

Fiscal distress and banking performance: The role of macroprudential regulation

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Abstract

Fiscal fragility can undermine a government's ability to honor its bank deposit insurance pledge and induces a positive correlation between sovereign default risk and financial (bank) default risk. We show that this positive relation is reversed if bank capital requirements in fiscally weak countries are allowed to adjust optimally. The resulting higher requirements buttress the banking system and support higher output and welfare relative to the case where macroprudential policy does not vary with the degree of fiscal stress. Fiscal tenuousness also exacerbates the effects of other risk shocks. Nonetheless, the economy's response can be mitigated if macroprudential policy is adjusted optimally. Our analysis implies that, on the basis of fiscal strength, fiscally weak countries would favor and fiscally strong countries would object to banking union.

Keywords: Fiscal distress, bank performance, optimal macroprudential policy, Greece, banking union

JEL classification: E3, E44, G01, G21, O52.

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1. Introduction

The recent sovereign debt and banking crises in the Eurozone have exemplified the tight connection between banking and sovereign credit risk. In Greece, the prospect of a possible sovereign debt default devastated the banking system. Reversely, the collapse of the banking system in Ireland wreaked havoc on the fiscal front.

In the literature, banks' exposure to domestic government debt provides the channel of transmission from the fiscal to the banking front, with lower bond prices leading to weaker bank balance sheets; and bank bail-outs provide the transmission from banks to the country's fiscal health due to the associated surge in the level of public debt. There are two strands in the extant literature. The first one (Acharya *et al.*, 2014, Brunnermeier *et al.*, 2017, Cooper and Nikolov, 2017, Fahri and Tirole, 2015) studies bilateral interactions between these two phenomena.¹ The second strand studies only the transmission of fiscal fragility to bank lending and macroeconomic performance. The alleged effects are contractionary. In Bocola (2016), news about future government default impacts directly on the banks' balance sheets and thus on their lending capacity. Moreover, it creates a precautionary motive for banks to deleverage in order to be better positioned vis-à-vis future sovereign default, which further dents bank lending and economic activity. In Broner *et al.* (2013) the domestic government is assumed to default selectively on foreign investors. Selective default makes domestic debt comparatively attractive to domestic banks and crowds out their investment in the real economy.

Our paper contributes to the latter branch and contains several new features relative to it. First, we emphasize a different transmission mechanism linking fiscal frailty to banking performance, namely, government bank deposit insurance guarantees,² rather than bank exposure to public debt. We let the share of bank deposits that is not recouped by the depositors in case of bank default (i.e. the amount of bail-in) be related to the sovereign's state of finances. Bank deposit riskiness arising from fiscal solvency played an important role in the recent Greek crisis. Second, we allow macroprudential policy –capital requirements– to vary optimally with the degree of deposit riskiness. This helps stifle contagion from the fiscal to the banking front, weakening the positive co-movement between the financial sector's and sovereign's credit risk that characterizes the extant literature. The extant literature shuns away from studying the role that prudential policy could potentially play in mitigating contagion from the fiscal to

¹ In Brunnermeier *et al.* (2017) and Cooper and Nikolov (2017), sovereign defaults and bank failures arise from self-fulfilling prophecies and there is a "doom" loop: worries about sovereign default generate concerns about the viability of banks due to their holding of sovereign bonds; and bank failures require debt funded bailouts. A similar doom loop arises in Fahri and Tirole (2015), but it is due to fundamentals instead.

² Deposit insurance –explicit or implicit– is a standard tool used by governments to protect bank depositors from incurring losses due to bank failures and thus prevent bank runs. The insurance schemes differ in terms of the amount and extent of insurance coverage, of whether the payments are per depositor or per depositor per account and so on. See Demirgüç-Kunt, Kane and Laeven (2015) for a comprehensive discussion of real world practices.

the banking front.³ And third, we allow for bank default in the model, and fiscal fragility to matter for it. Hence, financial solvency risk varies with sovereign solvency risk.

Our model is based on Clerc *et al.* (2015), a Dynamic Stochastic General Equilibrium (DSGE) model that features a rich financial sector afflicted by multiple agency problems, banking capital regulations, government-provided deposit insurance and bank default in equilibrium.⁴ The key implication of the model is that capital requirements reduce bank leverage and the default risk of banks but their relationship with social welfare is hump-shaped, reflecting a trade-off between bank default and underinvestment. We assume that the deposit insurance scheme is not full-proof due to the limited fiscal capacity of the government.⁵ This creates a wedge between the return on deposits and the risk-free interest rate and a link between the probability of bank default and the cost of funding for the banks.⁶

To trace out the macroeconomic effects of fiscal fragility, consider an increase in the probability that the government will not be able to meet its deposit guarantee pledge. This makes bank deposits more risky, inducing the households to change their savings and portfolio decisions. The cost of raising funds for the banks increases and their lending decreases. The higher cost of funding increases the probability of default for the banks' borrowers which translates into a higher probability of bank default. Sovereign and financial credit risks thus move in tandem, the typical scenario in the literature. There is a contraction, with output, consumption and investment all decreasing.

The change in the riskiness of deposits impacts on the optimal level of bank capital requirements. We show,⁷ that optimal requirements increase. Implementing the optimal adjustment leads to a lower rate of bank default, creating a negative correlation between sovereign and financial credit risks. This constitutes a key finding and raises an important qualification to the robustness of the standard, positive correlation assumed in the literature. The insulation of the banking sector through higher requirements improves welfare. But importantly, and unlike what one might have feared on the basis of their alleged cost for bank lending, they contribute to higher economic activity: the recession is less severe than what it would have been in the absence of policy adjustment. The positive effect on output is mainly due to the fact that the increase in higher requirements in the face of an increase in fiscal frailty ends up supporting a higher level of financial intermediation (in addition to helping save on direct default costs).

³ Fahri and Tirole (2015) represent an exception with regard to the latter feature. Their focus, however, is different, namely on how banking union can overcome the incentive for maximum supervisory leniency exhibited by national regulators.

⁴ Mendicino *et al.* (2017) extend the original 3D model and calibrate it to the Euro Area.

⁵ Fiscal capacity is limited by the amount of long term tax revenue that a sovereign can raise/pledge through distortionary taxes. We do not explicitly model this constraint. For our purposes, it is sufficient to consider the effects of exogenous changes in it.

⁶ We have also studied the case where this wedge varies over time as a function of either total credit in the economy, or total credit over output. The results are available from the authors upon request.

⁷ Stavrageva (2017) also finds a positive relationship between fiscal capacity and minimum bank capital requirements in a different model with moral hazard and pecuniary externalities. She does not, however, pursue the implications of this relation for the macroeconomic properties of the model.

In addition to studying the effects of an adverse fiscal shock on macroeconomic performance, we also examine how the presence of fiscal fragility modifies the effects of various risk shocks, for a given level of capital requirements and also under optimal policy. We find that fiscal tenuousness exacerbates the effects of these shocks but the economy's response can be mitigated if macroprudential policy is adjusted optimally. This insulation is even more pronounced during periods of high financial uncertainty (high variance of financial shocks).

Our model also makes a contribution to the literature on banking union. If the fiscal capacity of the banking union is the weighted average of those of its members, then the fiscally strong countries will face an increase in the level of optimal requirements when they join a union. The opposite is true for fiscally weak countries. Due to the tradeoffs associated with capital requirements, the fiscally strong countries end up *ceteris paribus* worse off and the weak better off in a banking union that has shared fiscal capacity for the provision of deposit insurance. Naturally, banking union contains many costs and benefits that are not present in our model, so the fiscal perspective we bring to the table is but only one of the factors that need to be considered. Nonetheless, even from such a narrow perspective, our model offers an explanation of why the "southern" EU countries have been strong proponents of banking union, while the northern countries have shown little enthusiasm: the later do not wish to share their fiscal capacity with fiscally weaker members of the union for the purpose of bank bail-outs.

The rest of the paper is organized as follows. In Section 2 we present the main ingredients of the model. Section 3 discusses the calibration of the model to Greece. Section 4 deals with the properties of the steady state. Section 5 describes the dynamics of the economy under different levels of fiscal frailty and capital requirements regulation. Section 6 discusses the combined effects of two sources of uncertainty, risk shocks and the degree of bail-in. Section 7 concludes.

2. The model

The model is based on Clerc *et al.* (2015). Our version includes the possibility that the government may not fully honor its deposit insurance pledge and instead subject depositors to a bail in. The formal model is described in the Appendix.

A key feature of the Clerc *et al.* (2015) model is that banks operate under limited liability and may default due to both idiosyncratic and aggregate shocks to the performance of their loan portfolios. In case of bank default, a fraction of deposits is guaranteed by a public deposit insurance agency (DIA). This creates a wedge between the return on deposits and the risk-free interest rate and a link between the probability of default and the cost of funding for the banks.

More specifically, the return on deposits, \tilde{R}_t^D , is defined as $\tilde{R}_t^D = R_{t-1}^D(1 - \gamma_t PD_t^b)$, where R_t^D is the gross, fixed interest rate on deposits in period t , PD_t^b is the economy-wide probability of bank default in period t , and γ_t , is the fraction of deposits that is not recovered when a bank defaults (the amount of depositor bail-in). We use γ_t as a proxy for the effects that the frailty of public finances may have on the government's capacity to honor its deposit insurance pledge. $\gamma_t = 0$ corresponds to full deposit insurance.

We assume that γ_t is determined according to the process⁸:

$$\gamma_t = \gamma_0 + \gamma_1(b_t - b^*) + \varepsilon_t^R, \quad (1)$$

where $\gamma_0 \geq 0$, b_t is total credit in the economy at time t and b^* is its corresponding steady state value; γ_1 is a feedback parameter; and ε_t^R is a fiscal capacity shock that follows an $AR(1)$ stochastic process of the form: $\varepsilon_t^R = \rho^R \varepsilon_{t-1}^R + e_t$, where ρ^R is the persistence parameter and $e_t \sim (0, \sigma_t^R)$. We are primarily interested in the behavior of economies that differ in terms of γ_0 so we report results when $\gamma_1 = 0$ (the more general case is treated in an Appendix).⁹

The incompleteness of the deposit insurance scheme leads to a risk premium on deposits and higher funding costs for the banks. The fact that this premium depends on the economy-wide default risk rather than on the individual bank's own default risk, induces banks to take excessive risk and provides a rationale for macroprudential policy.

The remainder of the model is as follows: The economy consists of households, entrepreneurs, and bankers. Households are infinitely lived and consume, supply labour in a competitive market and invest in housing. There are two types of households, patient and impatient, that differ in their subjective discount factor. In equilibrium, patient households are savers and impatient households are borrowers. The latter negotiate limited liability, non-recourse mortgage loans from banks using their holdings of housing as collateral. They can individually choose to default on their mortgage, in which case they lose the housing units against which the mortgage is secured.

Entrepreneurs are the owners of the physical capital stock and finance their purchases of physical capital with their inherited net worth and corporate loans provided by banks. Banks have limited liability and face default risk.

Bankers are the providers of inside equity to perfectly competitive financial intermediaries, the "banks". The latter provide mortgage and corporate loans that are financed with household deposits and the bankers' equity. The banks are subject to regulatory capital constraints and must back a fraction of their loans with equity funding. Default occurs due to both idiosyncratic and aggregate shocks to the performance of the loan portfolios.

Finally, the final good and new units of capital and housing are produced by perfectly competitive firms.

⁸ It should be understood that the value of γ actually arises as the solution to some maximization problem faced by the government. In our model, due to lump sum taxation, the optimal value of γ is always zero. Introducing a meaningful trade in order to obtain an interior solution for γ would complicate the model without adding much of substance to the results.

⁹ Available from the authors upon request.

3. Calibration of the model

The model is calibrated to the Greek economy at a quarterly frequency to match key features of the Greek data. The data sources are Eurostat and the Bank of Greece and span the period 2000-2010, unless otherwise indicated. The calibration is mainly based on Papageorgiou and Balfoussia (2016) and closely follows Mendicino *et al.* (2018) with regard to the financial variables. The calibrated parameters are summarized in Table 1 in the Appendix.

In line with Clerc *et al.* (2015), capital requirements are set at 8% for corporate loans and 4% for mortgage loans.¹⁰ The discount factor for patient households is calibrated using a quarterly interest rate on deposits equal to 0.77% (3.08% annually). The discount factor for impatient households is set equal to 0.977, that corresponds to a quarterly short-term interest rate for consumption loans equal to 2.32% (9.28% annually). As is usual in the literature, we set the Frisch elasticity of labour, η , and the preference parameter that governs the marginal disutility of labour, φ , equal to 1. To calibrate the utility weight of housing, ν , we use data from the Household Finance and Consumption Survey (wave 1). In particular, we choose the utility weight of housing for borrowers so that the value of housing for borrowers as a share of the total housing value produced by the model matches the share of indebted households in the data. The utility weight of housing for savers is calibrated in a similar manner. The depreciation rates on capital and housing investment, δ and δ^H , have been respectively set to match as closely as possible the average values of total investment (net of housing) to GDP and housing investment to GDP in the data. The labour share is computed from AMECO data that adjusts for the income of the self-employed persons, giving a value equal to 0.6. We set the consumption share of bankers and entrepreneurs, χ^b, χ^e , to match the value of dividends paid by financial corporations as share of GDP in the data.

We calibrate the steady-state deposit insurance parameter, γ_0 , to match the average value of the spread between the Greek and German deposit rates, that is, we assume that German bank deposits are fully safe. This gives a value for γ , expressed in annual terms, equal to 0.12, implying losses for depositors at failed banks of 12% of face value.

The variances of the idiosyncratic shocks that determine the probabilities of default for household and entrepreneurial loans, σ_m and σ_e respectively, are calibrated to pin down the average values of the household debt-to-GDP ratio and the corporate debt-to-GDP ratio found in the data. This yields $\sigma_m = 0.157$ and $\sigma_e = 0.49$, implying higher uncertainty in the corporate sector. Following the study of Clerc *et al.* (2015), we set the standard deviation of the risk shocks to corporate and mortgage banks, σ_F and σ_H , respectively, so that the probabilities of default for the two types of banks in the steady state are equal to 2%. The values are $\sigma_F = 0.0331$ and $\sigma_H = 0.0163$. The bankruptcy cost parameters imply losses of 30% of asset value for creditors repossessing assets from defaulting borrowers. The feedback parameter that captures the cyclical adjustments in the cost of default for depositors, γ_1 , is set equal to zero in the baseline calibration. The feedback parameter in the rule for capital requirements has been set to the lowest possible value so as to ensure that the equilibrium solution is stationary.

¹⁰ This is consistent with the weights of Basel I and with the treatment of non-rated corporate loans in Basel II and III. The capital requirement parametrization for mortgage loans is compatible with their 50% risk-weight in Basel I.

We choose the standard deviation and the persistence parameters of the exogenous shocks to capture certain second moments of the actual data. In particular, we set the standard deviation of the TFP shock, the shock to the variance of the mortgage risk shock, the shock to the variance of entrepreneurs risk shock and the fiscal capacity shock in order to replicate respectively the volatility and the persistence of real GDP, mortgage loans, corporate loans and the spread between the Greek and German deposit rate found in the data. We assume that the shocks to the variances of the idiosyncratic bank risk shocks are perfectly correlated across the two types of banks, and we set the standard deviation of the shocks in order to pin down the volatility and persistence of the expected default frequencies of Greek banks.¹¹ Finally, we set the adjustment costs for housing and business investment to match their volatilities in the actual data.

Table 2 in the Appendix summarizes the long-run solution of the model and Table 3 shows the second moment properties of key endogenous variables produced by the model.

4. Steady-state analysis

We start by examining the behavior of the economy for different levels of γ , holding capital reserve requirements constant at their *steady state* value. Figure 1 depicts the deposit spread, the bank default rate, entrepreneurs' default rate, credit, GDP and consumption as a function of γ . An economy with a lower capacity to guarantee bank deposits has riskier deposits (a higher deposit spread), higher bank and corporate default rates and a lower level of macroeconomic activity. The weaker economic activity is due to both direct effects (more output getting lost due to default) and indirect effects (less output being produced due to a lower level of deposits and credit).

Fiscal frailty is socially detrimental. Figure 2 shows that welfare is a negative, monotone function of γ . Steady-state welfare is computed as a weighted average of the utility of the patient, s , and impatient, m , households:

$$V \equiv \frac{c_0^s}{c_0^s + c_t^m} V^s + \frac{c_0^m}{c_0^s + c_t^m} V^m \quad (2)$$

where c_0^s and c_0^m denote respectively the steady-state consumption of the patient and impatient dynasties under the baseline policy. V^j is the steady-state expression of the intertemporal welfare $V_t^j = u_t^j + \beta^j E_t V_{t+1}^j$, where u_t^j is period t utility and $j = s, m$.

¹¹ Historical data for the expected default frequencies of Greek banks were provided by the European Central Bank.

Figure 1: Effects of fiscal frailty: Steady state

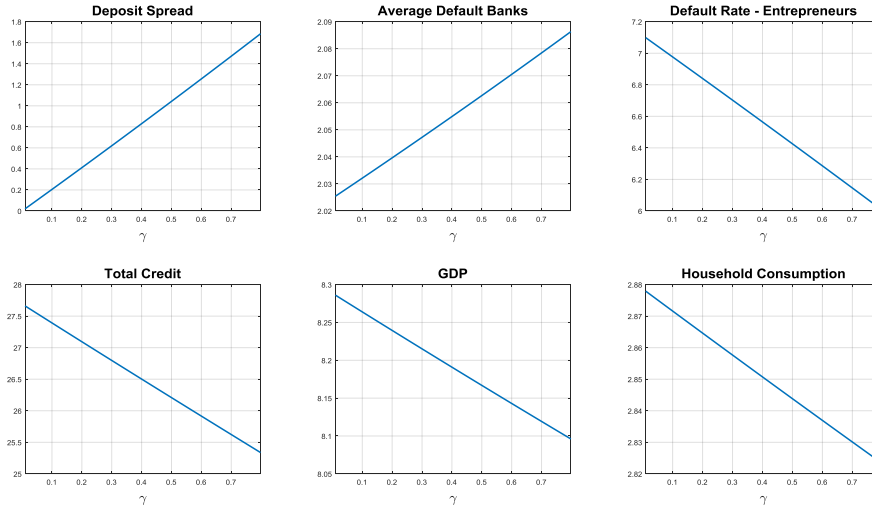
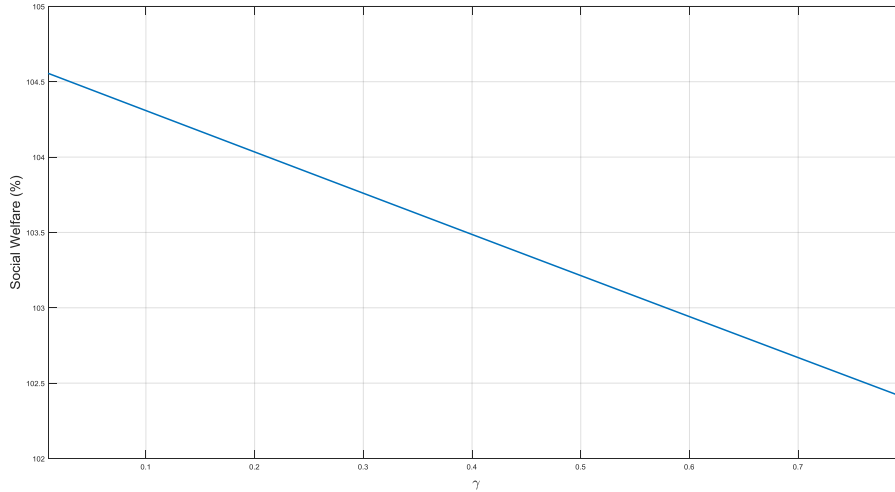


Figure 2: Fiscal frailty and welfare



The reason for the monotonicity is that deposit insurance is “cheap” to provide in our model, as the funds used to cover it are raised via lump-sum taxes (so the optimal value of γ is zero). And there exists no good substitute for it, as there is no monitoring of bank activity by depositors, irrespective of the degree of incompleteness of the insurance scheme.

How does the behavior of the same economy differ when the level of optimal capital requirements adjusts optimally to a change in γ ? Figure 3 provides information on the relationship between the

optimal level of capital requirements for corporate loans, ϕ^F , and γ (without loss of generality, we keep ϕ^H , at its steady state value). It shows that as deposits become riskier, the optimal level of capital requirements uniformly increases.

Figure 3: Fiscal frailty and optimal capital requirements

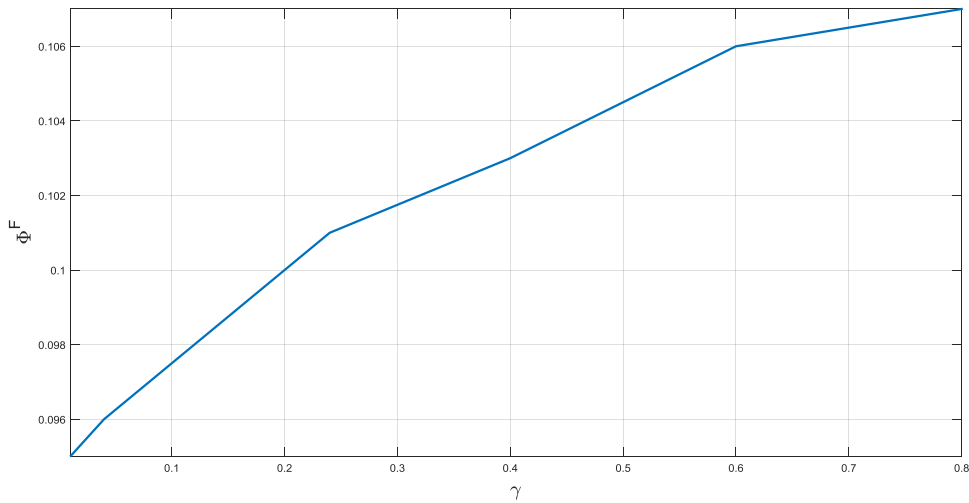


Figure 4: Steady-state effects of fiscal frailty under optimal capital requirements

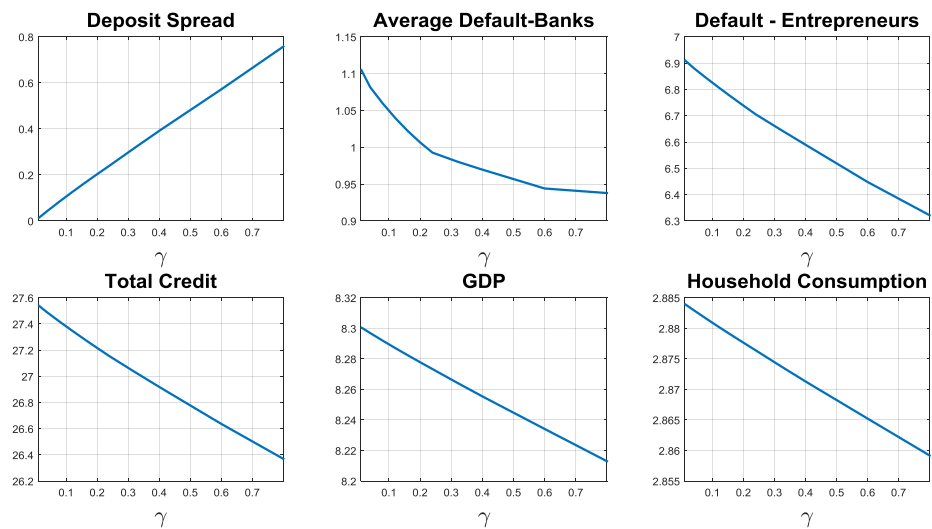


Figure 4 replicates Figure 1 under the assumption that capital requirements have been chosen optimally for each level of γ . The optimal use of macroprudential regulation makes banks safer by reducing the rate of bank default. It also lessens the severity of the output and credit contraction in comparison to the case where regulatory requirements are not allowed to vary with the level of fiscal frailty.¹² This result is by no means inevitable, because the higher capital requirements could have acted to reduce bank lending and thus depress output (see Diba and Loisel, 2017). In the general equilibrium of our model, however, by making banks safer, they end up mitigating the effect on deposits, bank credit and economic activity (always relative to the case of no policy adjustment).

Figure 5: Fiscal frailty and welfare: the role of optimal macroprudential policy

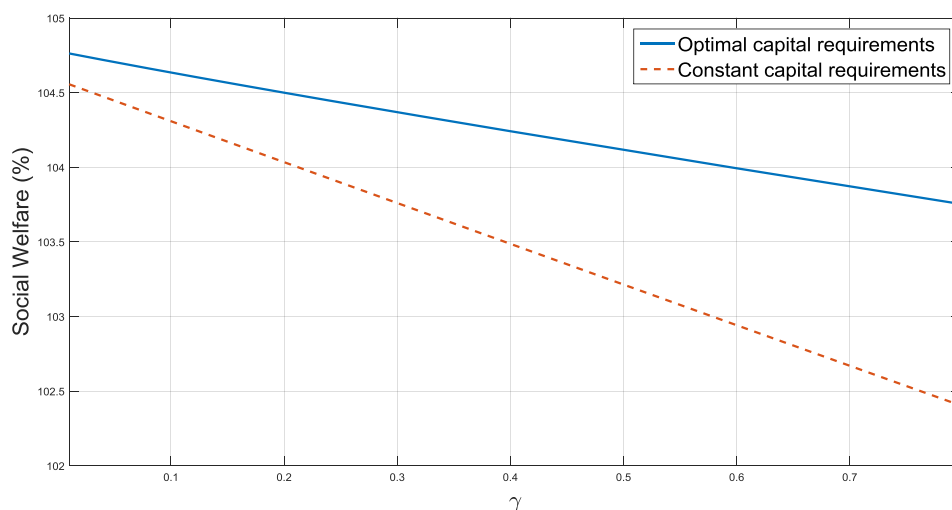


Figure 5 is the analogue to Figure 2 and shows welfare as a function of γ when optimal capital requirements adjust optimally (for comparison, the graph also includes the line from Figure 2). The adverse effects of deteriorating public finances are countered by optimal macroprudential policy in two distinct senses: first, for any given level of γ , welfare is higher when banking regulations adjust. And second, the adjustment in capital requirements becomes more important for preserving welfare at higher levels of γ (the gap between the two lines increases).

¹² While both direct –default cost savings– and indirect effects –the behavior of credit– matter for this result, we find that the indirect effects are the bigger contributor.

5. Dynamics

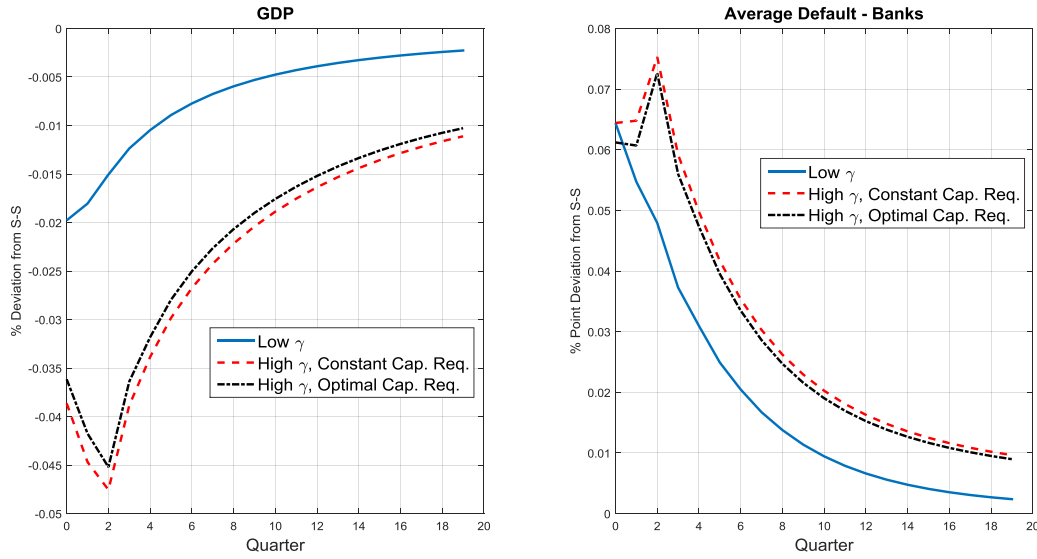
In this section we examine the role played by fiscal fragility for the dynamics of the model, and in particular, how it modifies the response of the economy to various disturbances. And also how optimal macroprudential policy can impact on this process. Optimal requirements are computed by solving the model at the second order and plugging the solution into a second order approximation of the social welfare function described in Section 4. The optimal level of capital requirements is the level that maximizes the unconditional second order approximation of the welfare function.

Figure 6a depicts the response of GDP and of the bank default rate to a one standard deviation negative bank risk shock and 6b to a one standard deviation shock to the probability of the depositors getting compensated in the event of bank default, under constant and optimal capital requirements, respectively. The thick blue line is the impulse response function for a low value of γ , namely the value in the steady state calibration and under the assumption that the reserve requirements have been chosen optimally to correspond that value of γ ($\phi^F = 0.1086$). The dashed red line is the impulse response function for a higher value of γ , namely $\gamma=0.5$, holding ϕ^F constant at the value ($\phi^F = 0.1086$), while the dotted black line is the impulse response function for the high value of γ but allowing for the capital requirements to adjust optimally ($\phi^F = 0.1184$).¹³ As can be seen, adjusting capital requirements optimally in the face of higher fiscal fragility plays a stabilizing role: while the outcomes worsen, the optimal deployment of the macroprudential tool can mitigate this adverse development.

The quantitative effects of the adjustment in optimal capital requirements are rather small. This is due to the fact that the economy was assumed to be operating under the optimal level of capital requirements before the increase in γ together with the fact that the welfare function is flat over the small range of capital requirements considered in our exercises. Carrying out the same exercise under the assumption that that capital requirements before the increase in fiscal fragility were fixed at their steady state level (which is lower) would lead to much bigger quantitative results.

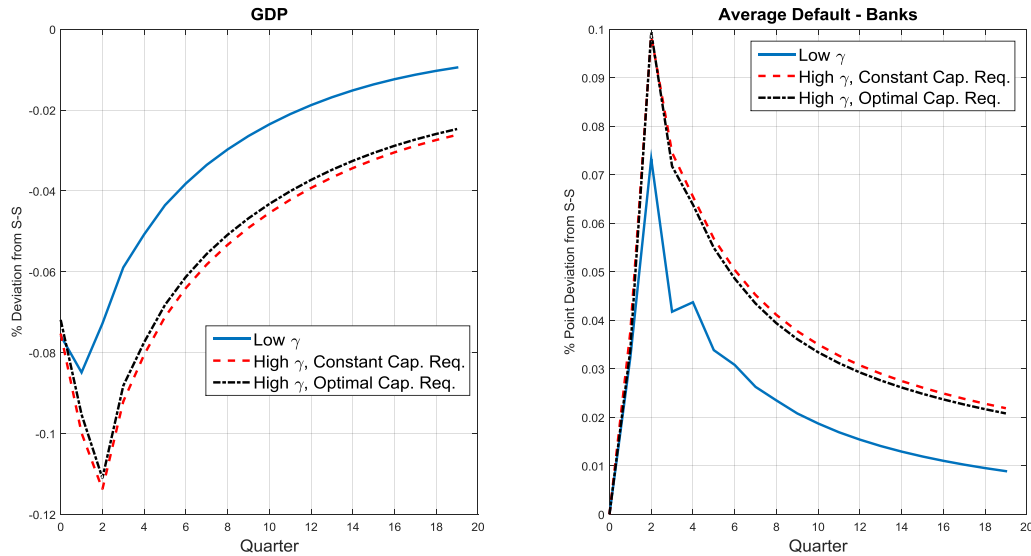
¹³ We have chosen to use the optimized value of ϕ^F in the baseline calibration so that the thick blue and the dotted black lines are drawn under optimal policy and their only difference concerns the value of fiscal frailty. Otherwise, the differences would confound the effects of differences in γ with those of differences in policy conduct.

Figure 6a: Effects of bank risk shocks for different γ ; constant and optimal capital requirements



Notes: i) In the case of “Low γ ”, γ is set equal to its baseline calibrated value (i.e. $\gamma = 0.12$) and ϕ^F is set equal to the corresponding optimal value of capital requirements, $\phi^F = 0.1086$, ii) In the case of “High γ , Constant Capital Requirements”, γ is set equal to an annualized value of 0.5 and ϕ^F is kept constant at its optimal level for $\gamma = 0.12$, iii) In the case of “High γ , Optimal Capital Requirements” γ is set equal to an annualized value of 0.5 and ϕ^F is adjusted to its optimal level for $\gamma = 0.5$, $\phi^F = 0.1184$.

Figure 6b: Effects of a shock to the probability that deposit insurance will be honored for different values of γ ; constant and optimal capital requirements



Notes: i) In the case of “Low γ ”, γ is set equal to its baseline calibrated value (i.e. $\gamma = 0.12$) and ϕ^F is set equal to the corresponding optimal value of capital requirements, $\phi^F = 0.1086$, ii) In the case of “High γ , Constant Capital Requirements”, γ is set equal to an annualized value of 0.5 and ϕ^F is kept constant at its optimal level for $\gamma = 0.12$, iii) In the case of “High γ , Optimal Capital Requirements” γ is set equal to an annualized value of 0.5 and ϕ^F is adjusted to its optimal level for $\gamma = 0.5$, $\phi^F = 0.1184$.

6. Interactions: Incomplete deposit insurance and changes in the variance of the risk shocks

Our non-linear model can be used to study interactions of the various types of uncertainty. Does incomplete deposit insurance exaggerate the effects of greater uncertainty? Does the optimal adjustment of capital requirements amplify or mitigate this interaction? Does greater economic uncertainty (risk) call for stricter or weaker¹⁴ capital requirements?¹⁵

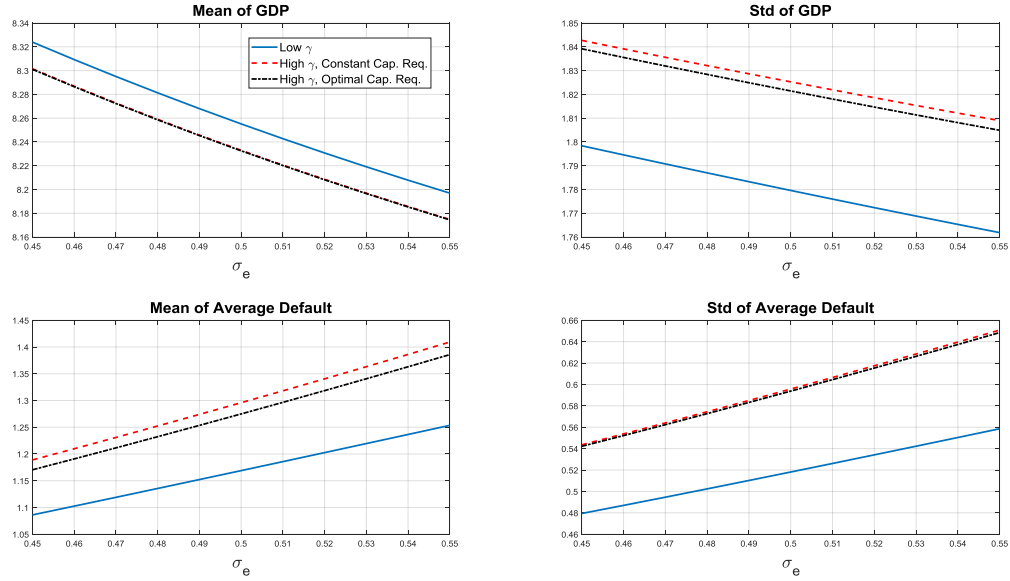
Figure 7a provides an affirmative answer to the first question with regard to the standard deviation of the entrepreneurial risk shock, σ_e . This graph shows that, holding capital requirements constant, the mean of output –modestly– decreases and its volatility increases as uncertainty about the shocks to σ_e increases; and the average bank default rate and its volatility decrease with higher uncertainty (blue lines). A higher probability of depositor bail-in (higher γ) exaggerates all these effects, that is, the two sources of uncertainty –risk of a higher bail-in and higher risk shocks to entrepreneurs– interact in a destabilizing fashion (red lines). This instability can be partly contained if macroprudential policy is adjusted optimally (black lines).

Figure 7b paints a similar picture for shocks to the variance of the idiosyncratic risk shock of corporate banks, σ_F . The mean of output decreases and its volatility increases as uncertainty about σ_F increases (the blue line). The behavior of bank default rates is now more intriguing. We see that to the left of $\sigma_F = 0.0331$ (the baseline calibrated value of σ_F), the average bank default rate is higher when policy optimally adjusts to the change in γ than when it does not; the reverse pattern is obtained to the right of that point. To understand this pattern, note that actual and optimal requirements coincide at the intersection of the red and black lines (at $\sigma_F = 0.0331$). And the actual requirements exceed the optimal level to the left but fall short of it to the right of the intersection point (a property that can be seen in Figure 8 below which shows how the optimal ϕ^F varies with σ). Consequently, the bank default rate is higher under optimal policy (to the left of the intersection) because actual requirements are higher than the optimal ones in that region, that is, the banks are sub-optimally overcapitalized; but it is lower to the right of the intersection because in that region banks are sub-optimally undercapitalized.

¹⁴ It is not a priori clear that in our model capital requirements ought to be optimally tightened in the face of greater economic uncertainty. The reason is that welfare in the model is a non-monotone function of capital requirements, because of the changing trade-off between bank default and the level of credit (economic activity).

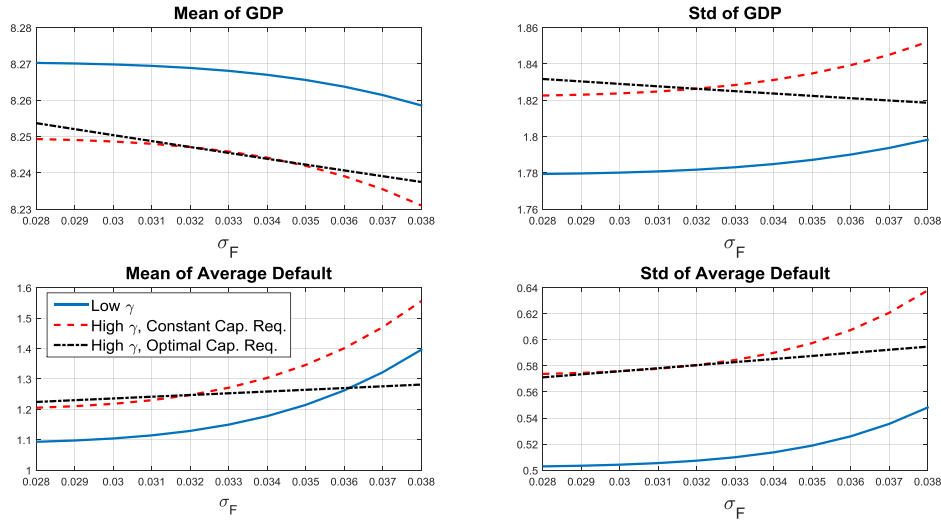
¹⁵ The determination of the optimal level of capital requirements is more complex in the case with varying variances of the risk shocks because any change in the variance of a risk shock changes the steady-state. As in Section 5, we use a second-order approximation to the solution of the model in a second order approximation of the welfare function. We compute the optimal level of capital requirements as the level that maximizes the unconditional second order approximation to welfare for different values of the variance of each one of the risk shocks (we vary only one variance at a time and set the variances of the other shocks to the values listed in Table 1). We also carry out this exercise for the variance of the fiscal capacity shock ε_t^R under the rule $\gamma_t = \gamma_0 + \varepsilon_t^R$.

Figure 7a: Fiscal frailty and risk shocks: Impact of σ_e on GDP and average bank default



Notes: i) In “Low γ ”, γ is set equal to its baseline calibrated value (i.e. $\gamma = 0.12$) and ϕ^F is set to its optimal value, $\phi^F = 0.1086$, ii) In “High γ , Constant Capital Requirements”, γ is set to twice its baseline calibrated value (i.e. $\gamma = 0.24$) and ϕ^F is kept constant at $\phi^F = 0.1086$, iii) In “High γ , Optimal Capital Requirements”, $\gamma = 0.24$ and ϕ^F is accordingly set to its optimal value for *each* value of σ_e .

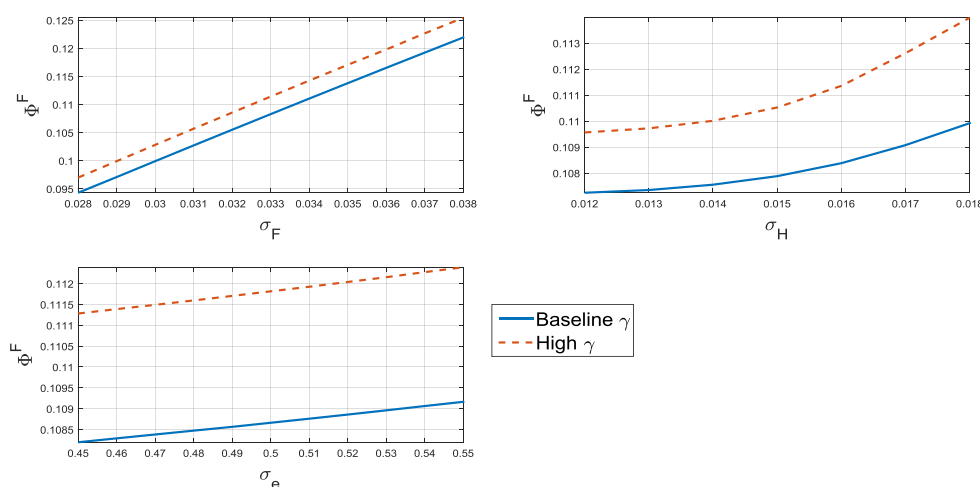
Figure 7b: Fiscal frailty and risk shocks: Impact of σ_F on GDP and average bank default



Notes: i) In “Low γ ”, γ is set equal to its baseline calibrated value (i.e. $\gamma = 0.12$) and ϕ^F is set to its optimal value, $\phi^F = 0.1086$, ii) In “High γ , Constant Capital Requirements”, γ is set to twice its baseline calibrated value (i.e. $\gamma = 0.24$) and ϕ^F is kept constant at $\phi^F = 0.1086$, iii) In “High γ , Optimal Capital Requirements”, $\gamma = 0.24$ and ϕ^F is accordingly set to its optimal value for *each* value of σ_F .

Figure 8 depicts the relationship between shocks to the variance of the risks shocks and the optimal requirements. It shows that optimal capital requirements increase at an increasing rate as the variance of the risk shocks increases, which helps contain the non-linear effect of the risk shock on economic activity. This means that countries with substantial financial (or aggregate) volatility have to have higher levels of capital requirements. Moreover, the combination of higher economic uncertainty and higher fiscal frailty has a magnifying effect on optimal requirements. Consequently, to the extent that such differences in economic uncertainty exist, banking union is problematic even if the fiscal dimension is removed from the picture (say, through an EU-wide bank deposit insurance scheme).

Figure 8: Risk shocks and optimal capital requirements



Notes: (i) In the case of “Baseline γ ”, γ is set equal to its baseline calibrated value (i.e. $\gamma = 0.12$), ii) In the case of “High γ ”, γ is set two times higher than its baseline calibrated value (i.e. $\gamma = 0.24$).

7. Conclusions

Weak public finances matter for the banking sector through a variety of channels. Higher sovereign risk premia have a negative impact on the balance sheet of banks that hold public debt, hindering their ability to make loans and, in extreme cases, threatening their solvency. Doubts about the government’s capacity to honor its deposit insurance pledge increase interest rates and reduce the volume of bank deposits and bank loans.

In this paper we have focused on the second mechanism, which has been overlooked in the extant literature on the relationship between sovereign and financial credit risk. Our main contribution regards the analysis of how the optimal response of macroprudential regulation to fiscal frailty, by safeguarding the banking system, can arrest a decline in output and welfare. We also show that while the effects of various risk shocks are exaggerated by a higher degree of fiscal frailty, the deployment of the capital

requirements tool can mitigate such negative effects. And that optimal policy can also help limit the strongly non-linear effects that arise from the interaction of two key sources of uncertainty: economic uncertainty and uncertainty about the degree of bail-in. In other words, when economic uncertainty is high, optimal macroprudential regulation is even more effective in severing the transmission of frailty from the fiscal sphere to the banking system.

Our analysis also has implications for banking union. To the extent that the fiscal capacity of the union is the weighted average of that of the individual members, fiscally weak countries will experience a decrease and fiscally strong countries an increase in their optimal capital requirements when forming a banking union. As capital requirements are a necessary but costly regulation due to their effect on credit and economic activity, the former set of countries benefits and the latter loses from participation in the union on the basis of this criterion. While fiscal considerations represent but one of the factors that play a role in the decision to form a banking union, they may represent an important reason for the differing positions held by the “northern” and the “southern” country groups regarding banking union in the EU.

8. References

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9. Appendix

9.1 Calibration

Table 1. Calibrated parameters

Description	Parameter	Value
Patient Household Discount Factor	β^s	0.992
Impatient Household Discount Factor	β^m	0.977
Patient Household Utility Weight of Housing	v^m	0.25
Impatient Household Utility Weight of Housing	v^s	0.25
Patient Household Marginal Disutility of Labor	φ^s	1
Impatient Household Marginal Disutility of Labor	φ^m	1
Inverse of Frisch Elasticity of Labor	η	1
Degree of Fiscal Frailty	γ	0.12
Household Bankruptcy Cost	μ^m	0.3
Entrepreneur Bankruptcy Cost	μ^e	0.3
Capital Requirement for Mortgage Loans	$\overline{\phi}^H$	0.04
Capital Requirement for Corporate Loans	$\overline{\phi}^F$	0.08
Mortgage Bank Bankruptcy Cost	μ^H	0.3
Corporate Bank Bankruptcy Cost	μ^F	0.3
Capital Share in Production	α	0.4
Capital Depreciation Rate	δ	0.024
Housing Depreciation Rate	δ^H	0.0148
Housing Adjustment Cost Parameter	ξ^H	0.001
Capital Adjustment Cost Parameter	ξ^K	0.4
Dividend Payout of Bankers (Entrepreneurs)	$\chi^b(\chi^e)$	0.037
Std of Mortgage Bank Idiosyncratic Risk Shock	σ_H	0.0163
Std of Corporate Bank Idiosyncratic Risk Shock	σ_F	0.0331
Std of Household Idiosyncratic Risk Shock	σ_m	0.157
Std of Entrepreneurial Idiosyncratic Risk Shock	σ_e	0.49
Std – TFP shock	σ^A	0.0084
Std of Fiscal Capacity Shock	σ^R	0.00026
Std of Shock to Mortgage Bank Risk Shock	σ^{σ_H}	0.8
Std of Shock to Corporate Bank Risk Shock	σ^{σ_F}	0.8
Std of Shock to Household Risk Shock	σ^{σ_m}	0.9
Std of Shock to Entrepreneurial Risk Shock	σ^{σ_e}	0.8
Persistence – Mortgage Bank Risk Shock	ρ^{σ_H}	0.8
Persistence – Corporate Bank Risk Shock	ρ^{σ_F}	0.8
Persistence – Household Risk Shock	ρ^{σ_m}	0.9
Persistence – Entrepreneurial Risk Shock	ρ^{σ_e}	0.8
Persistence – TFP shock	ρ^A	0.75
Persistence – Fiscal Capacity Shock	ρ^{σ_e}	0.8

Table 2. Long-run solution

Description	Data averages	Long run solution
Total consumption over GDP	0.64	0.596
Investment (related to the capital good production)/over GDP	0.147	0.147
Investment in housing/over GDP	0.084	0.088
The premium required by the depositor in order to deposit his money in the risky bank	0.231	0.246
Debt-to-GDP ratio of entrepreneurs (annualized)	0.491	0.489
Debt-to-GDP ratio of borrowers (annualized)	0.421	0.338

Table 3. Second moment properties

Variable x	Relative Volatility σ_x/σ_y		Persistence $\rho(x_t, x_{t-1})$	
	Actual Data	Simulated Data	Actual Data	Simulated Data
Real GDP	1	1	0.76	0.81
Housing investment	7.95	6.95	0.52	0.74
Business investment	4.71	4.19	0.79	0.89
Mortgage loans	1.64	1.63	0.92	0.76
Business loans	1.79	1.80	0.69	0.98
Spread	0.17	0.18	0.93	0.82
Average default rate	0.47	0.47	0.94	0.92
Standard deviation of GDP, σ_y	0.0195	0.0192		

Notes: (i) Quarterly data over the period 2000:1-2010:4, (ii) Actual data variables, with the exception of the spread and the default rate, are in logs and have been detrended by removing a quadratic trend. A quadratic trend has also been removed from the level of the spread. The standard deviation of the default rate has been computed from the original series in levels.

9.2 The model

Households

There are two representative dynasties of ex ante identical infinitely lived households that differ only in the subjective discount factor. One dynasty, indexed by the superscript s , is made up of relatively patient households with a discount factor β^s . The other dynasty, identified by the superscript m , consists of more impatient households with a discount factor $\beta^m < \beta^s$. In equilibrium, the patient households save and the impatient households borrow from banks.

Saving Households

The dynasty of patient households maximizes

$$E_t \left[\sum_{i=0}^{\infty} (\beta^s)^{t+i} [\log(c_{t+i}^s) + v^s \log(h_{t+i-1}^s) - \frac{\varphi^s}{1+\eta} (l_{t+1}^s)^{1+\eta}] \right] \quad (A1)$$

subject to

$$c_t^s + q_t^H h_t^s + d_t \leq w_t l_t^s + q_t^H (1 - \delta^H) h_{t-1}^s + \tilde{R}_t^D d_{t-1} - T_t + \Pi_t^s \quad (A2)$$

where c_t^s denotes the consumption of non-durable goods, h_t^s denotes the total stock of housing, l_t^s denotes hours worked, η is the inverse of the Frisch elasticity of labour supply and v^s and φ^s are preference parameters. Also, q_t^H is the price of housing, δ^H is the depreciation rate of housing units and w_t is the real wage rate. As owners of the firms, households receive profits, Π_t^s , that are distributed in the form of dividends.

\tilde{R}_t^D , is defined as $\tilde{R}_t^D = R_{t-1}^D (1 - \gamma_t PD_t^b)$, where R_t^D is the gross, fixed interest rate on deposits in period t , PD_t^b is the economy-wide probability of bank default in period t , and γ_t , is the fraction of deposits that is not recovered when a bank defaults (the amount of depositor bail-in). We will take the level of γ_t to represent the frailty of public finances, with $\gamma_t=0$ corresponding to full deposit insurance.

In general, we allow γ_t to vary over time, according to two alternative rules:

Rule A

$$\gamma_t = \gamma_0 + \gamma_1 (b_t - b^*) + \varepsilon_t^R, \quad (A3)$$

Rule B

$$\gamma_t = \gamma_0 + \gamma_1 \left(\frac{b_t}{y_t} - \frac{b^*}{y^*} \right) + \varepsilon_t^R, \quad (A4)$$

where b_t is the total credit in the economy at time t , y_t is GDP at time t , b^* and y^* are the corresponding steady state values, γ_1 is the feedback parameter and ε_t^R is a fiscal capacity shock that

follows an $AR(1)$ stochastic process of the form: $\varepsilon_t^R = \rho^R \varepsilon_{t-1}^R + e_t$, where ρ^R is the persistence parameter and $e_t \sim (0, \sigma_t^R)$.

The presence of a deposit risk premium raises the funding cost for banks while, in addition, the fact that this premium depends on the economy-wide default risk rather than on their own default risk induces an incentive for banks to take excessive risk and provides a rationale for macroprudential policy.

Borrowing Households

Impatient households have the same preferences as patient households except for the discount factor, which is $\beta^m < \beta^s$. The budget constraint of the representative dynasty is:

$$c_t^m + q_t^H h_t^m - b_t^m \leq w_t l_t^m + \int_0^\infty \max\{\omega_t^m q_t^H (1 - \delta^H) h_{t-1}^m - R_{t-1}^m b_{t-1}^m, 0\} dF^m(\omega_t^m) \quad (A5)$$

where b_t^m is aggregate borrowing from the banks and R_{t-1}^m is the contractual gross interest rate on the housing loan agreed upon in period $t - 1$. ω_t^m is an idiosyncratic shock to the efficiency units of housing owned from period $t - 1$ that each household experiences at the beginning of each period t . The shock is assumed to be independently and identically distributed across the impatient households and to follow a lognormal distribution with density and cumulative distributions functions denoted by $f(\cdot)$ and $F(\cdot)$, respectively. This shock affects the effective resale value of the housing units acquired in the previous period, $\tilde{q}_t^H = \omega_t^m q_t^H (1 - \delta^H)$, and makes default on the loan *ex post* optimal for the household whenever $\omega_t^m q_t^H (1 - \delta^H) h_{t-1}^m < R_{t-1}^m b_{t-1}^m$. The term in the integral reflects the fact that the housing good and the debt secured against it are assumed to be distributed across the individual households that constitute the dynasty.

After the realization of the shock, each household decides whether to default or not on the individuals loans held from the previous period. Then, the dynasty makes the decisions for consumption, housing, labour supply and debt in period t and allocates them evenly across households. As shown in Clerc *et al.* (2015), individual households default in period t whenever the idiosyncratic shock ω_t^m satisfies:

$$\omega_t^m \leq \bar{\omega}_t^m = \frac{x_{t-1}^m}{R_t^H} \quad (A6)$$

where $R_t^H = \frac{q_t^H (1 - \delta^H)}{q_{t-1}^H}$ is the ex post average realized return on housing and $x_t^m = \frac{R_t^m b_t^m}{q_t^H h_t^m}$ is a measure of household leverage. The net housing equity after accounting for reposessions of defaulting households can be written as:

$$(1 - \Gamma^m(\bar{\omega}_t^m)) R_t^H q_{t-1}^H h_{t-1}^m, \quad (A7)$$

where $\Gamma^m(\bar{\omega}_t^m) = \int_0^{\bar{\omega}_{t+1}^m} (\omega_t^m f^m(\omega_t^m)) d\omega_t^m + \bar{\omega}_{t+1}^m \int_{\bar{\omega}_1^m}^{\infty} (f^m(\omega_t^m)) d\omega_t^m$ is the share of gross returns (gross of verification costs) accrued by the bank and $(1 - \Gamma^m(\bar{\omega}_t^m))$ is the share of assets accrued to the dynasty.

Since each of the impatient households can default on its loans, the loans taken in period t should satisfy the participation constraint for the lending banks:

$$E_t(1 - \Gamma^H(\bar{\omega}_t^H))(\Gamma^m(\bar{\omega}_{t+1}^m) - \mu^m G^m(\omega_{t+1}^m))R_{t+1}^H q_t^H h_t^m \geq \rho_t \phi_t^H b_t^m \quad (\text{A8})$$

The left-hand side of the inequality accounts for the total equity returns associated with a portfolio of housing loans to the various members of the impatient dynasty. The interpretation of the banking participation constraint is that the expected gross return for bankers should be at least as high as the gross equity return of the funding of the loan from the bankers, $\rho_t \phi_t^H b_t^m$, where ρ_t is the required expected rate of return on equity from bankers (defined below) and ϕ_t^H is the capital requirement on housing loans. The term $\mu^m G^m(\omega_{t+1}^m)$ is the expected cost of default, where μ^m is the verification cost and $G^m(\omega_{t+1}^m) = \int_0^{\bar{\omega}_{t+1}^m} (\omega_{t+1}^m f^m(\omega_{t+1}^m)) d\omega_{t+1}^m$ is the share of assets that belong to households that default. Finally, $(1 - \Gamma^H(\bar{\omega}_t^H))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^H$ is the threshold level to the idiosyncratic shock of banks that specialize in mortgage loans (defined below).

Given the above, the problem of the representative dynasty of the impatient households can be written compactly as a contracting problem between the representative dynasty and its bank. In particular, the problem of the dynasty is to maximize utility subject to the budget constraint and the participation constraint of the bank:

$$\max_{\{c_{t+1}^m, h_{t+1}^m, l_{t+1}^m, x_{t+1}^m, b_{t+1}^m\}_{i=0}^{\infty}} E_t \left[\sum_{i=0}^{\infty} (\beta^m)^{t+i} [\log(c_{t+i}^m) + v^m \log(h_{t+i}^m) - \frac{\varphi^m}{1+\eta} (l_{t+1}^m)^{1+\eta}] \right] \quad (\text{A9})$$

subject to

$$c_t^m + q_t^H h_t^m - b_t^m \leq \omega_t l_t^m + \left(1 - \Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right)\right) R_{t+1}^H q_t^H h_t^m \quad (\text{A10})$$

and

$$E_t \left[(1 - \Gamma^H(\bar{\omega}_{t+1}^m)) \left(\Gamma^m\left(\frac{x_t^m}{R_{t+1}^H}\right) - \mu^m G^m\left(\frac{x_t^m}{R_{t+1}^H}\right) \right) R_{t+1}^H \right] R_{t+1}^H q_t^H h_t^m = \rho_t \phi_t^H b_t^m \quad (\text{A11})$$

Entrepreneurs

Entrepreneurs are risk neutral agents that live for two periods. Each generation of entrepreneurs inherits wealth in the form of bequests and purchases new capital from capital good producers and depreciated capital from the previous generation of entrepreneurs that they rent out to final good producers. They finance capital purchases with their initial wealth and with corporate loans from banks, b_t^e . The entrepreneurs derive utility from the transfers made to the patient households in period $t + 1$ (dividends), c_{t+1}^e , and the bequests left to the next cohort of entrepreneurs (retained earnings), n_{t+1}^e , according to the utility function $(c_{t+1}^e)^{\chi^e} (n_{t+1}^e)^{1-\chi^e}$, $\chi^e \in (0,1)$. Thus, the problem of the entrepreneurs in period $t + 1$ is:

$$\max_{\{c_{t+1}^e, n_{t+1}^e\}} (c_{t+1}^e)^{\chi^e} (n_{t+1}^e)^{1-\chi^e} \quad (\text{A12})$$

subject to $c_{t+1}^e + n_{t+1}^e \leq W_{t+1}^e$, where W_{t+1}^e is the wealth resulting from the activity in the previous period.

The optimization problem of the entrepreneur in period t is to maximize expected wealth:

$$\max_{\{k_t, b_t^e, R_t^F\}} E_t(W_{t+1}^e) \quad (\text{A13})$$

subject to the period t resource constraint $q_t^K k_t - b_t^e = n_t^e$ and the banks participation constraint (defined below), where $W_{t+1}^e = \max\{\omega_{t+1}^e (r_{t+1}^k + (1 - \delta) q_{t+1}^K) k_t - R_t^F b_t^e, 0\}$, q_t^K is the price of capital at period t , k_t is the capital held by the entrepreneur in period t , b_t^e is the amount borrowed from the bank in period t , r_t^k is the rental rate of capital, δ is the depreciation rate of physical capital and R_t^F is the contractual gross interest rate of the corporate loan. ω_{t+1}^e is an idiosyncratic shock to the efficiency units of capital which is independently and identically distributed across entrepreneurs. It is realized after the period t loan with the bank is agreed to and prior to renting the available capital to consumption good producers on that date. Similar to the case of borrowing households, entrepreneurs default on their loans whenever $\omega_{t+1}^e (r_{t+1}^k + (1 - \delta) q_{t+1}^K) k_t < R_t^F b_t^e$. As shown in Clerc *et al.* (2015), the entrepreneur will repay their corporate loan in period $t + 1$ whenever the idiosyncratic shock ω_{t+1}^e exceeds the following threshold:

$$\bar{\omega}_{t+1}^e \equiv \frac{R_t^F b_t^e}{R_{t+1}^K q_t^K k_t} \equiv \frac{x_t^e}{R_{t+1}^K} \quad (\text{A14})$$

where $R_{t+1}^K = \frac{r_{t+1}^k + (1 - \delta) q_{t+1}^K}{q_t^K}$ is the gross return per efficiency units of capital in period $t + 1$ of capital owned in period t , $x_t^e = \frac{R_t^F b_t^e}{q_t^K k_t}$ denotes the entrepreneurial leverage that is defined as the ratio of contractual debt repayment obligations in period $t + 1$, $R_t^F b_t^e$, to the value of the purchased capital at t , $q_t^K k_t$.

Given the above, the maximization problem of the entrepreneurs in period t can be compactly written as:

$$\max_{x_t^e, k_t} E_t \left[(1 - \Gamma^e \left(\frac{x_t^e}{R_{t+1}^K} \right)) R_{t+1}^K q_t^K k_t \right] \quad (\text{A15})$$

subject to

$$E_t \left[(1 - \Gamma^F(\bar{\omega}_{t+1}^F)) (\Gamma^e(\bar{\omega}_{t+1}^e) - \mu^e G^e(\bar{\omega}_{t+1}^e)) \right] R_{t+1}^K q_t^K k_t = \rho_t \phi_t^F (q_t^K k_t - n_t^e) \quad (\text{A16})$$

where $\Gamma^e(\bar{\omega}_{t+1}^e) = \int_0^{\bar{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e + \bar{\omega}_{t+1}^e \int_{\bar{\omega}_{t+1}^e}^{\infty} (f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the share of gross returns that will accrue to the bank, $G^e(\bar{\omega}_{t+1}^e) = \int_0^{\bar{\omega}_{t+1}^e} (\omega_{t+1}^e f^e(\omega_{t+1}^e)) d\omega_{t+1}^e$ is the fraction of the returns coming from the defaulted loans of entrepreneurs, μ^e denotes the verification costs incurred by the bank and $(1 - \Gamma^F(\bar{\omega}_t^F))$ is the share of assets accrued to bankers in the case of a bank default, where $\bar{\omega}_t^F$ is the default threshold level for the idiosyncratic shock of banks that specialize in corporate loans (defined below). Similar to the case of impatient households, the interpretation of the participation constraint is that, in equilibrium, the expected return of the corporate loans must equal to the expected rate of return on equity, ρ_t , that the bankers require for their contribution to the funding of loan, $\phi_t^F (q_t^K k_t - n_t^e)$, where ϕ_t^F is the capital requirement applied on corporate loans.

Bankers

Like entrepreneurs, bankers are risk-neutral and live for two periods. They invest their initial wealth, inherited in the form of bequest from the previous generation of bankers, n_t^b , as bank's inside equity capital. In period $t + 1$ the bankers derive utility from transfers to the patient households in the form of dividends, c_{t+1}^b , and the bequests left to the next generation of bankers (retained earnings), n_{t+1}^b , according to the utility function $(c_{t+1}^b)^{\chi^b} (n_{t+1}^b)^{1-\chi^b}$, where $\chi^b \in (0,1)$. Thus, the problem of the banker in period $t + 1$ is:

$$\max_{\{c_{t+1}^b, n_{t+1}^b\}} (c_{t+1}^b)^{\chi^b} (n_{t+1}^b)^{1-\chi^b} \quad (\text{A17})$$

subject to

$$c_{t+1}^b + n_{t+1}^b \leq W_{t+1}^b \quad (\text{A18})$$

where W_{t+1}^b is the wealth of the banker in period $t + 1$.

Regarding the decision problem of the bankers in period t , the banker born in period t with initial wealth n_t^b decides how much of this wealth to allocate as inside equity capital across the banks that specialize in housing loans (H banks) and the banks that specialize in entrepreneurial loans (F banks).

Let e_t^F be the amount of the initial wealth n_t^b invested as inside equity in F banks and the rest, $n_t^b - e_t^F$, in H banks. The net worth of the banker in period $t + 1$ is $W_{t+1}^b = \tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)$, where $\tilde{\rho}_{t+1}^F, \tilde{\rho}_{t+1}^H$ are the ex post gross returns on the inside equity invested in banks F and H respectively. The maximization problem of the banker is to decide on the allocation of their initial wealth in order to maximize the expected wealth:

$$\max_{e_t^F} E_t(W_{t+1}^b) = E_t(\tilde{\rho}_{t+1}^F e_t^F + \tilde{\rho}_{t+1}^H (n_t^b - e_t^F)) \quad (A19)$$

An interior solution in which both types of banks receive positive equity requires that $E_t \tilde{\rho}_{t+1}^F = E_t \tilde{\rho}_{t+1}^H = \rho_t$, where ρ_t denotes the required expected gross rate of return on equity investment at time t . This expected return is endogenously determined in equilibrium but it is taken as given by individuals and banks.

Banks

Banks are institutions that provide loans to households and entrepreneurs. There are two types of banks: banks indexed by H are specialized in mortgage loans and banks indexed by F are specialized in corporate loans. Both types of banks ($j = H, F$) issue equity bought by bankers and receive deposits from households.

Each bank maximizes the expected equity payoff, $\pi_{t+1}^j = \omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j$, that is, the difference between the return from loans and the repayments due to its deposits, where ω_{t+1}^j is an idiosyncratic portfolio return shock, which is i.i.d. across banks and follows a log-normal distribution with mean one and a distribution function $F^j(\omega_{t+1}^j)$, b_t^j and d_t^j are respectively the loans extended and deposits taken by bank at period t , R_{t+1}^D is the gross interest rate paid on the deposits taken in period t and \tilde{R}_{t+1}^j is the realized return on a well-diversified portfolio of loans of type j .

Each bank faces a regulatory capital constraint:

$$e_t^j \geq \phi_t^j b_t^j \quad (A20)$$

where ϕ_t^j is the capital-to-asset ratio of banks of type j . The regulatory capital constraint states that the bank is restricted to back with equity at least a fraction of the loans made in period t . The problem of each bank j can be written as:

$$\pi_{t+1}^j = \max\{\omega_{t+1}^j \tilde{R}_{t+1}^j b_t^j - R_t^D d_t^j, 0\} \quad (A21)$$

subject to the aforementioned regulatory capital constraint.

In equilibrium, the constraint will be binding so that the loans and deposits can be expressed as $b_t^j = \frac{e_t^j}{\phi_t^j}$ and $d_t^j = (1 - \phi_t^j) \frac{e_t^j}{\phi_t^j}$, respectively. Accordingly, the threshold level of ω_t^j below which the bank defaults is $\bar{\omega}_{t+1}^j = (1 - \phi_t^j) \frac{R_t^D}{\bar{R}_{t+1}^j}$ and the probability of default of each bank of type j is $F^j(\bar{\omega}_{t+1}^j)$. Thus, bank default is driven by fluctuations in the aggregate return \tilde{R}_{t+1}^j and the bank idiosyncratic shock ω_{t+1}^j . In the case in which a bank defaults, its deposits are taken by DIA.

Given the above, the equity payoffs can then be written as:

$$\pi_{t+1}^j = [\max\{\omega_{t+1}^j - \bar{\omega}_{t+1}^j, 0\}] \left(\frac{\tilde{R}_{t+1}^j}{\phi_t^j} \right) e_t^j = \left[\int_{\bar{\omega}_{t+1}^j}^{\infty} (\omega_{t+1}^j f^j(\omega_{t+1}^j)) d\omega_{t+1}^j - \bar{\omega}_{t+1}^j \int_{\bar{\omega}_{t+1}^j}^{\infty} (f^j(\omega_{t+1}^j)) d\omega_{t+1}^j \right] \times \left(\frac{\tilde{R}_{t+1}^j}{\phi_t^j} \right) e_t^j \quad (\text{A22})$$

where $f^j(\omega_{t+1}^j)$ denotes the density distribution of ω_t^j . Then, the equity payoffs can be written as:

$$\pi_{t+1}^j = \frac{[1 - \Gamma^j(\bar{\omega}_{t+1}^j)] \tilde{R}_{t+1}^j}{\phi_t^j} e_t^j$$

and the required ex post rate of return from the bankers that invest in the bank j is:

$$\tilde{\rho}_{t+1}^j = \frac{[1 - \Gamma^j(\bar{\omega}_{t+1}^j)] \tilde{R}_{t+1}^j}{\phi_t^j},$$

where $\Gamma^j(\bar{\omega}_{t+1}^j) = \int_0^{\bar{\omega}_{t+1}^j} (\omega_{t+1}^j f^j(\omega_{t+1}^j)) d\omega_{t+1}^j + \bar{\omega}_{t+1}^j \int_{\bar{\omega}_{t+1}^j}^{\infty} (f^j(\omega_{t+1}^j)) d\omega_{t+1}^j$ and

$$G^j(\bar{\omega}_{t+1}^j) = \int_0^{\bar{\omega}_{t+1}^j} (\omega_{t+1}^j f^j(\omega_{t+1}^j)) d\omega_{t+1}^j.$$

Finally, the average default rate for banks can be written as:

$$PD_t^b = \frac{d_{t-1}^H F^H(\bar{\omega}_{t+1}^H) + F^F(\bar{\omega}_{t+1}^F)}{d_{t-1}^H + d_{t-1}^F} \quad (\text{A23})$$

and the expression for the realized returns on loans after accounting for loan losses can be expressed as:

$$\tilde{R}_{t+1}^H = \left(\Gamma^m \left(\frac{x_t^m}{R_{t+1}^H} \right) - \mu^m G^m \left(\frac{x_t^m}{R_{t+1}^H} \right) \right) \left(\frac{R_{t+1}^H q_t^H h_t^m}{b_t^m} \right) \quad (\text{A24})$$

$$\tilde{R}_{t+1}^F = \left(\Gamma^e \left(\frac{x_t^e}{R_{t+1}^K} \right) - \mu^e G^e \left(\frac{x_t^e}{R_{t+1}^K} \right) \right) \left(\frac{R_{t+1}^K q_t^K k_t}{q_t^K k_t - n_t^e} \right) \quad (\text{A25})$$

Production sector

The final good in this economy is produced by perfectly competitive firms that use capital, k_t and labour, h_t . The production technology is:

$$y_t = A_t k_{t-1}^a l_t^{1-a} \quad (\text{A26})$$

where A_t is total factor productivity and a is the labour share in production.

Capital and housing production

Capital and housing producing firms are owned by patient households. Capital producers combine a fraction of the final good, I_t , and previous capital stock k_{t-1} to produce new units of capital goods that are sold to entrepreneurs at price q_t^K . The law of motion for the physical capital stock is given by:

$$k_t = (1 - \delta) k_{t-1} + \left[1 - S_K \left(\frac{I_t}{I_{t-1}} \right) \right] I_t \quad (\text{A27})$$

where $S_K \left(\frac{I_t}{I_{t-1}} \right) = \frac{\xi_K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2$ is an adjustment cost function that satisfies $S(\cdot) = S'(\cdot) = 0, S''(\cdot) = 0$.

The objective of the representative capital producing firm is to maximize expected profits:

$$E_t \sum_{i=0}^{\infty} (\beta^s)^i \left(\frac{c_t^s}{c_{t+i}^s} \right) \{ q_{t+i}^K I_{t+i} - [1 + S^K(I_{t+i}/I_{t+i-1})] I_{t+i} \} \quad (\text{A28})$$

Housing producers are modelled in a similar manner. In particular, the law of motion of the aggregate housing stock is:

$$h_t = (1 - \delta^H) h_{t-1} + \left[1 - S_H \left(\frac{I_t^H}{I_{t-1}^H} \right) \right] I_t^H \quad (\text{A29})$$

And the maximization problem of the representative housing producing firm is:

$$E_t \sum_{i=0}^{\infty} (\beta^s)^i \left(\frac{c_t^s}{c_{t+i}^s} \right) \{ q_{t+i}^H I_{t+i}^H - [1 + S^K(I_{t+i}^H/I_{t+i-1}^H)] I_{t+i}^H \} \quad (\text{A30})$$

Government

The budget constraint of the government is:

$$T_t = (1 - \gamma_t) PD_t^b d_{t-1} \quad (\text{A31})$$

where T_t represents lump sum taxes. That is, the only purpose of the government in this model is to provide deposit insurance.

Macroprudential policy

The macroprudential authority sets the capital requirements on bank lending in period t according to the following rule:

$$\phi_t^j = \bar{\phi}_0^j + \bar{\phi}_1^j [\log(b_t) - \log(\bar{b})], \quad j = H, F \quad (\text{A32})$$

where b_t is the total credit in the economy at time t , $\bar{\phi}_0^j$ is the reference level of capital requirements and $\bar{\phi}_1^j > 0$ is a feedback parameter that captures the cyclical adjustments in capital requirements that depends on the state of the economy.

Stochastic environment

Productivity shocks and the shocks to the variances of the idiosyncratic risk shocks follow an $AR(1)$ stochastic process of the form:

$$\ln S_t = \rho^S \ln S_{t-1} + \varepsilon_t^S \quad (\text{A33})$$

where ρ^S is the persistence parameter and $\varepsilon_t^S \sim (0, \sigma_t^S)$. The fiscal capacity shock, ε_t^R , follows an $AR(1)$ stochastic process of the form: $\varepsilon_t^R = \rho^R \varepsilon_{t-1}^R + e_t$, where ρ^R is the persistence parameter and $e_t \sim (0, \sigma_t^R)$.