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Karmakar, Sudipto

Banco de Portugal

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Macroprudential Regulation and Macroeconomic Activity

Sudipto Karmakar*

Abstract

This paper develops a dynamic stochastic general equilibrium model to examine the impact of macroprudential regulation on bank's financial decisions and the implications for the real sector. I explicitly incorporate costs and benefits of capital requirements. I model an occasionally binding capital constraint and approximate it using an asymmetric non linear penalty function. This friction means that the banks refrain from valuable lending. At the same time, countercyclical buffers provide structural stability to the financial system. I show that higher capital requirements can dampen the business cycle fluctuations. I also show that stronger regulation can induce banks to hold buffers and hence mitigate an economic downturn as well. Increasing the capital requirements do not seem to have an adverse effect on the welfare. Lastly, I also show that switching to a countercyclical capital requirement regime can help reduce fluctuations and raise welfare.

JEL Codes: G01, G21, G28

Key words: Capital Buffers, Prudential Regulation, Basel Core Banking Principles

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"The reason I raise the capital issue so often, is that, in a sense, it solves every problem." - Alan Greenspan to the Financial Crisis Inquiry Commission

1 Introduction

The banking sector is one of the most regulated ones in the world today. There are different forms of regulation but capital regulation is of paramount importance because bank capital is an extremely good indicator of the financial soundness of the bank and also its risk taking abilities.¹ Bank equity² is of utmost importance but has not really been given its due by traditional monetary macroeconomics albeit the trend seems to be changing recently. As has been documented in Van den Heuvel (2009), in most bank related work, the focus is on reserve/liquidity requirements and how they affect the decision to accept demand deposits. In these studies, the bank capital regulation is mostly discussed as an afterthought. My work focuses on bank capital regulation, capital buffers and the implications for the economy. The commercial banks in the United States face capital requirements based on the the Basel Core Banking Principles. In December 2011, the Government of the United States announced that the Basel III guidelines will be fully implemented soon.

I develop a general equilibrium model with a representative household, a representative bank and a non financial firms sector divided into a capital goods producing sector and a final goods producing sector. The household earns labor income by working in the final goods producing firms. They also hold deposits and unit equity in the bank earning a risk free rate of return and dividends. The bank tries to maximize shareholder value given that it is owned by the household. Every period, the bank must decide on how many deposits to accept, the volume of loans and the amount of dividend payout. Following Aiyagari and Gertler (1999), I define dividends as the difference between net

¹Berger, Herring and Szego (1995) and Santos (2001) contain surveys on the motivations behind capital regulation

²I use the terms bank equity and bank capital interchangeably

assets at the beginning of the period minus net assets in the end of the period. The bank will also have to satisfy a capital requirement constraint imposed by the regulatory authority. This constraint simply states that the bank must be able to finance a certain fraction of its new assets with its own equity. In other words, this constraint can also be interpreted as a cap on the amount of deposits to accept. Lastly, I also impose that the dividend payments have to be non negative. This point will be discussed at length at a later stage but for now, this assumption is important for the capital constraint to have force. This assumption makes sense because it can be prohibitively expensive to issue new equity especially when the economy is experiencing a downturn.

The non financial firms sector is divided into two parts, the capital goods producers and the final goods producers. The capital goods producers produce the investment goods and sell it to the final goods producers who in turn use this capital and labor, from households, to produce the final output. The capital goods producers maximize profits and are subjected to adjustment costs. The final goods producing firms are in need of resources to buy capital goods and they approach the bank for loans. These firms make zero profits.

I will allow for two exogeneous shocks namely a TFP shock and a capital quality shock following Gertler and Kiyotaki (2010). As in Gertler and Kiyotaki, I will think about this as a shock to the quality of capital rather than a physical depreciation shock. The bank will not realize the value of this shock till the decisions on the loans and deposits are made. This is one of the most crucial assumptions and will be discussed in the model section. One can also think of this as the amount of risk in the bank's balance sheet. If unregulated, the bank always has a tendency to take on excessive risk and that is the rationale for capital requirements in this model. I show that higher capital requirements can reduce the volatility in the economy. I do find a net gain in welfare as well. I also address a policy question about how strict should the regulation be? I show that with stricter regulation, the cost of insolvency is high and so the banks hold greater buffers and that can provide structural stability to the financial system by reducing volatility. Lastly, I modify the model to study countercyclical

capital requirements which is one of the main tenets of the recent macroprudential regulation proposed under Basel III. Switching from a flat capital requirement regime to a countercyclical regime also seems to reduce volatility and raise welfare.

This paper contributes to two strands of literature. The first one is the literature that tries to understand whether capital requirements are a boon or a bane for the economy. Giammarino (1993), Hellman et al. (2000) talk about the benefits of capital requirements owing to the moral hazard problem arising from deposit insurance. Admati et al. (2010) advocate for capital requirements much higher than what they currently are. They advocate for capital requirements as high as 20-25 percent, as in Britain. This is much higher than the current FDIC regulations which is around 8 percent, for tier 1 and tier 2 capital taken together. The question that immediately comes to mind is are there no costs of these capital requirements and how do they affect a bank's financial decisions? If there are no costs, why not have 100 percent capital requirements and have all bank assets financed by equity. Van den Heuvel (2008) talks about the welfare implications of these requirements and shows that it can lead to a decline in welfare. The rationale there is as follows. The capital requirements introduce a financial friction into the system by limiting the banks ability to create assets by accepting deposit type liabilities. The household values deposits as given deposit insurance, it is like holding an asset with a safe return. So do the benefits outweigh the costs? Or is it the other way around? What is the net impact on welfare? There has been no consensus reached on this entire issue. I try to explore this question in greater detail by incorporating both the costs and benefits of capital requirements in the same framework.

The second strand of literature that my work relates to is the one that explores how credit constraints might have an impact on the macroeconomy. Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999) and Gertler and Kiyotaki (2010) are some of the major papers in this literature, by no means an exhaustive list though. Gertler and Kiyotaki (2010) studies financial intermediation and it's effect on the business cycle. However it assumes an always binding flow of funds constraint which is

necessary to derive some intuitive analytical results. Additionally, there is no capital requirement constraint in that model. I will try to explore macroprudential policy in this paper keeping the set up similar to Aiyagari and Gertler (1999) and Gertler and Kiyotaki (2010). I pose the problem a bit differently. I not only allow for an explicit capital requirement constraint but also acknowledge that such a constraint is only occasionally binding. The difference between bank equity and the minimum requirements are defined as the capital buffer in the model. The bank holds a buffer capital so that it remains compliant with the regulatory authority's requirements should there be an economic downturn. This modification will also allow me to investigate the role of countercyclical buffers to stabilize the economy, in a modified version of the model. There is one immediate benefit of this approach. De Wind (2008) and Den Haan and Ocaktan (2009) document that it might well be that the constraint is binding in the steady state but not off steady state. Even in that case, the steady state results are greatly affected. I try to circumvent this problem by allowing for capital buffers. However, it must be acknowledged that solving such models with occasionally binding constraints can be computationally intense. Standard perturbation methods cannot be applied. Some people put forward a global solution but at the cost of losing tractability. I will be using the penalty function method, originally proposed by Judd (1998), to solve this model. Intuitively, this method allows anything to be feasible but penalizes the objective in case the constraint is violated. This method has gained quite a bit in popularity and has been widely used in a variety of settings by Den Haan and Ocaktan (2009) and Preston and Roca (2007) among others.³

The rest of the paper is organized as follows. Section 2 gives some stylized facts about the equity asset ratio of commercial banks in the United States. Section 3 introduces the model. Section 4 discusses the analytical solution. Section 5 poses the numerical solution method and the outline for solving the model, section 6 puts forward the calibration while section 7 modifies the model to study countercyclical capital requirements. Section 8 presents the results while section 9 concludes with plan

³I provide a detailed discussion in a separate section later.

for future research. The tables and figures have been placed in the appendix.

2 Stylized Facts about the Equity Asset Ratio

At the very outset, let us look at some stylized facts about the equity-asset ratios of the commercial banks in the United States. Capital regulations along the lines of Basel Core Banking Principles require the equity-asset ratio to be above a certain threshold called the minimum capital requirement. To be precise, Basel I proposed a flat risk based capital requirement of about 8%, tier 1 and tier 2 capital taken together. Basel II introduced a risk based capital requirement which is that the banks have to hold a certain fraction of their risk weighted assets, as capital. The risk weights could be determined by the bank's own risk management models. The risk weights on business loans were the highest while the ones on Government bonds received a zero risk weight. In what follows, I will document the movement of the equity-asset ratio over time and then demonstrate the comovement of this ratio with some key real macroeconomic variables.

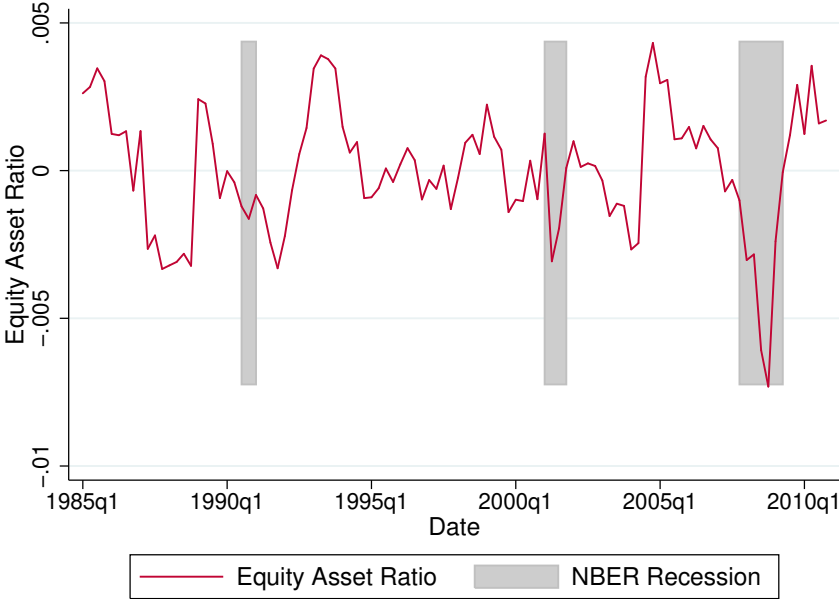


Figure 1: Time plot of the Equity-Asset Ratio

Figure 1 shows the time plot of the equity asset ratio since 1985.⁴ The equity shown above is just the banks common equity. The data covers a hundred and four quarters from 1985:Q1 to 2010:Q4. The data come from the Consolidated Report of Condition and Income, referred to as the Call Reports. The Federal Deposit Insurance Corporation requires all regulated financial institutions to file periodic information (financial and others). These data are maintained and published by the Federal Reserve Bank of Chicago.⁵ I plot the equity asset ratio superimposed on the NBER recession dates. As the figure shows, we have witnessed three recessions since 1985, the biggest one being the current one. The equity-asset ratio exhibits a procyclical pattern as one would expect. The reason for that is that during the recessions, the credit risk materialization is high and the amount of non performing assets (NPA) on a banks balance sheet rises which in turn causes the equity to shrink. If the banks are highly levered, then a small fraction of NPAs could bring about a substantial decline in equity and lead to insolvency. We will look into this issue later in the paper.

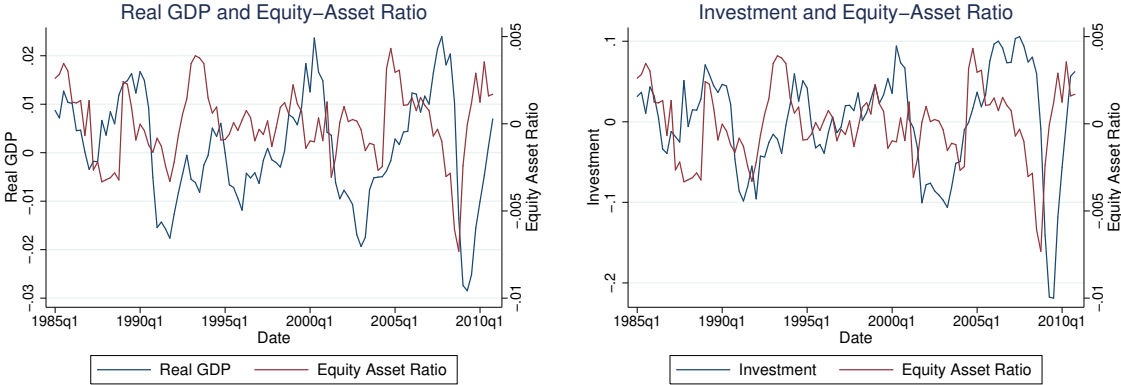


Figure 2: Equity-Asset Ratio, Real GDP and Investment

The figure above shows the comovement of the equity asset ratio with two main real variables namely the HP filtered GDP series and the gross private domestic investment in the economy.⁶

⁴HP filtered with smoothing parameter equal to 1600

⁵This data is available at <http://www.chicagofed.org>

⁶The data are available in the FRED database of the Federal Reserve Bank of St. Louis

The series co-moves or rather the equity-asset series seems to lead the series for output and investment. The data start at 1985 and it must be mentioned here that the Basel capital requirements were put into place for the first time in 1988-89. The potential cause for this comovement is the following. A decline in the equity-asset ratio triggered a shrinkage in the balance sheet of banks to remain compliant. The adjustment could not come from the numerator as it is difficult to raise capital, from the market, when the economic scenario is good. The liquidity crunch in turn meant a decline in investment and output. The data shows that this feedback takes roughly four quarters. The following figure shows the correlation of the equity asset ratio with leads of investment and output gap. The correlation peaks at around 4 quarters and then tapers off.

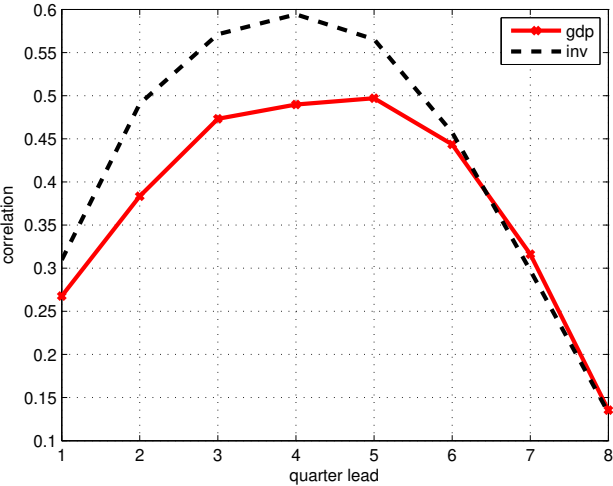


Figure 3: Equity Asset Ratio and lead GDP/Investment

Now that we have looked at the behavior of the equity-asset ratio it will be useful to define what we mean by capital buffers. The capital buffer is the excess of capital that a bank holds over and above the minimum level required by the regulator, the Federal Deposit Insurance Corporation (FDIC) in the context of the United States. A pertinent question is why would the bank want to hold buffers? The bank will not want to hold buffers as it means forgone lending opportunities. On the other hand it might

be prudent to hold buffers as that means the bank will not have to shrink its balance sheet, in an economic downturn, to meet the solvency requirements. What does the data say? It has been observed that the bigger banks in the United States, tend to hold zero or minimal buffers because they have implicit Government guarantees and better access to financial markets. The smaller banks on the other hand tend to hold larger capital buffers.

Since many of the bigger banks were highly levered during the period preceeding the financial crisis, a sharp decline in asset quality led to a substantial decline in the net worth forcing many financial institutions go below the minimum capital ratio. The Government had to intervene and bail out some financial institutions that were systemically important, by means of recapitalization. Given that the banking sector in the United States is pretty concentrated, it might be useful to look at the equity-asset ratio of the top four banks by assets namely J.P Morgan, Citibank, Bank of America and Wells Fargo. Figure (3) below shows how the capital asset ratio has evolved for these top four banks in the United States, in the years preceeding the financial crisis. These banks roughly account for two thirds of the market share in terms of assets and are hence a good proxy for the overall economy. Prior to the financial crisis, these banks remained very close to the statutory minimum requirements and even going below it sometimes.

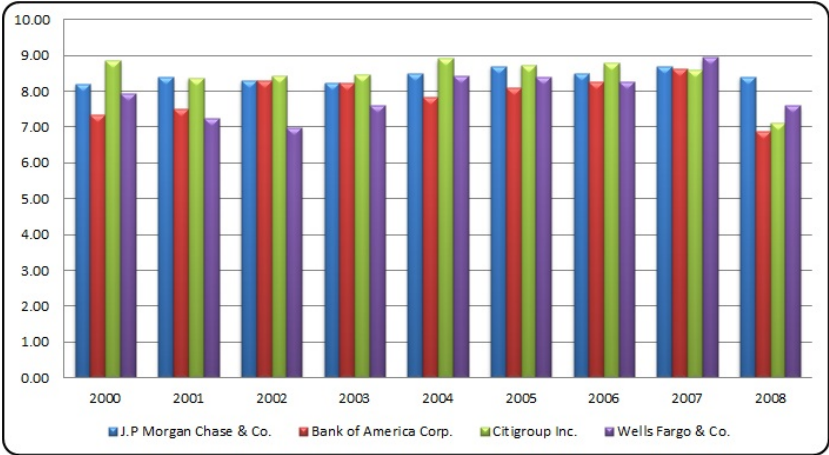


Figure 3: Capital/Asset Ratio of the top 4 bank holding companies

A well capitalized bank need not engage in aggressive adjustment of asset portfolios in an economic downturn, to maintain the minimum capital requirements. Countercyclical buffers⁷ will help the banks absorb losses. This will, thus, not result in a credit squeeze leading to a drop in overall economic activity. In the model I develop in the next section, I allow for endogeneous buffers and try to explore this issue a bit more.

3 The Model

The model builds on the model by Aiyagari and Gertler (1999) and also incorporates some features of Gertler and Kiyotaki (2010). The main point of difference is that I allow for an occasionally binding capital constraint (countercyclical buffers) and try to approximate the solution by a penalty function method. I depart from the Modigliani-Miller framework by introducing a capital requirement constraint. These two features can be easily incorporated without significant costs in that the framework still remains tractable and yields some interesting results.

3.1 The Physical Environment

There are a continuum of non financial firms of mass unity. The non financial firms produce the final output of the economy by employing labor and capital as inputs. The production function takes the standard Cobb Douglas form which is:

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha}, \tag{1}$$

⁷A simple way to compute the capital buffer is the following:

$$CB = \frac{Tier1 + Tier2}{RWA} - 0.08$$

where CB stands for capital buffer and RWA stands for risk weighted assets. In other words, it is the excess of tier 1 and tier 2 capital held by the bank over and above the regulatory 8% requirement. Tier 1 capital is the core measure of a bank's financial strength from a regulator's point of view. It primarily consists of common stock and retained earnings. It may also include non-redeemable non-cumulative preferred stock. Tier 2 capital represents supplementary capital such as undisclosed reserves, general loan-loss reserves and subordinated debt.

where A_t is the total factor productivity (TFP henceforth) and is governed by a Markov process and $0 < \alpha < 1$.

These firms producing the final output will hire labor from the households and buy capital goods from the capital goods producing firms. To buy these investment goods, the firm will have to approach the bank for loans. The price at which these loans are obtained and the price of capital goods is same and that means these firms earn zero profits. Denoting I_t as the aggregate investment and δ as the constant rate of depreciation, the law of motion for aggregate capital stock is given as:

$$K_{t+1} = [I_t + (1 - \delta)K_t]\theta_t, \quad (2)$$

where the interpretation of θ is as follows. Following Gertler and Kiyotaki (2010), I define θ as a capital quality shock. This is different from physical depreciation, which is captured by δ . The reference of the capital quality shock can be found in Merton (1973) and is a simple way of introducing an exogeneous source of variation in the value of equity.

The aggregate output of the economy is divided into household consumption, C_t , and investment, I_t . The resource constraint in this model is written as:

$$Y_t = c_t + c\left(\frac{I_t}{K_t}\right)I_t, \quad (3)$$

where the adjustment cost function exhibits constant returns to scale and will be discussed in detail in the section on calibration. I now introduce the other agents of the model namely the household that consumes, holds deposits and supplies labor, the representative bank that intermediates funds between the households and the manufacturing goods firms and also the non financial firms sector comprising the capital goods producers and the final goods producers.

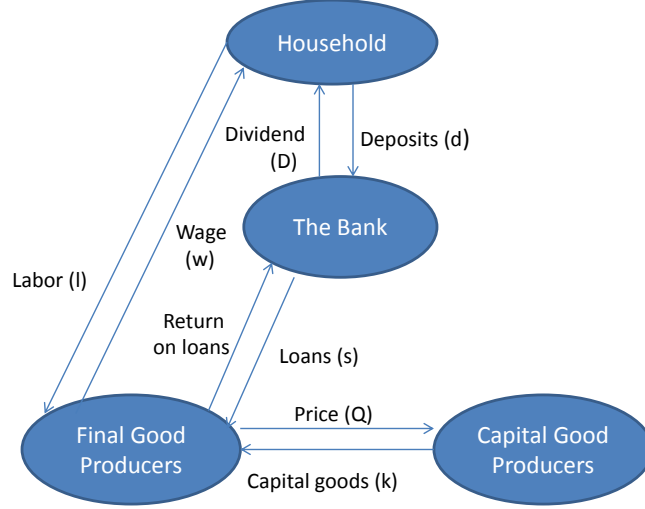


Figure: Flowchart of agents

The figure above shows the flow of resources across the economy as has been explained above.

3.2 The Household

In this model, I have a representative household that lends to non financial firms via the bank. The household does not hold capital directly but they put their deposits in the bank. They however own labor in exchange for which they earn wage income. They also own equity in the bank for which the bank pays dividends. The objective of the household will be to maximize its utility. The deposits that the household puts in the bank earn a one period risk free rate of return. The household preferences are given by:

$$U(c_t, d_t, l_t) = \frac{[ac_t^{1-b} + (1-a)d_t^{1-b}]^{\frac{1-\phi}{1-b}}}{1-\phi} - \chi \frac{l_t^{1-\varphi}}{1-\varphi} \quad (4)$$

where $(0 < a < 1)$, is the share parameter, $b, \varphi, \phi, \chi > 0$ and $b, \varphi, \phi \neq 1$, χ is the parameter measuring the disutility from supplying labor, φ is the Frisch elasticity of labor supply and $1/b$ is the constant elasticity of substitution between consumption and deposits. As b approaches zero, consumption and deposits become perfect substitutes. I abstract from many of the frictions in conventional DSGE modelling like habit formation of consumption, variable capital utilization and nominal wage and price rigidities. I however deviate from the Modigliani-Miller setup by having bank capital requirements, to be discussed shortly.

Let W_t denote the wage rate, d_t denote the deposits made this period, R_t the gross return on riskfree deposits and D_t the dividends received from the bank. This is justified given that the household owns the bank. The household budget constraint is then written as:

$$c_t + d_t = W_t l_t + D_t + R_t d_{t-1} \quad (5)$$

The left hand side shows the household expenditures every period. It consumes and sells deposits to the bank. The right hand side shows the total receipts that the household earns. It consists of labor income, dividends and earnings from one period riskless deposits. The household maximizes the expected discounted utility subject to the budget constraint to yield the the optimality conditions as follows:

$$\frac{u'_l(c_t, d_t, l_t)}{u'_c(c_t, d_t, l_t)} = W_t \quad (6)$$

$$u'_d(c_t, d_t, l_t) + \beta u'_c(c_{t+1}, d_{t+1}, l_{t+1}) R_{t+1} = u'_c(c_t, d_t, l_t) \quad (7)$$

where,

$$u'_c(c_t, d_t, l_t) = \left[a c_t^{1-b} + (1-a) d_t^{1-b} \right]^{\frac{b-\phi}{1-b}} a c_t^{-b},$$

$$u'_l(c_t, d_t, l_t) = \chi l_t^{-\varphi}$$

$$u'_d(c_t, d_t, l_t) = \left[a c_t^{1-b} + (1-a) d_t^{1-b} \right]^{\frac{b-\phi}{1-b}} (1-a) d_t^{-b}$$

Equation (7) differs from the standard Euler equation in that we now have our households derive utility from holding deposits. The right hand side shows the loss in utility by putting one unit more in deposits while the left hand shows the gain in utility from holding a unit deposit this period and the next periods gain in utility from consumption. Equation (6) is the standard equation governing the labor-leisure choice.

3.3 The Bank

The primary role of the bank in this model is to intermediate funds between the household and the non financial firms. This may be justified on the grounds that it minimizes transaction costs. The only way the firms can finance their investment is by taking loans from the bank. To finance these loans, the bank has to raise deposits from households and pay them a deposit interest rate. However, the bank has an additional capital requirement constraint to satisfy which stated in simple terms just says that the bank has to finance a certain fraction of its risky assets (loans in this model) by the bank equity. Stated differently, this imposes a cap on the amount of deposits that can be raised. This hinders the bank from engaging in excessive risk taking and aggressive lending.

In this model, the bank will try to maximize the present discounted value of current and all future dividends while satisfying the flow of funds constraint, the capital requirement constraint and the non negative dividend constraint, to be introduced shortly. At the beginning of every period, the aggregate state is realized but not the financial shock. The bank has to decide on its volume of loans, deposits and dividend payout before this shock is realized and this assumption is of paramount importance as will become clear shortly. This risk of non compliance with the authority's requirements motivates prudential regulation in the model. The financial friction in this model is the equity regulatory constraint. And because of the timing issue briefly mentioned above, the bank will have an incentive to hold buffers and not remain close to the minimum stipulated level. If the bank maintains a capital that is close to the minimum requirements,

then in the event of an economic downturn when credit risk materialization is high and loan recovery rates are low, the capital declines and there is a high probability that the bank might find itself non compliant with the regulations. Further, it is extremely difficult to raise fresh equity from the market during downturns. If the decline in this equity-asset ratio is sharp enough, it could also result in the loss of the entire charter value. To prevent that, the bank will have to cut back on lending in an effort to boost the equity-asset ratio. And this credit squeeze can further exacerbate the problem, something that we saw during the recent financial crisis.

In the context of the United States, the Federal Deposit Insurance Corporation requires all regulated financial institutions to provide some details (financial and others) every year. It monitors whether the financial institutions are sound enough and one of the main indicators of financial soundness is the capital position of the bank. In FDIC parlance banks with more than 10 percent equity as a fraction of risk weighted assets are called well capitalized, those having 8-10 percent are called adequately capitalized, below 8 percent are undercapitalized, below 6 percent are significantly undercapitalized and those below 2 percent are critically undercapitalized.

If a bank falls below the 8 percent level, the FDIC first declares it as undercapitalized, if it is below 6 percent, then it can bring about a change in management and if the distress persists and the bank capital falls below 2 percent, the bank can be declared as insolvent and taken over. However, the bank will try to avoid being declared as undercapitalized because of loss in franchise value and losing its customer base. In my solution methodology, I adopt a penalty function approach where the amount of penalty imposed is proportional to the shortfall in capital and that is motivated by the FDIC penalty structure just described. I do not claim to replicate the realistic penalty imposed but my approximation certainly has elements of the idea. In what follows, I present the bank's optimization problem and try to provide an intuitive analytical explanation of the occasionally binding capital constraint before presenting the simulation results.

The bank maximizes the present discounted value of current and future dividends:

$$V_t = E_t \sum_{i=0}^{\infty} \Lambda_{t+i} D_{t+i} \quad (8)$$

The dividends are defined as the difference between net assets at the beginning of the period and the end of the period. It is written as follows:

$$D_t = [(Z_t + (1 - \delta)Q_t)\theta_t s_{t-1} - R_t d_{t-1}] - (Q_t s_t - d_t) \quad (9)$$

The first parenthesis shows the net assets (total receipts less payments due) at the beginning of the period while the second parenthesis shows the net assets at the end of the period. Z_t is the gross return on capital and can also be thought of as the dividend payment at t on the loans the bank had made in $t - 1$. Q_t is the price of capital (loans in this case) and s_{t-1} is the amount of loans made last period. As has been mentioned earlier, R_t is the riskless deposit rate. It must also be noted that the gross payoff from the asset depends on the capital quality shock, θ_t . The last equation can also be thought of as balance sheet constraint. Rearranging the terms we get:

$$Q_t s_t - d_t = [(Z_t + (1 - \delta)Q_t)\theta_t s_{t-1} - R_t d_{t-1}] - D_t$$

This equation simply states that the assets minus liabilities have to equal the bank capital (net worth) net of dividends. Unlike Gertler and Kiyotaki, I abstract from interbank market in this framework. In addition to the flow of funds constraint above, the bank also has to satisfy a capital requirement constraint or a margin constraint which can be written as follows:

$$[(Z_t + (1 - \delta)Q_t)\theta_t s_{t-1} - R_t d_{t-1}] - D_t - \kappa Q_t s_t \geq 0 \quad (10)$$

The most simple interpretation of this constraint is that the bank must finance a certain fraction (κ) of assets with its own resources. In other words, after the bank incurs the payoff from assets net of deposit costs and pays out dividends, it must be left with

sufficient funds to finance κ^8 fraction of the new loans it makes in that period.

It may be helpful to look at equations (9) and (10) together. Substituting out dividends in (10) yields:

$$(1 - \kappa)Q_t s_t \geq d_t$$

This is just setting a bound on the amount of deposits that the bank can accept. More precisely, the bank can, at most, finance $(1 - \kappa)$ fraction of its new loans with deposits. The remaining will have to be financed by the bank's own resources.

Lastly, we need one more condition for the capital constraint to have force. If it were easy to issue fresh equity instantaneously and costlessly, then the bank would have no incentive to manage its capital in a prudent manner because the market will always stand ready to bail it out. This assumption of not being able to raise fresh equity is intuitive. When the economic scenario looks grim, it is not possible to raise resources from the market. I will not make any attempt to model other institutional or commitment factors that might lead banks to use leverage rather than new equity issuance. In terms of the model, the following constraint is tantamount to saying that the bank cannot issue new equity. The only way to raise capital is by retained earnings.

$$D_t \geq 0 \tag{11}$$

We refer to the last constraint as the dividend constraint. I claim that if the capital requirement constraint is binding, the dividend constraint has to bind. To see that this is intuitive, let us consider the counterfactual. What would have happened if the capital constraint was binding but not the dividend constraint? In such a scenario, the bank could easily reduce the dividend payments and once again satisfy the capital constraint. So it is imperative that when the equity constraint is binding, dividend payments have been reduced to zero.

⁸I will be considering a flat capital requirement structure and later extending to a countercyclical regime. In future work I intend to take up a risk sensitive capital requirement structure. Zhu (2008) considers such a regime.

An important question to ask is why would the bank want to hold this excess equity in the first place? In other words, what is the role of capital in the model? This question is nested in a bigger question which asks what is the role of capital in general? To answer this question we have to understand the bank's problem a little more. The key timing issue is that when the bank makes choices of loans, deposits and dividends, the capital quality shock is not realized yet. In terms of the real world, when a bank takes a decision on its loan portfolio, it does not know how many of those loans are going to default in the next period. If a lot of assets go bad, the bank equity can get wiped out quickly leading to insolvency. The bank will want to hold a buffer capital to prevent this from happening. In terms of the model, at the end of every period when the shock is realized, the total return from loans is known. Given the banks choice of dividends, it should also have enough resources to satisfy the regulatory constraint. If this is not the case, then the bank will have to face some unfavorable consequences. The bank will want to avoid such unfavorable consequences.

3.4 Capital Goods Producers

These firms produce the investment good by using the final output and are subjected to adjustment costs.⁹ They sell these goods to the final goods producing firms who need this capital and labor to produce their output. They choose investment by maximizing the following objective function:

$$\max E_t \sum_{\tau=0}^{\infty} \Lambda_{t,\tau} [Q_{\tau} I_{\tau} - c(I_{\tau}/K_{\tau}) I_{\tau}] \quad (12)$$

where,

$$c(I_t/K_t) = \left(\frac{b_1}{1-a_1} \left(\frac{I_t}{K_t} \right)^{1-a_1} + c_1 \right)$$

⁹The adjustment cost is a concave and increasing function that satisfies $c(\delta)=\delta$ and $c'(\delta)=1$ The only parameter that is of importance here is the curvature of this function or how sensitive is the investment-capital ratio to the price of capital (a_1). The value of this parameter is taken from the extensive literature on Q theory. Christiano and Fischer (1998), Jermann (1998), Boldrin et. al (2001) and Uhlig (2004) use a value of 0.23 for this parameter. The other two parameters are chosen to make the steady state independent of a_1 .

Profit maximization yields the following optimality condition.

$$Q_t = c_1 + b_1 \frac{(2 - a_1)}{(1 - a_1)} \left(\frac{I_t}{K_t}\right)^{1-a_1} \quad (13)$$

3.5 Final Goods Producers

As mentioned earlier, these firms play a crucial role in the model because they are the ones who demand loans from the bank to purchase investment goods. Put differently, these firms issue securities to the bank and this security price will respond sharply to changes in the bank's net worth position thereby affecting investment a great deal. These firms operate a CRS technology and use labor and capital goods as the inputs for their production process. The production function is standard Cobb Douglas. The wage rate and the gross return are given as follows:

$$W_t = (1 - \alpha) \frac{Y_t}{L_t} \quad (14)$$

$$Z_t = \frac{Y_t - W_t L_t}{K_t} = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \quad (15)$$

α is the share of output going to capital. These goods producers earn zero profits. Exploiting perfect competition, the price of loans and price of investment goods are identical in this set up.

3.6 Market Clearing

We now close the model by listing the various market clearing conditions. There are four markets in the model described namely, the goods market, the labor market, the securities market and the deposit market.

The final output is used for consumption and investment and so the goods market clearing condition or the resource constraint once again is:

$$Y_t = C_t + c \left(\frac{I_t}{K_t}\right) I_t \quad (16)$$

The security market clearing comes in next. Following Gertler and Kiyotaki, the total amount of securities issued/supplied must be equal to the aggregate capital accumulated and hence the condition is:

$$s_t = (I_t + (1 - \delta)K_t) \tag{17}$$

The labor market clearing condition requires that:

$$\frac{\chi L_t^\varphi}{C_t^{-\sigma}} = \frac{(1 - \alpha)Y_t}{L_t} \tag{18}$$

The deposit market clears by Walras law.

3.7 Timing

At the beginning of the period, the aggregate state of the economy i.e the TFP shock is realized. The bank shock or the capital quality shock is realized at the end of the current period. In other words, when the bank is making lending decisions it knows A_t but not θ_t . Next the capital quality shock is known and so is the bank's net income which is receipts from assets less deposit costs. If this is positive, the bank pays dividends and proceeds to the next period. If this is not the case, the regulator will set dividends equal to zero and prevent the bank from engaging in valuable lending. Note that if the net income is negative, the capital constraint is violated as well and this is precisely the role of capital in this model. If the bank does not hold a capital buffer, then it will be prevented from indulging in profit making opportunities in the event of a large unfavorable shock.

4 Analytical Results

In this section I present some analytical results and provide an intuitive explanation of the occasionally binding equity constraint. I present different cases when the constraint is binding or is likely to bind at some point in the future and explain the implications

for the real sector. The bank will choose loans, deposits and dividends to maximize the present discounted value of dividends subject to the flow of funds, equity and dividend constraints. The first order conditions for the problem as given below.

$$E_t[\Lambda_{t,t+1}\gamma_{t+1}R_{t+1}^e] + (1 - \kappa)\mu_t = \gamma_t \quad (19)$$

$$E_t[\Lambda_{t,t+1}\gamma_{t+1}R_{t+1}] = \gamma_t - \mu_t \quad (20)$$

$$\Omega_t + \mu_t = \gamma_t, \gamma_t \geq 1, \quad (21)$$

In the last equation, $\gamma_t = 1$ if $D_t > 0$. Also the return on loans is given as:

$$R_{t+1}^e = \theta_{t+1} \frac{(1 - \delta)Q_{t+1} + Z_{t+1}}{Q_t}$$

Ω and μ are the multipliers on the flow of funds and margin constraints respectively. The following cases are possible:

1. Case 1: $\mu_t = 0$: This is the case when the equity constraint is not binding in the current period. The Euler equation assumes the standard form and the risk free rate is the inverse of the expectation of the stochastic discount factor. As mentioned earlier, if the margin constraint binds at time, t , or at any $t + i$, the dividend constraint must bind at time t . The intuition is straightforward. If the bank is very close to the minimum requirements and there is a possibility of violating the constraint, then the bank must reduce dividends to zero and accumulate the retained earnings. If $D_t \geq 0$, then the Bank can easily reduce D and remain compliant with the regulations! The point is that in this case, we are in the standard asset pricing world. The bank accepts deposits and makes loans while remaining compliant with the regulations. The financial friction is not relevant in this case. However, as we will see in the following cases, this is not always the case. Let us explore a bit further.

2. Case 2: $\mu_t > 0$: The dividend on loans can be written as:

$$E_t R_{t+1}^e = \frac{\gamma_t - (1-\kappa)\mu_t - \text{cov}(\Lambda_{t,t+1}\gamma_{t+1}, R_{t+1}^e)}{E(\Lambda_{t,t+1}\gamma_{t+1})}$$

And, given the equation for risk free rate, I derive the expression for excess returns as:

$$E_t R_{t+1}^e - R_{t+1} = \frac{\kappa\mu_t - \text{cov}(\Lambda_{t,t+1}\gamma_{t+1}, R_{t+1}^e)}{E(\Lambda_{t,t+1}\gamma_{t+1})} \quad (22)$$

In this case, the equity constraint is binding in the current period. The asset pricing formulae will differ from the frictionless case. The risk premia is above the fundamental level which corresponds to the last case. When the capital constraint binds and the bank is not able to issue fresh equity instantaneously, it will have to reduce its holding of risk weighted assets to meet the requirement. In terms of the model, the bank is holding these securities issued by the final goods producers. When the bank is forced to unload some of its assets at a discount, it drives down asset prices and leads to a decline in investment and economic activity. This amplifies the economic downturn. An alternative and a different way of looking at the similar situation would be as follows. When the constraint binds, the bank will have to cut back on the amount of loans it finances and hence the final goods producers will not be able to purchase enough of investment goods and hence output and consumption would decline. Let us now turn to the final case.

3. Case 3: $\mu_{t+i} > 0$ for some $i \geq 1$: A similar mechanism will operate here. The covariance between γ_{t+1} and R_{t+1}^e is negative and so if there is some chance that the constraint will bind in the future, then that could lead to a higher risk premium on assets currently. This in turn will lead to the complications discussed in the last case and bring about a slump in economic activity. We thus find that this theory is indeed very powerful. It does not really matter whether the bank is

insolvent today or is likely to be insolvent in the near future. The implications for the real sector can be equally severe under both circumstances. The reason for the covariance being negative is the following. If γ_{t+1} is positive, that means the equity constraint is binding at $t + 1$. As discussed earlier, that will force the asset price at $t + 1$ to be below its fundamental level and hence the return on loans will be lower in $t + 1$.

5 Numerical Solution: Using The Penalty Function Methodology

In models with occasionally binding constraints, the standard perturbation methods cannot be employed as the policy function is non differentiable in the vicinity of the steady state. Some people may put forward a global solution by value function iteration methods but due to the curse of dimensionality, this may not be feasible if the state space is rich. I use the penalty function approach, originally proposed by Luenberger (1973) and Judd (1998). This approach has also been used by Preston and Roca (2007), Kim, Kollman and Kim (2009), Den Haan and Ocktan (2009) and more recently by Abo Zaid (2012).¹⁰

The idea is simple. We allow anything to be feasible but let the objective function have some unfavorable consequences if the constraint is violated. More precisely, the penalty imposed is zero when the constraint is not violated and goes to infinity as the constraint binds tightly. Thus this model nests the original model. By doing this, we convert the original model with inequality constraints into one that has only equality

¹⁰More examples are Christiano and Fischer (2000), Mendoza (2010) and Brunnermeier and Sannikov (2011). Preston and Roca (2007) use an interior function to ensure satisfaction of intertemporal budget constraints and hence in their framework, this interior function (penalty) approaches infinity as the capital holdings of agents approaches the borrowing limit. Kim, Kollman and Kim (2009) use a similar method to solve a heterogeneous agent model with aggregate uncertainty. They show that the model does pretty well to minimize Euler equation errors provided the capital at the beginning of the period is large enough. Den Haan and Ocktan also use this methodology to solve a heterogeneous agent model. Abo Zaid (2010) applies this method to solve a model with the zero lower bound.

constraints. Now we can apply standard perturbation methods to solve this model. There are a few penalty functions in the literature but I use the one presented in De Wind (2008). The primary reason for choosing this penalty function is that the function is asymmetric and generates a skewed response to shocks as we observe in the data. The table below shows the skewness of some of the most important macroeconomic variables and the performance of the model with this asymmetric penalty function.

Table 1: Skewness (Model Vs Data)

	Investment	Output	Cap. Buffer
Data	-0.8462	-0.0054	-0.4782
Model	-0.7448	-0.0029	-0.5011

Always binding constraints and symmetric penalty functions do not generate such a model behavior. Further, penalty parameter in this specification can be altered easily to change the curvature and without affecting the model properties. The form of the penalty function is as follows:

$$P = \psi^{-2} \exp[\psi(\kappa Q_t s_t + D_t - (Z_t + (1 - \delta)Q_t)\theta_t s_{t-1} + R_t d_{t-1})]$$

The term within the parenthesis is the capital buffer. If this term is negative, it means that the bank is compliant with the regulatory requirements and there is no penalty. However, once this term becomes negative, there are some unfavorable consequences.

The objective function of the bank is modified as follows:

$$V_t = E_t \sum_{i=0}^{\infty} \Lambda_{t+i} [D_{t+i} - \frac{d_{t+i-1}}{\psi^2} \exp[\frac{\psi}{d_{t+i-1}} (\kappa Q_{t+i} s_{t+i} + D_{t+i} - (Z_{t+i} + (1 - \delta)Q_{t+i})\theta_{t+i} s_{t+i-1} + R_{t+i} d_{t+i-1})]]$$

where the penalty function is normalized by the state variable to preserve the constant returns structure.

Once we incorporate the penalty function in the objective function, there is no need to write the capital requirement constraint separately while solving the problem. The parameter ψ governs the curvature of the penalty function and will be a key parameter in the analysis below.

On solving the above modified objective function subject to the budget constraint for the bank, we get expressions similar to the ones we obtained earlier and they are as follows:

$$E_t[\Lambda_{t,t+1}(\lambda_{t+1} + \Omega_{t+1})R_{t+1}^e] + (1 - \kappa)\lambda_t = \lambda_t + \Omega_t$$

$$E_t[\Lambda_{t,t+1}(\lambda_{t+1} + \Omega_{t+1})R_{t+1}] = \Omega_t$$

$$R_{t+1}^e = \theta_{t+1} \frac{Z_{t+1} + (1-\delta)Q_{t+1}}{Q_t}$$

$$\lambda_t + \Omega_t = 1$$

$$\text{and, } \lambda_t = \frac{1}{\psi} \exp\left[\frac{\psi}{d_{t-1}}(\kappa Q_t s_t + D_t - (Z_t + (1-\delta)Q_t)\theta_t s_{t-1} + (R_t d_{t-1}))\right]$$

λ is the punishment term in terms of the model terminology. In other words, it is the shadow valuation of violating the constraint. It is also the derivative of the penalty function with respect to the capital buffer.

Some important issues need to be discussed regarding the incorporation of a non linear punishment function. De Wind (2008) and Den Haan and Ocaktan (2009) have extensive discussion on these issues. The main point is as follows. The penalty function is highly non linear and so we might be tempted to put in a lot of curvature by choosing a high value of ψ . However, typically we are restricted to lower order perturbations and so putting in a lot of curvature might not be the best idea. In this paper, the model is solved using a third order approximation and so the problem is tackled here. The penalty function is highly non linear and I perturb at a sufficiently higher order. The choice of the order of approximation was also straightforward. A first order approximation is immediately ruled out given the non linearity of the penalty function. The third order is chosen to capture the asymmetric nature of the problem. In other words,

the bank is not penalized for holding excess capital but only when it falls short of the minimum requirements. The standard deviation of the shocks are expected to affect all the terms in the policy function and not just the constant.¹¹

Figure 4 demonstrates the class of penalty functions as the amount of curvature is changed. On the horizontal axis, I plot the level of buffers from negative five percent (equivalent to bank holding three percent capital) to positive two percent (equivalent to bank holding ten percent capital). On the vertical axis, I plot the penalty imposed for different levels of curvature, as a function of buffers. For $\psi = 130$, we get the most severe penalty while the reverse is true for $\psi = 50$. An important issue here is as follows. We can see that the greater the curvature the closer is penalty model to the original model. In my simulations, I work with a reasonable penalty i.e $\psi = 130$, which is permissible as the order of approximation is high in this particular case.

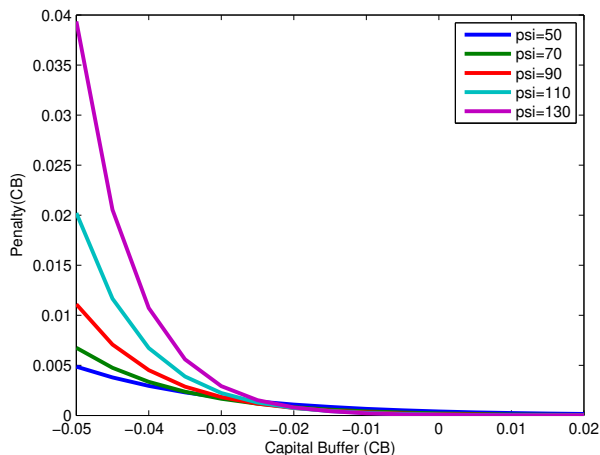


Figure 4: The Penalty Function for different levels of curvature

Ideally we want the constraint to be non binding in the vicinity of the steady state and so we want the penalty function to be flat in this region (slope should be small near

¹¹Recently user friendly softwares like Dynare and Dynare++ have made it possible to perturb at any order. I do not adopt higher orders as in those cases, the impulse response functions tend to be noisy owing to the presence of high degree polynomials. That problem can be taken care of by the method of pruning but the results have been unsatisfactory thus far. However, these issues will not be discussed in any more detail, in this paper. In the following figure, I plot the penalty functions for varying levels of curvature.

the steady state). However, a flat penalty function means that the steady state is farther away from the steep part of the function and in that case, given the magnitude of the shocks, we might not get the desired asymmetry. I chose the value of ψ keeping these issues in mind and also to match the skewness of some key macroeconomic variables in the data as has been documented earlier.

6 Calibration

I now discuss how the model was calibrated and in the next section I present some results of the numerical solution. Table 2 in the appendix lists the values of the parameters. Most of the parameters are standard. The discount factor, β , was chosen to get an annualized risk free return of four percent. The value of κ is set at eight percent which is in line with the Basel I requirements that the banks should hold eight percent of tier 1 and tier 2 capital as a fraction of it's risk weighted assets. Depreciation is set to be ten percent annually. The disutility of labor was calibrated to get a steady state labor supply of 0.3. Labor supply elasticity is set at two. The two shocks in the model are the total factor productivity shock and the capital quality shock. They follow independent Markov processes as follows:

$$\ln A_t = (1 - \rho_A)\ln A + \rho_A \ln A_{t-1} + u_t$$

$$\ln \theta_t = (1 - \rho_\theta)\ln \theta + \rho_\theta \ln \theta_{t-1} + v_t$$

The TFP shock has more persistence and less volatility than the financial shock. The AR(1) coefficient and the standard deviation of this shock is in line with the standard business cycle literature being 0.9 and 0.01 respectively. Estimates of Solow residuals yield a highly persistent AR(1) process in levels. The standard deviation replicates US postwar quarterly output growth volatility. The calibration of the financial shock follows Gertler and Karadi (2011). I think of this shock as a rare event but conditional on occurrence, it follows an AR(1) process. The persistence of this shock is 0.75 and

it has a standard deviation of 5 percent. The target is to get a ten percent decline in effective capital stock over eight quarters, investment remaining roughly same. Next we turn to the parameters of the utility function. Following standard business cycle literature, the inverse of the intertemporal elasticity of substitution, ϕ , is set equal to 2. The values of the share parameter, a , and the elasticity of substitution between consumption and deposits, b , are chosen to yield a deposit to consumption ratio of 0.7, a number that is consistent with the US data¹².

7 The Countercyclical Capital Requirement Regime

Capital regulations provide structural stability to the financial system which in turn makes the economy more resilient to adverse shocks. However, the question that arises is what form of prudential regulation is the best one? The Basel Committee on Banking Supervision has laid out a set of core principles popularly referred to as Basel I, II & III. Without going into the minute details, Basel I required that banks hold a certain fraction of their risk weighted assets as capital. Basel II was basically a shift to a risk based capital regime where banks had to hold a certain fraction of their risk weighted assets as capital and the risk weights were calculated by banks, based on their internal risk management systems. The debate that immediately cropped up is whether this transition generates extra procyclicality. This issue has been explored by many researchers and the evidence is mixed. But having said that, in the aftermath of the financial crisis, a consensus has emerged that there is need to amend the Basel II guidelines. This has paved the way for the discussion on macroprudential regulation. In this section, I will modify the model to study the implications of such a policy.

Without proceeding further to explore the other forms of prudential regulation in the context of the model, a discussion of the procyclicality issue is required. As has been mentioned earlier, some researchers have found evidence of capital requirements being procyclical. This is all the more true if the requirements are too low. In the event

¹²Van Den Heuvel (2008) and Chari, Kehoe and McGrattan have a discussion on this issue

of an economic downturn, the credit risk materialization is high and loan recovery rates are low. In such a situation, the bank capital declines, sometimes to the extent that the bank finds it difficult to remain solvent. The adjustment in the capital asset ratio could come from the numerator or the denominator. But, since in times of financial distress, it is difficult to raise capital from the market, banks will fire sell assets to boost the capital asset ratio. This brings about a credit crunch and exacerbates the already existing problem. In other words, the capital requirement reinforces the business cycle. Transitioning to the Basel II regime has certain implications for procyclicality as well. The reason for that is risk in itself is cyclical in quantity and value. In economic downturns, the risk is higher (Borio et al. 2001). Also the price of risk is low in booms and high in busts (Lowe 2002). I now consider how the model can be used to analyze countercyclical capital requirements as it is known to control the procyclicality problem.

In this section, the problem is modified so that the capital requirement is time varying and countercyclical in nature. Essentially, we allow κ to vary with time and this is governed by the following equations. The capital requirement constraint can be written as:

$$[(Z_t + (1 - \delta)Q_t)\theta_t s_{t-1} - R_t d_{t-1}] - D_t - \kappa_t Q_t s_t > 0$$

where κ evolves as follows,

$$\kappa_t = (1 - \rho_\kappa)\bar{\kappa} + (1 - \rho_\kappa)\Lambda_\kappa(\log Y_t - \log Y_{t-1}) + \rho_\kappa \kappa_{t-1} \quad (23)$$

If Λ_κ is positive, this means that the capital requirements are countercyclical. In good times, the banks will have to hold more capital and these requirements decrease in downturns. This should help us mitigate the procyclicality problem. The reason is that during a financial crisis, the capital requirements get lowered and so the bank does not have to embark on aggressive selling of assets and this spares the economy of the credit squeeze that we have observed.

More precisely, I perform two thought experiments and try to simulate the path of the economy in response to an adverse shock. The benchmark is the model with

flat capital requirements with $\kappa = 0.08$. I consider a mildly countercyclical policy and an aggressive countercyclical policy. The first regime corresponds to a decline in capital requirements from 8 percent to 7.5 percent over six quarters after the financial shock. The second regime corresponds to the more aggressive countercyclical capital requirement regime with κ declining from 8 percent to 6 percent over six quarters. $\Lambda_\kappa = 10.5$ corresponds to the first case while $\Lambda_\kappa = 41.8$ corresponds to the latter.

8 Results

In this section, I discuss the results of the numerical solution. The tables are in appendix 1 while the figures can be found in appendix 2. Some additional figures can be found in a separate appendix to this paper.¹³

8.1 Exploring the Asymmetry in the Model

As mentioned previously, the penalty structure in the model is asymmetric and non linear. It might be helpful to look at the differential behaviour of the model in response to an equal magnitude positive and negative unit financial shock. The results are presented in figure 5. The bank in the model holds a capital buffer of about 1 percent in the steady state. As is evident from the figure, the response to a positive shock is much subdued. In contrast, when the negative shock hits, the capital buffer gets squeezed and the bank hinges towards the minimum requirements. At this stage the penalty terms becomes different from zero and the bank has to shrink it's balance sheet which is observed in the figure as a drop in capital. The excess returns rise above the fundamental value and this leads to a decline in investment and asset prices. In turn, output and consumption decline as well. Exactly the opposite happens if the economy is hit by a positive shock. However, the reponse is much dampened as the bank is accumulating capital, penalty is close to zero, there is credit available to undertake investment, asset prices are high and the output and consumption situation also look

¹³Available in <http://people.bu.edu/sudipto/>

good. This figure replicates a key feature of the economy in general which is that recessions tend to be sharper than booms and the skewness figures presented earlier in the paper lend credence to this fact.

8.2 Changing the Capital Requirement

Figure 6 plots the impulse response¹⁴, of the key variables in the model, to a financial shock. The model was solved for three different levels of capital requirements i.e. eight, ten and fourteen percent. We observe a dampening in the amplification produced when the economy is hit by this adverse shock. Higher capital requirements means that banks have more resources to absorb shocks. The banks with lower capital are the ones that are highly levered and the impact of an economic downturn, on these banks, is much greater than their well capitalized counterparts. This is of paramount importance and this point needs to be stressed. In the period preceding the financial crisis, many financial institutions had leverage ratios between twenty and thirty. That meant that only a three and a half percent loss in assets would be enough to wipe out the entire bank equity. It is for this reason that higher capital requirements should be implemented. On the lines of Basel Core Banking Principles, there are other pillars to improve the financial health like quality of capital and liquidity requirements but that is beyond the scope of this paper. Here we focus only on capital requirements. Coming back to figure six, as capital requirements increase, the bank does not have to adjust as much, to the shock, and so the economy witnesses a much subdued response. The benchmark case here is the one with eight percent capital requirements. The steady state excess returns is about a hundred and thirty basis points.¹⁵ The financial shock leads to a fall in the bank net worth and a sharp rise in the excess returns. The bank has to adjust by reducing its asset holdings. This leads to a decline in asset prices and

¹⁴The paper presents impulse responses that are non linear. As in the case of non-linear IRFs, the starting point matters. For this analysis, I start from the steady state for all the plots.

¹⁵The average spread between mortgage rates versus government bond rates, BAA corporate bond rates versus government bonds and commercial paper rates vs T-Bill rates, in the pre 2007 period, was around a hundred basis points, Gertler and Kiyotaki (2010).

investment. The output and consumption also decline accordingly. The fall in asset prices has a second round effect on the bank capital as well. This is the key mechanism that operates in the model. It must be noted however, that when the bank is well capitalized, this mechanism is weakened because the impact of a shock on the balance sheet is proportional to how levered the bank is.

8.3 Altering the Penalty Parameter

An interesting question to ask is how do the impulse response of the key variables in the model look as we alter the amount of punishment imposed in case the capital requirement constraint is violated. The value of the punishment parameter, ψ , controls the curvature of the penalty function and the penalty term λ . More precisely, it shows how severely the bank is punished once it violates the capital requirement constraint. In figure 7, I construct the impulse responses for two levels of the penalty term (λ) - a high and a low one. This is done by altering the value of ψ . If we look at the impulse response for the key variables, namely consumption, investment, capital and output, we find the shock is amplified a great deal with a higher value of ψ . The red line corresponds to the value of $\psi = 160$. The blue line represents a higher penalty corresponding to a value of $\psi = 130$. Note that the higher value of ψ though ad hoc, is not of much importance. We are trying to gain some intuition on a bigger policy question here. What this figure really shows that it might be a good idea to impose a more stringent penalty if the bank fails to meet the capital requirements. If that is the case, the bank will try to maintain a capital buffer so that it does not have to shrink its balance sheet in a downturn to remain compliant with the regulations. The current FDIC penalties are such that the bank is declared critically undercapitalized only when the capital is 2 percent of risk weighted assets. That might be a bit too low and there is need to reformulate that structure, as it seems.

8.4 Time Varying Capital Requirements

Figure 8 plots the evolution of some key macro variables under three different capital requirement regimes. The red line is the model with flat capital requirements, the blue line is the model with mildly countercyclical capital requirements while the black solid line is the model with strongly countercyclical capital requirements.¹⁶ Clearly the models with time varying requirements generate less volatility than the benchmark model with flat requirements. The intuition is straightforward. If the banks do not have to meet higher capital standards during a downturn, they will not have to adjust rapidly. This can help mitigate the credit squeeze problem. The banking sector will continue lending and financing investment. After the financial crisis, a consensus has emerged that there is need to shift to such macroprudential policies. My model makes a similar policy recommendation. The last row of table 4 shows that by introducing time varying capital requirements, the correlation between the bank capital and output is also reduced to a great extent suggesting a solution for the procyclicality problem.

8.5 Welfare Implications

Lastly, let us address the question about welfare implications of capital requirements in the model. It has been mentioned in the literature that introduction of capital requirements might lead to a loss in welfare because it constrains the ability of banks to make loans by creating deposit type liabilities. This is true but there is no conclusive evidence on how severe this decline is. There might also be net gains from imposing such requirements as they provide stability to the financial system and forward looking individuals will incorporate this gain in their decision making. I compute the welfare under different levels of capital requirement and also under the countercyclical capital requirement regime. The objective is the households utility function which can be written recursively as follows:

¹⁶Please refer the section on Countercyclical Capital Requirements for a discussion of each of these regimes.

$$W_t = U(c_t, d_t, l_t) + \beta E_t W_{t+1} \quad (24)$$

I report the welfare results in tables 3 and 5 in the appendix. Table 3 shows some steady state numbers of consumption and welfare under the flat capital requirement regime. The thought experiment here is as follows. I simulated the model for three different levels of capital requirement, namely eight, ten and fourteen percent. I ask the question, what is the welfare gain/loss from operating at 8% instead of say, 14%? Can we do better by shifting to a regime with higher κ ? To report the welfare in consumption terms, I compute what amount of adjustment in consumption (ΔC) would generate the same steady state welfare as the hypothetical benchmark case which is the case with $\kappa = 0.14$. It is observed that there is a decline in consumption and welfare. In other words, there can be net gains from implementing higher capital requirements. Higher capital requirements reduce use of retail funding but also prevent insolvency which casts a negative externality on the household sector by choking off dividends. The benefits here are outweighing the costs.

How do the welfare figures look like if we transition to a world with countercyclical capital requirements? The results are presented in table 5. We can see that the welfare is higher under the countercyclical scheme than under the fixed capital requirements. In fact the strongly countercyclical regime generates a gain which is equivalent to about 1.11% of consumption. The intuition for these results is the following. During the downturn, the capital requirements are reduced and so the bank does not have to adjust as much to remain solvent. This prevents the credit squeeze and the overall decline in economic activity. The households being forward looking will anticipate this benefit. This is basically the justification for implementing macroprudential policies and the model supports this line of reasoning.

9 Conclusion

This paper builds a framework where the benefits and costs of capital requirements can be analyzed. It presents a set up to analyze macroprudential policy in a world of occasionally binding capital constraints. I show that higher capital requirements can actually help banks absorb shocks better. It is also shown that if the banks hold buffers, they will not need to sell assets, at a discount, in a downturn to remain compliant with the regulations but just reduce their buffers to absorb shocks. Moreover, stringent regulations might be necessary for banks to hold excess capital as holding capital can be costly. The model has some nice welfare results as well. Effect on welfare is a strong point of criticism against higher capital requirements. Based on my analysis, I propose that we might be operating in a suboptimal world with very low regulatory requirements. I show that this is indeed the case in my model. The model can also be easily modified to analyze countercyclical capital requirements. Countercyclical buffers do make the economy resilient to downturns and in terms of welfare, the society is much better off under such regulations than the current set of policies.

In future work, the question I want to explore, is about the quality of capital. We can have capital requirements as high as twenty percent but is that number enough? What if the capital is not of sufficiently high quality? The other question that I am interested in exploring concerns the optimal timing issue in countercyclical capital requirement regime. If capital requirements are raised too quickly in booms, we might hamper growth while if they reduced too rapidly in downturns, bank defaults become more likely. So what should be ideal window while implementing such prudential regulations? I believe more work on these lines is required especially at this time when macroprudential regulations are being gradually put in place.

References

- [1] Admati, Anat. R et al. (2010). 'Fallacies, Irrelevant Facts, and Myths in the Discussion of Capital Regulation: Why Bank Equity is Not Expensive'. *Rock Center for Corporate Governance at Stanford University*
- [2] Aiyagari, R., and M. Gertler (1999). 'Overreaction of Asset Prices in General Equilibrium'. *Review of Economic Dynamics*
- [3] Angelini, P., A. Enria, S. Neri, F. Panetta and M. Quagliariello (2010). 'Procyclicality of Capital Regulation: Is it a problem? How to fix it?'. *Occasional papers, Number-74, Banca d'Italia*
- [4] Ayuso, J., Perez,D. and Saurina,J., (2004) 'Are Capital Buffers Procyclical? Evidence from Spanish Panel Data'. *Journal of Financial Intermediation, 13, pp.249-264*
- [5] Benes, J and M. Kumhof (2011). 'Risky Bank Lending and Optimal Capital Adequacy Regulation'. *International Monetary Fund, WP/11/130*
- [6] Bernanke, B. S., M. Gertler, and S. Gilchrist (1999): 'The Financial Accelerator in a Quantitative Business Cycle Framework'. *The Handbook of Macroeconomics*
- [7] Boldrin, M., Lawrence J. Christiano and Jones D.M. Fisher. 'Habit Persistence, Asset Returns, and the Business Cycle', *AmericanEconomic-Review. March 2001; 91(1): 149-66.*
- [8] Brunnermeier, M. K., and Y. Sannikov (2011). 'A macroeconomic model with a financial sector.' *mimeo, Princeton University*
- [9] Christensen, I., C. Meh, and K. Moran, (2011), 'Bank Leverage Regulation and Macroeconomic Dynamics'. *Bank of Canada, WP 2011-32*

- [10] Christiano, L. J., and J. D. M. Fisher (2000). ‘Algorithms for solving dynamic models with occasionally binding constraints.’ *Journal of Economic Dynamics and Control* 24(8), 11791232
- [11] De Wind, Joris (2008). ‘Punishment Functions’. *M.Phil thesis, University of Amsterdam*
- [12] Den Haan, W.J., and J. De Wind, (2012). ‘Nonlinear and stable perturbation-based approximations’. *Journal of Economic Dynamics and Control*, 36(10), 1477-1479.
- [13] Den Haan, W.J., and Ocaktan, T. S, (2009). ‘Solving Dynamic Models with Heterogeneous Agents and Aggregate Uncertainty with Dynare or Dynare++’. *London School of Economics, WP series*
- [14] Diamond, D. W., and R. Rajan (2000): ‘A Theory of Bank Capital’. *Journal of Finance*, vol 55, no 6, 2431-2465.
- [15] Gertler, M., and N. Kiyotaki (2009). ‘Financial Intermediation and Credit Policy in Business Cycle Analysis’. *Handbook of Monetary Economics*
- [16] Gertler, M., and P. Karadi (2011). ‘A Model of Unconventional Monetary Policy’. *Journal of Monetary Economics*
- [17] Giammarino, R., M, Lewis, T., R and D. Sappington (2011). ‘An Incentive Approach to Banking Regulation’. *The Journal of Finance*, Vol. 48, No. 4. (Sep., 1993), pp. 1523-1542.
- [18] Iacoviello, M., (2005). ‘House prices, borrowing constraints, and monetary policy in the business cycle.’ *American Economic Review* 95(3), 739-764
- [19] Jermann, U.J. (1998). ‘Asset pricing in production economies’. *Journal of Monetary Economics* 41: 257-275

- [20] Judd, K.L (1998). ‘Numerical Methods in Economics’. *The MIT Press, Cambridge, Massachusetts*
- [21] Kim, S., R. Kollman, and J. Kim (2009). ‘Solving the Incomplete Markets Model with Aggregate Uncertainty using a Perturbation Method’. *Journal of Economic Dynamics and Control*
- [22] Kiyotaki, N., and J. Moore (1997). ‘Credit cycles.’ *Journal of Political Economy* 105(2), 211-48
- [23] Ogaki, M. and C.M Reinhart (1998). ‘Measuring Intertemporal Substitution: The Role of Durable Goods’. *Journal of Political Economy* 106, 1078-1098
- [24] Piazzesi., M, Schneider., M and S. Tuzel (2007). ‘Housing, Consumption and Asset Pricing’. *Journal of Financial Economics* 83 (2007 51-569)
- [25] Preston, B., and M. Roca (2006). ‘Incomplete Markets, Heterogeneity and Macroeconomic Dynamics’. *NBER Working Paper*
- [26] Schmitt-Grohe, S., and M. Uribe. ‘Solving Dynamic General Equilibrium Models Using a Second Order Approximation to the Policy Function’. *Journal of Economic Dynamics and Control*, 28(4), 755-775
- [27] Stoltz, S and Wedow, M. (2005), ‘Bank’s Regulatory Capital Buffer and the Business Cycle: Evidence for German Savings and Cooperative Banks’. *Deutsch Bundesbank Discussion Paper No. 07/2005*
- [28] Uhlig, H. (2004). ‘Macroeconomics and Asset Markets: some Mutual Implications’. *Humboldt University Berlin, Deutsche Bundesbank, CentER and CEPR*
- [29] Van den Heuvel, S. (2006). ‘The Bank Capital Channel of Monetary Policy’. *Society for Economic Dynamics*
- [30] Van den Heuvel, S. (2008). ‘The Welfare Cost of Bank Capital Requirements’. *Journal of Monetary Economics*, 55(2), 298-320

- [31] Zaid, Abo., (2011). ‘Optimal Long Run Inflation with Occasionally Binding Financial Constraints’. *Job Market Paper, University of Maryland*
- [32] Zhu, Haibin (2008). ‘Capital Regulation and Banks’ Financial Decisions’. *International Journal of Central banking*

A Appendix: Tables

Table 2: (Calibration)

Parameter	Symbol	Value
Discount Rate	β	0.99
Capital Requirement	κ	0.08
TFP shock persistence	ρ_A	0.90
Volatility of TFP shock	σ_u	0.01
Depreciation	δ	0.025
Penalty parameter	ψ	130
Share of Capital	α	0.33
Risk Aversion	σ	1.5
Mean of TFP	\bar{A}	1.00
Disutility of labor	χ	10.36
Inverse of Frisch Elasticity of labor supply	φ	0.5
Utility fn. share parameter	a	0.95
Intratemporal el. of Substitution	$1/b$	0.39
Persistence of Financial shock	ρ_θ	0.75
Volatility of Financial shock	σ_θ	0.05
Adjustment Cost Parameter	a_1	0.23

Table 3 (Steady State Results)¹⁷

Variable	$\kappa = 0.14$	$\kappa = 0.10$	$\kappa = 0.08$
Consumption	0.4603	0.4600	0.4559
Welfare	20.29	19.98	19.32
Welfare Decline (in cons. terms)	–	0.35 %	0.43 %

¹⁷The welfare reported is the sum of PDV of current and future utilities. For ease of interpretation, I also report the welfare gain in consumption terms

Table 4 (Business Cycle Statistics)

	Output	Consumption	Cap-buffer	Investment
Standard Deviations				
Data	0.0115	0.0056	0.0093	0.0419
Model	0.0188	0.0058	0.0099	0.0320
Model (cc κ)	0.01001	0.00529	0.00954	0.02801
First Order Autocorrelations				
Data	0.88	0.83	0.93	0.87
Model	0.96	0.89	0.99	0.92
Correlations with Output				
Data	1.00	0.88	0.96	0.91
Model	1.00	0.92	0.91	0.96
Model (cc κ)	1.00	0.79	0.64	0.94

Table 5 (Welfare)¹⁸

Variable	Flat κ	cc κ	Strongly cc κ
Welfare	19.32	20.07	21.78
Welfare Gain (in cons. terms)	--	0.76%	1.11%

¹⁸Sum of PDV of current and future utilities of the household.

B Appendix: Figures

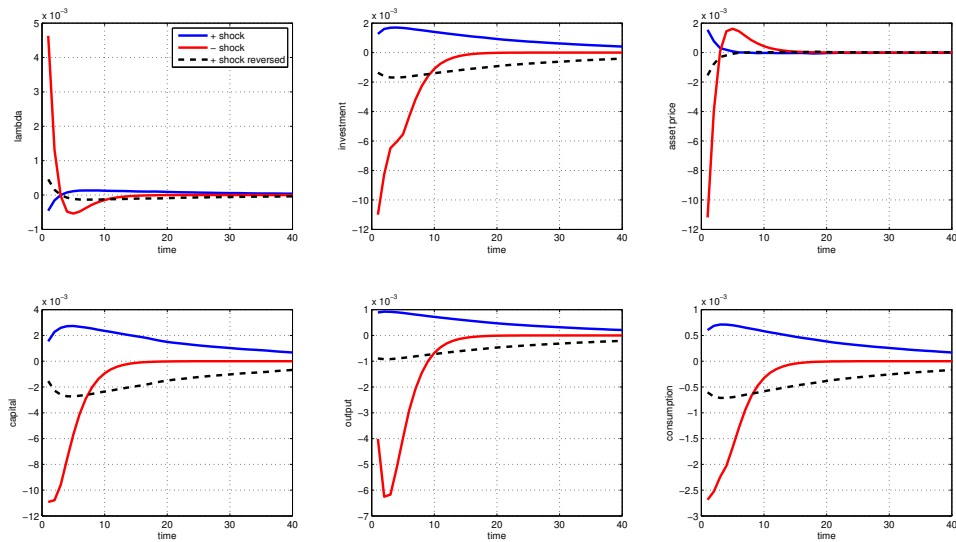


Figure 5: Asymmetric Response to a unit Financial Shock

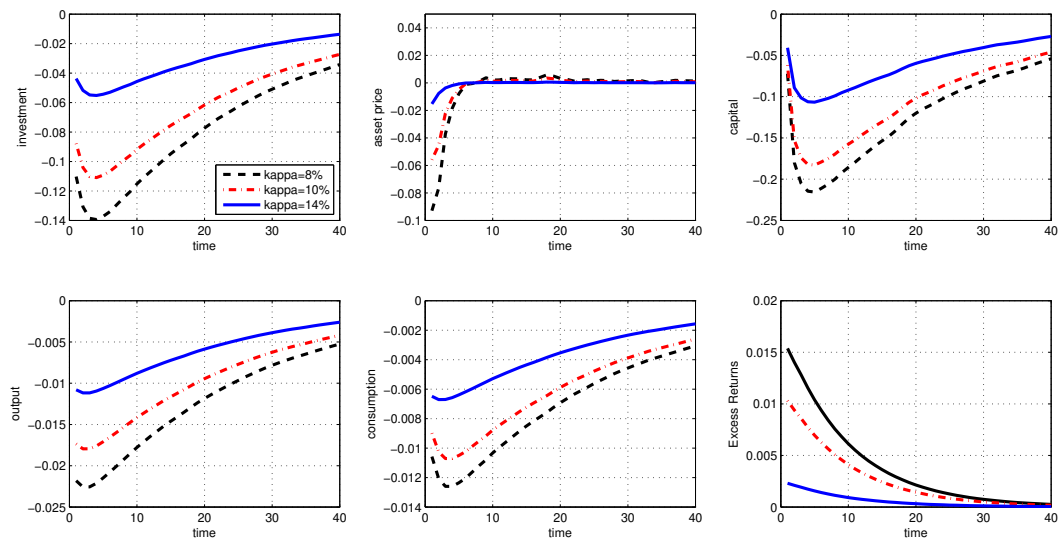


Figure 6: Altering the Capital Requirement

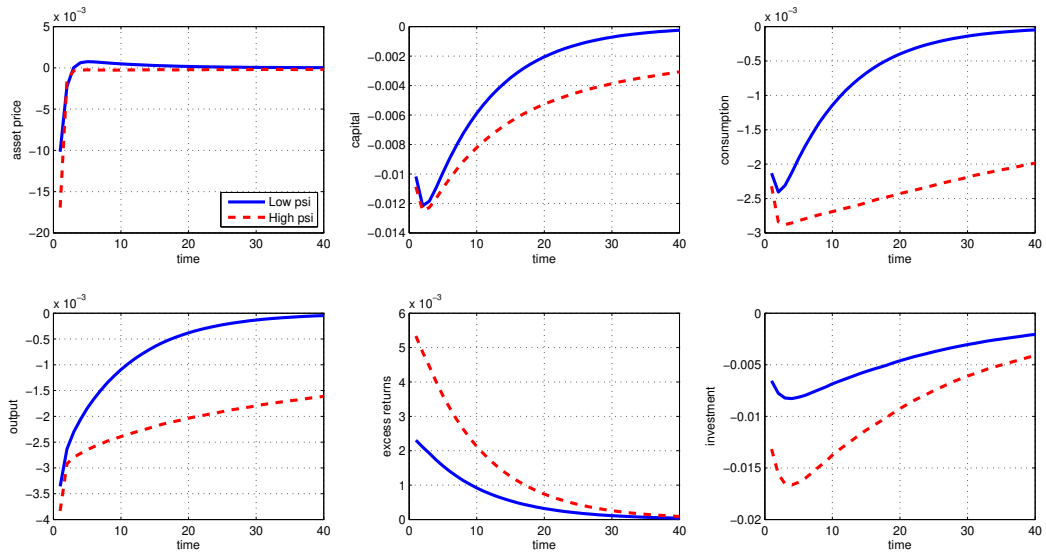


Figure 7: Altering the Penalty Parameter

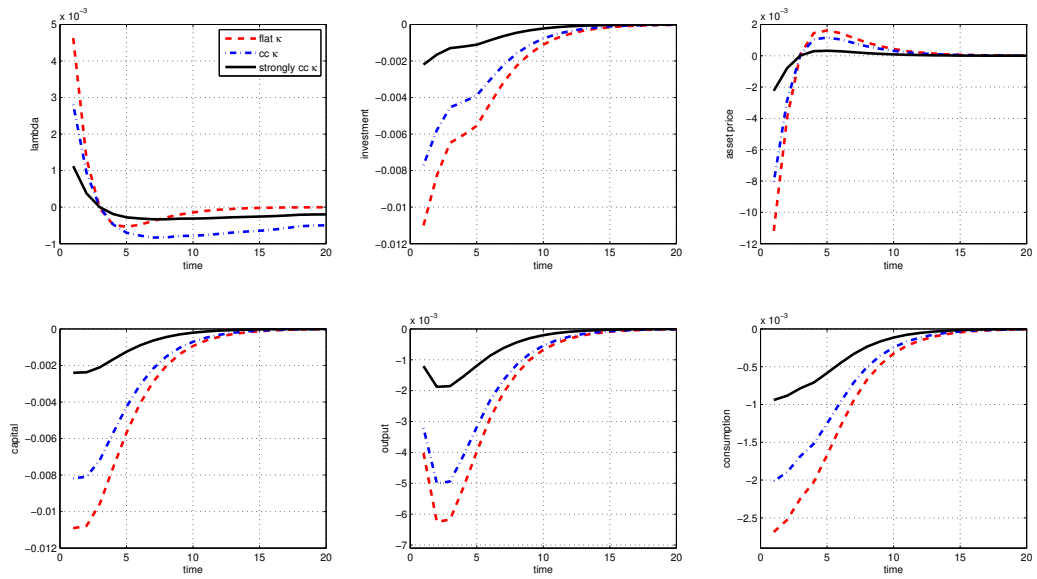


Figure 8: Flat vs countercyclical capital requirements