The Macroeconomic Consequences of Bank Capital Requirements

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Abstract

In the light of the recent crisis, there is now considerable concern about financial cycles and their implications for business fluctuations. Macroprudential policy has thus become part of the policy paradigm. In this work, a model of business cycles is developed which analyzes the macroeconomic consequences of a minimum bank capital standard. Numerical examples suggest that capital regulation can be useful in strengthening the resilience of the banking sector, and hence improve social welfare.

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1 Introduction

The concept of financial cycle, and its interactions with economic activity, fell out of favor during the Great Moderation. Financial factors came to be viewed as mere reflections of real variables. As such, they were often ignored when studying business fluctuations and their policy challenges.

The 2007-2008 financial crisis prompted a rethink on the transmission channels that exist between the financial and real sectors. Specifically, it showed that financial disturbances could have long lasting adverse consequences on economic activity. Consequently, (i) a better understanding of macro-financial linkages, as well as (ii) the development of a policy framework responsible for financial stability, are at the forefront of the policy agenda.

Despite the growing interest in the use of macroprudential policies, very little is known about their quantitative effects on the real economy. Traditionally, research on prudential regulation has focused on the safety and soundness of individual financial institutions. Consequently, it has ignored the interaction among financial intermediaries as well as between the financial sector and the real economy. As a result, it has failed to provide general equilibrium predictions. Against this backdrop, the present paper attempts to assess the quantitative effects of bank capital requirements on the real economy.

My analysis is based on a canonical small open economy real business cycle model driven by (i) disruptions in the flow of resources between corporate borrowers and banks (i.e. default shocks), and (ii) exogenous shocks to total factor productivity. In the model, local banks borrow from international investors and domestic depositors in order to lend to corporate borrowers. To explore the consequences of prudential regulation, relaxing the complete frictionless market assumption is warranted [Rochet (2008)]. With this mind, a financial friction is introduced in the market for external funds by considering a debt elastic interest rate premium [Schmitt-Grohe and Uribe (2015)].

Specifically, the interest rate faced by domestic banks is increasing in the countries' cross-sectional average level of debt. The latter is nonetheless taken as exogenously given by individual financial institutions, rather than as endogenous to the economy as a whole. In other words, banks ignore that their collective borrowing choices determine the strength of the financial friction. This gives rise to a pecuniary externality. The competitive equilibrium thus features a sub-optimal level of equity capital. The welfare consequences may be severe. It is in this context that minimum equity standards that strength banks' capital positions may be welfare improving.

One of the discerning features of financial cycles is their nonlinear nature. During periods of financial stress, credit markets freeze, risk tolerance declines and borrowing constraints become tight. In these instances, the behavior of market participants and of macro-financial aggregates notably differ from what is customary during normal times. This points to the importance of taking into consideration the highly nonlinear and asymmetric patterns displayed by the financial system. Otherwise, substantial biases and misleading advice should be expected [Benes et al. (2014)].

This is why I obtain the nonlinear solution to the model and focus on the global implications when bank capital requirements bind only occasionally. As a matter of fact, in my framework the minimum equity threshold is rarely hit. This occurs because banks build a precautionary equity cushion to avoid being caught with a binding constraint. Consequently, long run business cycles are similar to those of a frictionless economy. This is in complete agreement with the recent nonlinear DSGE models proposed by Mendoza (2010), Akinci and Queralt (2014) or Akinci and Chahrour (2015), and further supports the power of precautionary savings. Also, it is in line with existing empirical evidence [e.g. Peura and Jokivuolle (2004); Jokipii and Milne (2008)] which suggest that banks usually hold capital well in excess of the minimum required by regulators, and hence are seldom constrained[1].

In order to assess quantitatively the role of equity requirements in driving business cycles and its welfare implications, the model is calibrated to Spain's economy.

The results of the quantitative analysis shows that capital regulation can be useful in strengthening the resilience of the banking sector, and hence lowering business cycle fluctuations. It is in this manner that equity requirements can be welfare improving.

The remainder of the paper is organized as follows. Section 2 lays out the model, solution method and calibration. Section 3 presents the main results. The final section concludes.

[1]Matching this empirical fact is a challenge for a large class of quantitative general equilibrium models with macro-financial linkages. This is due to the fact that they often rely on linear approximations of the system dynamics. In consequence, they fail to take into consideration occasionally binding constraints, and instead impose that financial constraints are always binding [e.g. Clerc et al. (2015), Iacoviello (2015)].

2 A Model of Business Cycles with Capital Requirements

2.1 Setup

Consider a discrete time economy populated by three types of agents: households, firms and banks. The representative household consumes, works and holds bank deposits. The representative firm operates a Cobb Douglas technology that requires capital and labor to produce output. Following Mendoza (2010), Christiano et al. (2010), and others, input costs must be financed in advance of sales. Hence, the representative firm demands loans at the beginning of each period and repay them at the end.

In order to meet the demand for loans by local borrowers, a domestic representative bank borrows funds from both foreign lenders and domestic depositors. Note then the dual nature of the banking activity. The bank is a borrower vis-a-vis international investors and domestic households, whereas it is a lender when it comes to its relationship with local firms.

As mentioned above, a financial friction in the market for external funds is considered. More precisely, the model assumes a debt elastic interest rate premium. This generates a pecuniary externality, because individual banks disregard that their collective actions affect the strength of such a friction. The negative externality can thus generate inefficient borrowing.

In consequence, there is room for welfare improving prudential regulation. The model studies the effects of bank capital requirements. Specifically, the representative bank faces a minimum equity threshold, which sets a lower bound on the bank capital to loans ratio.

At the core of the paper is the notion that economic activity and the corresponding policy challenges cannot be understood without taking into consideration the financial cycle. Within the framework of this criterion, in the model business fluctuations are partly driven by exogenous disruptions in the flow of resources from local borrowers (i.e. firms) to domestic lenders (i.e. banks). These disturbances occur when a group of borrowers pays less than contractually agreed, thus defaulting on its debt obligations[2]. Mapped into the real world, this shock represent any exogenous disturbance that triggers a decline in the stock of bank capital. For instance, a non-performing loan or a wave of writedowns after a collapse in asset prices.

[2] This shock is inspired in Furfine (2001), Ghilardi and Peiris (2014) and Iacoviello (2015).

Households

The representative household chooses sequences of consumption (C), hours worked (H), bank deposits (D) and investment (I) in order to maximize its expected lifetime utility:

$$E_t\left[\sum_{t=0}^{\infty}\beta_h^t\left[\frac{C_t^{1-\sigma}-1}{1-\sigma}-\frac{H_t^{1+\omega}}{1+\omega}+\phi log(D_t)\right]\right] \tag{1}$$

where β_h is the discount factor parameter and E_t is an expectation operator. Its choices are constrained by:

$$C_t + D_t + I_t = w_t H_t + (1 + r^d_{t-1})D_{t-1} + Q_t + \Xi_t + r^k_t K_t \tag{2}$$

$$K_{t+1} = I_t + (1-\delta)K_t \tag{3}$$

where w is the wage rate, Q are wealth transfers between the bank and the household -to be specified below-, r^d is the interest rate of deposits, Ξ are dividends from local firms, r^k is the rental rate of capital and K is the capital stock, which depreciates at rate δ.

Note that the household values liquidity services. Specifically, the model assumes that the household's utility function is increasing in the amount of deposits.

Firms

The representative firm operates a Cobb-Douglas technology to produce output. As noted above, both the wage bill and the capital bill must be paid in advance of sales. In consequence, each and every period the firm demands an amount of loans (L) equal to:

$$L_t = w_t H_t + r^k_t K_t \tag{4}$$

where K_t and H_t are the amount of capital and labor services, respectively, used at period t. Therefore, the representative firm chooses capital and labor inputs to maximize dividend payments to the household (Ξ):

$$\Xi_t = A_t K_t^{\alpha} H_t^{1-\alpha} - (1 + r^l_t)(w_t H_t + r^k_t K_t) + \epsilon_t \tag{5}$$

taking as given input prices w and r^k as well as the interest rate of loans r^l. Productivity (A) evolves according to a 2-state Markov chain with transition matrix P.

The term ϵ denotes a default shock. Following Iacoviello (2015), I assume that such a shock transfers resources from the financial sector to local borrowers. In other words, the shock captures losses on banks which are gains to firms. Accordingly, the same shock appears in the law of motion for bank equity capital with opposite sign[3]. Regarding its stochastic properties, ϵ evolves according to a 2-state Markov chain with transition matrix Π.

Banks

Suppose a competitive environment in which each period a representative bank extends loans (L) to the representative firm. These loans are financed by combining borrowed funds from foreign investors (F), deposits from domestic households (D) and the bank's own net worth (N). Thus, the bank's balance sheet at period t is[4]:

$$L_t = N_{t-1} + F_t + D_t \tag{6}$$

The bank can also issue new equity (capital inflows) as well as pay dividends (capital outflows). Net external capital flows (Q) are thus positive whenever the overall amount of dividend payments exceeds the amount of new equity raised, and vice versa.

There is an extensive literature in corporate finance that argues that raising and shedding external capital is costly. For example, asymmetric information, market signaling, taxation and supervisory pressure are often cited as sources of these costs [Estrella (2004)]. In keeping with this literature, I bring adjustment costs explicitly into the model. More precisely, the bank faces convex costs when the net change in external capital flows differs from its steady state level ($\bar{Q}$). Formally, adjustment costs are represented as:

$$\Gamma_1(Q_t) = \frac{\gamma}{2}(Q_t - \bar{Q})^2$$

It is worth noting that the presence of convex adjustment costs implies that as the bank gets further away from its optimal equity level, the cost of getting quickly to the ideal target increases.

There is also a considerable literature that asserts that equity capital is more expensive than other forms of corporate liabilities[5]. Capital market frictions such as taxation and agency costs of equity are usually mentioned as the sources of this wedge [Myers (1977), Myers and Majluf (1984), Froot and Stein (1998), Peura and Keppo (2006)]. In keeping with this literature, I follow

[3] The nature of the shock is motivated by the notion that non-performing loans represent transfers of wealth from savers to borrowers. Aggregate wealth is therefore not affected by this type of disturbance. However, resources are indeed removed from productive activities (i.e. lending) to unproductive ones (i.e. lump-sum payments to households).

[4] It is important to stress that $[L, D, F]$ are control variables, whereas N is a state variable.

[5] Reviews of this literature can be found in Admati et al. (2013) and Martynova (2015).

Estrella (2004), Froot and Stein (1998) and others, and assume that holding equity capital incurs costs determined by the convex function

$$\Gamma_2(N_t) = \frac{\tau}{2}N_t^2$$

. Equity capital therefore evolves by:

$$N_t = N_{t-1} + r_t^l L_t - r_t^f F_t - r_t^d D_t - Q_t - \Gamma_1(Q_t) - \Gamma_2(N_{t-1}) - \epsilon_t \tag{7}$$

where r^f is the rate of return on international liabilities. Hence, operating profits and new issues of equity feed to the total net worth of the bank, whereas dividend payments and default shocks represent a leakage.

One point here deserves further comment. Banks are not usually able to recapitalize themselves immediately and costlessly. Were this true, capital regulation would be pointless. With this mind, two layers of imperfections relating to external capital flows are introduced. The first one is the convex adjustment cost, $\Gamma_1(Q)$, presented above. The second one is due to a timing assumption. Eq. (7) implies that when the bank raises new equity at time t, the collected funds are only available to make new loans at time $t+1$. The bank is therefore prevented from increasing its equity stock at the very moment of being subject to capital regulation (i.e., just before undertaking new lending).

Regarding capital adequacy regulation, the bank faces an equity requirement constraint. The latter ensures that bank capital is at least a fraction κ of loans:

$$\frac{N_{t-1}}{L_t} \geq \kappa \tag{8}$$

I am now in a position to state the bank's optimization problem. The objective of the bank is to maximize the discounted sum of future payouts to the household. Formally, the bank's problem is to choose sequences $\{L_t, F_t, Q_t\}_{t=0}^{\infty}$ to maximize:

$$E_t \sum_{t=0}^{\infty} \beta_b^t \Lambda_{t,t+1} Q_t \tag{9}$$

subject to Eq. (6), Eq. (7) and Eq. (8). Here $\Lambda_{t,t+1}$ is the household's stochastic discount factor.

International Capital Markets

I follow Schmitt-Grohe and Uribe (2015) and assume that the domestic economy faces a debt elastic interest rate premium in the international markets:

$$r_t^f = \bar{r} + \psi_0 \left[1 + e^{\psi_1(\hat{N}_{t-1} - \bar{N})}\right]^{-1} \tag{10}$$

Here $\hat{N}$ is the cross-sectional average of equity across local financial institutions.

Parameters ψ_0 and ψ_1 govern the strength of the financial friction in the market for external funds[6]. The intuition is straightforward. International investors regards the cross-sectional average level of equity capital as an indicator of the strength of the domestic banking industry. As a consequence, a decreasing (increasing) level of average equity causes the premium to increase (decrease) as investors' perceived risk of investing in the domestic economy increases (decreases).

The fact that the premium depends on the cross sectional average of bank capital gives rise to a pecuniary externality. This occurs because local financial institutions take the premium as given. In other words, they do not internalize the impact that their saving choices have on the interest rate they face[7]. As a result, the competitive equilibrium features a sub-optimal level of bank capital and therefore may be inefficient.

Nonetheless, because banks are assumed to be identical, in equilibrium the cross sectional average level equals the individuals level of equity; i.e. $\hat{N} = N$.

Two points here deserve further comment. First, at the core of the financial friction is the notion that the risk premium applies to a representative agent acting competitively. Second, under this specification, the representative bank's funding cost is associated with its risk profile[8].

2.2 Competitive Equilibrium and Capital Requirements

A competitive equilibrium consists on sequences of prices $\{w_t, r_t^d, r_t^l, r_t^f, r_t^k\}_{t=0}^{\infty}$ and allocations $\{C_t, I_t, H_t, D_t, L_t, F_t, Q_t, N_t, K_t\}_{t=0}^{\infty}$ that satisfy households', firms' and banks' optimality conditions, the laws of motion for capital and net worth, the bank's balance sheet identity, and the following market clearing condition:

$$A_t K_t^{\alpha} H_t^{1-\alpha} = C_t + I_t + r_t^f F_t \tag{11}$$

[6]Schmitt-Grohe and Uribe (2015) argue that the debt elastic interest rate formulation captures in a reduced form fashion financial frictions that may arise from various sources. For instance, theoretical frameworks with imperfect enforcement of contracts, occasionally binding borrowing constraints or portfolio adjustment costs predict that interest rate premiums increase with the level of total indebtedness.

[7]Clerc et al. (2015) have coined the term *bank funding costs externality* to describe this effect.

[8]This is consistent with conventional wisdom and has been stressed by a number of others [e.g. Admati et al. (2013); Arnold et al. (2015)].

Let me now look at the distortions introduced by the capital requirement constraint. First, it affects the bank's intertemporal decision rules. To see this point more clearly, the Euler equation for net worth is given by:

$$\eta_t = \beta_b E_t \left[\Lambda_{t,t+1} \left[\eta_{t+1}(1 + r^f_{t+1} - \tau N_t) + \mu_{t+1} \right] \right] \tag{12}$$

where η is the Lagrange multiplier on the law of motion for net worth, which equals the marginal utility of payouts to the household, and μ is the Lagrange multiplier on the capital requirement constraint. As usual, the Euler equation balances the marginal cost of accumulating an extra unit of equity, given by η, with its marginal benefit. When the constraint is expected to bind next period (i.e. $E_t \Lambda_{t,t+1} \mu_{t+1} > 0$) the marginal benefit of an extra unit of equity is not just given by the present discounted value of the payments it generates (i.e. $E_t \Lambda_{t,t+1} \eta_{t+1}(1 + r^f_{t+1} - \tau N_t)$), but by a larger value. This occurs because, in this case, such an extra unit of equity eases the capital requirement constraint next period. Thus, it carries a shadow benefit equal to $E_t \Lambda_{t,t+1} \mu_{t+1}$. Capital regulation therefore encourages precautionary savings, which in turn reinforces the resilience of the banking industry.

Second, the effects of the constraint on the lending rate can be derived from the bank's intratemporal optimality conditions. It can be shown that:

$$r^l_t = r^f_t + \kappa \frac{\mu_t}{\eta_t} \tag{13}$$

This is a standard condition equating the marginal product of loans with their marginal cost. During periods in which the constraint binds (i.e. $\mu_t > 0$), the bank faces a higher effective marginal financing cost, capturing a shadow penalty for trying to expand lending when equity requirements are tight.

This result is fairly intuitive. Given that in the model equity is a predetermined variable[9], cutting back on lending is the only available channel of adjustment when the constraint binds. In consequence, there is exceed demand for credit. The lending rate must therefore adjust upwards in order to ensure market clearing.

To sum up, the model predicts a tradeoff regarding the macroeconomic consequences of equity requirements. On the one hand, the term $\frac{\kappa}{\eta_t}\mu_t$ in Eq. (13) captures explicitly the notion that stricter capital regulation might be passed on to borrowers in the form of higher lending rates.

On the other hand, during periods of financial distress when equity capital falls short, the debt elastic interest rate premium may result in dramatic hikes in interest rates and hence in credit rationing. By encouraging precautionary savings, capital requirements reduce the probability of capital shortfalls

[9]The stickiness of bank equity has recently been documented by Adrian and Shin (2011).

and the credit crunches associated with them. It is in this sense that equity regulation can be welfare improving.

2.3 Solution Technique

The model is solved using the policy function iteration algorithm described in Richter et al. (2014). For a formal description of the numerical algorithm see Appendix A.1.

This method derives the full nonlinear solution of the model, thereby taking into consideration the occasionally binding capital requirement constraint. In addition, precautionary behavior is properly captured, because this technique fully accounts for shock uncertainty.

2.4 Calibration

In calibrating the model, I use quarterly data from Spain for the period 1997Q3 to 2015Q4. More details on the data are provided in appendix A.2. The values assigned to the model's parameters are displayed in Table 1.

Regarding the non-financial sector, there are 5 standard parameters (β_h, α , δ, σ and ω) for which I choose conventional values. In addition, I set the weight on leisure in the household utility function, χ, at 6.9991, implying a share of active time spent working of one third in the deterministic steady state. Furthermore, the parameter governing liquidity services, ϕ, is set to 0.0195, to match a deterministic steady state domestic liabilities to asset ratio of 82.4%.

Turning now to the financial sector, the parameter associated with the cost of holding equity capital, τ, is fixed at 0.1407. This implies a deterministic steady state equity to loans ratio of 8.6%.

The calibration strategy for the bank's discount factor parameter, β_b, is to be in line with the empirical literature that shows that banks usually hold far more equity than that imposed by regulators. A necessary condition for the bank not to be credit constrained in a neighborhood of the stochastic steady state is that $\beta_b > (1 + r^f)^{-1}$. I therefore set β_b to 0.999.

Information on the Solow residuals is employed to calibrate the parameters associated with the 2-state Markov chain governing productivity. Specifically, the approach laid out in Tauchen and Hussey (1991) is used to discretize an AR(1) process with standard deviation and persistent parameters equal to 0.0095 and 0.9361, respectively. Following the same procedure, information on the ratio loan losses to total assets by the financial sector is employed to calibrate the parameters associated with the default shock.

Table 1: Baseline Parameter Calibration

Parameter	Symbol	Value
Non Financial Sector		
Discount Factor	β_h	0.9800
Capital Share	α	0.3300
Capital Depreciation	δ	0.0250
Risk Aversion	σ	1.0000
Inverse Frisch Elast.	ω	1.0000
Labor Disutility	χ	6.9991
Liquidity Services	ϕ	0.0195
Trans. Prob. Matrix Productivity	π_{ii}	0.8614
Low Productivity state	A_l	0.9905
High Productivity state	A_h	1.0095
Financial Sector		
Discount Factor	β_b	0.9990
Bank Equity Costs	τ	0.1407
Adjustment Cost	γ	12.666
Trans. Prob. Matrix Defaults	p_{ii}	0.6293
Low Default state	ϵ_l	-0.0662
High Default state	ϵ_h	0.0113
International Capital Markets		
Interest Rate	$\bar{r}$	0.0044
Premium	ψ_0	0.0111
Premium	ψ_1	70

As for the international capital markets, I choose $\bar{r}$ and ψ_0 to hit two targets. First, a risk free rate of 1.77% per annum. That value equals the average 3 months Euribor rate. Second, an average country premium $(r^l - \bar{r})$ of 2.21% per annum.

It remains to specify the values for γ, and ψ_1. The estimation procedure is the simulated method of moments. It consists of choosing values for the two parameters to minimize the distance between a set of empirical targets and their theoretical counterparts. The time series of interest is the ratio total equity capital to total assets of Spanish financial institutions. The empirical targets are: (i) a standard deviation of 0.018 and (ii) a first order autocorrelation coefficient of 0.965. These are feasible targets, since their theoretical counterparts are closely linked to the parameters to be estimated.

3 Results of the Quantitative Analysis

In this section, I use numerical simulations to explore the qualitative and quantitative implications of the model.

3.1 Business Cycle Statistics

This subsection characterizes the behavior of the model through long run business cycle statistics. I simulate the model starting from the deterministic steady state for 100,000 periods. The first 1,000 periods are discarded to eliminate the transition from the deterministic steady state to the ergodic distribution of the economy. Table 2 displays key business cycle indicators in economies subject to different minimum capital standards (κ).

Regarding the relationship between capital regulation and economic activity, two observations stand out. First, lower capital standards are associated with higher output volatility. The intuition for this result is straightforward. Strict equity requirements reduce the volatility of bank capital, thereby diminishing the risk of experiencing dramatic increases in the cost of external funds for domestic financial institutions. This in turn reduces the cyclicality of the credit market and hence lowers business cycle fluctuations. It is in this manner that capital regulation enhances the resilience of the financial sector, and hence of the economy as a whole.

Second, capital regulation does not have a meaningful effect on the level of output. The rational for this result is as follows. The capital requirement constraint is usually either slack or not too tight due to the power of precautionary savings. Consequently, the costs associated with hitting the minimum

Table 2: Long Run Business Cycle Statistics

		κ (%)				
Moments	Data	0.00	0.06	0.07	0.08	0.09
Output						
Mean	-	0.795	0.795	0.789	0.782	0.777
Std. Dev.	.0134	.0142	.0140	.0139	.0136	.0124
Equity to Assets						
Mean	0.086	0.086	0.087	0.090	0.095	0.103
Std. Dev.	0.018	.0142	.0137	.0118	.0107	.0103
Local Lending Rate						
Mean	0.010	0.010	0.010	0.010	0.011	0.011
Std. Dev.	0.002	.0020	.0050	.0059	.0092	.0117

equity threshold, namely higher lending rates and distorted lending decisions, are seldom significant[10].

Overall, there is not much of a tradeoff between the volatility of output and its mean. This result is in line with Admati et al. (2013) and supports the idea that capital requirements need not impose an insidious cost on economic activity in the long run.

Let me now turn to the bank's balance sheet. As noted above, financial intermediaries are encouraged to hold an equity buffer in excess of the minimum required by the regulator. Banks do engage in precautionary savings because they anticipate that equity requirements may become binding in the future, as a result of shocks yet unrealized. In other words, they try to stay clear of the constraint via precautionary savings.

Also, more stringent capital requirements strongly reduce the volatility of the equity to asset ratio. This is due to: (i) banks adjust their balance sheets in order to minimize the risk of hitting the constraint[11], and (ii) as κ augments, the states of nature in which the constraint binds increases, thereby reducing the amplitude of bank capital fluctuations.

Overall, this line of reasoning suggest that equity requirements can be a powerful tool for strengthening financial fundamentals in the long run. Specifically, equity requirements result in better capitalized financial institutions, thereby leading to more favorable financial conditions, and hence reducing the

[10] Of course, overly stringent capital requirements could distort the credit market too often, thereby imposing a constant penalty on economic activity.

[11] Breaching the minimum capital standard is costly for the banks. Specifically, it prevents them from smoothing exogenous disturbances.

amplitude of business fluctuations. The intuition behind this argument is the power of the precautionary saving motive.

These findings need to be interpreted with caution though. This is due to the fact that they are exclusively based on long run business cycle moments. Nevertheless, as was mentioned earlier, in the short run capital requirements may affect credit markets negatively, and hence penalize economic activity. The existence of this trade-off between short and long run effects should thus be considered when deciding the optimal minimum equity threshold. To see this point more clearly, the following subsection provides quantitative evidence of the role played by capital requirements in shaping the economy's cyclical behavior.

3.2 Generalized Impulse Response Functions

3.2.1 A Wave of Non Performing Loans

This section analyses the response of the economy to a wave of non performing loans. The latter is generated by feeding into the model a sequence of four negative realizations of the default shock (ϵ). The results are based on 10,000 Monte Carlo simulations of the model[12]. The latter start from the long run equilibrium where, on average, the capital requirement constraint is slack.

Figure 1 shows the results of this experiment in economies subject to different levels of capital requirements. The sequence of negative default shocks impairs banks' equity capital, thus strengthening the financial friction and leading to tighter financial conditions. Loans therefore fall, which drags consumption and investment down. This in turn induces a decline in both the capital stock and total output.

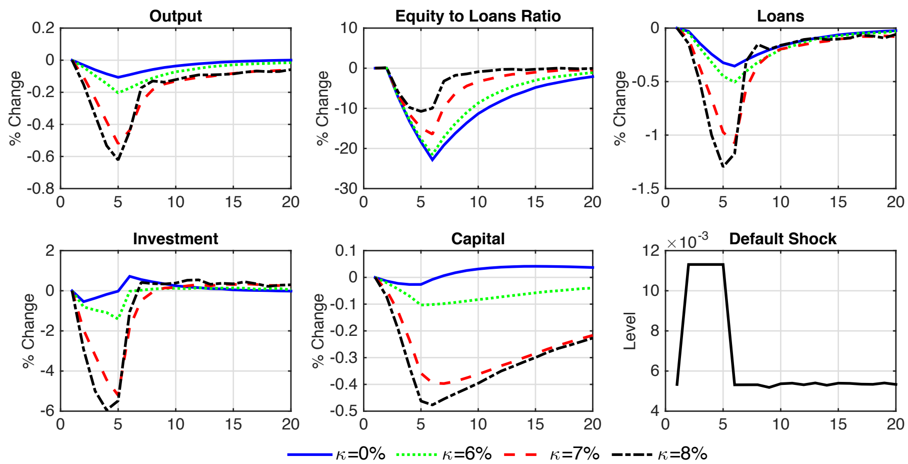
Remarkably, capital adequacy regulation amplifies such adverse consequences. This occurs because the wave of non performing loans brings regulated banks up against their constraints. As a result, they are forced to cut back on lending[13], thereby creating a shortage in the credit market. This begins a vicious circle of simultaneous reduction in credit, employment, investment and output, thus amplifying financial distress.

In sum, capital regulation can play an important role in propagating financial shocks over the business cycle. It does so by distorting banks' balance sheet management decisions, and thus affecting the credit market adversely. Hence, equity requirement can indeed impose significant cost on economic activity.

[12]Please refer to Appendix A.3 for details about non linear impulse responses.

[13]As noted above, cutting back on lending is the only channel of adjustment when the constraint becomes binding, since equity capital is a predetermined variable.

Figure 1: A Wave of Non Performing Loans



3.2.2 Boom Bust Cycles

Let me now turn to the role of capital regulation in reducing procyclicality. In order to do so, I study the economys dynamic behavior during a boom-bust cycle. The latter is generated by feeding into the model a sequence of four positive realizations of the productivity shock (A) followed by four negative ones. Figure 2 shows the results of this experiment.

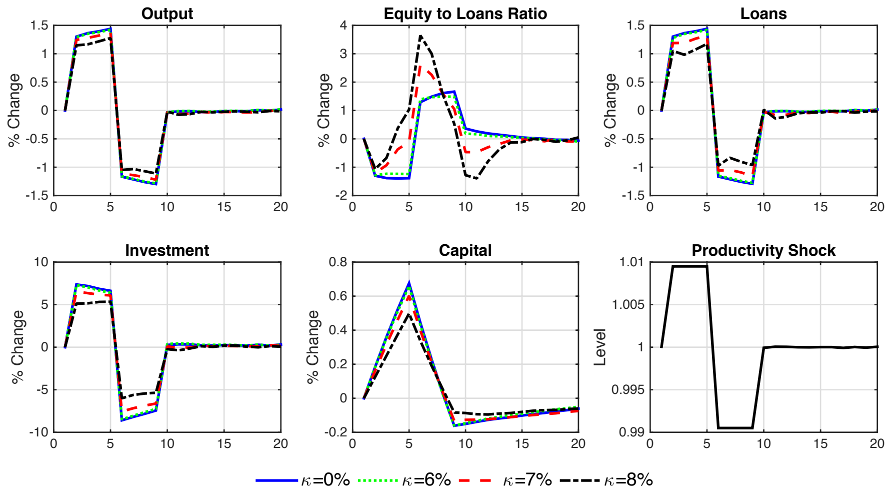
The single most remarkable result is that equity requirements can be a powerful tool for reducing macroeconomic volatility. That is, in the face of real shocks (i.e. productivity shocks), a minimum capital standard acts as an automatic stabilizer and hence reduces procyclicality.

The mechanism at play is straightforward: capital regulation enhances banks' risk profile by making them more *cautious*. As a result, it curbs the buildup of financial imbalances. Specifically, it limits the supply of credit during booms, whereas it ensures easier financial conditions during economic slowdowns. By doing so, it reduces the amplitude of business fluctuations and hence can be welfare improving.

4 Concluding Remarks

My main contribution is to examine the macroeconomic consequences of capital requirements. The findings of this study suggest the existence of two competing effects. On the one hand, by encouraging precautionary behavior capital regulation can increase the resilience of the banking industry and the

Figure 2: Boom Bust Cycles



economy as a whole. By doing so, it can reduce macroeconomic volatility and hence be welfare improving.

On the other hand, equity requirements can propagate and amplify the transitory adverse consequences of financial shocks, thereby penalizing economic activity. This occur because capital regulation may distort financial markets by restricting the supply of credit, which in turn leads to a misallocation of resources.

Taken together, my results indicate that the first effect seems to dominate, particularly in the long run. In other words, equity requirements can be a powerful tool to enhance social welfare. Nonetheless, the existence of the aforementioned trade-off should be considered when deciding the optimal minimum equity threshold.

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Table 3: Discretized State Space

State Variables	Lower Bound	Upper Bound	Grid Points
A	A_1	A_2	2
ϵ	$\epsilon 1$	$\epsilon 2$	2
N	$0.7\bar{N}$	$1.3\bar{N}$	100
K	$0.95\bar{K}$	$1.04\bar{K}$	10

An "overbar variable" refers to the deterministic steady state.

Appendix

A.1 Solution Method

The model is solved using the policy function iteration with time iteration and linear interpolation algorithm described in Richter et al. (2014). Information regarding the construction of the discretized state space is provided in Table 3. The endogenous state variables N and K are chosen from evenly spaced discrete grids.

The policy functions are calculated by taking the following steps[14]:

1. Obtain initial conjectures for Q_t, H_t and D_t on each grid point from the log-linear solution of the model. I use Sims (2001) *gensys.m* program to obtain these conjectures.
2. Using initial guesses and the equilibrium conditions of the model, solve for all time t variables.
3. Using linear interpolation, compute the time $t+1$ values for labor and the lending rate.
4. Calculate the time $t+1$ values of the variables appearing inside time t expectations.
5. Compute conditional expectations.
6. Minimize the Euler equations. To this end, I use Sims (1999) *csolve.m* optimization routine. The output of *csolve.m* is the updated decision rules.
7. If the distance between the updated and guessed policy values is smaller than a tolerance parameter, an approximation to the decision rules has been obtained. Otherwise, employ the updated policy function as the new initial conjecture and return to step 2.

[14] The general procedure for implementing the algorithm is laid out in Richter et al. (2014).

Table 4: Data Sources

Variable	Source
Gross Domestic Product	OECD
Gross Domestic Product: Implicit Price Deflator	OECD
Total Employment	OECD
Total Hours Worked	OECD
Lending Rate C&I Loans Up to 1 Year	ECB
3 months Euribor Rate	ECB
Gross Fixed Capital Formation	OECD
Total Loan Losses of Financial Institutions	BDE
Total Assets of Financial Institutions	ECB
Total Equity of Financial Institutions	ECB
Total Foreign Liabilities of Financial Institutions	ECB
Total Domestic Liabilities of Financial Institutions	ECB

A.2 Data Description

The dataset includes quarterly data from Spain for the period 1997Q3 to 2015Q4. The data come from three sources: (i) the European Central Bank,(ii) the Central Bank of Spain (BDE), and (iii) the Organization for Economic Co-operation and Development (OECD). Information regarding individual time series is provided in table 4.

A.3 Non-linear Impulse Response Functions

The general procedure for calculating non-linear or generalized impulse response functions (GIRFs) can be found in Koop et al. (1996). The reader is referred there for a formal statistical background.

As remarked by Weise (1999), there are three major differences between the impulse responses originated from a linear model and those generated from a nonlinear model. First, linear impulse responses are invariant to history, whereas nonlinear responses are state-dependent. In other words, nonlinear responses are sensitive to initial conditions. As a result, in the nonlinear case the history of shocks must be treated as a random variable.

Second, in the linear case future shocks can be set to their expected value -that is, to zero. This is not the case for nonlinear models: future shocks must be drawn from a particular distribution and their effects averaged out over a large number of draws.

Third, linear responses are invariant to the size of the shock. In contrast, in nonlinear model disturbances of different sizes give rise to different impulse responses.

For all of the foregoing reasons, impulse responses generated from nonlinear models should be calculated as the average of Monte Carlo simulations of the model [Gavin et al. (2015)]. The following algorithm is used to compute the generalized impulse response functions:

1. The model is simulated N times conditional on N random histories of shocks, $\Xi^A = \{A_t, Z_t, u_t\}_{t=0}^T$. Let $\bar{x}_t^A = \frac{1}{N}\sum_{i=0}^N x_t^i(\Xi^A)$ be the average across these simulations.

2. The first τ, for $\tau = 1, ..., \tau^*$, elements of each history of shocks are replaced by the τ shocks of interest. A new collection of exogenous disturbances, Ξ^B, is therefore created.

3. The model is (re-)simulated conditional on Ξ^B. Let $\bar{x}_t^B = \frac{1}{N}\sum_{i=0}^N x_t^i(\Xi^B)$ be the average across the second set of simulations.

4. GIRFs may then be defined in percentage change as $(\bar{x}_t^B/\bar{x}_t^A - 1) * 100$ or in percentage difference as $(\bar{x}_t^B - \bar{x}_t^A) * 100$.

In this paper, I set T to 20 and N to 10,000.