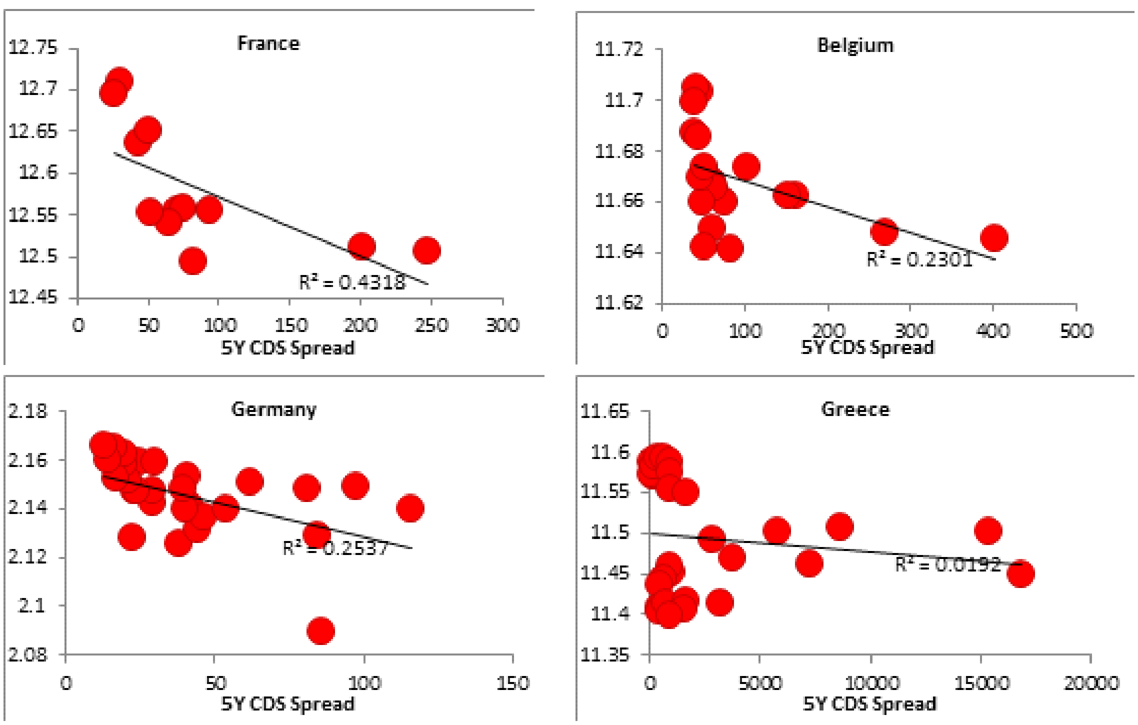

Figure 1. Banks' short-term liabilities versus sovereign CDS spreads over period 2009Q1-2015Q4.

The above figure shows a negative relation between banks' short term liabilities and sovereign risk, confirming the sovereign/liquidity nexus.

[15] Data on STL are not available on a meaningful span for Spain and Ireland. They are available for Italy, but the regression is not significant.

Interestingly the link holds for both Northern as well as Southern European countries and for distressed as well non-distressed countries. Indeed German and French banks were also highly exposed to national sovereign bonds and, albeit in relative terms, an increase in sovereign risk provided a signal of their poorly diversified portfolios.

Second, I examine the link between sovereign risk and banks' funding costs, as proxied by banks' funding spreads. Table 1 shows correlations of banks' CDS spreads (median across all banks in each country) and sovereign CDS spreads for a set of EU countries. Data are monthly and cover the sample period January 2008 to August 2013. For banks highly exposed to sovereign bonds an increase in sovereign risks increases both asset and liability risk. Both facts imply an increase in banks' CDS spreads[16], as shown in Table1[17].

3 Model with Sovereign and Banks' Liquidity Risk

The macro model economy is populated by households/workers who invest in banks' short term liability (often labelled as uninsured or demand deposits) and risky government bonds, by entrepreneurs who acquire loans from banks to invest in risky projects and by banks, which act as delegated monitors on behalf of investors[18]. Production of final goods takes place in a competitive sector which employes capital and labour. A second sector produces physical capital goods. Firms in this sector obtain funds from banks to finance risky investment projects, but have incentives to exert low efforts. Banks obtain funds through short term liabilities and equity capital: they are also prone to moral hazard since monitoring of loans is costly. The dual moral hazard problem is disciplined through a three party contract which leads to endogenous equity ratios. Banks face liquidity risk since investors of short term liabilities can coordinate and run in face of bad news on banks' assets. Banks can insure against liquidity short-falls in a repo market, but this requires collateral in the form of government bonds. The fiscal sector features exogenous government spending. Budget deficits are funded through risky bonds and labour taxes, the latter obeying a fiscal rule. From now

[16] Also documented Darraq-Paries, Faia and Palenzuela[18].

[17] Notice that for Greece there are some missing data. This might explain the relatively low correlation compared to other countries.

[18] Entrepreneurs and banks are finitely lived and risk neutral agents. The assumption prevents buffer asset accumulation that would overcome the need of external finance. It also allows aggregation via simple averaging of individual optimizing decisions.

onward the index h will denote investors variables, the index e will denote entrepreneurs variables and the index b will denote bankers variables.

3.1 Households

A continuum of households consume, work in the production sector, invest in banks' short term liabilities, risky government bonds and physical capital. They take consumption decisions to maximize the following lifetime expected utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{U(C_t) - V(H_t)\} \tag{1}$$

where C_t denotes households consumption and H_t labour hours. Sovereign risk is introduced by assuming that government bonds (with B_t^{hh} denoting the fraction invested by households) are infinitely lived and pay each period a geometrically decreasing coupon, with a decay rate δ_c. Let us denote with a z_t the price of a bond paying a coupon of 1 in period t[19]. Households' budget constraint, in real terms, reads as follows:

$$C_t + q_t I_t^h + D_{t+1} + (z_t - 1)B_{t+1}^{hh} = (1 + r_t^n)D_t + r_t^k K_t^h + \delta_c (1 - \Delta_t) z_t B_t^{hh} + (1 - \tau_t^w)\frac{W_t}{P_t}H_t - \tau_t \tag{2}$$

where q_t denotes the price of capital, I_t^h denotes capital investment done by households, whose accumulation is governed by $K_{t+1}^h = (1-\delta)K_t^h + I_t^h$, $(1 + r_t^n)$ is the gross nominal interest rate received on short term liabilities (the latter are labelled through the variable D_t), r_t^k is the real rental rate of capital, K_t^h is the amount of physical capital invested by households, $\frac{W_t}{P_t}H_t$ is real labour income, τ_w is distortionary taxation of labour income, Δ_{t+1} is the expected default on government debt in period $t+1$ and τ_t are lump sum taxes. Notice that the introduction of taxation of labour income serves the purpose of constructing a meaningful fiscal sector, whose specification is laid down in section 4.2. The timing of events in the bond market at period t is as follows. The default haircut Δ_t (which will be described and derived in the next section) is applied to previous period government debt B_{t-1}. Existing bonds are sold and purchased at price z_t. Afterwards new bonds are issued. Coupons are paid to the bond owners at period t. The first order conditions of the above problem read as follows:

$$u'(C_t) = \beta E_t \left\{ u'(C_{t+1}) \frac{(1 + r_t^n)}{\pi_{t+1}} \right\} \tag{3}$$

[19] See also Rudebusch and Swanson [35].

$$q_t = \beta E_t \left\{ \Lambda_{t,t+1}(q_{t+1}(1-\delta) + r^k_{t+1}) \right\} \tag{4}$$

$$(z_t - 1) = \delta_c \beta E_t \left(\Lambda_{t,t+1} \left(1 - \Delta_{t+1}\right) \frac{z_{t+1}}{\pi_{t+1}} \right) \tag{5}$$

$$(1-\tau_w)\frac{W_t}{P_t} u\prime(C_t) = -v\prime(H_t) \tag{6}$$

Equation 3 is the standard Euler conditions with respect to short term liabilities, where $\pi_{t+1} = \frac{P_{t+1}}{P_t}$ and where $\Lambda_{t,t+1} = \beta \frac{u\prime(C_{t+1})}{u\prime(C_t)}$ is the stochastic discount factor. Equation 4 is the first order condition with respect to capital holding. Finally, equation 6 is the first order condition with respect to labour hours. Equation 5 represents the optimality condition with respect to government bonds. The set of first order conditions must hold alongside with a no-Ponzi condition on wealth.

3.2 Sovereign Bonds Risk and Pricing

Since coupons are paid in period t, the effective market value of the bond (upon coupon payment) is $z_t - 1$[20]. The duration of the infinitely lived bond just described can be parametrized using the formula $\delta_c = \frac{1}{\beta}\left[1 - \frac{1}{1+\Xi}\right]$, where Ξ is the Macaulay[26] duration. One unit of bonds is purchased at a cost $(z_t - 1)$ and can be sold at price $\delta_c z_{t+1}$ in the following period. Therefore the ex-post return on bonds is given by:

$$1 + r^g_t = (1 - \Delta_t) \frac{\delta_c z_t}{z_{t-1} - 1} \tag{7}$$

The bond term premium is a function of the default free rate, which is defined as $z^{DF}_t = 1 + \delta_c E_t \left(\Lambda_{t,t+1} z^{DF}_{t+1}\right)$, and the risk-neutral rate, which is defined as $z^{RN}_t = 1 + \frac{\delta_c}{1+r^n_t} E_t \left(z^{RN}_{t+1}\right)$, where r^n_t is the risk-free rate. The bond term-premium can then be defined as follows:

$$TP_t = \log\left(\frac{\delta_c z^{DF}_t}{z^{DF}_{t-1} - 1}\right) - \log\left(\frac{\delta_c z^{RN}_t}{z^{RN}_{t-1} - 1}\right) \tag{8}$$

I add sovereign default to the model by following the notion of fiscal limit detailed in Bi[10] and operationalized in Corsetti et. al. [17]. Whenever the debt level raises above the fiscal limit default occurs. Following Corsetti et. al. [17] I assume that the fiscal limit, which is determined stochastically, is drawn from a generalized Beta distribution with parameters α and β, and $\frac{B}{Y} b_{\max}$

[20] Notice that financial intermediaries purchase only bonds whose coupon has already been paid. Hence, the book value of a quantity B^b_t of bonds is $(z_t - 1)\, B^b_t$.

is the upper bound on the steady state debt to output ratio. The ex ante probability of default is given by the cumulative density of the Beta distribution and the expected haircut reads as follows:

$$\Delta_t = \varepsilon_{f,t}\Phi_t\Gamma_t(\frac{B}{Y}b_{\max}, \alpha, \beta) \tag{9}$$

where $\varepsilon_{f,t}$ is a sovereign risk shock, Φ_t is the loss given default, Γ_t is the Beta distribution. Notice that I employ a specification of the haircut which includes a sovereign shock, which is meant to capture exogenous changes in sovereign risk, as unrelated to fundamentals. In the simulations I will also explore the possibility of news driven shocks on the sovereign haircut to capture anticipatory effects.

3.2.1 Bankers and Entrepreneurs

There exist a continuum of bankers and entrepreneurs which are ex ante identical. Both are risk neutral and finite lived agents[21]. Their respective probability of exiting their business each period are γ^b and γ^e. Their respective net wealth at period t are denoted BK_t and NW_t . Given the linearity of preferences corner solutions characterize consumption. I assume that both those agents consume their entire wealth when they exit and save their entire wealth otherwise[22]. This also implies that individual wealth is accumulated over their lifetime in business. The performance of the project returns are i.i.d. across entrepreneurs and bankers[23]. This assumption implies that idiosyncratic project returns do not turn into aggregate risk. Hence by law of large number aggregate wealth is given by the individual wealth weighted by the agents' survival probability. Similarly consumption is given by the wealth of agents who exit the economy at time t (fractions $(1-\gamma^b)$ and $(1-\gamma^e)$), conditional on being in the business at date t. At time t surviving entrepreneurs and bankers receive the contract proceeds in the form of capital goods, hence $K_t^e = p_h R_t^e I_t$ and $K_t^b = p_h R_t^b I_t$. Those proceeds generate revenues as capital can be rented to the production sector. Both agents consume all available resources at the end of their life according to fractions $(1-\gamma^e)$ and $(1-\gamma^b)$, hence aggregate consumption schedules are $C_t^e = (1-\gamma^e)q_t p_h R_t^e I_t; C_t^b = (1-\gamma^b)q_t p_h R_t^b I_t$[24].

[21] This assumption is needed to prevent that sufficient precautionary savings offsets the external funding constraints.
[22] This assumption also facilitates aggregation.
[23] As in Holmström and Tirole [23] projects returns are perfectly correlated within the portfolio of a single intermediary, but not across banks.
[24] I assume that bond trading profits are not consumed by exiting bankers, but are transferred to the newly entering bankers.

Entrepreneurial and bankers' wealth accumulates according to the returns from renting capital goods, multiplied by the end of period capital.

Given the consumption and saving profiles and given risk neutrality, the sum of total discounted expected utility, respectively for bankers and entrepreneurs, is given by:

$$V_t^b = E_t \left\{ \sum_{i=1}^{+\infty} \gamma^b \left(1-\gamma^b\right)^{i-1} BK_{t+i} \right\} \tag{10}$$

and

$$V_t^e = E_t \left\{ \sum_{i=1}^{+\infty} \gamma^e \left(1-\gamma^e\right)^{i-1} NW_{t+i} \right\} \tag{11}$$

Those value function will also be used to share surplus in the three party contract. The above value functions can of course also be written recursively knowing that the per period agents' utilities are given by, $\left[r_t^k + q_t\left(1-\delta\right)\right] p_h R_{t-1}^b q_{t-1} I_{t-1}$ and $\left[r_t^k + q_t\left(1-\delta\right)\right] p_h R_{t-1}^e q_{t-1} I_{t-1}$, respectively for bankers and entrepreneurs.

3.3 Moral Hazard and Financial Contract

Entrepreneurs have incentive to exert low effort and banks have an incentive to save on monitoring costs. Those moral hazard incentives are disciplined through a three party contractual agreement. The latter is an inter-temporal extension of the contract laid down in Holmstrom and Tirole[23]: the inter-temporal dimension allows me to highlight the impact of long term bond risk on banks' profits. At this stage it is useful to detail the timing of events. Within period t banks acquire funds from investors, firms acquire funds from banks and start projects. Capital goods are produced at the beginning of period $t+1$, are then rented to intermediate good producers and production takes place. Next, consumption and investment decisions and the financial contract is signed. After the contract is signed, the realization of an idiosyncratic news shocks $\varepsilon_{n,i,t}$ on banks' asset returns is drawn and interbank lending takes place[25]. At the end of the period projects' returns, R, are realized and shared between agents (s_t^b, s_t^e and s_t^h). Entrepreneurs and bankers consume if they exit the economy and invest in capital otherwise.

Entrepreneurs plan for an initial investment of I_t units of consumption good in period t, which returns RI_t units of capital goods at the beginning of period $t+1$ if the project succeeds and 0 units

[25] Notice that withdrawals of liquidity does not affect the contract ex ante since the banks can rollover liquidity in the repo market and avoid projects' liquidation.

if it fails. The entrepreneurs finance the project using partly their own funds, NW_t, and partly by borrowing, $L_t = (I_t - NW_t)$. Entrepreneurs can privately choose between three different projects: a project with high probability of success p_h and 0 private benefit, projects with low probability of success p_l and private benefits respectively equal to bI_t and BI_t , with $b < B$. Bank's monitoring technology can prevent the undertaking of the project with low probability of success p_l and high private benefits BI_t , but cannot prevent the extraction of low private benefits bI_t[26]. Monitoring entails a non-verifiable cost cI_t in final goods for the bank and this creates a second moral hazard problem between the bank and investors. Bank capital, BK_t, stakes into the projects serve the purpose of disciplining banks' moral hazard. Moral hazard allows entrepreneurs and bankers to extract rents. Banks's funding, $BK_t + D_t$, are used to fund projects, to cover monitoring costs and to buy government bonds which serve as collateral in repo markets. The linear allocation of funds deliver the following feasibility constraint:

$$(I_t - NW_t) + (z_t - 1) B_t^b \leq BK_t - cI_t + D_t \tag{12}$$

The dual moral hazard is disciplined through an inter-temporal three party contract[27] which determines among other things the sharing of the assets' returns among the three parties according to the fractions s_t^h, s_t^e, s_t^b[28]. Total per period banks' assets returns are given by projects' returns (in case of success), $q_t RI_t = \left[r_{t+1}^k + q_{t+1}(1-\delta)\right] RI_t$, and government bonds' returns:

$$\Pi_{t+1}^{success} = \left[r_{t+1}^k + q_{t+1}(1-\delta)\right] RI_t + \frac{\left(1 + r_{t+1}^g\right)}{\pi_{t+1}} (z_t - 1) B_t^b \tag{13}$$

The three parties agree through an underlying bargaining at date t to share the returns of the successful project in the following way:

$$\Pi_{t+1}^e = s_t^e \hat{\Pi}_{t+1}^{success}; \Pi_{t+1}^b = s_t^b \hat{\Pi}_{t+1}^{success} + \frac{\left(r_{t+1}^g - r_t^n\right)}{\pi_{t+1}} (z_t - 1) B_t^b; \Pi_{t+1}^h = s_t^h \hat{\Pi}_{t+1}^{success}$$

where $s_t^h = 1 - s_t^e - s_t^b$ and where:

$$\hat{\Pi}_{t+1}^{success} = \left[r_{t+1}^k + q_{t+1}(1-\delta)\right] RI_t + \frac{\left(1 + r_t^n\right)}{\pi_{t+1}} (z_t - 1) B_t^b \tag{14}$$

[26] Monitoring reduces the incentive to shirk, but not fully. This assumption retains a role for entrepreneurial and bank capitalists' net worth as a discipline devices.
[27] See Holmstrom and Tirole [23].
[28] Limited liability ensures that no agent earns a negative return.

. Importantly notice the dependence of bankers profits upon government bonds trading profits. As sovereign risk raises and bonds' price fall a fall in bankers' net wealth values materialize.

Payoffs in the contract are the sum of each party total discounted utility. Given the inter-temporal nature of the contract and in order to preserve the contract recursivity I assume anonymity across periods[29]. The optimal contract determines investment I_t, bank capital, BK_t, short term liabilities, D_t, the liquidity buffer, B_t^b, and the shares of returns, s_t^e, s_t^b, s_t^h, to maximize the entrepreneurs expected return[30]:

$$\max_{\{I_t, BK_t, D_t, B_t^b, s_t^e, s_t^b, s_t^h\}} V_t^e \tag{15}$$

and is subject to the following constraints. First, the entrepreneurs' incentive compatibility constraint, which implies that the expected next period returns associated to the project with high probability of success, p_h, are higher than those associated with the project with the low probability of success p_l, but with private benefit b:

$$E_t\left(q_t p_h s_t^e R I_t\right) \geq E_t\left(q_t p_l s_t^e R I_t\right) + q_t I_t b \tag{16}$$

The inter-temporal nature of the above constraint emerges from noting that from 4 $q_t = \sum_{i=0}^{\infty} \Lambda_{t,t+i} \beta^i (1-\delta)^i r_{t+i}^k$. Second, the bankers' incentive compatibility constraint, which implies that bankers' expected next period returns under monitoring are higher than in absence of it:

$$E_t\left(q_t p_h s_t^b R I_t\right) \geq E_t\left(q_t p_l s_t^b R I_t\right) + c I_t \tag{17}$$

Third, the bankers' participation constraint, which at the beginning of time t ensures that bankers engaging in the lending activity receive a future discounted sum of utilities which is larger than the proceeds from an outside investment opportunity:

$$V_t^b \geq BK_t\left(1 + r_t^m\right) \tag{18}$$

where $(1 + r_t^m)$ is a market interest rate. Fourth, the investors' participation constraint, upon which investors's returns from the contract shall compensate returns from investing in an alternative

[29] Alternatively one can assume that only exiting entrepreneurs and bankers have an incentive to shirk. For those agents indeed the reputational costs of shirking are nil.

[30] Entrepreneurs have the whole bargaining power.

risk-free asset:

$$E_t\left(\Lambda_{t,t+1}\Pi^h_{t+1}\right) \geq E_t\left(\Lambda_{t,t+1}\frac{(1+r^n_t)}{\pi_{t+1}}D_t)\right) \tag{19}$$

At last, the contract is also subject to the project feasibility constraint, to the linear returns' distribution and to a bank collateral constraint for repo trading:

$$(z_t - 1)\, B^b_t \geq \rho_t D_t \tag{20}$$

where ρ_t indicates the probability that a news shock will trigger a bank run (details on this are given in the next section). Following the liquidity theory laid down by Holmstrom and Tirole [22] it is assumed that banks, which are subject to the risk of runs, rollover liquidity by borrowing in repo markets where they use government bonds as collateral. Notice that constraint 20 also prevents project liquidation in the event of a run. Following the logic in Holmström and Tirole [23] all constraints hold with equality. The contract delivers the following shares:

$$s^e_t = \frac{b}{R\,(p_h - p_l)};\, s^b_t = \frac{c}{q_t R\,(p_h - p_l)};\, s^h_t = 1 - \frac{b}{R\,(p_h - p_l)} - \frac{c}{q_t R\,(p_h - p_l)} \tag{21}$$

The above equations show that bankers' and entrepreneurs' moral hazard allows them to extract rents. Both agents have to be compensated for the cost of being disciplined. The feasibility constraint coupled with the self-insurance constraint, 20, deliver the optimal investment schedule:

$$I_t = \frac{BK_t + NW_t + D_t(1-\rho_t)}{(1+c)} \tag{22}$$

For given run probability, ρ_t, a fall in bond prices (due to an increase in sovereign risk) implies that banks have to advance more collateral, B^b_t, in repo markets. This implicitly reduces the available resources for projects' investment (effectively producing a credit crunch) and investment. The fall in investment in turn reduces the profits' shares accruing to investors, Π^h_{t+1}, which in fact depends upon I_t.As we will in the next section as news of falls in banks' asset returns reach investors, the latter run the bank, thereby adding further liquidity strains. Overall, an increase in sovereign risk triggers liquidity spirals and restrains banks' funding.

3.4 Liquidity Risk and Repo Rollover

We assume n identical banks start operating at the beginning of period t . Each bank owns $\frac{1}{n}$ of total capital BK_t, receives $\frac{1}{n}$ of total short term liabilities D_t, and finances $\frac{1}{n}$ of the total investment I_t. Bankers in this model face the risk of sudden liquidity needs due to runs[31]. Let us assume that banks' investors for each single bank n are represented by a continuum of mass 1. Variables specific to the investor i in the bank n are denoted using the subscript n, i . After financial contracts have been signed some banks is subject to "market rumors". Investors receive a private signal $\varepsilon_{n,i,t}$ (news shocks) about the expected probability that the project funded by bank n will succeed, $p_h : E_{n,i,t}(p_h) = \exp(\varepsilon_{n,i,t}) p_h$.

The signal $\varepsilon_{n,i,t}$ follows the distribution Γ_t with density function g_t and cumulative distribution G_t , which is the same for all investors i and banks n . Investors withdraw their funds from bank n when the expected return on investment $E_{n,i,t}(p_h)$ is so low that the bank could become insolvent. Specifically, investors in short term liabilities do not roll-over their funding whenever the banks' asset losses go beyond gross returns to equity capital:

$$\exp(-\varepsilon_{n,i,t}) p_h R q_t I_t \geq p_h R_t^b q_t I_t \tag{23}$$

or equivalently when[32]:

$$\varepsilon_{n,i,t} = \tilde{\vartheta}_t = \ln\left(\frac{R}{R_t^b}\right) \tag{24}$$

The above threshold strategy, 24, can be obtained as the unique equilibrium of a global game among depositors who have a binary decision with two actions: “run” and “no run”. The game can be staged as follows. Ex ante there are $m = \{1, ..., M\}$ depositors and a fraction of them, η, is expected to run the bank. Each depositor, m, receives a private signal regarding the realization of banks' non-liquid asset returns which takes the following form[33]:

$$\vartheta_{m,t} = \varepsilon_{i,t} + \mu_{m,t} \tag{25}$$

[31] Deposit withdrawals do not entail resource destruction in the model, as deposits are simply moved from one bank to another. To avoid costly liquidation in the project interim period banks rollover liquidity in repo markets.

[32] As all banks are ex-ante identical, we can drop the subscript n in the inequalities.

[33] Since now on I skip the bank index n since the information coordination problem among investors is the same for all banks.

where μ_m are small errors which are independently distributed with a cumulative distribution $\mathbb{F}$ given by the normal distribution, $N(0, \sigma_\mu^2)$. The signal can be thought of as the depositor private information or opinion regarding bank i's health. Each depositor decides whether to run or not depending on the signal. The latter gives indications on the bank i health, but also on the probability that the other depositors will run (based on some iterative-higher order expectations of the investors' probability to run conditional on their signal). Seeing a bad signal about bank i assets' returns ultimately provides information about the probability that a run occurs. More detailed on the game as well the proof of Proposition 1 below are provided in Appendix A.

Lemma 1. *The unique equilibrium for the run game amounts to all depositors of bank i choosing the threshold strategy:*

$$\tilde{\vartheta}_t \leq \exp(\widetilde{\varepsilon}_t) = \frac{R}{R_t^b} \tag{26}$$

Given the above unique threshold, for any bank n, the share of withdrawing investors is given by $\rho_t = \int_{-\infty}^{\tilde{\vartheta}_t} g_t(\varepsilon) \, .d\varepsilon = G_t\left(\tilde{\vartheta}_t\right)$.

Notice that the liquidity short-fall does not affect the ex ante contract negotiation. It is assumed that liquidity withdrawals from one banks are simply transferred to another bank (not subject to bad news) and do not entail aggregate project liquidation. Aggregate project liquidation can be avoided in two ways. First, banks holding government bonds can rollover liquidity in repo markets. This can be done in an interim period between the occurrence of a deposit run and the completion of the project. Second, the emergence of any background risk (inability to fully rollover in repo markets) can be insured through a common guarantee fund, which is funded by banks subject to high asset returns and provides resources to banks subject to low asset returns. Ex post pooling of profits, implies that ex ante the shock realization, $\varepsilon_{n,t}$ does not affect banks' financial contract negotiation.

3.4.1 Bankers and Entrepreneurial Wealth Accumulation

Bankers' and entrepreneurs' wealth accumulation consists of the aggregate wealth of non-exiting bankers and entrepreneurs[34]. Wealth aggregation takes place at the end of period t. Given the

[34] Given the assumption on projects returns' correlations the law of large number implies that the exit probability is equivalent to the fraction of agents that exit business.

timing of events described in section 3.4 the period t capital of the bank is the sum of the proceeds from past period investment and from the previous period holdings of government bonds B_t^b sold at market value z_t:

$$BK_t = \gamma^b \left[r_t^k + q_t (1-\delta) \right] p_h R_{t-1}^b q_{t-1} I_{t-1} + \Pi_t^{bonds} \tag{27}$$

where $\Pi_t^{bonds} = \delta_c (z_{t+1} - 1) B_t^b$.Through the last channel fluctuations in bond price z_t affect banks' net wealth, which in turn affects credit supply and investment[35]. Entrepreneurial aggregate wealth reads as follows:

$$NW_t = \gamma^e \left[r_t^k + q_t (1-\delta) \right] p_h R_{t-1}^e q_{t-1} I_{t-1} \tag{28}$$

3.4.2 Monopolistic competitive sector

Different varieties are assembled by final good firms through a standard Dixit- Stiglitz aggregator, $Y_t \equiv \int_0^1 [(Y_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$. The optimal allocation of expenditure on each variety is given by $Y_t^i = \left(\frac{P_t^i}{P_t}\right)^{-\varepsilon} Y_t$, where $P_t \equiv \int_0^1 [(P_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ is the aggregate price index. To analyze the effects of monetary policy we introduce nominal rigidities in the form of quadratic adjustment costs on pricing decisions, $\frac{\vartheta}{2}(\frac{P_t^i}{P_{t-1}^i} - 1)^2$, where the parameter ϑ measures the degree of nominal price rigidity. Each monopolistic firm chooses $\{K_t^i, H_t^i, P_t^i\}$, taking nominal wages W_t and the rental rate of capital r_t^k, as given, in order to maximize expected discounted nominal profits:

$$E_0 \{ \sum_{t=0}^{\infty} \Lambda_{0,t} [P_t^i Y_t^i - (W_t H_t^i + P_t^i r_t^k K_t^i) - \frac{\vartheta}{2} \left[\frac{P_t^i}{P_{t-1}^i} - 1 \right]^2 P_t] \} \tag{29}$$

subject to the constraint $A_t (H_t^i)^{\alpha} (K_t^i)^{1-\alpha} \leq Y_t^i$, where $\Lambda_{0,t}$ is the households' stochastic discount factor at time 0. First order conditions of the above problem (under the symmetry assumption lead to):

$$\frac{W_t}{P_t} = mc_t A_t \alpha (H_t)^{\alpha-1} (K_t)^{1-\alpha}; r_t^k = mc_t A_t (H_t)^{\alpha} (1-\alpha)(K_t)^{-\alpha} \tag{30}$$

[35] Note that Π_t^{bonds} is expected to be positive in steady-state for two reasons: first since government bonds pay a risk premium and second since long term government bonds carry a term premium.

$$U_{c,t}(\pi_t - 1)\pi_t = \beta E_t\{U_{c,t+1}(\pi_{t+1} - 1)\pi_{t+1}\} + +U_{c,t}A_t(H_t)^{\alpha}(K_t)^{1-\alpha}\frac{\varepsilon}{\vartheta}(mc_t - \frac{\varepsilon - 1}{\varepsilon}) \tag{31}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross aggregate inflation rate and mc_t is the Lagrange multiplier on aggregate production and plays the role of the real marginal cost of production.

3.5 Monetary Policy, Fiscal Policy and Equilibrium Conditions

Governments finance an exogenous stream of government spending, G_t, through taxes and government debt. Real government debt is given by $B_t^{Stock} = B_t^{Issue} + \dfrac{\delta_c B_{t-1}^{Stock}}{\pi_t}$. New issuances are used to balance the period t government budget:

$$\frac{T_t}{P_t} + z_t B_t^{Issue} = 1 * (1 - \Delta_t)\, B_t^{Stock} + \frac{G_t}{P_t} + \frac{T_t^C}{P_t} \tag{32}$$

.Fiscal revenues come from taxes, T_t, and new bond issuance $z_t B_t^{Issue}$, whereas expenditures come from government consumption, G_t, and the service of the debt stock B_t^{Stock}, including bonds emitted in current period $\dfrac{T_t^C}{P_t}$[36]. The government budget constraint can also be written as:

$$\frac{T_t}{P_t} + (z_t - 1)\, B_t^{Stock} = \frac{\delta_c z_t B_{t-1}^{Stock}}{\pi_t} + \frac{G_t}{P_t} \tag{33}$$

In each period the government repays the past debt B_{t-1}^{Stock} at market price $\delta_c z_t$ and sells new bonds B_t^{Stock} at a price $(z_t - 1)$. The taxes are given by: $\dfrac{T_t}{P_t} = \tau_t^w \frac{W_t}{P_t} H_t$. Labour taxes are set according to the following fiscal rule:

$$(\tau_t^w - \tau_w) = \phi_y^f (Y_t - Y) + \phi_b^f (B_t - B) \tag{34}$$

High values of ϕ_y^f and ϕ_b^f denote a fiscal strategy with a consolidation target.

Monetary policy is conducted by means of the standard Taylor rule:

$$\ln\left(\frac{1 + r_t^n}{1 + r^n}\right) = (1 - \phi_r)\left[\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{Y}\right)\right] + \phi_r \ln\left(\frac{1 + r_{t-1}^n}{1 + r^n}\right) + m_t \tag{35}$$

[36] Exogenous government spending is calibrated so that sovereign default never materializes, even though households give a positive probability to this event.

, where m_t is a monetary policy shock which follows an AR (1) process. All variables are deviations from the target or steady state (symbols without time subscript). $\phi_\pi = 1.5$,$\phi_y = 0.5/4$ and $\phi_r = 0.8$ are respectively the rates on inflation, output and the interest rate smoothing.

Equilibrium conditions imply that the bond market clears, $B_t = B_t^b + B_t^{hh}$, where B_t^{hh} is the fraction of bonds held by households, that capital is linearly allocated, $K_t = K_t^h + K_t^e + K_t^b$, where $K_{t+1} = (1-\delta)K_t + p_h RI_t$, and that the following resource constraint holds:

$$Y_t - cI_t = C_t + C_t^e + C_t^b + I_t + G_t$$

where $-cI_t$ is the resource cost induced by banks' monitoring.

3.5.1 Sovereign Risk and Banks' Funding Composition

Before moving to the quantitative simulations it is useful to highlights the main channels operating in the model through some analytics. I examine here the effects of sovereign risk on banks' funding composition, banks' funding costs (and implicitly liquidity risk) and on banks' credit to firms. Results will be assessed quantitatively in the simulation section.

I start from examining the broad measure of banks' short term liability, D_t. From the investors' participation constraints short term liabilities are given by:

$$D_t = s_t^h q_t p_h RI_t + (z_t - 1)\, B_t^b \tag{36}$$

Even without the risk of runs the above equation makes clear that an increase in sovereign risk (a fall in bond prices) causes a fall in short term liabilities. As overall banks' profits soar, banks wish to save on monitoring costs. This in turn discourages investors from participating to the contract. Deposits fall and banks are forced to offer higher returns to depositors.

The fall in deposit is further amplified by investors' coordination problem. As investors receive signals of non-performing banks' assets, the probability of a run raises.

As investors run, the bank can re-finance the liquidity short-fall via repo trading. A fall in sovereign prices however reduces banks' collateral values and their ability to insure liquidity risk. This has an overall impact on short term liability which can well be understood by substituting the repo market collateral constraint, $(z_t - 1)\, B_t^b = \rho_t D_t$ into 36 to obtain the following reduced form for the ratio between short-term liability and investment:

$$\frac{D_t}{I_t} = \frac{s_t^h q_t p_h R I_t}{1 - s_t^h \rho_t} \tag{37}$$

While the supply of short term liabilities decreases, banks start to change funding composition and shift toward more stable funding sources. Moreover the increase in asset risk (due to the increase in sovereign risk) induces an endogenous increase in the optimal equity ratio, which in the model acts as a discipline device. The optimal amount of equity capital in the model can be derived through the bankers' participation constraint, $BK_t = \frac{\pi_{t+1} q_t p_h s_t^b I_t}{(1+r_t^m)}$. Using the latter and the optimal amount of deposits (see 37), it is possible to derive the bank capital ratio:

$$bk_t = \frac{BK_t}{BK_t + D_t} = \frac{cp_h R q_t I_t}{cp_h R q_t I_t + [Rq_t(p_h - p_l) - bq_t - c] \left[R q_t I_t p_h + (z_t - 1) B_t^b\right] (1 + r_t^m)} \tag{38}$$

Notice that for given investment an increase in sovereign risk (which implies a fall in bond prices) requires an increase in the bank capital ratio. In this model the bank capital ratio acts as discipline devise. As banks' asset risk increases the cost of monitoring raises. To maintain banks' incentives to monitor it is necessary to increase banks' stakes into the projects. Hence this implies an increase in the amount of bank capital funding relative to short term liabilities, D_t. Bank capital is more costly than short term funding: bank capitalists extract rents due to the moral hazard problems, hence they require higher compensation. Hence an increase in sovereign risk also raises banks' cost of long term funding.

As explained above sovereign risk increases liquidity risk. The latter in turn affects bank's funding costs. By substituting the repo collateral constraint, 20, and the optimal deposit to investment ratio into 38 the bank capital ratio one obtains:

$$bk_t = \frac{BK_t}{BK_t + D_t} = \frac{cp_h}{cp_h + [R_t q_t(p_h - p_l) - bq_t - c] \left[p_h + \frac{\rho_t s_t^h p_h}{1 - s_t^h \rho_t}\right] (1 + r_t^m)} \tag{39}$$

Notice that the model can capture well also the two-way feedback loop between sovereign and bank risk. From the above expression it is clear that an increase in liquidity risk, ρ_t, requires an increase in the bank capital ratio. This in turn increases banks' funding costs since equity capital is more costly than short term liabilities. The increase in equity capital retention as well as the increase in banks' funding costs induces banks' to reduce their portfolio exposure in sovereign bonds. In turn the fall in banks' demand for sovereign impairs debt sustainability. Hence not only sovereign risk affects banks' balance sheets and risk, but also the reverse.

At last I examine the impact of sovereign risk on banks' credit to firms and investment. Notice that NW_t does not directly depend upon sovereign risk, hence to fix ideas I assume it fixed. This implies that banks' credit, $L_t = I_t - NW_t$ co-moves with investment. The impact of sovereign risk on investment can be assessed by examining equation22. As sovereign risk raises banks' bonds profits, Π_t^{bonds}, fall. This brings about a fall in bankers' net wealth, BK_t, as per equation 27. The fall in BK_t, coupled with the fall in the short term liabilities, D_t, unequivocally brings about a fall in I_t. Hence an increase in sovereign risk also triggers a credit crunch.

3.6 Calibration

In this section I detail the calibration used in the numerical simulations.

Household preferences and production. The time unit is the quarter. The utility function of households is $U(C_t, H_t) = \frac{C_t^{1-\sigma}-1}{1-\sigma} + \nu \log(1 - H_t)$, with $\sigma = 2$, as it is in most real business cycle literature aimed at capturing risk aversion. The parameter ν is set equal to 6 and has been chosen so as to generate a steady-state level of employment of $H \approx 0.3$. The discount factor is set to $\beta = 0.99$, so that the annual real interest rate is equal to 4%. The production function is a Cobb-Douglas, $F(\bullet) = K_t^{\alpha}(H_t)^{1-\alpha}$, with $\alpha = 0.3$. The quarterly aggregate capital depreciation rate δ is 0.025.

Banks. The parameters characterizing the contract among bankers, uninformed investors and entrepreneurs, p^h, p^l, c, R, b, and the wealth accumulation parameters, γ^e, γ^b, are calibrated as follows. The p^h is set equal to 0.9 to reproduce firms' quarterly failure rate in industrialized countries, as reported in most of the macro literature on firm dynamic and/or in the financial accelerator literature. The remaining parameters are set in the two models so as to induce the following steady state values. 1) A capital adequacy ratio, $\frac{BK}{BK+D}$, of 19% in line with BIS data [6]. 2) A ratio of investment over output, $\frac{I}{Y}$, approximately of 0.15, a value compatible with most RBC studies. 3) A ratio of capital over output, $\frac{K}{Y}$, of 6.6, value set in accordance with ranges considered in the RBC literature. 4) A ratio of investment over entrepreneurial net worth of, $\frac{I}{NW}$, equal to 2. And 5) a return on bank equities (ROE), $\gamma^b \left[Z_{t+1} + q_{t+1}(1-\delta)\right] p_h R_t^b$, of 16%, a value compatible with data reported in Berger [8], who looks at historical averages. 6) Banks operating costs of 5 percent of investment. 7) A share of short term liabilities subject to runs, ρ, of 0.2.

Sovereign risk and the fiscal sector. Parameters in the fiscal rules are set as follows: $\phi_Y^T = 0$; $\phi_B^T = 0.5$. The expected sovereign bond premium, Δ_t, is computed using a Beta distribution with the following parameters, $\alpha^{BG} = 3.70$, $\beta^{BG} = 0.54$, and a maximum debt to output ratio of 2.56. To set those numbers we used evidence in Rudebusch and Swanson [35] and Cruces and Trebesch [?].

Shocks. The shocks considered include the standard macro shocks (productivity and government spending) as well as financial and liquidity shocks. Productivity shock are modeled as AR(1) processes, $A_t = A_{t-1}^{\rho_\alpha}\exp(\varepsilon_t^\alpha)$, where the steady-state value A is normalized to unity, $\rho_\alpha = 0.95$ and $\sigma_{\varepsilon^\alpha} = 0.008$. Log-government consumption evolves according to the following exogenous process, $\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) + \varepsilon_t^g$, where the steady-state share of government consumption, g, is set so that $\frac{g}{y} = 0.25$ and ε_t^g is an i.i.d. shock with standard deviation σ_g. Empirical evidence for the US in Perotti (2004) suggests $\sigma_g = 0.0074$ and $\rho_g = 0.9$. The monetary policy shocks are calibrated as follows. Autoregressive coefficient of 0.2; this is consistent with Rudebusch [34]. Based on the evidence of Angeloni, Faia and Lo Duca [3], and consistently with other empirical results for US and Europe, the standard deviations of the shocks is set to 0.006. To calibrate the sovereign shock I fit an AR(1) process into CDS premia for the period 2008-2013. The resulting parameters are 0.06 for the variance of the i.i.d. component and 0.9 for the autocorrelation. At last the sovereign shock, $\varepsilon_{f,t}$, is modelled as an AR(1) process. While there is quite much agreement that this shock is persistent, there is no univocal value holding for all countries. By fitting an AR(1) process into the data for CDS sovereign spreads presented in section 2, one recovers estimated persistence which varies significantly across countries but have a minimum value of 0.2. A number of papers estimating VAR models which include both sovereign and bank risk generally find that sovereign spreads are highly persistent (particularly so in the spot market) with values ranging from 0.6 to 0.9[37]. I use a conservative value of 0.7 for the persistence of the $\varepsilon_{f,t}$ process and experiment with different values. The qualitative results presented in the sections below indeed do not change when changing this parameters[38].

At last a few words about the simulation method. I use higher order approximation methods

[37] See Stanga[36] among others.

[38] Where significative quantitative differences emerge they will be signalled.

around a deterministic steady state. First order approximations are used for the standard macro shocks (as those have primarily first order effects), while second or higher orders of approximation are used when assessing the impact of news shocks.

4 Quantitative results

I will articulate the quantitative results along two dimensions First, I wish to assess the overall impact of sovereign risk onto the economy. I do so by simulating standard macro shocks (productivity and government spending) and by comparing the model with and without sovereign risk and by simulating the effect of sovereign shock, with and without anticipatory effects. Those simulations allow me to establish that the model is capable of reproducing a variety of stylized facts characterizing the recent euro area sovereign crisis.

I then use the model to assess the effects of consolidation policy. To account for the uncertainty surrounding fiscal policy implementation I account for noisy signal extractions on the policy parameters of the fiscal rule.

4.1 Effects of Sovereign Risk

Figure 1 shows impulse responses of selected variables to a 1% (negative) technology shock in the model with (dashed line) and without (solid line) risk on government bonds. The latter scenario is achieved by setting, $\Delta_t = 0$. As expected, output, consumption and investment go down due to the contractionary nature of the shock. When investment demand and the return to investment fall, both entrepreneurial net worth and bank capital (not shown for brevity) fall. The fall in overall project returns (coupled with the fall in bonds' trading returns) brings about a fall in banks' asset returns, which in turn triggers a depositors' run. Deposits fall because it is more difficult to entice investors to participate in the contract and because rumors of non-performing loans spread. The optimal bank capital ratio raises. The fall in productivity brings about a fall in asset prices. Banks' monitoring becomes (proportionally) more costly, the moral hazard problem steepens and it is more difficult to meet the incentive compatibility constraints for both the bank and the entrepreneur. Bankers need to be compensated for the higher costs stemming from the monitoring activity, hence the share of project returns accruing to them, R_t^b, must raise. The raise in the bankers' returns and the overall increase in banks' asset risk induces banks to increase bank capital ratios, as the latter work as discipline device within the optimal contract. Consistent with evidence equity capital behaves counter-cyclically (with respect to the business cycle). Not unexpectedly the contractionary shock produces a credit crunch (fall in banks' loans). The latter is governed in this model by three channels. First, the fall in banks' liquidity reduces funds available for credit. Second, the fall in projects' returns and bonds' trading profits induces a fall in banks' balance sheet values, which in turn reduces banks' capacity to lend. Third, the increase in equity capital (required to discipline monitoring) forces banks to hold funds away from risky investment.

Let's now examine the quantitative difference between the models with (dashed line in the panels) and without sovereign risk. The recessionary effects of the shock are much more pronounced in the model with sovereign risk. The fall in consumption (and its return to the steady state) implies a fall in the stochastic discount factor, $\Lambda_{t,t+1}$. From equation 5, the fall in the stochastic discount factor implies a fall in the price of bond, z_t, which in turn determines a fall in the value of bonds. Several additional channels are activated. First, banks' bond profits fall and this induces a fall in banks wealth as per equation 27. The fall in the value of banks' balance sheet triggers sharper falls in banks' loans, hence in investment. The latter in turn triggers sharper falls in banks' asset returns. Demand deposits fall by more with sovereign risk for two reasons. First, the fall in the discount factor and in asset prices induce a fall in demand deposits through the investors' participation constraint. Investors perceive that banks' moral hazard incentives are more severe, hence it is more difficult to meet their participation constraint. Second, as the deterioration in banks' asset returns is sharper under this scenario the extent of the bank run is larger. The chain of effects highlighted so far are part of the *banks' assets-liquidity risk* channel. However in the model there is also a *collateral channel.* Government bonds are indeed used by banks as collateral in repo refinancing agreements. Hence the fall in bond prices makes repo market liquidity scarce, thereby producing further strains on banks' funding and ultimately on banks' credit to firms. At last notice that the fall in available liquidity increases the banks' funding premium. The increase is much larger in presence of sovereign risk as investors are hesitant to engage in banks' investments.

The effects of government spending shocks (not shown for brevity) have similar implications. In response to falls in government spending (due for instance to a consolidation effort) output, investment, entrepreneurial wealth fall, while bank capital ratios and bankers returns from the investment project increase. As before the presence of sovereign risk amplifies the responses.

Figure 2 shows the effects of a 1% shock to sovereign risk Δ_t (solid line in each panel). The impulse responses (numbers on the y-axis are in percentage values) make even more evident the channels described above and shown analytically in section 3.5.1. The shock is recessionary and its transmission is consistent with the well know crowding out effect of sovereign debt on private debt. Output, consumption and investment all fall. Banks' profits from sovereign trading fall sharply and banks' asset risk increases. Due to this investors withdraw deposits, which indeed fall. Since now government bonds are valued less, banks' collateral capacity in the repo market declines. Hence overall banks' short term liabilities decrease and banks experience difficulties to rollover the short-fall in deposits through the repo market. In line with the BIS [11] report the liquidity short-fall is accompanied by an increase in the bank funding premium, namely the ratio between returns paid to investors (R_t^h and R_t^b) and the returns from projects. Generally speaking banks have to pay higher returns to entice investors to supply short term funds. Banks' loans fall too, again for three reasons. First the fall in banks' liquidity and the increase in STL costs reduces banks' available resources for loans. Second, the fall in bonds trading impairs banks' balance sheets and this reduces banks' capacity to supply firms' credit. Third, the overall increase in asset and liquidity risk forces banks to increase the optimal capital buffer, which in turn forces banks to shrink assets. Worth of note is that the fall in banks' credit is actually rather sharp (16% on impact and with hump-shaped dynamic at the fifth quarter) and takes almost 35 periods to come back to the steady state.

The model responses to sovereign risk are well in line with the Figures presented in section 2, upon which an increase in sovereign risk produces a fall in banks' short term liabilities and an increase in funding costs.

To fully assess the ability of the model with sovereign risk to reproduce data stylized facts I examine several aspects of the model implied statistics and their comparison to the data equivalent.

First, table 2 below shows the ratios of the volatilities of output, employment, investment and bank capital in the models with and without sovereign risk. Volatilities are computed for the model in response to a set of standard macro and policy shocks which include productivity, government spending and monetary policy, all calibrated as in section 3.6. The model numbers are compared to the ratios for the volatilities of the same variables for Greece over Germany, Ireland over Germany and Portugal over Germany [39]. The model/data comparison shows clearly that the presence of sovereign risk amplifies volatilities. The model statistics lie somewhat in between the data statistics for the chosen countries, being closer to the ratios between Ireland and Germany and Portugal and Germany respectively. The model volatilities have been computed in response solely to standard macro shocks and this explains the discrepancy with the most severe distress experienced in Greece. Greece had in the realm experienced an additional source of instability given by the large sovereign risk shock. Indeed, by adding sovereign risk shocks in the computation of the model statistics, numbers get closer to the ratios between Greece and Germany. Also notice that the ratios between bank capital volatilities in Greece and Ireland vis-a-vis Germany are quite high in the data. This is due to the fact that the Greek and the Irish banking system had been subject to several waves of bank capital actions prescribed by the regulators. In the case of Greece a first round of large recapitalization of 48.2 bn euros was conducted in June 2013 by the Hellenic Financial Stability Fund mainly for the four largest banks. The latter acquired further private capital at minimum 10% of the conducted recapitalization. A second round was conducted in May 2014 for an amount of 8.3bn euros, entirely financed by private investors. Those recapitalizations are all together very large considering the extent of Greek banks' assets.

Next, I compute in response to standard macro shocks (productivity, government spending and monetary policy) the correlation between sovereign risk, Δ, and banks' liquidity risk, ρ_t. The value returned in the baseline calibration is 0.79, which is very close, albeit slightly smaller, to the values reported in Table1 for the correlation between banks' funding and sovereign risk for a set of 12 euro area countries, plus the UK.

4.2 News on Sovereign Risk

As is well know actual sovereign defaults are rare events and much of the transmission of sovereign risks comes also from announcement effects. Rating agencies provide periodic estimations of sovereign risk and communicate them to market participants. Those announcements actually have large effects on the financial markets, the banking system and also on agents' decisions. Empirical

[39] A similar computation is done for the combinations with respect to France. Numbers are not reported for brevity, but are available upon request and provide a similar message.

evidence (see Gande and Parsley[20] and more recently Almeida et. al. [1]) shows for instance that the effects of announcements from rating agencies has significant effects on financial spreads and on the real economy. Based on this evidence I explore the effects of news shocks on sovereign risk in my model[40].

I employ a specification of news shocks standard in the literature. I then assume an implementation delay between the news and the actual realization following the convention in Mertens and Ravn[28][41], they indeed examine the impact of news shocks on fiscal policy. While Mertens and Ravn [28] focus on tax cuts or government spending, I introduce news shocks on sovereign premia. This implies that the timing of the delay between the announcement and the implementation might also depend upon financial market reactions. However notice that credit agencies assign sovereign ratings often by examining developments in fiscal policy and/or in the country's productivity[42], hence it is fair to assume that the same uncertainty surrounding the country' fiscal sustainability affects news on sovereign premia. Notice that beyond the benchmark specification for the implementation delay robustness checks confirm the qualitative results concerning news of sovereign risk spikes, which can be summarized as follows. Figure 2 shows a 1% news shock on sovereign risk with a 6 quarters implementation delay (dashed line in each panel). The overall qualitative effect is not dissimilar to the one observed for the actual realization of the sovereign shock. In a nutshell, news of an imminent increase in sovereign premia have contractionary effects (output, consumption and investment fall). Agents, who hear news of impeding increases in sovereign risk, anticipate the imminent fiscal adjustment and also the upcoming fall in the value of their wealth (exposed to sovereign bonds). In response to this they adjust consumption demand. In presence of sticky prices the fall in demand triggers a fall in output and investment. Banks also act in anticipation. They anticipate the upcoming fall in their profits and raise bank capital in response. This reduces the amount of bank funds available for firms' credit, thereby causing a further shrinkage in investment. Also, due to the sovereign-bank risk nexus, banks' liquidity premia increase. Investors foresee that banks highly exposed to sovereign risk will experience a shrink in asset value, hence they liquidate

[40] News are information signals. However notice that this signal is different in nature from the signal triggering the bank run. The first, is an aggregate signal, equal among investors, which does not require an information coordination problem, while the second does.

[41] Using a narrative approach on tax shocks the authors suggest an implementation delay of 6 quarters.

[42] See Cantor and Packer[15].

deposits in anticipation. As liquidity soars banks have to offer higher returns to investors, which results in an increase in banks' funding costs. Compared to the case of the actual realization, news shocks have a much larger and persistent quantitative impact. Overall the recessionary effects of an anticipation in sovereign risk spikes are much larger and the increase in banks' funding costs are much sharper. The main channels that contributes to the amplification are the wealth effects and the banks' liquidity channel. News shocks act as an additional confidence shock on both investors and banks. Consumers/investors become pessimistic about the future value of their wealth (exposed to sovereign). In their quest for safety they increase precautionary saving, off-load government bonds and deposits and front-load the consumption adjustment. Banks also become pessimistic about their possibility of raising funds in the future. For this reason they shift toward more stable funding means (equity capital) and reduce overall asset exposure. In the past literature the impact of news shocks (either on productivity or on fiscal policy[43]) materialized primarily through consumption fluctuations In my model the banks' liquidity and balance sheet channels render significant the impact of news shocks also on credit and investment.

4.3 Uncertain Consolidation Policy with Noisy Signal Extraction

A first response to the sovereign crisis in the euro area was the implementation of large fiscal consolidation packages in distressed countries. The goal was that of reducing sovereign risk, and its consequences, by brining debt onto a sustainable path. By containing sovereign risk consolidation policies are beneficial in that they contribute to mute the extent of the bank-sovereign risk nexus. In a dynamic context restrictive fiscal policies have also beneficial effects through anticipation of lower taxes in the future. They however also have perverse effects in that they reduce growth, hence tax revenues, thereby hampering the consolidation itself. A model where sovereign risk impacts banks' resilience and sustainability is the right laboratory economy to explore the various dimensions of fiscal consolidation. Specifically, I consider the effects of fiscal consolidation announcements in the form of a stochastic increase in ϕ_Y^T. This formulation is well in line with the implementation of the *European fiscal compact* (Title III) approved in 2011 for which automatic adjustments are done to business cycle output gaps[44]. Notice that fiscal consolidation announcements are often surrounded

[43] See among others Beaudry and Portier[7] or Mertens and Ravn [28].

[44] For countries under the Troika program prescribed adjustment is usually steepened in years in which growth is foreseen. Notice however that if the same news shock is inserted on the parameter ϕ_b^f the transmission is similar.

by large uncertainty. Agents consider part of the announcement as a real news and part as noise that will be revised in the future. The large uncertainty is due to the fact that even externally imposed consolidation programs (like those of the Troika or foreseen in the fiscal compact) are subject to Parliamentary discussion and votes. This implies that agents receiving news of fiscal consolidation have to solve a signal extraction problem. Notice that this signal (as well as the signal on sovereign risk spreads) are different in nature from the signal triggering the bank run. The first, is an aggregate signal, equal among investors, which does not require the solution to an information coordination problem, while the second does.

The noisy signal is modelled along the lines of Blanchard, L'Huillier and Lorenzoni[12][45]. More specifically I assume that the policy parameter, ϕ_Y^T, follows the process:

$$\overset{\wedge}{\phi}_{TY,t} = (1-\rho)\overset{\wedge}{\phi}_{TY,ss} + \rho\overset{\wedge}{\phi}_{TY,t-1} + \sigma^2_{\phi,t}\epsilon_{t-6} \tag{40}$$

where the index $\wedge$ indicates logs, the error term (also to be interpreted in logs) is as follows $\epsilon_t \sim N(0, \sigma^2_\epsilon)$. Agents receive a signal on the consolidation announcement. The signal conveys partly relevant information ϵ_t (that will realize at time t) and partly noise, v_t (non-fundamental changes), with v_t representing a Gaussian white noise, orthogonal to ϵ_t at all leads and lags:

$$s_t = \epsilon_t + v_t;\ v_t \sim N(0, \sigma^2_v) \tag{41}$$

To infer the variance $\sigma^2_{\phi,t}$ we can define the operator $h_{\phi,t} = \frac{1}{\sigma^2_{\phi,t}}$. The latter obeys to the following restriction (again to be interpreted in logs) obtained through a linear project problem:

$$h_{\phi,t} = \frac{\sigma^2_{\varepsilon\phi} + \sigma^2_\epsilon}{\sigma^4_{\varepsilon\phi}} + \sigma^2_{vt}v_t \tag{42}$$

See Appendix B to for details on the derivations of 42.

The above formulation can be rationalized as follows. The agents receive announcements about the future path of the fiscal policy variable, $\phi^T_{Y,t}$. The announcement contains a permanent autoregressive component, $(1-\rho_{\phi^T_Y})\overset{\wedge}{\phi}_{TY,ss} + \rho_{\phi^T_Y}\overset{\wedge}{\phi}_{TY,t-1}$, and a news component, $\sigma^2_{\phi,t}\epsilon_{t-6}$[46]. The news component is uncertain as it is scaled up by a the volatility of a noise component. Agents

[45] While those authors examine the effect of noisy signals for productivity shocks on output, I introduce noisy signals on fiscal parameters.

[46] Notice that I am still following Mertens and Ravn[28] convention on the timing of the news.

are not sure about how much of the news will materialize and in this respect they face a signal extraction problem.

Figure 3 below shows the impact of a 1% a news shock to the policy parameter $\phi^T_{Y,t}$ according to the above specification. I focus on the anticipated component of the fiscal consolidation (rather than on the noise[47]) as the main interest lies in assessing the effects of enacted austerity measures. Agents however discount that not all of the announced measures will materialize as they re-scale the news by $\sigma^2_{\phi,t}$.

The figure shows that announcement of a consolidation policy has recessionary effects at short horizons (for the first ten quarters). Agents expect tax hikes, hence reduce consumption. The ensuing fall in output (due to sticky prices) shrinks investment demand, which in turn reduce firms' loans and induces banks to increase bank capital ratios. As banks profitability falls (in this case due to lower firms' project profitability) investors run the bank and deposits fall. Banks' profits from bond trading also fall. This is mainly due to the decreased supply of government bonds, which also reduce their price. After 10 quarters however impulse responses temporarily revert. The consolidation effort reduces overall sovereign risk. Agents feel wealthier as bonds' price raise again, hence increase their consumption. The increase in demand brings about an increase in output, investment and firms' loans. The over-shooting lasts roughly until quarter 25, when all variables return to the steady state. The medium run expansionary effect of reduced sovereign risk is compatible with the literature on the effects of risk shocks on the business cycle (see Bloom [13] and Bloom et. al.[14]).

5 Conclusions

There is ample evidence that increases in sovereign risks have an impact on banks' funding composition and costs, and in turn on banks' credit. I construct a model which rationalizes the channels highlighted in the data and accounts for the sovereign-bank risk nexus. When banks are exposed to sovereign risk, an increase in sovereign premia operates primarily through two channels. First, there is a *asset-liquidity risk* channel. As banks' asset risk increases investors of short term liabilities run the bank. Second, since sovereign bonds are used by banks to rollover liquidity in repo markets,

[47] The impulse response for the noise shock is available upon request.

a fall in bonds' values reduces their collateral capacity, thereby producing further spiralling effects that induce liquidity shortages. Overall the liquidity short-fall coupled with increased asset risk raises banks' funding costs. This is so since banks have to offer higher returns to outside investors in order to attract liquidity. The strains on the liability side have also an impact on banks' credit extensibility to firms.

I use the model as laboratory to test the effects of anticipatory effects of sovereign risk and to assess the role of consolidation policies announcements in an uncertain environment. I find that news shocks on sovereign risk sharpen recessions. As agents hear news of sovereign distress they anticipate the upcoming fiscal consolidation and adjust demand in anticipation. In presence of sticky prices the adjustment in demand translates into an output adjustment. Banks also act in anticipation of the upcoming raise in sovereign risk and increase equity capital, which in turn reduces banks' credit. Due to the sovereign-bank risk nexus, banks' liquidity premia increase. Investors anticipate that banks highly exposed to sovereign risk will experience a shrink in asset value, hence they liquidate deposits.

In such laboratory economy announcements of consolidation policies have mixed results. I realistically assume that announcements are surrounded by uncertainty. Indeed most austerity measures undertaken to contain debt are often reverted back at later stages due to the political uncertainty. In this context noisy news (with signal extraction) of consolidation policies are recessionary in the short run, as they contribute to investors and banks pessimism, and mildly expansionary in the medium run, as the reduction in sovereign risk produces wealth effects. The liquidity channel highlighted throughout the paper is crucial in accounting for the realm of the fiscal transmission.

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6 Appendix A. Investors Coordination Game

The unique cut-off for the new shock triggering investors' run:

$$\tilde{\vartheta}_t \leq \exp(\widetilde{\varepsilon}_t) = \frac{R}{R_t^b} \tag{43}$$

can be rationalized through an information coordination game (see [?] and [?]). Specifically the above threshold can result as the unique equilibrium of a global game among investors who have a binary decision with two actions: "run" and "no run". Let us assume that there are $m = \{1, ..., M\}$ investors and define η as the fraction of depositors who run the bank. Each depositor, m, receives a private signal regarding the realization of banks' asset returns which takes the following form:

$$\vartheta_{m,t} = \varepsilon_{i,t} + \mu_{m,t} \tag{44}$$

where μ_m are small errors which are independently distributed with a cumulative distribution $\mathbb{F}$ given by the normal distribution, $N(0, \sigma_\mu^2)$. The signal can be thought of as the investors' private information or opinion regarding bank i's health. While agents have heterogenous signals, none has an informational advantage. The signal gives indications on the status of bank's health, but also provides information about other investors' signals. The decision to run or not is taken by setting expected payoffs equal to zero. Guessing other depositors' actions is of fundamental importance in informational games with complementarities. Indeed investors binary decision depends upon expected payoffs from the run, which in turn depend upon the amount of bank i funds which are left after other depositors have run.

The ex ante expected payoff (conditional on the signal and on the other investors' probability of a run) for the investors in our model can be constructed as follows. The payoffs that investors expect to receive if they run is given by the difference between the ex ante overall return on assets and the return accruing to bank capitalists, weighted by the fraction of investors who have not yet run and divided by the fraction of investors who still have to run. Each marginal investors runs when this expected payoff becomes equal to zero.

Lemma 1. *The unique equilibrium for the run game amounts to all depositors of bank i choosing the threshold strategy:*

$$\tilde{\vartheta}_t \leq \frac{R}{R_t^b} \tag{45}$$

Proof. We start by computing the expected payoff of each depositor, m, of bank i from running conditional on signal ϑ_m and conditional on depositors $j \neq m$ running when $\vartheta_j \leq h$. The value is as follows:

$$\Upsilon(\vartheta_{m,t}, h_t) = \left[\mathbb{E}\left[\varepsilon_{i,t} \mid \vartheta_{m,t}\right] p_h R q_t I_t - p_h R_t^b q_t I_t\right] \frac{1-\eta}{\eta} \mathbb{F}\left(\frac{h_t - \vartheta_{m,t}}{\sqrt{2}\sigma_\mu}\right) \tag{46}$$

The depositor who decides to run gets the expected value of bank i assets, $\mathbb{E}\left[\varepsilon_t \mid \vartheta_{m,t}\right] p_h R q_t I_t$, net of the proceeds to be given to equity capitalists and weighted by the fraction $1-\eta$ of depositors who have not run previously and in proportion of the depositors who have not yet run the bank. The mass of depositors who have run previously is given by the fraction η multiplied by the probability that the signal of those depositors is below the threshold h_t, namely $\mathbb{F}\left(\frac{h_t - \vartheta_{m,t}}{\sqrt{2}\sigma}\right)$. Notice that the probability mass $\mathbb{F}\left(\frac{h_t - \vartheta_{m,t}}{\sqrt{2}\sigma}\right)$ has been obtained using the fact that $\vartheta_{j,t} \mid \vartheta_{m,t} \sim N(\vartheta_{m,t}, 2\sigma_\mu^2)$. Each depositor m will run when the expected payoff in 46 equals zero. Given the above we can re-write the expected payoff as follows:

$$\Upsilon(\vartheta_{m,t}, h_t) = \left[\vartheta_{m,t} p_h R q_t I_t - p_h R_t^b q_t I_t\right] \frac{1-\eta}{\eta \mathbb{F}\left(\frac{h_t - \vartheta_{m,t}}{\sqrt{2}\sigma}\right)} \tag{47}$$

The function in 46 is monotonically increasing with respect to $\vartheta_{m,t}$ and with respect to h_t. Therefore there must be a unique value of $\vartheta_{m,t}$ (in every period) for which the function is zero and that defines the switching strategy common to all depositors (hence when $\eta = 1$). This threshold can formalized as follows: $s_{m,t}(\vartheta) =$ run if $\tilde{\vartheta}_t \leq \frac{R}{R_t^b}$ and $s_{m,t}(\vartheta) =$ no run otherwise. Through an iterative argument one can show that this switching strategy survives even after many iterations of the game. Notice that in $\tilde{\vartheta}_t = \exp(\widetilde{\varepsilon}_t)$ in the main text of the paper.

7 Appendix B. Sovereign Risk Signal Extraction Problem

Let's assume an AR(1) process for the law of motion of the fiscal rule 'parameter' $\phi_{TY,t}$, with 6-quarters ahead announced shock ϵ_t and stochastic volatility $\sigma_{\phi,t}^2$:

$$\phi_{TY,t} = (1-\rho)\phi_{TY,ss} + \rho\phi_{TY,t-1} + \sigma_{\phi,t}^2 \epsilon_{t-6} \tag{48}$$

where $\epsilon_t \sim N(0, \sigma_\epsilon^2)$.

The signal surrounding the news conveys partly relevant information ϵ_t (that will realize at time t) and partly noise, v_t (non-fundamental changes), with v_t representing a Gaussian white noise, orthogonal to ϵ_t at all leads and lags:

$$s_t = \epsilon_t + v_t;\ v_t \sim N(0, \sigma_v^2) \tag{49}$$

In this imperfect information setup, the agents' expectations on news are conditional on the signal and by linear projection of ϵ_t on v_t one gets:

$$\begin{aligned} E(\epsilon_{t-6}|s_t) = \frac{\sigma_\epsilon^2}{\sigma_s^2} s_{t-6} = \frac{\sigma_\epsilon^2}{(\sigma_\epsilon^2 + \sigma_v^2)} s_{t-6} = \\ = \alpha s_{t-6} \end{aligned} \tag{50}$$

Where $\alpha = \frac{\sigma_\epsilon^2}{(\sigma_\epsilon^2 + \sigma_v^2)}$ is the noise-to-signal ratio (Beaudry and Portier[7]), measuring the relative importance of news on the signal. Hence, the conditional variance of the news on the signal is:

$$V(\alpha s_{t-6}) = \frac{\sigma_\epsilon^4}{(\sigma_\epsilon^2 + \sigma_v^2)} = \sigma_{\phi,ss}^2 = \alpha \frac{1}{\sigma_\epsilon^2} \tag{51}$$

The above specification implies that agents attach a variance to the news in 48 that is conditional on the information available at time t about the news (signal) and it depends on the noise-to-signal ratio. We can define the operator $h_{\phi,t} = \frac{1}{\sigma_{\phi,t}^2}$, whose mean (in the steady state) we assume to be the inverse of the conditional variance of the news $h_{\phi,ss} = \frac{1}{\sigma_{\phi,ss}^2} = \frac{(\sigma_\epsilon^2 + \sigma_v^2)}{\sigma_\epsilon^4}$. Its law of motion is a white noise process with non-zero mean and variance σ_v^2:

$$h_{\phi,t} = \frac{(\sigma_\epsilon^2 + \sigma_v^2)}{\sigma_\epsilon^4} + \sigma_v^2 v_t \tag{52}$$

The above specification describes well the two limiting information cases. In the first case the announcement is transmitted fully and perfectly to agents and it will be realized at time t. In the second case the announcement is entirely a noisy signal.

- $\underline{Perfect\, signal}: (\sigma_v^2 = 0), \alpha = 1, h_{\phi,t} = \frac{1}{\sigma_\epsilon^2}, \sigma_{\phi,t}^2 = \sigma_\epsilon^2$

- $\underline{Noisy\, signal}: (\sigma_v^2 \to \infty), \alpha = 0, h_{\phi,t} \to \infty, \sigma_{\phi,t}^2 \to 0$

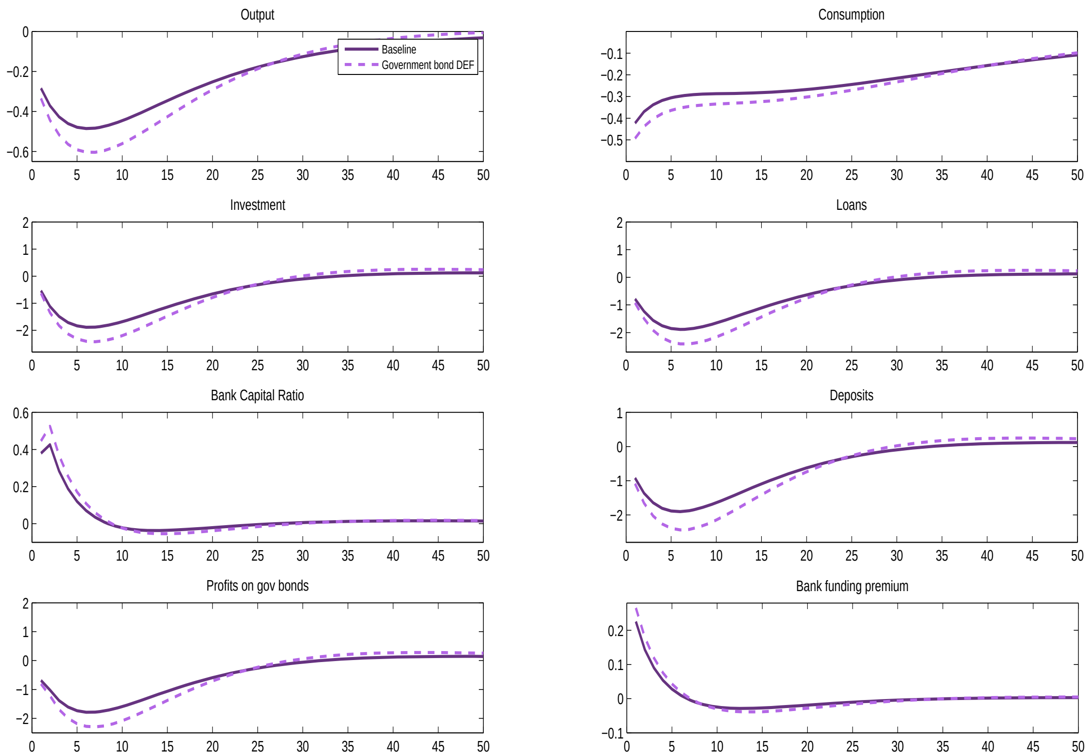

Figure 1: Impulse response of selected variables to 1% productivity shock in the models with and without sovereign risk.

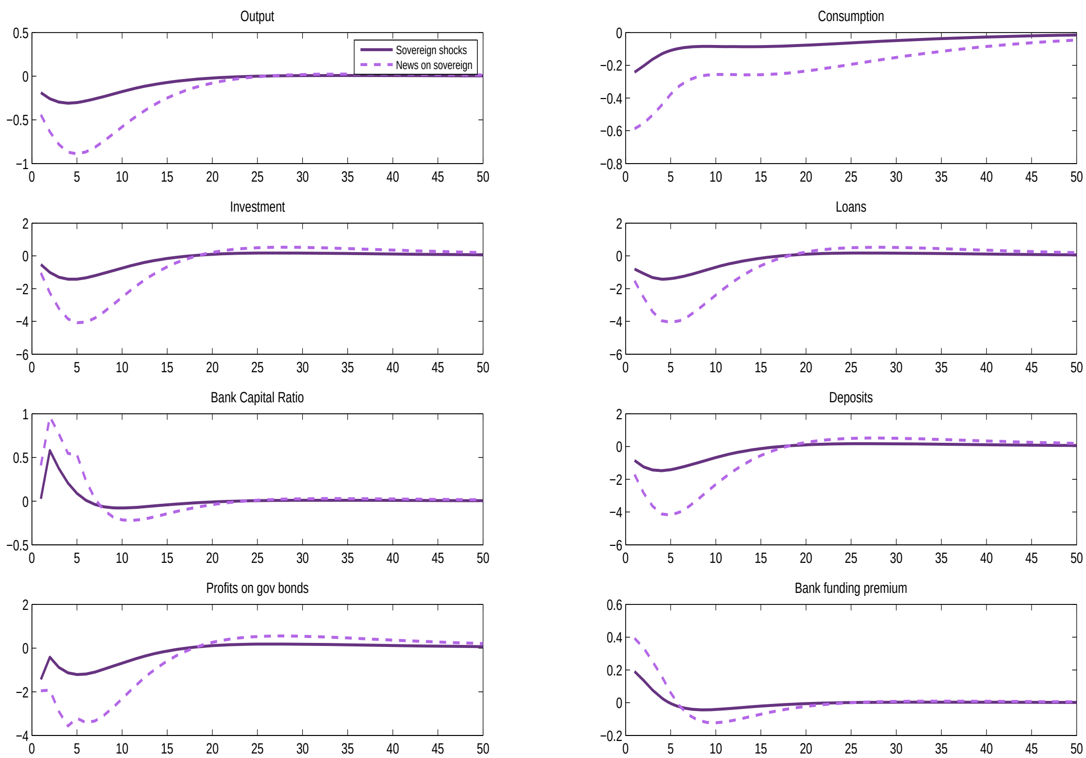

Figure 2: Impulse response of selected variables to 1% sovereign risk shock (solid line) and to news shock on sovereign risk (dashed line).

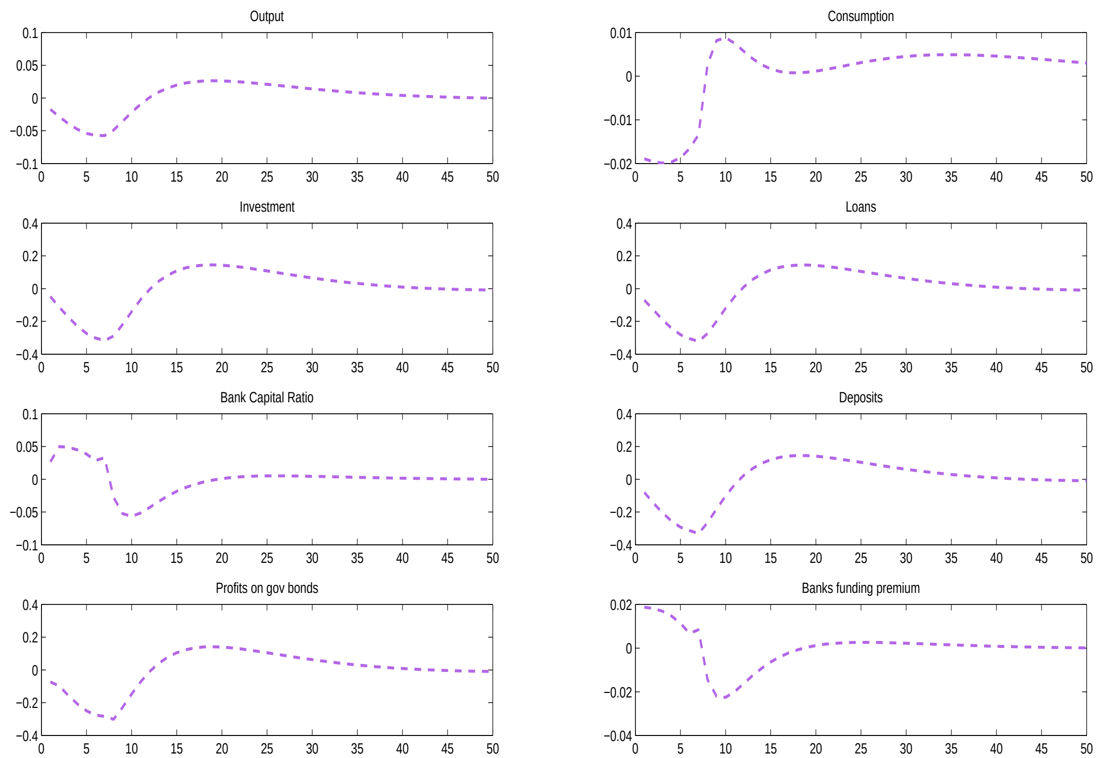

Figure 3: Impulse responses of selected variables to a 1% news shock to the parameter governing the tax rule (consolidation policy).

Table 1: Correlations of banks CDS and sovereign CDS for median banks in selected countries. Sample period 2008-2013.

AT	BE	DE	ES	FR	FIN	FR
0.90	0.86	0.88	0.84	0.94	0.89	0.94
FR	GR	IR	IT	NL	PT	UK
0.94	0.61	0.90	0.95	0.94	0.92	0.50

Table 2: Ratios of second moments of selected variables in the model and in the data. Data refer to combinations of the following countries: Ireland versus Germany, Greece versus Germany and Portugal versus Germany.

Ratios of S.D.	Model	Ireland/Germany	Greece/Germany	Portugal/Germany
Output	1.18	1.64	3	0.94
Employment	1.02	1.52	1.78	0.84
Investment	1.21	5.05	2.97	1.6
Bank capital	3.81	13.91	13.33	3.95