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BANK AND SOVEREIGN RISK INTERDEPENDENCE IN THE EURO AREA

Abstract

We develop a dynamic stochastic general equilibrium model to study bank risk and sovereign risk interdependence in the Euro Area. We find that an increase in capital investment risk shock, results in a considerably deeper recession when sovereign risk is also present. This result has three policy implications. First, Euro Area policies dealing with failing banks aggravated the recession. Second, although there has been a supranational effort with the creation of the EFSF/ESM to provide loans to sovereigns, as long as there is no direct mechanism for financial sector rescues, Euro Area policies continue to exacerbate the recession. Third, in favor of austerity measures used in the EA, we find that government spending multipliers are smaller in the presence of sovereign risk.

JEL Classification: E32, E44, E52, E58, E62, E63, G21 and H3
Keywords: bank rescues, cyclicality, DSGE model, government spending multiplier, investment risk and sovereign risk

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1. Introduction

Historically, financial crises tend to be followed by sovereign debt crises (Reinhart and Rogoff (2009)). But, the vicious circle between systemic bank failures and rising sovereign debt has nowhere been more profound than in the Euro Area (EA). On the one hand, in the absence of supranational coordination in dealing with failing banks, responsibility for the rescue of national banking systems falls with member states.[1] Given the size and the systemic nature of banks across the Euro area, fiscal consequences of rescuing banks are overwhelming.[2] On the other hand, domestic banks hold on their balance sheets a considerable amount of debt issued by their own and other European governments.[3] This is because government bonds are appealing, as they are easily used as collateral by banks and as the Basel regulatory framework allowed for zero risk weighting of bonds issued by EA governments. In addition, governments may have exercised pressure on banks to hold their debt. The large size of government debt holdings by EA banks, explains how concerns about sovereign solvency, immediately affect the stability of the banking system. The resulting two way bank-sovereign link constitutes one of the specific features of the EA that renders it especially vulnerable to shocks. Evidently, channels through which financial shocks, particularly those emanating from sovereign debt markets, propagate from the financial system to the real economy are of great importance. As shown in Figure 1, CDS premia on European banks and sovereigns have been increasing and are higher than the US rates. Beyond any doubt, a vicious cycle is been created where financial sector rescues in response to the financial crisis have resulted in a sovereign crisis that

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[1]Until recently, there has been no supranational mechanism dealing with failing financial institutions. The European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM) helped EA sovereign members with loans earmarked for that purpose but they were not entitled to inject capital directly to the respective sovereign's financial system. Further ECB's asset purchases, under the Securities Market Programme, have been limited compared to the Fed's. Recently, there have been efforts towards supranational approaches in dealing with bank solvency, directly. The ESM introduced the direct recapitalization mechanism (DRI), allowing for direct recapitalization of financial institutions and the ECB launched a bond-buying program with €60bn in purchases per month, up to €1.08 trillion.

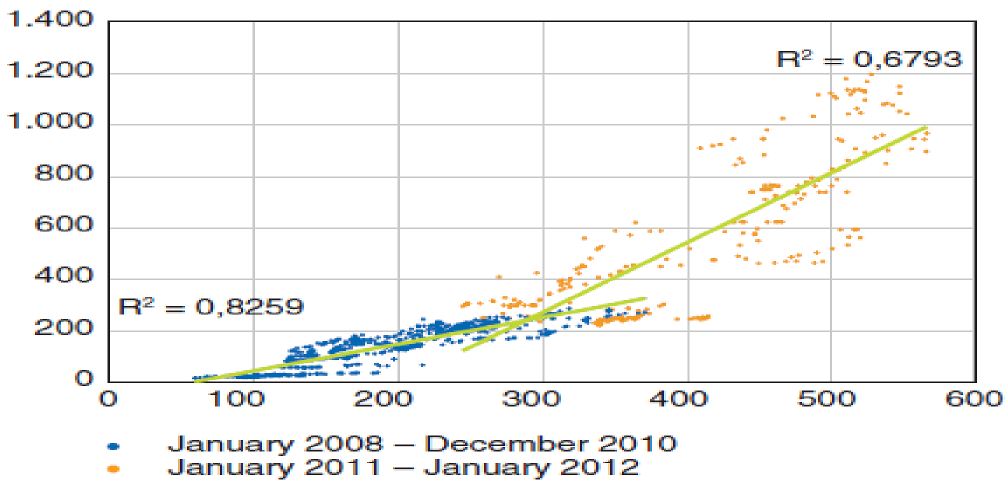
[2]As shown in Merler and Pisany-Ferry (2012b), still in 2010 the ratio of total bank assets to government tax receipts was high in EA countries with Ireland amounting to 45 times.

[3]As shown in Merler and Pisany-Ferry (2012a), just before the outbreak of the financial crisis the share of government debt held by domestic banks was very large especially for countries that have been subject to great pressure in the sovereign debt market (Greece, Ireland, Italy, Portugal and Spain). More worryingly these holdings have increased substantially during the crisis. Further, based on OECD (2011) calculations banks in the EA held considerable volumes of bonds of other European sovereigns. Belgian, Italian, and Spanish debt held by banks was 188%, 209%, and 171% of the Core Tier I capital in Belgium, Italy and Spain respectively, and over 50% in France and Germany.

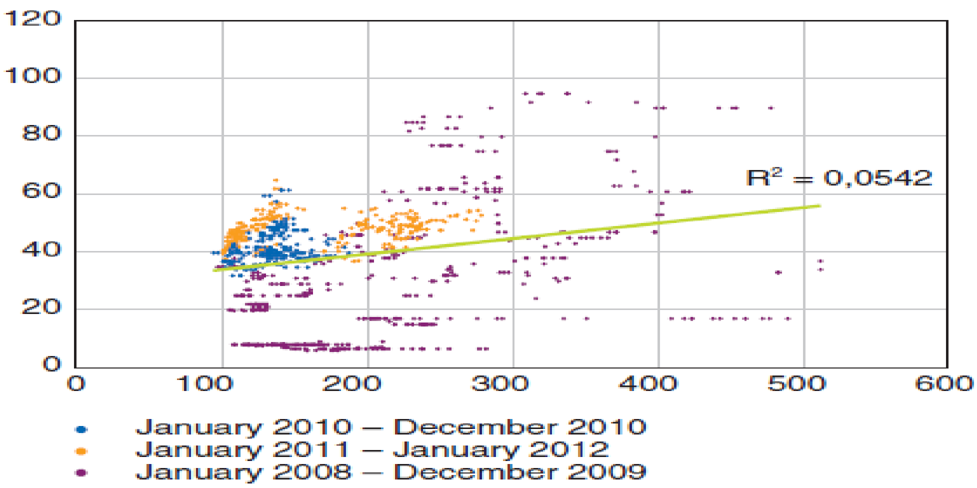
is further transmitted to the financial sector through their holdings of government debt.[4]

<u>Figure 1</u>
Correlation of sovereign and bank CDS: 2008 – 2012
(x-axis bank CDS 5 years, y-axis sovereign CDS 5 years)

EA



US



Source: Merler and Pisany-Ferry (2012b)

These facts on the EA debt crisis raise new important economic questions that need to be addressed: (a) What is the effect of an adverse financial shock on the business cycle when a sovereign debt – financial intermediation channel is present? (b) What

[4]The cycle is evident in the case of the Greek debt restructuring and the resulting Greek bank recapitalization. Following Greece's debt restructuring in April 2012 Greece's four biggest banks wrote down about €25bn in the combined value of their Greek government bond holdings. In May, Greece handed €18bn to those banks through the Hellenic Financial Stability Fund (HFSF), followed by a second trance in December of €16bn. The HFSF was set up to funnel funds from Greece's bailout programme to recapitalise banks.

are the implications for EA financial sector rescue policies? How effective was EA financial sector bailout policy? Has the EA been building the right supranational framework for supporting its financial sector? In this paper, then, we construct a model framework where the state bears the costs of such rescues, triggering a sovereign debt – financial intermediation interdependence, to look into these questions. In particular, we access quantitatively the impact of this interdependence on economic activity and draw implications about EA policy on financial sector bailouts.

In order to examine financial intermediation-sovereign interactions, we need to construct a model framework with a non trivial role for financial intermediaries, where frictions exist in the financial intermediation process and the financial sector has an important role as a source of business cycle fluctuations, as well as a framework that allows for the possibility of sovereign default, where sovereign risk affects business cycle dynamics. To model financial frictions we follow the model of Bernanke, Gertler and Gilchrist (BGG) (1999).[5] Financial frictions amplify the macroeconomic impact of exogenous changes. Financial frictions exacerbate the recession but not cause the recession. A negative shock first happens in the non-financial sector. Recent economic events starting with the financial crisis of 2008 suggest that the financial sector plays an important role as a source of business cycle fluctuations. The importance of financial shocks – shocks that originate from the financial sector – has started to be explored only recently. Recent papers stressing the role of financial factors for business cycle dynamics include, Gertler and Karadi (2009), Gertler and Kiyotaki (2010), Kiyotaki and Moore (2008), Curdia and Woodford (2009) and Christiano, Motto and Rostagno (CMR) (2010). As shown in CMR (2010), the BGG model is very successful in empirical applications and provides a suitable environment to access the effects of shocks in the financial sector.

[5]BGG (1999) analyze financial frictions in a general equilibrium setup using a costly state verification framework due to Townsend (1979) and Gale and Hellwig (1985). They assume that the borrower has a random return that is not observable to the lender, unless he pays an audit cost. In equilibrium a financial accelerator arises. The key link involves the inverse relationship between the external finance premium, i.e., the difference between the cost of external funds and the opportunity cost of internal funds, and the borrower's net worth. The inverse relationship arises because when the borrower has little wealth to contribute to the project, he requires a greater loan that comes with a greater spread reflecting potentially higher agency costs. To the extent to which net worth varies procyclically, the external finance premium will vary countercyclically, amplifying swings in borrowing and thus investment, spending and production.

To model sovereign risk we assume that the government faces a stochastic fiscal limit reflecting uncertainty in political negotiations. The government defaults if the endogenous level of debt surpasses the fiscal limit. We restrict ourselves to the case of no actual default. However, the probability of default arising from the stochastic fiscal limit setup may affect the value of debt even in the case of no current default. Further we assume that the required funds for the bail-out of the financial sector are an increasing function of financial sector risk as captured by the external finance premium. These funds are financed through increased government debt. The above way of modeling sovereign risk relates to the recent literature on stochastic fiscal limits.[6] Bi (2012) and Bi and Traum (2012), assume that government defaults when it is bounded by the fiscal limit. Default occurs when outstanding government debt breaches a maximum sustainable debt-output ratio. This ratio can depend upon the state of the economy and/or stochastic fluctuations in political risk. Finally, to quantitatively investigate the effect of the financial-sovereign interdependence for economic activity and policy we choose to embed our model in a New Keynesian (NK) Dynamic Stochastic General Equilibrium (DSGE) setup along the lines of Christiano, Eichenbaum and Evans (2005).[7]

We compute model impulse response functions to a shock in the financial sector. We compare the impulse response functions to the same financial shock of the following models: a) our baseline model with sovereign-financial interactions; b) a model with

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[6] In early literature Eaton and Gersovitz (1981), and a number of authors including Arellano (2008) and Mendoza Yue (2010) model sovereign defaults as strategic decisions made by a welfare maximizing government that balances the gains from foregone debt services against the costs of exclusion from international markets. In equilibrium this implies that the probability of default increases in the level of debt. The above literature can be used to study sovereign default in emerging market economies. However, the predicted level of government debt at which the sovereign default occurs is much lower than the debt level at which the sovereign risk premia are observed in developed countries, making it difficult to use those models for policy making in developed countries.

[7] The basic structure of their model incorporates sticky wages and prices, variable physical capital utilization, investment adjustment costs and habit persistence in preferences. In recent years, NK DSGE models have become a main tool in business cycle and policy analysis. The idea of using a model as a representation of the actual economy has been around for many years. But it was not until the work of Kydland and Prescott (1972) that models were used to simulate the economy and were judged according to how well the simulated data could replicate various properties of the actual data. As reviewed by Christiano, Trabandt and Walentin (2010) in the Handbook of Monetary Economics, the NK model simulates data of the actual economy well. With a combination of price and wage frictions it resolves a classic empirical puzzle about the effects of monetary policy: the slow response of inflation to a monetary disturbance. Moreover the model simultaneously explains the dynamic response of the economy to other shocks. In addition, the NK model rivals a-theoretical statistical models in terms of out of sample forecasting as demonstrated by Smets and Wouters (2003, 2007). In part because of these successes, a consensus has formed around this particular model structure.

the same financial frictions as our baseline model but without financial sector rescue funds and sovereign debt and risk.[8] Our baseline model is referred to as the Sovereign Risk (SR) model and the latter model as the Financial Accelerator (FA) model. Through this comparison, we can access the effect the additional financial-sovereign risk channel has for economic activity, compared to the FA and draw policy implications. First, an adverse financial sector shock, simulated by an increase in capital investment risk (risk shock), results in a considerably deeper recession, when sovereign risk-financial intermediation interactions are operating. The drop in net worth is substantial; the drop in loans is not as severe; however, the external finance premium is higher. The result is a substantial drop in investment and output, in the order of one and a half times bigger than that obtained under the FA model. The initial drop in consumption is more than double than in the FA model, rebounding as the drop in loans decelerates. To understand the mechanism that leads to this outcome we need to analyze the impact of our shock the FA and SR models. In the FA model a rise in the risk shock results in a rise in the external finance premium. The external finance premium inversely depends on the borrowers net worth, because when entrepreneurs have little net worth to contribute in project financing, agency costs are higher. To the extent which borrowers net worth is procyclical, due to the procyclicality of profits and assets prices, the external finance premium is countercyclical, amplifying swings in borrowing, investment, spending and production. The amplification of swings in the FA model is known as the financial accelerator effect.In the SR model simulations, an increase in financial sector risk, caused by a shock in the financial sector, results in a rise of funds needed for the rescue of the financial sector. The additional funds needed result in higher government debt. The higher level of debt increases the probability of default of the sovereign, resulting in higher sovereign and financial spreads. Higher spreads result in a higher external finance premium. As a result, the bank-sovereign interdependence reinforces the initial financial accelerator mechanism. The deeper recession in the sovereign risk model strongly depends on the government's countercyclical stand on required reserves for the costs of financial sector rescues. These cause the higher financing costs for banks that are further transmitted to non-financial corporations

[8] This is the BGG (1999) model incorporated in the NK setup of CEE (2005).

with a higher premium. Thus, our model replicates the effects of the vicious cycle created in the EA.

Our model has three policy implications. The first and main implication of our model for EA policies dealing with failing banks is that they aggravated the recession. The SR model captures the main features of the EA policy in dealing with failing banks, whereby each member state is responsible for the bail out of these banks. The SR model predicts the strong correlation between sovereign and financial spreads, as observed in the EA sovereign debt crisis (Figure 1). On the contrary, the simple FA model replicates a hypothetical scenario where the EA countries had not engaged in such financial sector bailouts, thus not causing such a correlation. As discussed above, comparing the SR model to the simple FA model, where financial sector bailouts are not present, the SR model predicts a deeper recession. Thus, our model comparison suggests the EA bank rescue policy has resulted in a deeper recession. Recently, there have been efforts towards supranational approaches in dealing with liquidity and sovereign solvency. However, until recently, there was no supranational mechanism dealing with failing financial institutions. The European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM) has helped EA sovereign members with loans earmarked for that purpose but they were not entitled to inject capital directly to the respective sovereign's financial system.[9] In addition ECB's asset purchases have been minimal compared to the Fed's. The ECB under the Securities Market Program from May 2010 – February 2012 conducted direct purchases of public and private debt securities, however the size of the program that by the end of 2010 was just over €70 billion and reached about €200 billion, was small compared to Federal Reserve purchases of over $1 trillion in mortgaged backed securities by early 2010.[10] Thus, the second policy implication of our model is that as long as bank solvency remains a national matter, continues to contribute to the recession in the manner identified above. The third policy implication of our model relates to the so called austerity policies.We use our model to access whether such measures can be self-defeating. This is done by comparing government spending multipliers of the FA and SR models. We find thatan increase in government spending

[9]In December 2014, the ESM's direct recapitalization mechanism (DRI), allowing for direct recapitalization of financial institutions under specific circumstances became operational.
[10]In January 2015, ECB announced a new government bond-buying program with €60bn in purchases per month, up to €1.08 trillion.

has a smaller impact on output in the presence of sovereign risk. An increase in government spending increases debt which in turn increases the probability of default of government bonds. This results in higher interest rates counteracting the initial positive impact of government spending on output. This suggests that austerity measures are less likely to be self-defeating in the presence of sovereign risk.[11]

The plan of the paper is as follows: In Section 2 we present the model framework used is our analysis. In Section 3 we present the workings of our model. Finally, in Section 4 we discuss the various policy implications and in Section 5 we provide a conclusion.

2. Model

The model economy is composed of households, firms, banks, entrepreneurs, capital producers, a government and a monetary authority. Households consume, hold bank deposits and supply a differentiated labor input to firms. Banks operate in a perfectly competitive environment. They use household deposits and injected bank rescue funds from the government to fund loans to entrepreneurs and government. Entrepreneurs use their net worth plus bank loans to purchase new installed physical capital. They rent capital services in competitive markets to firms. Agency costs introduce frictions into the entrepreneur-bank relationship. Capital producers combine investment goods with used, depreciated capital, purchased by entrepreneurs at the end of the period, to produce new capital. They face adjustment costs in production. Firms operate in a standard Dixit-Stiglitz framework for final good production. Final good firms are perfectly competitive and use intermediate goods to produce final output. Final output is converted to consumption goods and investment goods. Intermediate good producers use labor and capital. They face Calvo type frictions in setting prices. Government issues debt to finance government expenditures. These expenditures include funds for the costs of bank rescues. Government can default and not repay its debt. Monetary authority conducts monetary policy according to a standard Taylor rule, reacting on inflation and output changes.

[11] This result is in line with recent empirical and theoretical findings (see e.g. Corsetti (2012, 2013)).

2.1 Final and Intermediate Good Producers

There is a competitive, representative final good firm that produces a homogeneous final good, Y_t, using as inputs a continuum of intermediate goods, $Y_{j,t}$, $j \in [0,1]$, according to: $Y_t = \left[\int_0^1 Y_{j,t}^{(1/\lambda_f)} dj \right]^{\lambda_f}$, where λ_f, $1 \le \lambda_f < \infty$, represents the degree of substitutability between intermediate goods in the production of the final good. We assume that final output can be converted into consumption and investment goods one-for-one. The final good firm, being competitive, takes the price of the final good, P_t and the prices of intermediate goods $P_{j,t}$, $j \in [0,1]$, as given. It chooses the amount of inputs that maximize profits: $P_t Y_t - \int_0^1 P_{j,t} Y_{j,t} dj$, subject to its above mentioned production technology constraint. This implies that the the demand for intermediate good *j* is given by: $Y_{j,t} = \left(\frac{P_t}{P_{j,t}} \right)^{\frac{\lambda_f}{\lambda_f - 1}} Y_t$. This, in turn implies the following relationship between the price of intermediate good j, $P_{j,t}$, and the price of the final good, P_t: $P_t = \left[\int_0^1 P_{j,t}^{(\frac{1}{1-\lambda_f})} \right]^{(1-\lambda_f)}$.

Next, we assume that the j^{th} intermediate good producer is a monopolist that chooses its price, $P_{j,t}$, subject to Calvo type price setting frictions, so as to satisfy whatever demand materializes at its posted price. And, the j^{th} intermediate good producer rents capital services, $K_{j,t}$, and labor services, $l_{j,t}$, taking the rental price of capital services, $P_t r_t^k$ and the wage rate, W_t, as given. Then, we assume that the production costs of the j^{th} intermediate good producer is given by:

$$S_t(Y_{j,t}) = \min_{K_{j,t}, l_{j,t}} \left\{ P_t r_t^k K_{j,t} + W_t l_{j,t} \middle| Y_{j,t} = \begin{cases} K_{j,t}{}^a (z_t l_{j,t})^{1-a} - \Phi z_t, \, if \;\; K_{j,t}{}^a (z_t l_{j,t})^{1-a} \ge \Phi z_t \\ 0 \qquad\qquad\qquad\qquad , otherwise \end{cases} ; 0 < a < 1 \right\}$$

where: z_t represents the trend growth in technology and moves according to $z_t = \mu_z z_{t-1}$, $\mu_z \in (0,\infty)$ and Φz_t denotes the fixed cost of production.[12]It follows that the (real) marginal production cost of any intermediate good producers given by:

$$s_t = \left(\frac{1}{1-a}\right)^{1-a} \left(\frac{1}{a}\right)^{a} \frac{\left(r_t^k\right)^a \left(W_t / P_t\right)^{1-a}}{z_t^{1-\alpha}} \tag{1}$$

and that the input combination must be such that the (real) rental cost of capital services is equal to the marginal production cost divided by the marginal product of capital services:

$$r_t^k = \frac{s_t}{\alpha\left(\frac{z_t l_t}{K_t}\right)^{1-\alpha}} \tag{2}$$

where $K_t = \int_0^1 K_{j,t} dj \;\; and \;\; l_t = \int_0^1 l_{j,t} dj$.

Once an intermediate good producer has solved its cost minimization problem, it chooses its output price so as to maximize profits subject to the demand it faces and its price setting frictions constraint. In particular, we assume that intermediate good producers set prices a la Calvo, where a fraction$1-\xi_p$ of intermediate good firms can reoptimize their price in period *t* and a fraction ξ_p sets price as: $P_{j,t} = \tilde{\pi}_t P_{j,t-1}$. We define the inflation rate as $\pi_t = {P_t}/{P_{t-1}}$ and take $\tilde{\pi}_t = \pi_{t-1} = {P_{t-1}}/{P_{t-2}}$.[13]Next we consider intermediate good producers that can reoptimize in period *t*. These firms take into account the possibility that the maybe stuck with this price for several periods in the future and thus solve a dynamic problem. All adjusting firms in period *t* solve the same problem and hence have the same solution. Therefore, we can let $P_{j,t} = \tilde{P}_t$ for all firms that reoptimize. Then, the problem for the *t*-period reoptimizing firm maybe stated as follows: $\max_{\tilde{P}_t} E_t \sum_{i=0}^{\infty} (\beta\xi_p)^i \lambda_{t+i} [\tilde{P}_{t+i} Y_{j,t+i} - P_{t+i} s_{t+i} Y_{j,t+i}]$, where λ_t is the

[12]Fixed costs are used to rule out entry and exit into the production of the intermediate good *j*. In order to ensure this fixed costs must be specified in such a way that intermediate good production profits are zero in steady state. Thus, fixed costs grow at the same rate as the growth rate of output as specified in the model.

[13] $\tilde{\pi}_t$ is, in general, an index applied on last year's price and has different specifications in the literature. One of the simplest is the one adopted here.

Lagrange multiplier associated with the household's budget constraint. Since households are the owners of intermediate good firms it is natural that the firms should weight profits according to $\beta^i \lambda_{t+i}$ .Moreover, note that real marginal cost, s_t , has already been determined and therefore it is taken as given, in solving the above problem. Finally, E_t stands for the conditional expectations operator based on the information available at the beginning of period t. Using the fact,

$P_t = \left[\int_0^1 P_{j,t}^{(\frac{1}{1-\lambda_f})} \right]^{(1-\lambda_f)} = \left[(1-\xi_p)(\tilde{P}_t)^{\frac{1}{1-\lambda_f}} + \xi_p (\tilde{\pi}_t P_{t-1})^{\frac{1}{1-\lambda_f}} \right]^{1-\lambda_f}$, the first order conditions associated with this problem can be expressed as follows:[14]

$$\frac{1-\xi_p \left(\frac{\tilde{\pi}_t}{\pi_t} \right)^{\frac{1}{1-\lambda_f}}}{1-\xi_p} = \left(\frac{J_{p,t}}{F_{p,t}} \right)^{\frac{1}{1-\lambda_f}} \tag{3}$$

$$E_t \left[P_t \lambda_t Y_t + \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda_f}} \beta \xi_p F_{p,t+1} - F_{p,t} \right] = 0$$

$$(4)\ E_t \left[\lambda_f P_t \lambda_t Y_t s_t + \left(\frac{\tilde{\pi}_{t+1}}{\pi_{t+1}} \right)^{\frac{\lambda_f}{1-\lambda_f}} \beta \xi_p J_{p,t+1} - J_{p,t} \right] = 0 \tag{5}$$

where: $J_{p,t} \equiv E_t \sum_{i=0}^{\infty} (\beta \xi_p)^i A_{t+i} \lambda_f s_{t+i}$, $F_{p,t} \equiv E_t \sum_{i=0}^{\infty} (\beta \xi_p)^i A_{t+i} X_{t,i}$,

$A_{t+i} = P_{t+i} \lambda_{t+i} Y_{t+i} X_{t,i}^{(-\frac{\lambda_f}{\lambda_f - 1})}$ and $X_{t,i} = \begin{cases} \frac{\tilde{\pi}_{t+i} \tilde{\pi}_{t+i-1} \ldots\ldots \tilde{\pi}_{t+1}}{\pi_{t+i} \pi_{t+i-1} \ldots\ldots \pi_{t+1}}, & i > 0 \\ 1, & i = 0 \end{cases}$. Conditions (3) – (5) fully describe the transition of the average price level, P_t .

2.2 Capital Producers

There is a large fixed number of identical and competitive capital producers. They are owned by households and the latter receive any profits or losses in terms of lump sum transfers. Capital producers purchase depreciated capital and investment goods to produce new capital according to the following technology:

[14] For details see Christiano, Trabandt and Walentin (2010).

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + [1 - v(I_t / I_{t-1})]I_t \tag{6}$$

where: I_t denotes investment in physical capital in period t and $\bar{K}_t$ denotes physical capital stock at the beginning of period t; and $v_t \equiv v(I_t / I_{t-1})$ is a strictly increasing, strictly convex capital adjustment costs function, such that:

$$v_t = \exp\left[\sqrt{\frac{1}{2}v''}\left(\frac{I_t}{I_{t-1}} - \frac{I}{I_{-1}}\right)\right] + \exp\left[-\sqrt{\frac{1}{2}v''}\left(\frac{I_t}{I_{t-1}} - \frac{I}{I_{-1}}\right)\right] - 2$$

where: I / I_{-1} denotes the steady state growth rate of investment and v'' is a parameter whose value is the second derivative of v_t evaluated at the steady state I / I_{-1}.

Capital adjustment costs introduce curvature in the tradeoff between consumption and additional capital and therefore the price of capital deviates from P_t. Investment goods however, are purchased in the final goods market at price P_t. Let Q_t .denote the price of capital in period *t*. Then, the *t*-period profits for the representative capital producer are given by: $\Pi_t^k = Q_t\bar{K}_{t+1} - Q_t(1-\delta)\bar{K}_t - P_t I_t$. The capital producer's profit maximization problem is dynamic, due the presence of adjustment costs and can be written as: $\max_{I_t} E_t\left\{\sum_{i=0}^{\infty}\beta^i\lambda_{t+i}\Pi_{t+i}^k \middle| \bar{K}_{t+1} = (1-\delta)\bar{K}_t + [1 - v(I_t / I_{t-1})]I_t\right\}$.The first order condition associated with this problem is:

$$E_t\left[\lambda_t Q_t\left(1 - v_t - v_t'\frac{I_t}{I_{t-1}}\right) - \lambda_t P_t + \beta\lambda_{t+1}Q_{t+1}v_{t+1}'\left(\frac{I_t}{I_{t-1}}\right)^2\right] = 0 \tag{7}$$

where v_t' stands for the first derivative of v_t. Condition (8) links the price of capital to the price of investment goods.

2.3 Entrepreneurs

There is a large number of entrepreneurs that rent to intermediate good producers capital they buy from capital producers. An entrepreneur's state at the beginning of period *t*+1 is determined by its level of net worth, N_{t+1}. Entrepreneurs combine their net worth and a bank loan to buy from capital producers newly installed physical capital, $\bar{K}_{t+1}$. Then, they experience an idiosyncratic shock, ω, that transforms $\bar{K}_{t+1}$ into $\omega\bar{K}_{t+1}$. We assume that ω is a log-normally distributed random variable, across all entrepreneurs, with cumulative distribution $F_t(\omega)$. The mean and variance of $\log\omega$ are μ and σ_t^2, respectively. Moreover, μ is set so that, $E(\omega)=1$, when σ_t^2 takes its steady state value, σ^2. Time variation in σ_t captures the notion that riskiness of entrepreneurs varies over time. We follow the literature in referring to σ_t^2 as the risk shock. These assumptions about ω imply that entrepreneurs' investment in capital is risky. Further, we assume that ω is observed by entrepreneurs but can be observed by a bank only if the latter pays a fixed monitoring cost, μ. Next, we assume that capital utilization is endogenous. By introducing endogenous capital utilization, we differentiate between capital services and capital stock. Thus, at the beginning of period t+1 entrepreneurs rent out capital services $K_{t+1}=u_{t+1}\omega\bar{K}_{t+1}$.And, choose their capital utilization rate in any period t+1, u_{t+1}, so as to maximize profits: $[u_{t+1}r_{t+1}^k - a(u_{t+1}-1)]\omega\bar{K}_{t+1}P_{t+1}$, where $a(u_{t+1}-1)\omega\bar{K}_{t+1}$ is the adjustment cost from deviating from the "natural" utilization rate of 100%: $a(u_t-1)=\frac{1}{2}\sigma_a(u_{t+1}-1)^2+r^k(u_{t+1}-1);\quad \sigma_a\geq 2r^k$, where r^k stands for the steady state level of r_t^k. Clearly, this specification implies that capital utilization costs are positive and rise at the margin with any deviation of u_{t+1} from 1.The introduction of variable capital utilization and convex capital utilization costs is motivated by a desire to explain the slow response of inflation to a monetary policy shock.[15] Now, the first order condition associated with an entrepreneur's problem is given by:

$$r_t^k - a'(u_t) = 0 \tag{8}$$

At the end of any given period t+1, entrepreneurs sell back the undepreciated fraction $1-\delta$ of their capital to capital producers at price Q_{t+1}. Entrepreneurs' earnings

[15] In standard models prices are heavily influenced by costs and these in turn are influenced by the elasticity of factors of production. If factors of production can be expanded with a small rise in cost then inflation will not rise so much after a positive monetary policy shock. Allowing for variable capital utilization is a way to make capital services more elastic. If there is relatively small curvature in the rental cost function, entrepreneurs are able to expand capital services without a big increase costs.

therefore, come from renting out capital and from changes in the value of capital they have already purchased. Total earnings in period *t+1*, in currency units, of an entrepreneur with idiosyncratic shock ω are $\left\{[(u_{t+1}r_{t+1}^{k}-a(u_{t+1})]P_{t+1}+(1-\delta)Q_{t+1}\right\}\omega\bar{K}_{t+1}$. It is convenient to re-express an entrepreneur's payoff from buying capital as $(1+R_{t+1}^{k})Q_{t}\omega_{t+1}\bar{K}_{t+1}$, where:

$$1+R_{t+1}^{k}\equiv\frac{(u_{t+1}r_{t+1}^{k}-a(u_{t+1}))P_{t+1}+(1-\delta)Q_{t+1}}{Q_{t}} \tag{9}$$

is the real averagerate of return on capital. As already mentioned, we assume that entrepreneurs have net worth $N_{t+1}<Q_{t}\bar{K}_{t+1}$ and therefore, need a loan, L_{t+1}, to finance capital purchases. That is, $L_{t+1}=Q_{t}\bar{K}_{t+1}-N_{t+1}$. Depending on the realization of ω, entrepreneurs may or may not be able to pay back their loan. In this setup, first analyzed by Townsend (1979) and known as costly state verification, it has been shown to be optimal for the lender to offer the borrower a standard debt contract[16]. If the borrower pays the interest rate there is no monitoring. If the borrower cannot pay the interest, then borrower is monitored and the bank takes whatever the borrower has left. We define the endogenously determined cutoff point $\bar{\omega}_{t+1}$, for which entrepreneurs can just pay back their loan, as $\bar{\omega}_{t+1}(1+R_{t+1}^{k})Q_{t}\bar{K}_{t+1}=(1+R_{t+1}^{L})L_{t+1}$.Entrepreneurs with $\omega\geq\bar{\omega}$ pay interest R_{t+1}^{L} on their bank loan. Entrepreneurs with $\omega<\bar{\omega}$ cannot pay this interest and must give whatever they have left to the bank. Bankrupt entrepreneurs are monitored by the bank. The funds loaned to entrepreneurs by the bank in period *t* are obtained by banks from households. We suppose that banks can secure these funds by accepting deposits that pay a nominal interest rate R_{t+1}^{D}. Following CMR (2010), it is assumed that this interest rate is not state contingent on the realization of *t+1* shocks. This assumption allows the model to articulate Fisher's (1933) "debt-deflation" hypothesis. Thus, an unexpected change in the price level during the period of a loan contract, reallocates wealth between entrepreneur and lenders.

[16]Under a costly state verification framework, it can be shown that when borrowers and lenders are risk neutral, any efficient incentive compatible contract is a standard debt contract, which is fully described by the interest charged and the loan amount given.

Banks operate in perfectly competitive credit market and therefore have zero profits from intermediating funds between households and entrepreneurs. That is: $[1-F_t(\bar{\omega}_{t+1})](1+R^L_{t+1})L_{t+1}+(1-\mu)\int_0^{\bar{\omega}_{t+1}}\omega\, dF_t(\omega)\,(1+R^k_{t+1})Q_t\bar{K}_{t+1}=(1+R^D_{t+1})L_{t+1}$. The first term on the LHS of this equation is the fraction of non-bankrupt entrepreneurs times the interest and principal paid by each one of them. The second term on the LHS corresponds to the funds received by the bank from bankrupt entrepreneurs net of monitoring costs. The term on the RHS is the quantity of funds the bank must pay to households.

The entrepreneur's expected payoff is: $\int_{\bar{\omega}_{t+1}}^{\infty}[\omega(1+R^k_{t+1})Q_t\bar{K}_{t+1}-(1+R^L_{t+1})L_{t+1}]dF_t(\omega)$. The entrepreneur chooses the parameters of the standard debt contract, that is the loan amount, L_{t+1}, and the interest rate, R^L_{t+1}, so as to maximizes its expected payoff, subject to the zero-profit condition for the bank. In view of the definition of the cutoff point $\bar{\omega}_{t+1}$, and the entrepreneur's balance sheet, both the loan amount and interest rate can be substituted out for $\bar{\omega}_{t+1}$ and the entrepreneur's leverage, $\frac{Q_t\bar{K}_{t+1}}{N_{t+1}}$. Then, the bank's zero profit condition can be re-stated as:

$$\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})=\frac{1+R^k_{t+1}}{1+R^D_{t+1}}\left(1-\frac{N_{t+1}}{Q_t\bar{K}_{t+1}}\right) \tag{10}$$

And, the entrepreneur's maximization problem may be expressed as follows:[17]

$$\max E_t\left\{[1-\Gamma_t(\bar{\omega}_{t+1})]\frac{1+R^k_{t+1}}{1+R^D_{t+1}}\frac{Q_t\bar{K}_{t+1}}{N_{t+1}}\middle|\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})=\frac{1+R^k_{t+1}}{1+R^D_{t+1}}\left(1-\frac{N_{t+1}}{Q_t\bar{K}_{t+1}}\right)\right\}$$

where: $\Gamma_t(\bar{\omega}_{t+1})=G_t(\bar{\omega}_{t+1})-\bar{\omega}_{t+1}[1-F_t(\bar{\omega}_{t+1})]$ and $G_t(\bar{\omega}_{t+1})=\int_0^{\bar{\omega}_{t+1}}\omega dF_t(\omega)$. Then, the first order condition associated with the entrepreneur's problem is given by:

$$E_t\left\{[1-\Gamma_t(\bar{\omega}_{t+1})]\frac{1+R^k_{t+1}}{1+R^D_{t+1}}+\frac{\Gamma'_t(\bar{\omega}_{t+1})}{\Gamma'_t(\bar{\omega}_{t+1})-\mu G'_t(\bar{\omega}_{t+1})}\left[\frac{1+R^k_{t+1}}{1+R^D_{t+1}}\left(\Gamma_t(\bar{\omega}_{t+1})-\mu G_t(\bar{\omega}_{t+1})\right)-1\right]\right\}=0 \tag{11}$$

[17]This transformation is done toovercome the technical problem of the non-convex representation of the entrepreneur's preferences over the *Z-L* space.

As it turns out, under some regularity conditions, (11) gives a unique solution to the contracting problem.[18] Condition (11) implies that every entrepreneur, regardless of his net worth, receives a loan contract with the same rate of interest and with a loan amount that is the same fraction of his net worth.[19] After the entrepreneur has settled his debt with the bank in period *t+1* and the entrepreneurs capital has been sold to capital producers the entrepreneur's *t+1* level of net worth is determined. At this point the entrepreneur exits the economy with probability $1-\gamma$ and survives for another period with probability γ. Each period new entrepreneurs enter in such a way that the number of entrepreneurs remains constant. New entrepreneurs entering in period *t+1* receive a transfer, W^e. This exit and entry process ensures that entrepreneurs never accumulate enough net worth to become independent of external financing. Then, the evolution of net worth is given by:

$$N_{t+1} = \gamma \left\{ (1+R_t^k) Q_{t-1}\bar{K}_t - \left[1 + R_t^D + \frac{\mu \int_0^{\bar{\omega}_t} \omega dF_t(\omega)(1+R_t^k)Q_{t-1}\bar{K}_t}{Q_{t-1}\bar{K}_t - N_t} \right] (Q_{t-1}\bar{K}_t - N_t) \right\} + W^e \tag{12}$$

The term in braces in (12) represents total receipts of entrepreneurs minus total payments to banks. The term in square brackets in (12) is the unit cost of borrowing. And, in particular, the expression $\frac{\mu \int_0^{\bar{\omega}_t} \omega dF_t(\omega)(1+R_t^k)Q_{t-1}\bar{K}_t}{Q_{t-1}\bar{K}_t - N_t}$ is the external finance premium.

2.4 Banks

As already mentioned there is a continuum of identical competitive banks. Banks intermediate funds between households and entrepreneurs and finance government debt. Since, the number of banks and entrepreneurs are arbitrary in this model, there is no problem in denoting the total loans made by the representative bank to

[18]Details can be found in Bernanke et al (1999).
[19]Using this implication we have avoided aggregation issues over entrepreneurs with different levels of net worth.

entrepreneurs in period t+1 also denoted by L_{t+1}. And, let the total loans made by the representative bank to the government in period *t+1* denoted by B_{t+1}. The representative bank finances its loans by issuing deposits, D_t. Further, the bank gets government injections, Ξ_t. Thus, the bank's balance sheet equation is: $B_{t+1} + L_{t+1} = D_t + \Xi_t$ and bank profits, given the bank's zero profit condition for loans, can be expressed as: $R^B_{t+1}B_{t+1} + R^D_{t+1}L_{t+1} - R^D_{t+1}D_t$, where R^B_t denotes the return on bonds. The first order condition for maximization of the bank's profits, implies that the return on bonds must be equal to the return on deposits:

$$R^B_t = R^D_t \tag{13}$$

2.5 Households

There is a continuum $j \in (0,1)$ of households, that: consume the final good, C_t, provide deposits to banks, D_t,and supply a differentiated labor input, $h_{j,t}$, to intermediate good producers for a (nominal) wage rate, $W_{j,t}$. Since uncertainty is idiosyncratic, different households will work different amounts and earn different wage rates. So in principle, each household should be heterogeneous with respect to consumption and asset holdings. We assume, however, that there exist state-contingent securities, so that, in equilibrium, households are homogeneous with respect to consumption and asset holdings.[20]Households receive profits from capital producers, banks, and intermediate good producers, Π_t. Also, households receive an amount, $A_{j,t}$, which is the net payoff on the state contingent securities the j^{th} household purchases to insure against uncertainty arising from wage optimization. Finally, all households pay a lump sum tax, W^e_t, to finance the transfer payments made to the γ old entrepreneurs that survive and the $1-\gamma$ new entrepreneurs that enter, in period t. Thus, the j^{th} household's budget constraint is given by: $W_{j,t}h_{j,t} + (1+R^D_t)D_{t-1} + \left[\Pi_t + A_{j,t} - W^e_t\right] \geq D_t + P_tC_t$. Preferences of the j^{th} household are characterized by the conditional lifetime

[20]See Erceg, Henderson and Levin (2000).

utility: $E_0\sum_{t=0}^{\infty}\beta^t[\log(C_t - b_c C_{t-1}) - \psi_L \frac{h_{j,t}^{1+\sigma_L}}{1+\sigma_L}], 0 \le \beta \le 1, \sigma_L \ge 0$. Here, $1/\sigma_L$ is the Frisch labor supply elasticity and $b_c > 0$ is the degree of habit persistence in consumption.[21]Next, we assume that employment services used by intermediate good producers, l_t, are related to the differentiated labor services of households according to the technology: $l_t = \left[\int_0^1 (h_j)^{1/\lambda_w} dj\right]^{\lambda_w}$, $1 \le \lambda_w < \infty$. Thus, household *j* faces the following demand for its labor: $h_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{\frac{\lambda_w}{1-\lambda_w}} l_t$, where $W_t = \left[\int_0^1 (W_{j,t})^{1/(1-\lambda_w)} dj\right]^{(1-\lambda_w)}$ is the average wage rate in period t (i.e., the wage rate associated with l_t). Finally, we assume that households face wage setting frictions a la Calvo, whereby, a household chooses its wage optimally with probability $1-\xi_w$ and with probability ξ_w sets its wage rate according to: $W_{j,t} = \pi_{t-1}\mu_z W_{j,t-1}$. Then, note that since each household that is able to re-optimize sets the same wage rate, we can denote this wage rate by $\tilde{W}_t$. And, the demand for labor faced by the j^{th} household and the average wage rate can be restated as: $h_{j,t} = \left(\frac{\tilde{W}_t}{W_t}\right)^{\frac{\lambda_w}{1-\lambda_w}} l_t$ and $W_t = [(1-\xi_w)\tilde{W}_t^{1/(1-\lambda_w)} + \xi_w(\pi_{t-1}\mu_z W_{t-1})^{1/(1-\lambda_w)}]^{(1-\lambda_w)}$, respectively. Now, the household's problem is to maximize its expected utility subject to its budget constraint, the demand for its labor and the Calvo wage-setting frictions. Let $w_t = \frac{W_t}{P_t z_t}$, $\pi_{w,t} = \frac{W_t}{W_{t-1}}$ and $\tilde{\pi}_{w,t} = \pi_{t-1}$. The first order conditions associated with the j^{th} household's problem can be stated as follows:[22]

$$E_t[-\lambda_t + \beta\lambda_{t+1}(1+R_{t+1}^D)] = 0 \tag{14}$$

$$E_t[u'(C_t - bC_{t-1}) - b_c\beta u'(C_{t+1} - bC_t) - \lambda_t P_t] = 0 \tag{15}$$

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[21] This is motivated by VAR-based evidence according to which a positive monetary policy triggers a persistent reduction in the interest rate and a hump-shaped response in consumption. For $b_c = 0$ a fall in the interest rate would cause people to rearrange consumption intertemporally so consumption is highest exactly after the shock and lower later, by allowing however $b_c > 0$ we get the desired hump-shaped response.

[22]For details see Christiano, Trabandt and Walentin (2010).

$$J_{w,t} = w_t F_{w,\mathrm{t}} \left[\frac{1-\xi_w \left(\frac{\tilde{\pi}_{w,t}}{\pi_{w,t}} \mu_z \right)^{1/(1-\lambda_w)}}{1-\xi_w} \right]^{1-\lambda_w(1+\sigma_L)}$$

$$(16)\ E_t \left\{ l_t \frac{\lambda_z}{\lambda_w} + \beta \xi_w \mu_z^{\frac{1}{1-\lambda_w}-1} \left(\frac{1}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}} \frac{\tilde{\pi}_{w,t+1}^{\frac{1}{1-\lambda_w}}}{\pi_{t+1}} F_{w,t+1} - F_{w,t} \right\} = 0$$

$$(17)\ E_t \left\{ l_t^{1+\sigma_L} + \beta \xi_w \left(\mu_z \frac{\tilde{\pi}_{w,t+1}}{\pi_{w,t+1}} \right)^{\frac{\lambda_w}{1-\lambda_w}(1+\sigma_L)} J_{w,t+1} - J_{w,t} \right\} = 0$$

(18)

Conditions (16)-(18) are associated with the wage setting and employment decisions.

2.6 Government and Sovereign Risk

Government spends resources on the acquisition of government consumption goods, $P_t G_t$, and repayment of debt services, $(1+R_t^B)B_t$. In addition, government spends resources in acquiring funds for the bailout of the banking sector, Ξ_t. Further, we assume that government obtains resources from lump sum taxes to households, T_t and debt issuance, B_{t+1}. Government's budget constraint, defining that its total resources must equal its total expenditure, is given by:

$$B_{t+1} + T_t = (1+R_t^B)B_t + P_t G_t + \Xi_t \qquad (19)$$

Following Bohn (1998), we assume that the government follows the following fiscal rule for its tax policy: $T_t = \phi_\tau B_t$. Taxes are raised in a lump sum way as a fraction of outstanding debt, ensuring a no-Ponzi scheme. To ensure a balanced growth path we model government expenditures for the bailout of banks as increasing at the rate of technological progress.These funds are assumed to be a positive and strictly increasing function of banking risk as measured by the external finance premium: $\Xi_t = \xi_t P_t z_t$, where $\xi_t = \xi(e_t)$, $\xi'(\cdot) > 0$ and

$e_t = \bar{\omega}_t (1+R_t^k) \dfrac{Q_{K,t-1}K_t}{Q_{K,t-1}K_t - N_t} - (1+R_t^D)$. The rationale behind this formulation is to capture the notion that governments face increasing burdens due to costs of financial sector rescues. Risk in the financial sector is reflected in the external finance premium entrepreneurs end up paying on loans. Further, as proved by Bernanke et al. (1999), the external finance premium depends negatively on the share of the entrepreneur's capital investment that is financed by his own net worth. Therefore, our formulation of government provisions for the banking sector reflects the fact that bail-out funds rise in the presence of a weak financial sector[23], where entrepreneurs' net worth is low.[24]

In standard NK models, the return on government bonds, R_t^B, would be set equal to the safe rate, R_t, set by the monetary authority. In the case where there is sovereign risk, however, the return on government bonds may differ from the safe return. Consider the following setting based on the recent growing literature of fiscal limits. For each unit of the bond the government promises to pay the household/bank one unit of consumption next period. However the bond contract is not enforceable. At each period a stochastic fiscal limit is drawn from its distribution $b_t^* \sim B^*$.[25] The fiscal limit denotes a level of debt that if government surpasses will go bankrupt. We assume that this limit is determined by political negotiations. We therefore model the fiscal limit as a random variable reflecting uncertainty in political negotiations.[26] If

[23]The model does not attempt to incorporate macroprudencial financial regulations for banks as currently suggested among policy makers and Basel III regulations.

[24]Related literature provides support for modeling bank rescue funds as a function of the external finance premium. As shown by CMR (2010), the external finance premium is a good proxy for the risk shock: 87% of the fluctuations in the external finance premium in the Euro Area and 97% in the US are due to fluctuations in the risk shock, when modeled with a news shock structure[24]. As discussed by Gilchrist, Yankov and Zakrajsek (2009), research on the role of financial asset prices in cyclical fluctuations stresses the information content of credit spreads for the state of the economy. Information content of credit spreads likely reflects disruption in the supply of credit stemming from the worsening of the quality of borrowers' balance sheets and the deterioration in the soundness of financial intermediaries. Disruptions in credit markets have important consequences for macroeconomic outcomes.

[25]We model the cumulative density function of the fiscal limit distribution as a logistic function following Bi and Traum (2012). In that way we capture the strong non-linearity of the endogenous distribution of the fiscal limit derived by Bi (2012) – once the default probability begins to rise it does so rapidly. In addition the logistic function approximates the endogenous distribution implied by models of strategic default (see the distribution in Gordon and Guerron-Quintana (2013)).

[26]Bi (2012) models the fiscal limit as a function of both the Laffer curve, which is endogenously determined and political uncertainty. He assumes that the government pays back its debt unless it hits the peak of the Laffer curve. In addition the government might be constrained by some political limit

government debt surpasses its fiscal limit the government defaults. The default decision can be summarized by:

$$\delta_t = \begin{cases} 0 \; if \;\; b_{t-1} < b_t^* \\ 1 \; if \;\; b_{t-1} \geq b_t^* \end{cases}$$

where we have expressed government debt as a stationary real variable $b_t = \dfrac{B_t}{z_t P_t}$.

Note that the level of debt is endogenous in our model and is a function of bank risk. So the default decision depends upon the risk in the banking sector of the economy. The higher the bank risk the higher the debt and the higher the probability of government default.

In the above setting, the economy switches endogenously between default and non-default regimes. Thus, the model cannot be solved using a first order approximation.[27] In order to be able to solve the model using first order approximations we focus on the case where there is no actual default in the current period. The probability of default however, might affect the value of the bond. This modification is in line with evidence reported by Yeyati and Panizza (2011), who find that the output costs of default materialize in the run-up to defaults rather than the time when the default actually takes place.

Thus, we determine the price of the bond under the above setup, in the case where there is no actual default. We denote that price with $\overline{q}$. Let $s = (B, d, b^*)$ denote the aggregate state at the beginning of the period. It describes the endogenous level of debt *B*, the default history *d* and some exogenous variable b^*. We assume that *b** follows a Markov process and that all decisions are described in terms of the state *s*. The probability measure describing the transition from *b** to *b*'* shall be denoted with $\mu(db^{*\prime} | b^*)$. We assume debt is valued in financial markets where risk neutral

that is much lower than the peak of the Laffer curve. For simplicity we consider the fiscal limit as being purely stochastic. This simplification is in line with Bi and Traum (2012), where the estimate the fiscal limit for Greece. They argue that political considerations may make the government unwilling and unable to achieve the fiscal limit, due to features such as political inability to raise taxes. In the case of Greece, the protests against austerity measures suggest the relevance of such political considerations. They therefore take the fiscal limit distribution as exogenously given.

[27] Such models can be solved using the monotone mapping method, Coleman (1991) and Davig (2004).

traders discount future debt repayments at some return *R*. Given the level of debt and no past defaults, *d=0*, let $D(B)=\left\{b^{*}\middle|\delta(s)=1\ for\ s=(B,0,b^{*})\right\}$ be the default set, and let $A(B)=\left\{b^{*}\middle|\delta(s)=0\ for\ s=(B,0,b^{*})\right\}$ be the set of all *b**, such that government will not default and instead, continue to honor its debt obligations. Then, the market price of debt, in case of no current default is:

$$\overline{q}(B';s)=\frac{1}{R}\int_{b^{*\prime}\in A(B)}\mu(db^{*\prime}\left|b^{*}\right.)$$

This follows from risk neutral discounting and the hypothesis of no default today. Note that over the set *A(B)* the price of the bond is continuous. Thus by restricting ourselves to the non default set we can solve the model using first order approximations. Further, defining the probability of a continuation next period as $P(B';s)=\Pr ob(b^{*\prime}\in A(B')\left|s\right.)$ we can rewrite the above expression as:

$$\overline{q}(B';s)=\frac{1}{R}P(B';s)$$

It is clear from the above expression that sovereign bond prices are reflecting expected default risk, even when there is no current default.

In the case of sovereign risk we therefore have:

$$R_t^B=\frac{R_t}{P(b_{t+1})} \tag{20}$$

The return on bonds inversely depends on the probability of default of the government. Sovereign risk affects the interest rate on bonds and thus other interest rates in the economy.

2.7 Monetary Policy

We assume that monetary policy is set according to the following Taylorrule:

$$\hat{R}_{t+1}=\rho_i\hat{R}_t+(1-\rho_i)\frac{a_y}{4R}(\hat{y}_t-\hat{y}_{t-1})+(1-\rho_i)a_\pi\frac{\pi}{R}(\hat{\pi}_t-\hat{\pi}_{t-1}) \tag{21}$$

where the “^” above a variable denotes its percentage deviation from its steady state value.

2.8 Resource Constraint

We develop the aggregate resource constraint for this economy. The aggregate production function is given by:[28]

$$Y_t = K_t^{\,a}(z_t l_t)^{1-a} - \Phi z_t \qquad (22)$$

Market clearing for final goods implies:

$$\mu \int_0^{\bar{\omega}_t} \omega \, dF(\omega)(1+R_t^k)\frac{Q_{K,t-1}K_t}{P_t} + C_t + I_t + G_t \le Y_t \qquad (23)$$

where the first term on the LHS of (24) represents final output used up in bank monitoring and the last term on LHS represents resources used for government expenditures. Combining the above two expressions we get the aggregate resource constraint of the economy.

3. Workings of the Model

3.1 Equilibrium Conditions

We consider a sequence-of-markets equilibrium defined by a set of allocations, rates of return and prices which has the property that plans of households, final and intermediate good producers, entrepreneurs and banks are chosen optimally and goods and loan markets clear. We let the following transformations of variables: $w_t = \frac{W_t}{P_t z_t}$, $\bar{k}_{t+1} = \frac{\bar{K}_{t+1}}{z_{t+1}}$, $\lambda_{z,t} = \lambda_t P_t z_t$, $q_t = \frac{Q_{K,t}}{P_t}$, $n_{t+1} = \frac{N_{t+1}}{z_{t+1}P_{t+1}}$, $c_t = \frac{C_t}{z_t}$, $i_t = \frac{I_t}{z_t}$, $y_t = \frac{Y_t}{z_t}$, $b_t = \frac{B_t}{P_t z_t}$, $g_t = \frac{G_t}{z_t}$, $\xi_t = \frac{\Xi_t}{P_t z_t}$. We adopt the convention that *t*-period variables decided in period *t* appear with time subscript *t*. And, *t*-period variables that have

[28] Where following Yun (1996), we have ignored Yun’s distortion as it does not matter for first order linear approximations.

already been decided in period *t* appear with time subscript *t-1* in period *t*. The equilibrium is summarized by conditions (1)-(23), above. We therefore have 23 equations to be solved for the following 23 endogenous variables, defined by vector Z_t:

$$Z_t = \left(s_t, F_{p,t}, J_{p,t}, \pi_t, \lambda_{z,t}, R_t^k, i_t, r_t^k, l_t, w_t, q_t, \bar{\omega}_t, n_t, y_t, c_t, \bar{k}_t, R_t^D, b_t, R_t^B, R_t, u_t, F_{w,t}, J_{w,t} \right)'$$

3.2 Steady State

In the Appendix we develop an algorithm for computing the steady state of the model, $Z = \left(s, F_p, J_p, \pi_t, \lambda_z, R^k, i, r^k, l, w, q, \bar{\omega}, n, y, c, \bar{k}, R^D, b, R^B, R, u, F_w, J_w \right)'$, such that $Z_t = Z, \quad \forall t \in \mathbb{N}_+$. The existence of this algorithm proves that an interior steady state exists. However, the uniqueness of this steady state in not proved in this paper.

3.3 Fundamental Shocks

The model's stochastic environment is represented by the vector of shocks:

$$\Upsilon_t = \left(\sigma_t, g_t \right)'$$

The first shock, the risk shock is associated with financial sector of the model. The second shock is associated with government consumption. We model shocks, in percentage deviations from steady state, with the following first order autoregressive representation:

$$\hat{\sigma}_t = \rho_\sigma \hat{\sigma}_{t-1} + u_t^\sigma \ , u_t^\sigma \sim iid$$

$$\hat{g}_t = \rho_g \hat{g}_{t-1} + u_t^g \ , u_t^g \sim iid$$

We study the response of the simulated economy to a financial shock by a positive jump in the risk shock. The risk shock is an important shock when fed in a NK DSGE model for, it generates responses that resemble the business cycle.[29]By triggering such a shock in the financial sector we mimic the financial crisis of 2008.[30]The government spending shock is used to access the implication of financial intermediation sovereign risk interdependence on the government spending multiplier.

3.4 Solution

The model's equilibrium conditions in terms of stationary variables presented in the previous section can be written in the following form: $E_t f(Z_{t+1}^{+}, Z_t, Z_{t-1}^{-}, \Upsilon_t) = 0$ where Z_t is the vector of endogenous variables, Z_t^{+} is the subset of variables of Z_t that appear with a lead and Z_t^{-} is the subset of variables of Z_t that appear with a lag and Υ_t is the vector of exogenous variables. The model solution involves a log linear approximation around the models non-stochastic steady state, Z, and then solving the resulting linear system of stochastic difference equations. The solution method follows Villemot (2011), where the procedure for solving the stochastic dynamic model in the form above is outlined. We calibrate the parameters of our model for the EA using values from the literature. We compute model IRF's to a shock in the financial sector. We compare the impulse response functions of our SR model to a financial shock to those of a FA model to that shock. The FA model includes the same financial frictions as our baseline model but abstracts from bank bailout funds and sovereign debt and risk. In that way, we can access the effect the additional financial-sovereign channel we have introduced has for economic activity, compared to the FA model.

3.5 Calibration

We calibrate the model for the EA. For all preference, technology and financial frictions parameters we use conventional values from the literature. In particular we use the parameters from CMR (2010). They divide the parameters into two sets. The one take standard values from the literature and reproduce key sample averages in the

[29] CMR (2010).
[30] CMR (2013) argue that the accelerated collapse in economic activity that occurred in late 2008 was largely due to increase in risk at the time.

data. The second is estimated using Bayesian methods. For the additional model specific parameters we introduce, relating to government debt and financial sector rescue funds, we proceed as follows. We set ϕ_t at 12.5%, so that most of government expenditures are financed by debt.[31] And, we set the government bank rescue function so that an increase in the risk shock results in an increase in funds at 11% of steady state GDP, following the actual total funds being injected by various EA countries.[32] Finally, we calibrate the logistic distribution for the probability of default, so that the resulting increase in debt, following the risk shock, increases the probability of default by 0.12 from its steady state value. Such an increase has been observed by various EA countries such as Greece, Portugal and Ireland since 2008.[33]

Table 1
Model Parameters

Firms		
a	Share on capital	0.36
μ_z	Growth rate (APR)	1.5
β	Discount rate	0.999
ξ_p	Calvo prices	0.719
λ_f	Intermediate good firms markup	1.20
Capital Producers		
v''	Investment adjustment cost	39.149
δ	Depreciation rate	0.02
Entrepreneurs		
σ_a	Capacity utilization	26.730
μ	Financial sector inefficiency	0.1
γ	Percent of entrepreneurs who survive	97.80
$F(\bar{\omega})$	Percent of businesses that go bankrupt	2.60
σ	Variance of log of idiosyncratic uncertainty	0.12
W	Transfer to entrepreneurs	0.03
Households		
b_c	Habit persistence	0.56

[31] Following the ability of EA countries tax income to bail-out their respective banks as calculated by Pisany-Ferry (2012).
[32] IMF (2011a) estimates for Belgium, Ireland, Germany, Greece, Netherlands and Spain.
[33] Lucas et al. (2013).

λ_w	Supply of labor markup	1.05
ξ_w	Calvo wages	0.747
ψ_L	Labor functional form parameter	6
σ_L	Curvature of disutility of labor	1
Policy		
ϕ_τ	Fraction of gov. spending financed by tax	0.125
ρ	Coeff. on lagged interest rate	0.871
α_π	Weight on inflation on taylor rule	1.824
α_y	Weight on output growth in Taylor rule	0.251
Shocks		
ρ_σ	Riskiness shock	0.958
ρ_g	Government spending shock	0.988
σ_σ	Riskiness shock	0.0458
σ_g	Government spending shock	0.0121

We calibrate parameters common to both models to the same values. Since this is a comparative models exercise, our results turn out to be robust to these common values. Parameters that relate only to the SR model can affect the numerical magnitude of our outcomes. For example, using the total committed funds for EA bailouts instead of actual would result in a higher probability of default and a deeper recession. Indeed in Greece and Portugal the rise in the observed probabilities of default way surpassed 0.12 reaching 0.20.

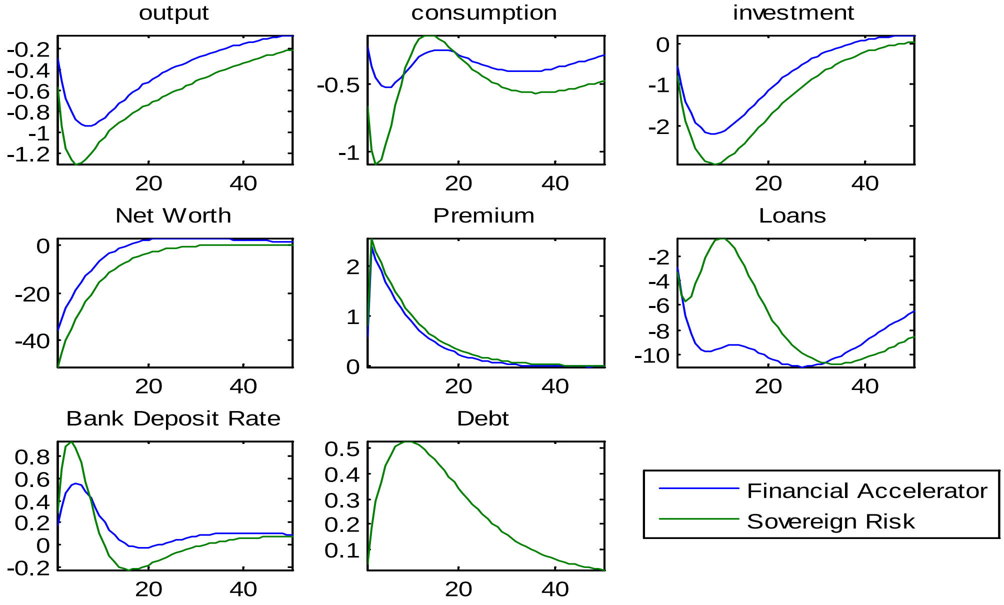
3.6 The Standard Financial Accelerator Model

In the FA model a rise in the risk shock, σ_t results in a rise in the external finance premium. When the risk is high, the credit spread is high and the credit extended to entrepreneurs is low. Entrepreneurs then acquire less physical capital. Since investment is a key input in the production of capital, it follows that investment falls. With this decline output falls as well as consumption. Furthermore, the net worth of entrepreneurs, an object that can be identified with the stock market, falls. This is due to the fact that rental income earned by entrepreneurs on their capital falls with the reduction in economic activity. In addition, the fall in the production of capital results in a fall in the price of capital which results in capital losses for entrepreneurs. The risk shock therefore, predicts countercyclical interest rate premium and procyclical investment, consumption, the stock market and credit, amplifying swings in borrowing, investment, spending and production. The amplification of swings in the FA model is known as the financial accelerator effect.

3.7 Sovereign Risk Model

In the baseline model simulations, an increase in financial sector risk increases the external finance premium which in turn increases government debt. The higher level of debt increases the probability of default of the sovereign resulting in higher interest rates on bonds and bank deposits. The higher interest rates result in a higher external finance premium. As a result the bank-sovereign interdependence reinforces the initial financial accelerator mechanism. We find that an increase in the risk shock results in a considerably deeper recession when financial intermediation-sovereign interactions are also present. Output, consumption, investment and net worth all decline substantially. As shown in Figure 2, debt increases as a result of government injections to banks. The drop in loan is not as severe owing to these injections. However, the premium is higher. The fall of investment, net worth, and output is in one and a half times bigger than the one obtained under the FA model. And, the initial drop in consumption is more than double than that of the FA model.

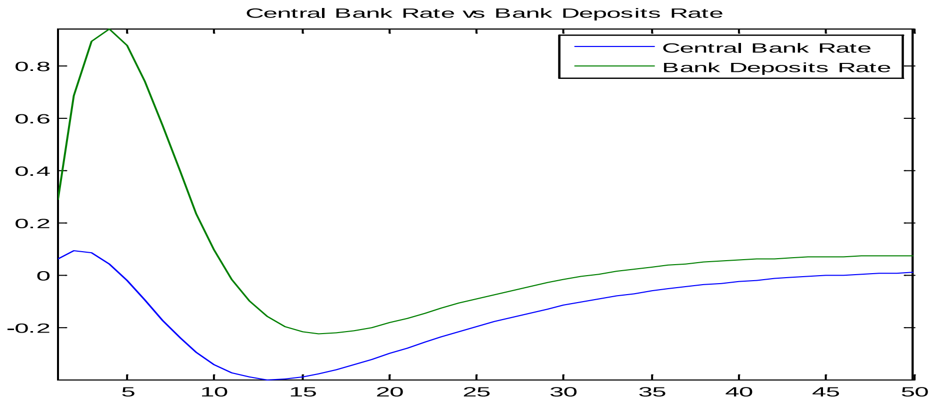
Figure 2
Response to a positive risk shock



The deeper recession in the sovereign risk model strongly depends on the government's countercyclical stand on required reserves for the costs of financial sector rescues. These cause the higher financing costs for banks that are further transmitted to non-financial corporations with a higher premium. What is important for the determination of the conditions of direct financing in financial markets and deposit funding for banks are developments in benchmark interest rates. These include, the key ECB interest rates, money market rates and government bond yields, with the latter containing the term structure of risk free interest rates, sovereign risk and liquidity premia. In tranquil times these interest rates co-move and by controlling the ECB rate the central bank can affect the funding cost of the economy. When there is sovereign risk, however, the funding cost of the economy no longer depends solely on the ECB key interest rates but also on the sensitivity of the euro-zone crisis. Increases in sovereign credit risk can lead directly to higher financing costs for the private sector via capital markets as well as bank lending rates. In our model Government bond yields function as the benchmark interest rate, particularly in that they contain sovereign credit risk. An increase in sovereign credit risk can lead directly to higher financing costs for the private sector via bank lending rates. As seen in Figure 3, while in response to a risk shock the interest set by the monetary authority remains unchanged, the interest rate on government bonds, rises by almost 1%.

Figure 3

Economy's interest rates



This implies that the monetary authority has limited control over the benchmark interest rate and therefore on the financing conditions of the economy.[34] Our model predicts the observed positive co-movement between sovereign spreads, financial spreads and private lending rates. The higher interest rates on bank deposits are transmitted to non-financial corporations with a higher premium. As a result our model predicts a recession similar to the one experienced by many EA countries today. In that way our model captures the effects of the vicious cycle created in the euro area. In the EA banks play a key intermediary role. Bank based financing is the predominant source of external debt financing for the non financial private sector. The increased cost of financing for banks is transmitted, through increased bank lending rates, to the financing conditions of firms and households affecting economic activity and the business cycle.

4. Policy Implications

Our model has three policy implications. The first and main implication of our model for EA policies dealing with failing banks is that they aggravated the recession. The SR model captures the main features of the EA policy in dealing with failing banks, whereby each member state is responsible for the bail out of these banks. On the

[34]Note that our model does not include a zero lower bound to capture the inability of the monetary authority to counteract the crisis by cutting interest rates. However, the simple Taylor rule used is not aggressive enough to offset the recession brought about by the increase in the risk shock. A more aggressive monetary policy cut, following a modified Taylor rule, reacting to financial risk, could counteract the recession.

contrary, the simple FA model replicates a hypothetical scenario where the EA countries had not engaged in financial sector bailouts, in response to the 2008 financial crisis. As discussed in the previous section, comparing the SR model to the simple FA model, where financial sector bailouts are not present, the SR model predicts a deeper recession. Thus, our model comparison suggests the EA bank rescue policy has resulted in a deeper recession. The outcome of our analysis is supported in practice when comparing the EA with the US. In the US no interdependence is observed (Figure 1). The reliance on the specific government where the bank is located to fund the bailouts is in contrast to policy within the US, where the specific state location is not the determinant of who bears costs. Both bank support (through the FDIC and in the case of capital injections through the TARP) and bank regulation takes place at the US currency union level. One can imagine that if the State of Washington had to bear the fiscal burden when Washington Mutual collapsed with nearly $200bn in deposits, there is no way its fiscal resources could have borne the cost. Instead, FDIC was able to broker a deal with JP Morgan and avoid any fiscal cost. In the EU setup, a currency union wide fund may have loaned the State of Washington the financing necessary, but state tax payers would be responsible for whatever funding they provided. The mutualization of bank losses across states can only reasonably be achieved if there is area wide supervision and area wide funding resources, such as the FDIC. Financial institutions in Europe were operating across borders, and with the same currency and lender of last resort, but with different supervision and without any mutual bank support across countries.[35]

Realizing the problem, onMay 9,2010, the European Financial Stabilization Fund (EFSF) was created. The EFSF has acted to stave off insolvency of sovereigns. The EFSF was created as a temporary rescue mechanism. On September 27, 2012, the EA member states created a permanent rescue mechanism, the European Stability

[35]In response to the additional funding problems at banks, following the sovereign crisis, a supranational approach was employed to solve liquidity, but not solvency, problems in the financial sector. The liquidity problem has been a supranational issue countered by the ECB, where the ECB provided liquidity to the financial sector through Long Term Refinancing Operations (LTROs).In doing so the ECB filled the liquidity needs for banks, but relative to a policy of purchasing assets from the market, it has left any credit risk to the balance sheets of banks. In that sense LRTOs are notably different from the quantitative easing policies followed by the Federal Reserve where the Fed purchased assets outright rather than help banks ability to purchase them. Further, the LRTOs were used to fund more sovereign debt purchases, strengthening the connection between banks and sovereigns. These findings lead to question the effectiveness of ECB provision of liquidity to banks as a means to alleviate the sovereign crisis.

Mechanism (ESM). The ESM can provide instant access to financial assistance programs for the EA member states in financial difficulty, with a maximum lending capacity of €500 billion.[36] Although part of the funds has been used to recapitalize financial sectors of member countries, the EFSF/ESM has not mutualized bank losses in a way that would break the sovereign-bank link. The EFSF/ESM has been unable / unwilling to provide capital directly to banks, instead it provided loans to countries with solvency issues which in turn provided funds to their banks. Thus, the second policy implication of our model is that as long as bank solvency remains a national matter, continues to contribute to the recession in the manner identified above. Our finding, suggests that recent efforts for dealing directly with bank solvency with the implementation of the ESM's DRI and the ECB's €60bn a month bond buying program up to €1.08 trillion are in the right direction.

The third policy implication of our model relates to the so called austerity policies. These policies have been implemented as a response to rising concerns about sovereign solvency. However, such measure can be self-defeating, as the success of austerity depends on the fiscal multiplier. Ceteris paribus, fiscal austerity is more likely to be self-defeating if the multiplier is large.We study the effect of a government spending shock in both the SR and FA models. The effects of a government spending shock are discussed based on the impulse response functions of the endogenous variables generated by the log-linearized version of the model. We apply a 1% shock to government spending Comparing the FA model with the SR model, we can provide insights about the impact of austerity measures. A smaller multiplier in the case of sovereign risk would provide evidence in favor of the above mentioned austerity measures employed in various EA countries.

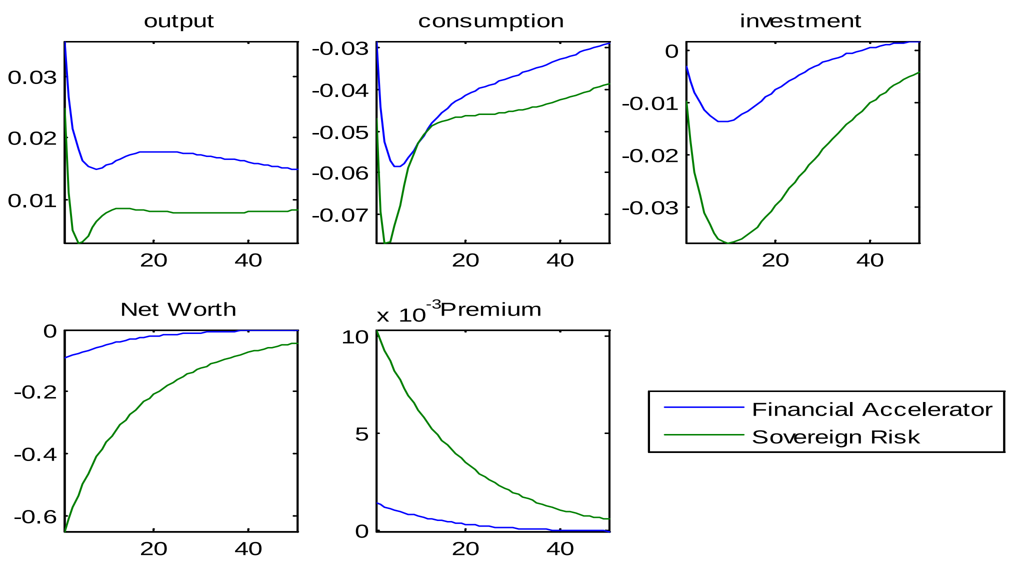
In the FA model output increases on impact, but strong crowding out effects on both household consumption and investment are present. Inflation increases since an increase in aggregate demand raises marginal production costs. Monetary authority

[36]The EFSF in concert with the IMF and EFSM has provided funds to Greece, Ireland and Portugal to prevent disorderly default. The ESM has provided funds to Spain for the recapitalization of the country's banking sector and Cyprus to address financial, fiscal and structural challenges. For details see: http://ec.europa.eu/economy_finance/assistance_eu_ms/index_en.htm

raises nominal interest rate to counteract upward pressure on inflation and this drives up the real interest rate. The rise in government spending alleviates risk premium in credit markets as increase in demand drives up the net worth of entrepreneurs. In the SR model an increase in the probability of default following a rise in deficit financed public expenditures leads to higher financing costs. As seen in Figure 4, the premium in the case of sovereign risk is higher. Although the value of the multiplier is close to zero in both models, there is a comparably big drop in net worth, investment and consumption. The impact of an increase in government spending has a smaller effect on output in the case of sovereign risk. The sovereign risk channel therefore, presents an alternative fiscal transmission mechanism through which increase in deficit financed government spending and associated increases in risk premia crowd out household and firm consumption and investment through higher private credit risk.

Figure 4

Response to an increase in government spending



Thus, the multiplier in the sovereign risk model is smaller than the FA models.[37] We conclude that forcountries with high public debt, a fiscal stimulus introduces

[37]In related empirical literature, Corsetti et al. (2012) find that the fiscal multiplier increases markedly during times of financial crises being 2.3 at impact and 2.9 at the peak. They also find that fiscal strains may take the multiplier into negative territory. Coenen et al (2012) show that monetary policy stance is important. When central banks follow a Taylor rule fiscal multiplier is small. If monetary policy is accommodative – interest rate kept constant – multiplier is greater. Recent studies based on modern

deterioration of public finances and hence increases in sovereign risk premium, which in turn reduces the size of the multiplier, favoring austerity measures used in EA countries.

5. Conclusion

In this paper we present a DSGE model with financial intermediation – sovereign risk interactions that can be used to study the effect of such interactions for economic activity and policy. Interactions in our model arise from the government's financial sector rescue policy. Such a policy increases government debt, which affects the interest on bonds and deposits raising bank funding conditions. Higher bank funding costs result in higher financial spreads and a further need for government rescues, creating a vicious cycle. This policy replicates EA response to the crisis were each member state was responsible for rescuing its financial system. We find that an increase in capital investment risk, (risk shock), originating in the financial sector, results in a considerably deeper recession when financial intermediation-sovereign interactions are also present. The recession strongly depends on the government's countercyclical policy on required funds for financial sector rescues. Our model predicts the observed positive co-movement between sovereign and financial spreads. Thus, our model replicates the effects of the vicious cycle created in the euro area. The above finding implies that EA national policy measures adopted in response to crisis have not been effective. Further, despite the strong degree of monetary integration reached in the EA, states remain individually responsible for rescuing banks in their jurisdiction. The EFSF/ESM, can help them with loans earmarked for that purpose but until recently was not entitled to inject capital directly to the banking system. EA policy where the EFSF/ESM provides assistance to sovereigns coupled with austerity measures does not break the sovereign-bank link. Although our model provides evidence in favor of austerity, as long as the cost of recapitalizing banks

business cycle models have made clear that the multiplier is likely to be large if monetary policy is constrained by the zero lower bound on nominal interest rates (Eggertsson (2011) and Christiano et al. (2009)). In related theoretical literature, Canzoneri et al. (2014) find that government spending multipliers in recessions are large exceeding 2. Corsetti et al. (2013), analyze the effects of fiscal retrenchment in a NK model where sovereign risk affects private sector interest rate spreads, but not the other way around. They find that when monetary policy is constrained and unable to offset changes in the sovereign risk premium, the multiplier becomes negative for a sufficient degree of sovereign risk.

remains with individual states the resulting vicious cycle will continue to drag the economy. A main current issue is the existence of a supra-national system for failing banks. Area wide policies to help recapitalize banks (through the EFSF/ESM and the ECB) might take pressure of the currently stressed sovereigns by removing the question of whether they will need to extend further bailouts as well as restarting lending in the euro are countries. Our model framework creates a platform for such additional policy issues to be addressed.

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Appendix

The algorithm used in computing the steady state values,

$Z=\left(s, F_p, J_p, \pi_t, \lambda_z, R^k, i, r^k, l, w, q, \varpi, n, y, c, \bar{k}, R^D, b, R^B, R, u, F_w, J_w\right)'$ has as follows:

Step 1 (Inflation):Since in the steady state, $\tilde{\pi}=\pi$, it follows from the Taylor Rule, (21), that π is set equal to the target inflation rate of the Rule.

Step 2 (Starting value): Fix the value of the real rental cost of capital services, r^k .

Step 3 (Financial variables):From (14), (7), and (8):

$$1+R^D=\frac{\pi\mu_z}{\beta}, \tag{A.1}$$

$$q=1, \tag{A.2}$$

and

$$u=1, \tag{A.3}$$

respectively. Then, in view of (A.7) and (A.8), (9), gives:

$$1+R^k=(1+r^k-\delta)\pi \tag{A.4}$$

From (11),

$$[1-\Gamma(\varpi)]\frac{1+R^k}{1+R^D}+\frac{\Gamma'(\varpi)}{\Gamma'(\varpi)-\mu G'(\varpi)}\left[\frac{1+R^k}{1+R^D}\left(\Gamma(\varpi)-\mu G(\varpi)\right)-1\right]=0 \tag{A.5}$$

But with $1+R^D$ and $1+R^k$ determined as in (A.1) and (A.4), (A.5) can be solved for ϖ . Moreover, (10) gives:

$$\frac{n}{\bar{k}}=1-\frac{1+R^k}{1+R^D}[\Gamma(\varpi)-\mu G(\varpi)] \tag{A.6}$$

which, in view of (A.1), (A.4) and the solution of (A.5), allows us to compute $n/\bar{k}$.

Furthermore, (12) gives $n=\frac{\gamma}{\pi\mu_z}(R^k-R^D-\mu\int_0^{\varpi}\omega dF(\omega)R^k)\frac{\bar{k}}{n}n+w^e+\frac{\gamma\ (1+R^D)}{\pi\mu_z}n.$ The latter can be solved for n , to get:

$$n=\frac{w^e}{1-\frac{\gamma}{\pi\mu_z}(R^k-R^D-\mu\int_0^{\varpi}\omega dF(\omega)R^k)\frac{\bar{k}}{n}-\frac{\gamma\ (1+R^D)}{\pi\mu_z}} \tag{A.7}$$

In view of (A.1), (A.6), (A.7) allows us to compute entrepreneurs steady state net worth, n .

Next, from the public debt transition equation, we have:

$$b = \frac{(g+x)}{\pi\mu_z - (1+R^B) + \phi_\tau} \qquad \text{(A.8)}$$

Since (13) implies that $R^B = R^D$, (A.8) allows us to compute steady state government bonds, b. Therefore, (20) implies that the steady state safe rate of return can be computed from:

$$R = R^D P(b), \qquad \text{(A.9)}$$

where $P(b)$ is the probability of government default at the steady state level, b.

Step 4 (Real economy variables): In view of (A.6) and (A.7), steady state capital, $\bar{k}$, can be computed from:

$$\bar{k} = \left(\frac{\bar{k}}{n}\right) n \qquad \text{(A.10)}$$

And, in view of (A.10), steady state capital investment, i, can be computed from the capital transition equation, (6), to get:

$$i = \left(1 - \frac{(1-\delta)}{\mu_z}\right)\bar{k} \qquad \text{(A.11)}$$

Next, we compute steady state marginal cost of aggregate output, the real wage rate, the capital – labor ratio and eventually, labor demand. Since, $\tilde{\pi} = \pi$ in the steady state, it follows from (3)-(5) that:

$$s = \frac{1}{\lambda_f} \qquad \text{(A.12)}$$

Then, in view of(1) and (2), the real wage rate and the capital - labor ratiocan be computed from:

$$w = s(1-\alpha)\left(\frac{k}{\mu_z l}\right)^{\alpha} \qquad \text{(A.13)}$$

and

$$\frac{k}{l} = \mu_z\left(\frac{\alpha s}{r^k}\right)^{\frac{1}{1-\alpha}} \qquad \text{(A.14)}$$

But, since (A.3) implies that $\bar{k} = k$ and in view of (A.10), labor demand can be computed from:

$$l = \left(\frac{l}{k}\right) k \qquad \text{(A.15)}$$

Finally, we turn to the aggregate real economic activity variables. First, we compute Φ to guarantee that profits of intermediate good producers are zero in steady state. Write sales of final good firms as $y - \Phi$. Also, real marginal cost is constant in steady state thus total costs of the firm are sy. The zero profit condition implies: $sy = y - \Phi$. Hence, in view of the aggregate production function (22):

$$y = \left(\frac{k}{\mu_z} \right)^a l^{1-a} - \Phi \tag{A.16}$$

Φ is given by:

$$\Phi = \left(\frac{k}{\mu_z} \right)^\alpha l^{1-\alpha} \left(1 - \frac{1}{\lambda_f} \right) \tag{A.17}$$

Substituting Φ in (A.16), by the left hand side of (A.17), we have aggregate output in the steady state:

$$y = \frac{1}{\lambda_f} \left(\frac{k}{\mu_z} \right)^a l^{1-a} \tag{A.18}$$

Next, in view ofthe economy’s resource constraint, (23), we have:

$$\mu \int_0^{\bar{\omega}} \omega \, dF(\omega) R^k \frac{k}{\mu_z \pi} + c + i + (1-\psi)[(1+R^B)b + g + x] = y \tag{A.19}$$

Then, (A.19) allows us to compute*c*. And, in turn, since the household Euler condition(15), implies:

$$\lambda_z = \frac{1}{c} \ , \tag{A.20}$$

we can compute the steady state value of the Lagrange multiplier associated with the household’s budget constraint from (A.20).

Step 5 (Labor market equilibrium and the adjustment of the the real rental cost of capital services, r^k): A simple count of the equilibrium conditions (i.e., (1)-(23)) makes clear that we have taken into account all of them except the labor supply conditions (16) – (17).Since in the steady state, $\tilde{\pi}_w = \pi_w$, (16)-(17) imply that, labor supply in the steady state is given by:

$$h = \left(\frac{\lambda_z w}{\lambda_w \psi_L} \right)^{1/\sigma_L} \tag{A.21}$$

in equilibrium it must be that, labor demand, l, computed in (A.15) is equal to labor supply, h, computed in (A.21). Then, since l (h) in increasing (decreasing) in r^k, if for the value of r^k we started with in Step1: $l > (<) h$, we try an arbitrarily small decrease (increase) in this value and repeat Steps 3-4, until we find a value of r^k such that: $l = h$.(Obviously, this is a trial and error process and we are not certain for the uniqueness and the global asymptotic stability of the steady state obtained with such an algorithm.)