ESSAYS ON MACROECONOMICS OF BANKING: CREDIT FRICTIONS, BUSINESS CYCLE AND BANK CAPITAL

por

Maria Inês Ferreira Drumond de Sousa

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Orientada por:
Álvaro Aguiar e José Jorge

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Vita

Maria Inês Ferreira Drumond de Sousa was born on the 27^{th} of March of 1973, in Porto, Portugal.

She graduated in Economics from the *Faculdade de Economia da Universidade do Porto* (FEP) in 1997, and holds, since 2001, a M.S. in Economics from the same institution. Her Masters' dissertation, entitled *Sistema Financeiro e Crescimento Económico Endógeno* (*Financial System and Endogenous Economic Growth*), was supervised by Álvaro Aguiar and published in *Série Moderna Finança, Euronext Lisbon*. She has been a Ph.D. student at FEP since 2001.

She is a lecturer at FEP since 1997, having taught Macroeconomics (1997/98-2001/02; 2006/07).

She is a graduate researcher at CEMPRE - *Centro de Estudos Macroeconómicos e de Previsão*.

Her main scientific areas of research interest are Macroeconomics, Business Cycles, Macro Finance and Banking Regulation.

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Abstract

The role of financial frictions in the propagation of exogenous shocks in the economy has been subject of much debate in the literature and of significant implications at the institutional level. The main issue at stake is whether financial frictions are able to transform small exogenous shocks to the economy into amplified and persistent movements in aggregate output.

This dissertation fits in this line of research by centering its attention on how microeconomic structures, such as the bank funding structure and the relationship between banks and borrowers, interact with macroeconomic conditions. It contributes to clarify the role of bank capital and its regulatory environment in the propagation of business cycles, taking into account the current institutional changeover from Basel I to Basel II bank capital requirements.

After Chapter 1, that brings together the theoretical literature on the relationship between bank capital and the business cycle with the literature on the regulatory capital requirements under the Basel Accords, Chapter 2 proposes a dynamic general equilibrium model in which banks are constrained by a risk-based capital requirement. Taking into account that bank capital is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion), we explore an additional channel through which the effects of exogenous shocks on real activity are amplified - the bank capital channel. This amplification effect is larger under Basel II than under Basel I rules.

To evaluate more accurately the potential procyclical effects of Basel II, we embed, in Chapter 3, the bank-borrower relationship into a heterogeneous-agent model, in which firms have different access to bank credit depending on their credit risk. We conclude that, to the extent that it is more costly to hold bank capital during recessions and that the bank's loan portfolio is characterized by a significant fraction of highly leveraged and small firms, the introduction of Basel II accentuates the procyclical tendencies of banking, amplifying business cycle fluctuations.

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Chapter 1

Bank Capital Requirements, Business Cycles and the Basel Accords: An Integrating Analysis

1.1 Introduction

The role of financial frictions in the propagation of exogenous shocks in the economy has been subject of much debate in the literature and of significant implications at the institutional level. The main issue at stake is whether financial frictions, such as imperfect information in credit markets, are able to transform small exogenous shocks to the economy into amplified, persistent and asymmetric movements in aggregate output.

This dissertation fits in this line of research by centering its attention on how microeconomic structures, such as the bank funding structure and the relationship between the bank and the borrower, interact with macroeconomic business conditions. In particular, this thesis contributes to clarify the role of bank capital and its regulatory environment in lending conditions and, consequently, in the propagation of technology and monetary and fiscal policy shocks.

An additional motivation lies in current changes in the banking regulatory environment. In fact, the study of bank capital - business cycle interactions is quite up to date, both at the academic and institutional level, due to the implications of the changeover from Basel I to Basel II bank capital requirements rules, whose implementation have begun in

January 2007.[1] Rather than focusing on questions such as whether bank regulation is itself optimal and what type of regulation is most appropriate, we pay particular attention to the hypothesis that the introduction of Basel II bank capital requirements may accentuate the procyclical tendencies of banking, with potential macroeconomic consequences (the Basel II procyclicality hypothesis). We thus follow a positive approach, rather than a normative one: our objective is not to design the optimal regulatory rules, but to analyze the macroeconomic consequences of a given regulation, namely, the capital requirements regulation and its potential procyclical effects.

In this context, this first chapter discusses and brings together the theoretical literature on the relationship between bank capital and the business cycle with the literature on the regulatory framework of capital requirements established by the Basel Accords. We conclude that several theoretical studies predict that the introduction of bank capital requirements, by limiting banks' ability to supply loans, accentuates the procyclical tendencies of banking, leading to amplified macroeconomic effects of monetary and other exogenous shocks. However, whether or not Basel II capital requirements will add to this amplification effect is still subject to much debate, as the discussion in Chapter 1 makes clear.

The existence of empirical evidence that the bank funding structure, or, more specifically, the bank capital, affects its supply of loans and, consequently, real activity, has motivated our modelization, in Chapter 2, of the banking relationships in the context of a dynamic general equilibrium model.

First, one strand of this empirical literature indicates that lending growth after a monetary policy shock depends on the level of bank capital. See, for instance, Kishan and Opiela [57, 58], Van den Heuvel [93] and Gambacorta and Mistrulli [43], who argue that the real effects of monetary policy are generally stronger when banks are small and low-capitalized. Also in this line of research, Hubbard *et al.* [51] find that, even after controlling for information costs and borrower risk, the cost of borrowing from low-capital banks

[1] Basel I refers to the bank capital regulation framework established by the Basel Accord of 1988 and introduced by the Basel Committee of Banking Supervision. Basel II is the new Basel Accord, released by the same committee and seeking to improve on the rules set forth in the 1988 Accord, by aligning regulatory capital requirements more closely to the underlying risks that banks face.

is higher than the cost of borrowing from well-capitalized banks; that is, capital positions of individual banks affect the interest rate at which their clients borrow.

Second, as mentioned by Van den Heuvel [92], the importance of bank capital on lending has increased since the implementation of Basel I, which, by imposing risk-based capital requirements, limits the ability of banks with a shortage of capital to supply loans. There is a considerable number of papers that test the hypothesis of a "credit crunch" - a significant leftward shift in the supply curve for bank loans - that may have occurred in the U.S. during the early 90s, simultaneously with the implementation of Basel I. The idea behind those studies is that, given the common perception that bank capital is more costly than alternative funding sources (such as deposits), regulatory capital requirements can have real effects: in order to satisfy those requirements, banks may choose to reduce loans and, in such an event, some otherwise worthy borrowers cannot obtain them. The allocation of credit away from loans can, in turn, cause a significant reduction in macroeconomic activity, given that many borrowers cannot easily obtain other sources of funding in public markets. On this credit crunch literature, see, for instance, Bernanke and Lown [18], Berger and Udell [12], Peek and Rosengren [73, 74], Furfine [42], and Sharpe [85] for a review.

Some studies in this literature are, however, quite skeptical about the role of the credit crunch in worsening the 1990 recession in the U.S. (*e.g.*, Bernanke and Lown [18]): they suggest that demand factors, including the weakened state of borrowers' balance sheet, were instead the major cause of the lending slowdown. In contrast, Peek and Rosengren [74], for instance, identified an independent loan supply disruption and argued that this shock had substantial effects on real economic activity in the U.S..

The model developed in Chapter 2 contributes to evaluate the relative importance of these loan supply and demand effects, by bringing together, in a dynamic general equilibrium model, the borrowers' balance sheet channel developed by Bernanke *et al.* [17], with an additional channel working through bank capital, which also amplifies the real effects of exogenous nominal and real shocks.

Theoretically, our model has been motivated by Bernanke *et al.* [17]'s suggestion, in their concluding remarks, to introduce the specific role of banks in cyclical fluctuations:

we explicitly consider the role of banks in financing two entities in financial deficit (the public sector and nonfinancial firms) using the funds of the households. We also assume that banks are constrained by a risk-based capital ratio requirement according to which the ratio of bank capital to nonfinancial loans cannot fall below a regulatory minimum exogenously set. Banks are, thus, limited in their lending to nonfinancial firms by the amount of bank capital that households are willing to hold. Taking into account that bank capital is more expensive to raise than deposits, since households require a liquidity premium to hold bank capital in their portfolios, and that this difference tends to widen (narrow) during a recession (expansion), we explore the additional channel through which the effects of exogenous shocks on real activity are amplified - the bank capital channel.

The liquidity premium effect, through which the bank capital channel works in our model, is strictly related to the financial accelerator effect associated with the borrowers' balance sheet channel: when the liquidity premium and the financial accelerator effects are both present, the external finance premium responds not only to borrowers' financial position (as in Bernanke *et al.* [17]), but also to the liquidity premium required by households to hold bank capital. This exacerbates the (countercyclical) response of the external finance premium to a monetary policy shock, since the liquidity premium also moves countercyclically and influences positively the external finance premium, thus amplifying the real effects of the exogenous shock. According to the model, the liquidity premium effect amplifies business cycle fluctuations the more significantly the closer the regulatory rules are to Basel II, rather than to Basel I, therefore supporting the Basel II procyclicality hypothesis.

The potential procyclical effects of Basel II rest on the fact that the minimum bank capital requirements under the new regulatory framework become dependent on the riskiness of each particular bank exposure. Specifically, the risk weights used to compute bank capital requirements under Basel II are determined both by the institutional nature of bank borrowers (as in Basel I), and by the riskiness of each particular borrower: the higher the credit risk of a given bank exposure, the higher the risk weight assigned to that exposure. The general concern is that if, during a recession, the non-defaulted bank borrowers are downgraded by the credit risk models in use, the minimum bank capital requirements will increase. Consequently, to the extent that it is difficult or costly for the bank to raise external capital in bad times, this co-movement in bank capital requirements and the business cycle may induce banks to further reduce lending during recessions, thereby amplifying the initial downturn. This hypothesis motivated us to introduce, in Chapter 3, the bank-borrower relationship into a heterogeneous-agent model, in which firms differ in their access to bank credit depending on their financial position, that is, depending on their perceived credit risk.

The Basel II procyclicality hypothesis has recently been subject to some empirical research - see, for instance, Segoviano and Lowe [84], Kashyap and Stein [56], Altman *et al.* [4] and Catarineu-Rabell *et al.* [28]. These studies generally point out that the procyclical effects of Basel II will depend on how the minimum capital requirements will react over the business cycle, which, in turn, depend (*i*) on banks' customer portfolios, (*ii*) on the approach adopted by banks to compute their minimum capital requirements, (*iii*) on the nature of the rating system used, (*iv*) on the view adopted concerning how credit risk evolves over time, (*v*) on the capital buffers over the regulatory minimum held by the banking institutions, and (*vi*) on the market and supervisor intervention under Basel II.

The theoretical model developed in Chapter 3 contributes to evaluate the potential procyclical effects of Basel II, and to what extent those effects might depend both on banks' customer portfolios and on how borrowers' credit risk evolves over the business cycle. We depart from the model developed in Chapter 2 by considering that firms have different leverage ratios, that is, have different levels of credit risk and, consequently, face different access to bank credit. Compared with the representative-firm, this heterogeneous-firm framework allows for a more accurate inference of the potential procyclical effects of the changeover from Basel I to Basel II capital requirements: by introducing risk-sensitive capital requirements into a model with heterogeneous firms that differ on credit risk, we may properly analyze to what extent the riskiness of a bank's loan portfolio may accentuate the procyclical tendencies of banking under Basel II.

Since bank capital is more costly to raise than deposits, due to households' preferences for liquidity, the general equilibrium model in steady state illustrates that the introduction of regulatory capital requirements under both Basel I and Basel II has a negative effect on the economy's aggregate output. Specifically, the introduction of regulatory capital requirements, by forcing banks to finance a fraction of loans with bank capital, increases the banks' loan funding cost and, consequently, the banks' lending rates, thereby leading to a lower aggregate amount of loans granted to firms and, thus, lower physical capital accumulation and output. Besides, in a stationary equilibrium characterized by a significant fraction of high credit risk firms, the former effect is stronger under Basel II than under Basel I. It is worthwhile to mention here that our model abstracts from the positive effects of banking regulation, which may counteract the aforementioned result. We ignore, for instance, the role of bank capital regulation in avoiding financial crises - because this is not the focus of this thesis -, which certainly affects the macroeconomic equilibrium.

To the extent that it is costly to hold bank capital in bad times and that the representative bank's loan portfolio is characterized by a significant fraction of highly leveraged firms, the introduction of an aggregate technology shock into a partial equilibrium version of the former heterogeneous-agent model supports the Basel II procyclicality hypothesis: the introduction of Basel II capital requirements exacerbates the (countercyclical) response of the firms' financing cost to an aggregate technology shock, leading to a more amplified decrease in firms' physical capital accumulation and output. This amplification effect rests, not only on the countercyclical required return on bank capital, but also on the risk profile of the bank's loan portfolio. The model predicts that the financing cost of highly leveraged firms is very sensitive to changes in the required return on bank capital, under the new regulatory framework. As the economy's stationary equilibrium is characterized by a significant fraction of this type of firms, the average firms' financing cost responds more strongly to the aggregate technology shock under Basel II, leading to more amplified effects on capital accumulation and output than under Basel I.

This result supports Kashyap and Stein [56]'s argument that Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges that may be quite large depending on a bank's customer mix. According to our results, the Basel II procyclical effect should be greater, the greater the fraction of firms who begin with relatively high leverage ratios, that is, with relatively high credit risk. The distribution of firms over the leverage ratio, which in our model proxies for the credit risk, is therefore crucial to evaluate the potential procyclical effects of the new bank capital requirements rules.

In sum, in addition to the present chapter, this dissertation comprises Chapter 2, which builds a bank capital channel into a general equilibrium model, and Chapter 3, which evaluates the potential procyclical effects of Basel II in the context of a heterogeneous-agent model. The conclusion of Chapter 3 also summarizes the state of this research project.

1.2 The Bank Capital Channel: Related Theoretical Literature

The theoretical literature distinguishes three channels of propagation of the effects of monetary policy, through mechanisms related to financial imperfections: *(i)* the bank lending channel, considering that banks finance loans in part with liabilities that carry reserve requirements, *(ii)* the borrowers' balance sheet channel, focusing on borrowers' financial position and its effect on the external finance premium that borrowers face and, more recently, *(iii)* the bank capital channel, arguing that monetary policy affects bank lending, in part, through its impact on bank capital.[2]

The traditional bank lending channel and the borrowers' balance sheet channel have been more extensively studied - see Bernanke [14] and Bernanke and Gertler [16], for a review. Instead, we focus on the bank capital channel theoretical models, discussing the main implications of those models, summarized in Table 1.1 and classified according to:

- The motivation for bank capital holdings (market or regulatory capital requirements);
- The nature of bank capital (issued capital and/or retained earnings);
- The effects of exogenous shocks on lending and/or on the business cycle.

[2]As both the bank lending channel and the bank capital channel build on the hypothesis that monetary policy works, in part, by affecting banks' supply of loans, they are sometimes treated as part of a broader bank lending channel, notwithstanding being based on different transmission mechanisms. Note, for instance, that in contrast with the traditional bank lending channel, the borrowers' balance sheet and the bank capital channels may operate in response to factors other than changes in monetary policy.

	Capital Requirements (CR)		Bank Capital	Effect of exogenous shocks on lending and/or business cycle
Chen (2001)	Market			Amplified and more persistent*
Sunirand (2003)	Market		Retained Earnings	Amplified with the introduction of a double CSV approach
Aikman and Paustian (2006)	Market		Retained Earnings + Endowment	Amplified and more persistent with the introduction of an asym. inform. problem between depositors and banks and between banks and firms
Meh and Moran (2007)	Market		Retained Earnings	More persistent*
Blum and Hellwig (1995)	Regulatory	Binding	Fixed (no new equity issue)	Amplified with the introduction of binding CR
Thakor (1996)	Regulatory	Binding		$\uparrow$ Risk-based CR $\Rightarrow$ decrease in aggregate lending; Expansionary MP when CR are binding may not increase lending
Repullo and Suarez (2000)	Regulatory	Binding	Retained Earnings	Contractionary MP $\Rightarrow$ $\downarrow$ of bank lending relative to market lending
Furfine (2001)	Regulatory	Not Binding	Retained Earnings + Issued Equity	$\uparrow$ Risk-based CR $\Rightarrow$ decrease in loan growth; Negative shock to bank capital $\Rightarrow$ decrease in loan growth
Chami and Cosimano (2001)	Regulatory	Binding/Not Binding	Issued Equity (but predetermined)	*Bank capital accelerator effect* : amplifies the impact of MP on the economy; Asymmetric effects
Van den Heuvel (2002a)	Regulatory	Binding/Buffer	Retained Earnings	*Bank capital channel* (BCC): with CR, lending overreacts to the MP shock; The BCC amplifies the standard interest rate channel of MP
Tanaka (2002)	Regulatory	Bank faces penalty if it doesn't satisfy CR	Fixed (no new equity issue)	$\downarrow$ Bank Capital or $\uparrow$ CR $\Rightarrow$ shift IS curve to the left and make it steeper $\Rightarrow$ $\downarrow$ equilibrium output and subsequent MP will be less effective
von Peter (2004)	Resembles a Regulatory CR	Binding/Not Binding	Retained Earnings	Procyclicality: neg. shock $\Rightarrow$ $\downarrow$asset prices $\Rightarrow$ firms default $\Rightarrow$ loan losses $\Rightarrow$ $\downarrow$bank capital $\Rightarrow$ $\downarrow$ credit (if CR are binding) $\Rightarrow$ $\downarrow$ asset prices
Kopecky and VanHoose (2004)	Regulatory	Binding	Issued Equity	$\uparrow$ Risk-based CR reduces the effects of MP
Berka and Zimmermann (2005)	Regulatory	Binding	Issued Equity	Negative aggregate shock $\Rightarrow$ credit crunch; But negative ag. shock and procyclical CR (tighter during recession) soften the loan decrease
Cecchetti and Li (2005)	Regulatory	Binding/Not Binding	Moves with aggregate output (by assumption)	Confirms Blum and Hellwig (1995)'s results + Optimal MP neutralizes the procyclical impact of binding CR
Van den Heuvel (2005)	Regulatory	Binding/Not Binding	Issued Equity	$\uparrow$ CR reduces welfare
Bolton and Freixas (2006)	Regulatory	Binding	Issued Equity	Potential amplifying effect of MP: tightening in MP $\Rightarrow\downarrow$ incentives to raise bank capital $\Rightarrow$ further decline of lending
Markovic (2006)	Regulatory	-	Issued Equity	Amplification of output response to a contractionary MP

*When compared to a situation where information frictions between banks and depositors are absent
MP = Monetary Policy; CR = Capital Requirements

Table 1.1. The Bank Capital Channel - Related Theoretical Models

The rationale for bank capital holdings builds on the premise that banks may hold capital for market and/or regulatory reasons. Market capital requirements, as defined by Berger *et al.* [11], are associated with the capital ratio, *i.e.*, the ratio of bank equity to assets, that maximizes the value of the bank in the absence of regulatory capital requirements, but in the presence of the remaining regulatory structure that protects the safety and soundness of the banking system. According to these authors, market requirements can be justified (*i*) by the costs of bank financial distress, which tend to increase if the bank capital ratio decreases, (*ii*) by the existence of transaction costs when issuing equity, associated with substantial financial distress costs from low capital, and (*iii*) by the existence of agency problems between shareholders and creditors.

As reported in Table 1.1, Chen [31], Meh and Moran [68], Aikman and Paustian [1] and Sunirand [87] focus on this type of bank capital requirements. The first three models are built upon Holmstrom and Tirole [50] formulation that features two sources of moral hazard. The first source affects the relationship between banks and borrowers: entrepreneurs (borrowers) can choose between different projects and have an incentive to undertake the riskier projects in order to enjoy private benefits. To deter entrepreneurs from going after those private benefits, banks require them to invest their own funds in the project. The second source of moral hazard influences the relationship between banks and households (depositors) and justifies the existence of market capital requirements: since banks may not dutifully monitor the entrepreneurs, households only lend to banks which invest their own net worth (bank capital) in the financing of the entrepreneurs' projects. That is, since banks act as delegated monitors for depositors, they must be well capitalized to convince depositors that they have enough stake in the entrepreneurs' projects.

In this context, Chen's model predicts that, since both bank capital and firms net worth are used as collateral, a change in their level has a direct effect on bank lending and, thus, on the economy's investment: when banks suffer capital erosion, they find it difficult to seek alternative sources of finance, due to the second source of moral hazard mentioned above, and are forced to cut back lending. This initial effect tends to persist over time: with less investment from the previous period, entrepreneurs and banks earn less revenue and end up with a lower level of net worth. This further weakens the lending capability of banks and borrowing capacity of entrepreneurs.

Meh and Moran [68] go a step further and embed Holmstrom and Tirole [50]'s framework within a dynamic general equilibrium model. In particular, according to Meh and Moran's model, a contractionary monetary policy raises the opportunity cost of the external funds that banks use to finance investment projects and leads the market to require banks and firms to finance a larger share of investment projects with their own net worth. Since banks and firms' net worth are largely predetermined, bank lending must decrease to satisfy those market requirements, thereby leading to a decrease in investment. This mechanism implies a decrease in banks and firms' earnings and, consequently, a decrease in banks and firms' net worth in the future. Therefore, there is a propagation of the shock over time after the initial impulse to the interest rate has dissipated. Aikman and Paustian [1]'s model also builds on the earlier work by Chen [31], predicting that financial frictions lead to both more amplified and more persistent response of macroeconomic variables to technology, monetary and bank capital shocks, relative to the benchmark case of no financial imperfections. The amplification effect rests on the introduction of external capital adjustment costs in the model: a contractionary monetary policy, for instance, reduces the net worth of both entrepreneurs and banks, and, as in Kiyotaki and Moore [59], a negative feedback effect arises from net worth to asset prices, and then back from asset prices to net worth, which greatly magnifies the impact of the initial shock.

Sunirand [87], using an alternative framework, also supports the amplification hypothesis. In particular, by extending the financial accelerator model of Bernanke *et al.* [17] to consider a two-sided costly state verification (CSV) framework, Sunirand was able to dissociate the amplification effect caused by the moral hazard problem between depositors and banks, from the amplification effect caused by the asymmetric information problem between banks and firms. According to the CSV framework, first introduced by Townsend [91], the lender must pay a cost in order to observe the borrower's realized return. In Sunirand's model, banks act as delegated monitors on firms' investment projects, as in Bernanke *et al.*, and depositors perform the role of 'monitoring the monitor', as in Krasa and Villamil [62].[3] The two-sided costly state verification framework leads to a wedge between the internal and external cost of funds, thereby motivating an endogenous role for firms' and banks' capital in the model. Sunirand then shows that embedding the informational asymmetry between households and banks into the financial accelerator model, amplifies and propagates the effects of a negative monetary shock on aggregate output and investment.

Among the studies in the second group, *i.e.*, assuming bank capital requirements imposed by banking regulation, are Blum and Hellwig [19], Thakor [90], Repullo and Suarez [80], Chami and Cosimano [30], Van den Heuvel [92, 94], Berka and Zimmermann [13], Bolton and Freixas [21] and Markovic [66]. Blum and Hellwig [19], one of the pioneer studies on this subject, predicts that a rigid link between bank capital and bank lending may act as an automatic amplifier for macroeconomic fluctuations, leading banks to lend more when times are good and to lend less when times are bad, thus reinforcing any underlying shocks. Assuming that banks cannot issue new capital and that firms do not fully replace bank loans by other sources of finance, the amplification mechanism works as follows: if many banks experience low return realizations at the same time, they may all become undercapitalized at the same time. Thus, they may all have to cut back lending (or to recapitalize) at the same time, in the presence of a capital adequacy requirement. This is likely to reduce investment, which reduces aggregate demand and, therefore, the cash flow that firms obtain from current production. The reduction in cash flow, in turn, affects the ability of firms to pay their debts and hence the returns that banks receive on their loans. A given initial shock to asset returns may thus be amplified by a rigid application of a capital adequacy requirement (Blum and Hellwig [19], pp. 741-742).

Also assuming regulatory capital requirements, Repullo and Suarez [80] provide an explanation for the decline of bank loans relative to market lending during episodes of tight money: since some long-term bank assets involve fixed interest rates whereas the returns of many short term bank liabilities are closely linked to market interest rates, a monetary tightening will generate losses to the banks, thereby reducing bank capital. A

[3] See also Zeng [98] on this approach.

decrease in bank capital or an increase in capital requirements will, in turn, produce a credit crunch: bank lending and investment will fall, and the higher quality bank borrowers tend to shift to market finance.

Van den Heuvel [92] also assumes that banks are exposed to interest rate risk (as in Repullo and Suarez [80]) and are not able to issue new capital (as in Blum and Hellwig [19]). According to Van den Heuvel's model, an increase in funds rate (due to a contractionary monetary policy) and, consequently, an increase in bank's cost of funding, induces a decrease in bank's profits, given the maturity mismatch on the bank's balance sheet. This, in turn, weakens the bank's future capital position - since banks may only increase their capital through retained earnings -, increasing the likelihood that its lending will be constrained by an inadequate level of capital. Therefore, new lending overreacts to the monetary policy shock, when compared to a situation of unconstrained banks. Van den Heuvel refers to this channel by which monetary policy influences the supply of bank loans through its impact on bank capital as the bank capital channel. The strength of this channel depends on the capital adequacy of the banking sector and the distribution of capital across banks. In particular, lending by banks with low capital is delayed and then amplified in reaction to interest rate shocks, relative to well capitalized banks.

Finally, Chami and Cosimano [30], Berka and Zimmermann [13], Bolton and Freixas [21] and Markovic [66] also consider regulatory capital requirements, but, in contrast with Van den Heuvel, assume the possibility of issuing equity. However, equity issuance may involve costs, as in Bolton and Freixas [21], who introduce a cost of outside capital for banks by assuming information dilution costs in issuing bank equity: outside equity investors, having less information about the profitability of bank loans, will tend to misprice the equity issues of the most profitable banks. In this context, the presence of binding regulatory capital requirements may magnify the effects of a contractionary monetary policy, since this policy may cause a decrease (or prevent an increase) in bank capital: a contractionary monetary policy may render bank loans insufficiently lucrative when information dilution costs in issuing bank equity are taken into account.

Markovic [66] also explores the asymmetric information relationship between banks and their shareholders, by developing a theoretical model that extends Bernanke *et al.*

[17]'s work to account for three distinct bank capital channels: (*i*) the adjustment cost channel, which builds on the allocation cost necessary to reduce the aforementioned asymmetric information problem; (*ii*) the default risk channel, which arises from the possibility of banks defaulting on their capital; and (*iii*) the capital loss channel, based on the assumption that, during a recession, banks' shareholders anticipate a future fall in the value of bank capital. All channels trigger an increase in the required return on bank capital by shareholders, and thus an increase in the cost of bank capital, during a recession. This higher cost is then transferred to firms, which borrow from banks, thereby leading to lower firms' investment and output. All the three channels thus work to amplify the output response to a contractionary monetary policy.

In Berka and Zimmermann [13], when an initial negative shock hits the economy, bank capital becomes riskier and households channel their savings away from capital and into deposits. The banks are then squeezed by the binding regulatory capital requirements and have to decrease their loan supply and invest more in government bonds. Without capital requirements, banks could supply more loans, in principle, by charging even higher loan rates, and entrepreneurs would still be ready to pay these rates.

In a slightly different perspective, Van den Heuvel [94] quantifies the welfare costs of bank capital requirements by embedding the role of liquidity creation by banks in a general equilibrium model, with no aggregate uncertainty. The households' preferences for liquidity play here a major role: equilibrium asset returns reveal the strength of these preferences and allow the quantification of the ("neither trivial nor gigantic", according to the author) welfare costs of bank capital requirements. Regulators, thus, face a trade-off between keeping the effective capital requirement ratio as low as possible while keeping the probability of bank failure acceptably low.

Diamond and Rajan [39] and Gorton and Winton [47] also suggest that bank capital may be costly by reducing banks' ability to create liquidity through deposits: an increase in bank capital, may reduce the probability of financial distress, but also reduces liquidity creation by banks by decreasing the aggregate amount of deposits (the "financial fragility-crowding out effect", in the words of Berger and Bouwman [10]). However, Berger and Bouwman [10] also point out that other contributions suggest the opposite outcome: an increase in bank capital leads to increased banks' risk bearing capacity, thereby leading to an increase in liquidity creation (the "risk absorption" hypothesis). Berger and Bouwman construct liquidity creation measures and test these opposing theoretical predictions, using data on U.S. banks from 1993-2003, and concluding that, for large banks, capital has a statistically significant positive net effect on liquidity creation whereas, for small banks, the effect is significantly negative. The net effect may depend on both bank size and the level of bank capitalization. As mentioned by the authors,

> "the financial fragility-crowding out effect may be relatively strong for small banks because they tend to raise funding locally, whereas large banks more often access capital markets, so that it is less likely that capital crowds out deposits for large banks. In contrast, the risk absorption effect may be relatively strong for large banks because these institutions are subject to more regulatory and market discipline. Combining these relatively strengths suggests that the financial fragility-crowding out effect may more likely empirically dominate for small banks while the risk absorption effect may more likely dominate for large banks. Similarly, the risk absorption effect may be relatively strong for banks with low capital ratios of any size because these banks have thin buffers to absorb risks and tend to face more regulatory, market, and/or owner pressures to control risk taking." (Berger and Bouwman [10], p. 2)

In sum, the majority of the theoretical models reported in Table 1.1 predict that the introduction of bank capital requirements, for market or regulatory reasons, tends to amplify the effects of monetary and other exogenous shocks. The amplification effect usually rests on the existence of imperfect markets for bank capital: in some models banks are not able to raise capital on the open market, implying that bank capital becomes determined by banks' retained earnings and changes in asset values, whereas in other models banks may issue capital but face an issuance cost, which tend to increase during economic downturns. In this context, if the value of bank capital decreases or its issuance costs increase, the banks' cost of funds tend to increase, particularly when the amount of bank capital is not much higher than the level demanded by regulators or the market. This higher cost is then transferred to firms, when borrowing from banks, thereby leading to lower investment and output.

1.3 Capital Requirements within Banking Regulation

The preceding analysis reveals that the bank capital channel literature considers that banks, for market or regulatory reasons, are required to hold capital in their balance sheet. We now take a closer look to regulatory capital requirements, focusing on whether the new Basel Capital Accord will strengthen or weaken the potential amplification effects which underlie the bank capital channel.

1.3.1 Banking Prudential Regulation

Regulatory bank capital requirements are one of a broad set of instruments used in banking prudential regulation. According to Freixas and Rochet [41], other instruments are often used, such as, (*i*) deposit interest rate ceilings, (*ii*) entry, branching, network, and merger restrictions, (*iii*) portfolio restrictions, (*iv*) deposit insurance, (*v*) and regulatory monitoring (including closure policy).

The justification for any regulation is usually associated with market failures, such as externalities, market power or asymmetric information. Lind [64] points out three factors which justify, in particular, bank regulation: (*i*) certain banking activities are intrinsically vulnerable;[4] (*ii*) even minor disturbances can threaten overall financial stability through contagion; (*iii*) banks are the dominant providers of some key services as the payment system and the lending to small and medium-sized enterprises.

Santos [83], in turn, argues that one of the two most presented justifications for banking regulation is the inability of depositors to monitor banks.[5] According to Dewatripont and Tirole [38], small depositors protection is indeed one of the primary concerns of current prudential regulation of banks. Asymmetric information leads to substantial moral hazard and adverse selection in banking. Therefore, investors must perform several monitoring activities, such as screening and auditing. However, these activities are complex, expensive, and time-consuming and their exercise is a 'natural monopoly', in that their duplication by several parties is technically wasteful. Since bank debt is primarily held

[4]For instance, as loans usually have a longer duration than deposits, banks may lose a large proportion of their deposits rather quickly while their loans remain outstanding.

[5]The other being the risk of a systemic crisis.

by a very large number small depositors, who are most often unable to understand the specificities of balance and off-balance sheet banking activities, a free riding problem emerges: bank customers have little individual incentive to perform the various monitoring functions. This free riding gives rise to a need for private or public representatives of depositors (Dewatripont and Tirole [38], pp. 31-32). To ensure that there is better public information, regulators can also require banks to follow certain standard accounting principles and to disclose a wide range of information that helps to assess the quality of a bank's portfolio (Mishkin [70], p. 268).[6]

As mentioned before, the prudential regulation of banks is also motivated by the systemic risk prevention. In particular, Santos [83] points out that a bank run, that is triggered by depositors' panic or by the release of information when there is asymmetric information among depositors about bank returns, leads to the premature liquidation of bank assets and may trigger contagion runs, which may culminate in a banking system failure. Among the proposals to insulate banks from runs are the development of narrow banks - banks that invest the deposits of the public in traded securities -, the development of banks that finance loans entirely with equity, the suspension of convertibility, the central bank's role as lender of last resort and the development of deposit insurance.[7] In this context, Allen and Herring [2] argue that reserve, capital and liquidity requirements designed to ensure that banks will be able to honor their liabilities to their depositors, have a consumer protection and microprudential rationale as well as a macroprudential rationale to safeguard the system against systemic risk.

However, the creation of a government safety net for depositors may sometimes generate excessive risk taking on behalf of banks' managers, calling for additional regulation. As Mishkin [70] points out, with a safety net depositors know they will not suffer huge losses if a bank fails and, therefore, tend not to withdraw deposits when they suspect that the bank is taking on too much risk. For instance, to avoid bank panics and their so-

[6] It is true that large corporations are also financed by the public: stocks and bonds issued by large companies are in fact widely diffused. However, there are two differences, according to Freixas and Rochet [41]: these securities are not used as a means of payment, and the ratio of debt to assets is substantially higher for financial intermediaries than for nonfinancial firms. Therefore, the free rider problem involved in the monitoring of widely held firms seems to be quantitatively much more serious in the case of banks (Freixas and Rochet [41], p. 264).

[7] See Santos [83] for details.

cial costs, the authorities of many countries have established deposit insurance schemes. Under such schemes each bank pays a premium to a deposit insurance company, and in exchange its depositors have their deposits insured up to a fixed limit in the case the bank fails. As mentioned by Gorton and Winton [48], once deposit insurance has been adopted, there is a further need for government intervention via bank regulation because of the incentive of banks to take additional risks once they have (underpriced) government deposit insurance.[8] Regulatory capital requirements should thus be introduced as part of the prudential regulation, to reduce the tendency towards excessive risk taking by banks, diminishing the bank insolvency risk. Beside providing a cushion against losses, bank capital also works to discipline banks' managers: when a bank is forced to hold a large amount of capital, it has more to lose if it fails (Mishkin [70], p. 265). In this context, Kashyap and Stein [56] perceive capital regulation as an instrument the regulator uses to get each bank to internalize the systemic costs, such as losses absorbed by government deposit insurance and disruptions to other players in the financial system, which are not fully borne by the bank in question.

Capital standards may also be an important instrument to implement the optimal governance of banks as those standards can be used to define the threshold for the transfer of control from banks' shareholders to the regulator (Santos [83], p. 59). Additionally, Morrison and White [71] argue that capital regulation should also have the effect of discouraging unsound and unreliable institutions from setting up operations: capital requirements can be used to solve adverse selection problems, that is, to select out bad banks from the system.

In this context, and as mentioned by Santos [83], rules on bank capital are one of the most prominent aspects of banking regulation. This prominence results mainly from the role of bank capital in banks' soundness, risk-taking incentives and corporate governance, as the studies mentioned above indicate.

[8]There is a large body of literature on the moral hazard issue of deposit insurance. See Santos [83] for a review.

1.3.2 Bank Capital Regulation: the Basel Accords

The bank capital regulation framework established by the Basel Accord of 1988 (Basel I, hereafter), and adopted, not only by the countries belonging to the Basel Committee,[9] but by more than 100 countries around the world, established banks' obligation to continually meet a risk-based capital requirement. In short, each bank, under Basel I, must maintain a total risk-weighted capital ratio, defined as the ratio of bank capital to the bank's risk-weighted assets, of at least 8%. The weights for assets on the balance sheet depend, in turn, on the institutional nature of the borrower. For example, a zero weight is assigned to a government security issued in the OECD, meaning that the bank can finance such asset through deposits without adding any capital. Other three weights are permitted, all meant to reflect credit risk: 0.2 (*e.g.*, for interbank loans in OECD countries), 0.5 (*e.g.*, for loans fully secured by mortgages on residential property) and 1 (*e.g.*, for industrial and commercial loans).[10]

The same risk weight thus applies to all loans of a particular category ('one-size-fits-all' approach). Consequently, this categorization does not reflect the risk that a particular borrower actually poses for the bank. The failure to distinguish among loans of very different degrees of credit risk created the incentive for arbitrage activities. As mentioned by Jones [53], p. 36,

> "in recent years, securitization and other financial innovations have provided unprecedented opportunities for banks to reduce substantially their regulatory measures of risk, with little or no corresponding reduction in their overall economic risks - a process termed regulatory capital arbitrage (RCA)."

As explained by Jones, RCA, in general, exploits differences between a portfolio's true economic risks and the risk measurements defined by the bank regulation, usually involving the unbundling and repackaging of a bank's portfolio risks so that a disproportionate amount of that portfolio's true underlying credit risk is treated as lower risk-weighted assets, or as having been sold to third-party investors. According to this author, from a

[9] The Basel Committee on Banking Supervision ('the Basel Committee') consists of central bank and supervisory authority representatives from Belgium, Canada, France, Germany, Italy, Japan, Luxembourg, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[10] See Basel Committee on Banking Supervision [8], for a detailed description of the rules introduced by Basel I, and Dewatripont and Tirole [38], for a short review.

regulatory perspective, capital arbitrage has thus undermined the effectiveness of Basel I. At least for large banks, capital ratios under this framework are no longer consistent measures of capital adequacy: available evidence suggests that the volume of RCA activities is large and growing rapidly, especially among the largest banks.[11] Furthermore, financial innovation is making RCA more accessible to a wider set of banks than in the past.[12]

In this context, a new framework for capital requirements, also released by the Basel Committee on Banking Supervision (BCBS), emerged to address some of the major shortcomings of Basel I and foster stability in financial system: the new Basel Accord - Basel II, hereafter. One of the central changes proposed by Basel II, whose implementation has begun in January 2007, is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank has to hold against a given exposure becomes a function of the estimated credit risk of that exposure. Consequently, the constant risk weight of 100% for commercial and industrial (C&I) loans, for instance, is replaced by a variable weight, so that the C&I loans with a low credit rating and a high probability of default are thus assigned a high risk weight. That is, under Basel II, the risk weights used to compute bank capital requirements are determined both by the category of borrower and by the riskiness of a particular borrower, thus aiming to reduce regulatory capital arbitrage.

Basel II is built on three complementary pillars:[13]

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[11] Nevertheless, Jones also argues that RCA has been beneficial in minimizing allocative inefficiency in lending markets: RCA permits banks to compete effectively with nonbanks in low-risk businesses they would otherwise be forced to exit owing to high regulatory capital requirements.

[12] Gorton and Winton [47] also suggest that national regulators have consistently weakened the 1988 Basel agreement both by applying capital guidelines selectively and by redefining what is meant by 'capital'. Even as international bank regulators have been revising the 1988 Basel Accord to strengthen it (*e.g.*, the statement issued by the Basel Committee on "Instruments Eligible for Inclusion in Tier 1 Capital"), "the national regulators have successfully lobbied to weaken these standards by broadening the definition of capital." (Gorton and Winton [47], p. 2). von Thadden [96], in turn, argues that according to its major critics, Basel I, besides giving rise to regulatory arbitrage, ignored modern credit risk management techniques, failed to take account of the dynamic distortions of capital regulation, and neglected complementary regulatory instruments such as supervisory monitoring or prompt corrective regulatory action.

[13] See Basel Committee on Banking Supervision [9] for details. On July 2006, the BCBS issued a comprehensive version of the Basel II framework. This document is a compilation of Basel Committee on Banking Supervision [9], the elements of the Basel I that were not revised during the Basel II process, the 1996 Amendment to the Capital Accord to Incorporate Market Risks, and the 2005 paper on the Application of Basel II to Trading Activities and the Treatment of Double Default Effects. For a short chronology of the Basel II process see Dierick *et al.* [40], p. 9, box 1.

- Pillar 1 (minimum regulatory capital requirements) establishes the capital requirements for credit risk, market risk and operational risk;[14]

- Pillar 2 (supervisory action) comprises the 'supervisory review process', which outlines the requirements on banks' management of risks and capital and defines the roles and powers of the supervisors. Basel II should thus involve supervisors more directly in the review of banks' risk profiles, risk management practices and risk-bearing capacity than Basel I;

- Pillar 3 (market discipline) sets out requirements on banks for public disclosures. In particular, banks will be required to publish information on their business profile, risk exposure and risk management. Market participants will thus have better information on banks, improving the functioning of market discipline.

As we intend to study the relationship between regulatory capital requirements and the business cycle, our attention focuses on capital requirements for credit risk under Pillar 1.

According to Basel II rules, banks may adopt one of the following approaches to compute their minimum capital requirements for credit risk:

- The Standardized Approach. Under this approach, the risk weight associated with each loan is based on an external rating institution's evaluation of counterpart risk. This may reflect a considerable differentiation in the risk weights used compared to Basel I: for instance, the less risky C&I loans can be assigned a risk weight of 20% whereas the loans granted to the riskiest C&I firms are assigned a risk weight of 150%. Capital charges for loans to unrated companies remain essentially unchanged when compared to Basel I. Some authors (*e.g.*, Hakenes and Schnabel [49]) thus argue that, in practice, the standardized approach may become similar to the regulation imposed by Basel I, since in many countries no external ratings exist for a large fraction of corporate loans;[15]

[14] Credit risk is the risk of losses in balance and off-balance sheet positions resulting from the failure of a counterparty to perform according to a contractual arrangement; Market risk is the risk of losses in balance and off-balance sheet positions arising from movements in market prices and volatilities; Operational risk is the risk of losses resulting from inadequate or failed internal processes, people or systems, or from external events.

[15] An exception being the U.S., where many corporate borrowers are rated. However, the standardized approach is not supposed to be implemented in this country.

- The Internal Ratings Based (IRB) Approach. The estimated credit risk and, consequently, the risk weights used to compute capital requirements, are assumed to be a function of four parameters associated with each loan: the probability of default (PD), the loss given default (LGD), the exposure at default (EAD) and loan's maturity (M). Banks adopting the "Advanced" variant of the IRB approach are responsible for providing all four of these parameters themselves, using their own internal rating models. Banks adopting the "Foundation" variant of the IRB approach will be responsible only for providing the PD parameter, with the other three parameters to be set externally by the regulatory authorities.

Therefore, the IRB approach, considered one of the most innovative elements of Basel II, permits the use of internal credit risk models by banks (as long as they are validated by the regulatory authority) to assess the riskiness of their portfolios and to determine their required capital. By aligning required capital more closely to banks' own risk estimates, Basel II should decrease the gap between regulatory and market capital requirements, thus encouraging banks to improve their risk assessment methods.

Basel II contains a long list of minimum requirements that a bank has to fulfill to be eligible for the IRB approach. Consequently, as mentioned by Hakenes and Schnabel [49], the introduction of this approach requires high fixed costs which may deter smaller and less sophisticated banks from adopting it. Nonetheless, Lind [64] points out that banks still have an incentive to move to the IRB approach since the required capital will then be more closely aligned with each bank's actual risk.[16] In addition, the adoption of the IRB approach may imply a lower capital requirement. The Committee of European Banking Supervisors [33], for instance, concludes, using a sample of European banks, that the minimum required capital under Pillar 1 would decrease relative to Basel I and that this decline would be amplified if banks move to more advanced approaches to compute their minimum capital requirements. Note, however, that, as mentioned in the report, these results might be influenced by the fact that the study was carried out in a period of favorable macroeconomic conditions in most countries.

[16] See Repullo and Suarez [81] and Hakenes and Schnabel [49], for instance, on the banks' optimal choice between the IRB and the standardized approaches.

Concerns have been raised that Basel II may raise the financing costs of small and medium-sized enterprises (SMEs) due to banks' potential perception that these firms are riskier and, hence, carry higher capital requirements than under Basel I (Altman and Sabato [5]). Accordingly, the last version of the new framework recognizes a special treatment for these firms:[17] subject to certain conditions, aggregate exposures to a SME can be treated as "retail exposures", which is advantageous compared to the treatment of other corporate lending. Even SMEs considered as corporate can benefit, under certain conditions, from a preferential treatment based on an adjustment relative to the firm's size. In fact, as Figure 1.1 illustrates, the risk weights, under the IRB approach, differ across banks' asset classes, and, for a given probability of default, the risk weights assigned to retail or to SMEs exposures are smaller than the risk weight assigned to a corporate exposure.

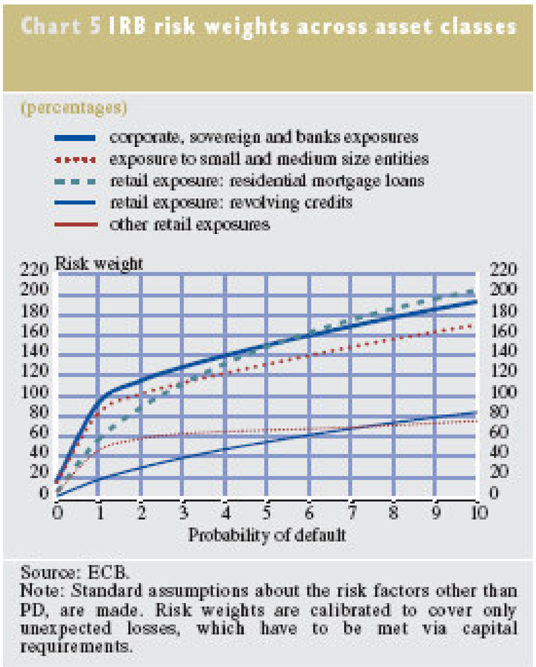

Figure 1.1. Risk weights under the IRB approach (Source: Dierick *et al.*, 2005, "The New Basel Capital Framework and its Implementation in the European Union", *European Central Bank Occasional Paper Series*, No. 42)

[17] Based on the fact that default probabilities for smaller firms are observed to be less correlated with the overall state of the economy (Dierick *et al.* [40]).

Basel II implementation has started in January 2007. In the U.S. only the large internationally active banks will be required to follow the Advanced IRB approach for credit risk. However, other banks that meet the requirements for the use of this approach can also adopt Basel II.[18] In this context, and according to Dierick *et al.* [40], approximately twenty banks fall into these two categories.[19] All the other banks operating in the U.S. will continue to follow Basel I rules or may adopt the U.S. Basel IA proposal, designed to modernize the Basel I framework, improving its risk sensitivity without making it overly complex for smaller banks. In the E.U., Basel II framework (transposed into E.U. legislation by means of the Capital Requirements Directive) will apply to all banks and investment firms, independent of their size or the geographical scope of their activity. As mentioned by The Economist (November 4, 2006, p. 86), since Basel II is being applied in stages, full compliance in the E.U. is not due until 2008, and 2009 in the U.S.

Basel II Capital Requirements and Procyclicality

As argued by Lowe [65], Allen and Saunders [3] and Amato and Furfine [6], the banking industry is inherently procyclical, regardless of the design of capital requirements, due mainly to the existence of asymmetric information and market imperfections: on the one hand, banks tend to decrease lending during recessions, because of their concern about loan quality and repayment probability, exacerbating the economic downturn as credit constrained firms and individuals decrease their real investment activity. On the other hand, banks tend to increase lending during expansions, thereby contributing to a possible overheating of the economy. Procyclicality here thus refers to the tendency of the financial system to reinforce the business cycle.

The introduction of the new bank capital requirements rules proposed by Basel II may accentuate the procyclical tendencies of banking, with potential macroeconomic consequences. Under both the standardized and the IRB approaches the higher the credit risk of a given asset, the higher the capital that a bank will have to hold against it. If the credit risk of the banks' assets is countercyclical, the risk weights used to compute capi-

[18]Only the most advanced approach of Basel II will be implemented in U.S.

[19]Or twenty six, according to The Economist (November 4, 2006, p. 86).

tal requirements and, consequently, the minimum bank capital requirement, will increase during recessions.[20] The implementation of Basel II thus raises some concerns, from a macroeconomic point of view: a co-movement in capital requirements and the business cycle may induce banks to further reduce lending during recessions due to high capital requirement. As mentioned by Daníelsson *et al.* [36], p.15,

> "the riskiness of assets varies over the business cycle. Risk assessments, whether based on credit rating agencies' assessments or internal ratings, reflect this procyclicality - possibly more so in the case of internal ratings, which typically do not attempt to assess risk 'through the cycle'. This procyclicality in ratings will create a similar procyclicality in capital charges, with the implication that banks hold less capital or overlend at the cusp of a cycle - exactly when the danger of a systemic crises is largest - while they will hold too much capital or underlend during the downturn when macroeconomic stabilisation requires an expansion of lending. As a result, regulation not only renders bank crises more likely but could also destabilise the economy as a whole by exaggerating fluctuations."

To further clarify the Basel II procyclicality hypothesis, consider the potential effects of an economic downturn under Basel I and Basel II. Under Basel I, minimum capital requirements are fixed through time, and may become binding when banks' capital declines following the recognition of credit losses. Under Basel II, in turn, capital requirements can become binding, not only because of the former effect (capital decline), but also because existing non-defaulted loans are likely to become significantly riskier: as loans move to higher risk classes, the minimum capital requirement increases. To the extent that it is difficult or costly to raise external capital in bad times, as predicted by many of the theoretical models analyzed in Section 1.2, banks will be forced to cut back on their lending activity, thereby contributing to a worsening of the initial downturn. Consequently, Basel II may lead to a greater financial amplification of the business cycle than Basel I, counteracting capital regulation's goal to foster financial stability.

The Basel II procyclicality hypothesis has recently been subject to some empirical research. Segoviano and Lowe [84], using data on internal ratings from banks operating in Mexico over the second half of the 1990s, analyze how much regulatory capital requirements might move through time under Basel II. Their results indicate that, under the new

[20] See Lowe [65] and Allen and Saunders [3] for a review on the relationship between the measures of credit risk exposure (namely, PD, LGD and EAD) and the macroeconomic conditions.

Basel accord, measured risk is likely to increase in economic downturns and decrease in economic booms. Consequently, the banks' required amount of capital would have risen steeply after the crisis in 1994 and then declined as the economy recovered. This same pattern is likely to be translated into regulatory capital requirements, with the minimum requirements increasing when times are bad and decreasing when times are good.[21] Carling *et al.* [24]'s empirical results, using data from a major Swedish bank for the period of 1994 to 2000, also suggest that the application of the IRB approach would increase the credit risk sensitivity in minimal capital charges and accentuate the procyclical tendencies of banking.

Kashyap and Stein [56] simulate the degree of capital charge cyclicality that would have taken place over the four year interval 1998-2002 - a time period characterized by marked economic slowdowns in both the U.S. and Europe - had the Basel II foundation IRB approach been in use. These simulations, which use data on the U.S., some European countries and the 'Rest of the World', suggest that Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges that may be - depending on a bank's customer mix and the credit-risk models that it uses - quite large.

Altman *et al.* [4] point out that the procyclical effects of Basel II may be even more severe than expected if banks use their own estimates of LGD: low recovery rates when defaults are high will amplify cyclical effects, which will tend to be especially strong under the advanced IRB approach, where banks are free to estimate their own recovery rates and may tend to revise them downward when defaults increase and ratings worsen. The use of long term recovery rates by banks should attenuate this effect, but would also force banks to maintain a less updated picture of their risks, thereby substituting stability for precision, in Altman *et al.*'s words.

Concerning the standardized approach of Basel II, Carpenter *et al.* [27]'s estimates on how risk-weighted C&I loans might have evolved over the last three decades if banks had been using this approach, suggest very little cyclical impact compared to Basel I. That is, the variation in ratings over the business cycle would not have been substantial enough

[21] Note that this work is based on Basel II's proposal released in 2001, and does not take into account the latest version of 2004 which introduced some measures to attenuate the potential procyclical effects of Pillar 1, as we will analyze later on in this section.

to imply much additional cyclicality under the standardized approach of the new accord when compared to Basel I. Recall that, under the standardized approach of Basel II, unrated firms are treated as in Basel I and the risk weights assigned to rated firms are based on ratings of external agencies. Many of those rating agencies follow a *through-the-cycle* approach to compute the default probability over the life of the loan, rating borrowers according to their ability to withstand a recession. One advantage of this approach, according to Segoviano and Lowe [84], is that it makes ratings less sensitive to the business cycle. Amato and Furfine [6], using data on all U.S. firms rated by Standard & Poor's, support this idea showing that a firm's rating, conditional on its underlying financial and business characteristics, does not generally exhibit excess sensitivity to the business cycle.

However, as argued by Carpenter *et al.* [27], while the through-the-cycle approach may create a presumption against changes in ratings over the business cycle, the additional information available during actual downturns may nevertheless induce some cyclical effects. As noted by Pederzoli and Torricelli [72], if actual conditions are worse than the scenario considered by the rating agencies, downgrades are likely to follow. Tanaka [89] also points out that credit ratings derived from the existing through-the-cycle models tend to lag rather than lead business cycles, so that the capital requirements based on external credit ratings are likely to be lax during booms and stringent during recessions. According to Amato and Furfine [6], the difficulty in assessing whether ratings are excessively procyclical is in determining what is an appropriate degree of co-movement between ratings and the cycle. They argue that since most of the studies, which examine ratings behavior over time, perform an analysis unconditional with respect to the specific characteristics of firms, they cannot conclude that ratings are assigned in a procyclical manner, but only that ratings move procyclically. Amato and Furfine's results indicate that the co-movement between through-the-cycle credit ratings and the business cycle is generally driven by cyclical changes to business and financial risks, and not to cycle related changes to rating standards.

An alternative to the through-the-cycle approach, is the *point-in-time* approach, followed by several banking institutions. The point-in-time rating systems assign ratings according to the ability of the borrowers to fulfil obligations over the credit horizon, typically one year, and are likely to be more sensitive to the business cycle than the through-the-cycle approach.

The extent of additional procyclicality associated with the IRB approach of Basel II should thus depend on the nature of the rating system used by banks, as Catarineu-Rabell *et al.* [28]'s empirical study shows. According to this study, if banks use internal ratings close to those of the main rating agencies, which are designed to be relatively stable over the cycle (*e.g.*, Moody's rating system), the increase in capital requirements during a recession is quite small (around 15%). However, if banks choose an approach based on point-in-time rating systems, the increase in capital requirements during a recession will be much more pronounced (around 40% to 50%). As mentioned by Pederzoli and Torricelli [72], the final version of Basel II, released in 2004, implicitly requires a through-the-cycle rating system, by recognizing that banks adopting the IRB approach are required to use a time horizon longer than one year in assigning ratings and to assess ratings according to the "borrower's ability and willingness to contractually perform despite adverse economic conditions or the occurrence of unexpected events" (Basel Committee on Banking Supervision [9], par. 415). However, Repullo and Suarez [82] argue that, although Basel II implicitly requires a through-the-cycle rating system, "industry practices based on point-in-time rating systems, the dynamics of rating migrations, and composition effects make the effective capital charges on a representative loan portfolio very likely to be higher in recessions than in expansions." (Repullo and Suarez [82], p. 1)

The procyclical effects of Basel II may also depend on the view adopted concerning how credit risk evolves through time. According to Lowe [65] and Segoviano and Lowe [84], for instance, one possible view is that the current performance of the economy can be taken as the best guess of its future performance (the *random walk view*). This view leads to risk being measured as low in an expansion and high in a recession, yielding to higher regulatory capital requirements in a downturn than in a boom. An alternative view, pointed out by the same authors, suggests that the forces that drive economic booms often (although not always) sow the seeds of future economic downturns by generating imbalances in both real and financial sectors. Segoviano and Lowe argue that these imbalances increase risk by increasing uncertainty about the financial strength of individual borrowers, by making default probabilities more highly correlated, and by making future collateral values more uncertain. In this context, the increase in defaults during a recession might be thought of as the materialization of risk built up during the boom. That is, this view - the *predictability view* - is consistent with the proposition that risk builds up in the boom but materializes in the downturn, and opens the possibility of measured credit risk being relatively high when times are good.

As mentioned by Pederzoli and Torricelli [72], while the existence and the nature of the relationship between real activity and default rates, as a measure of the materialized risk, are not controversial, the debate is still ongoing regarding the relationship between risk accumulation and the economic conditions. This debate is crucial to assess the potential procyclical effects of Basel II, as the adoption of one of the two views described above will influence the path of the risk-based capital requirements during the business cycle: depending on the view adopted, ratings may decline when economic conditions are depressed or when financial imbalances emerge in good times.

Finally, some authors argue that procyclicality may not be a problem at all. In Dierick *et al.* [40]'s opinion, for instance, although some empirical evidence indicates that capital rules can exacerbate the economic cycle, during the development of the new rules of Basel II various changes were made to accommodate this possibility. Besides, Jordan *et al.* [54] point out that the improved risk-sensitivity under Basel II will encourage banks to recognize and correct capital inadequacies earlier in the cycle, and therefore may prevent the sudden declines in capital adequacy that cause credit crunches. Ayuso *et al.* [7], drawing on a large panel of Spanish banks over the period 1986-2000, find a robustly significant negative relationship between the business cycle and the capital buffers, that is, the excess of current capital over the minimum capital requirements, that Spanish banks held throughout the period. This results comes from the era of Basel I but, according to von Thadden [96], if it carries over the era of Basel II, the current concerns about the procyclicality of the new capital regulation may be exaggerated: if banks build up capital buffers in downturns without being forced to do so by regulation, then the new regulation, that makes part of this build-up mandatory under Pillar 2, may have little effect.[22] Nevertheless, Ayuso *et al.* [7] argue that their result offers some support to the view that some banks may behave in an excessively lax manner during upturns because they do not take properly into account the cyclical nature of output and, therefore, tend to underestimate risks under economic upturns. This should justify a closer monitoring of banks' own resources during good times by supervisors under Pillar 2 of the new Basel Accord. It is also worthwhile to mention that, according to Repullo and Suarez [82]'s theoretical model, the cyclical pattern of the buffers gets reversed in Basel II, relative to Basel I, for precautionary reasons. According to these authors, the capital buffers contribute to dampen, but do not eliminate, the procyclicality of Basel II and it is inaccurate to accept that the cyclical behavior of capital buffers under Basel II can be predicted from the empirical behavior of capital buffers under Basel I: "If buffers are endogenously affected by the prevailing bank capital regulation (even if they appear not to 'bind'), reduced-form extrapolations from the Basel I world to the Basel II world do not resist the Lucas' critique." (Repullo and Suarez [82], p. 25).

In sum, this discussion shows that whether or not Basel II capital requirements will add to the procyclical effects predicted by some of the theoretical models analyzed in Section 1.2, is subject to much debate. Whereas some authors argue that the introduction of the new bank capital requirements rules proposed by Basel II will accentuate the procyclical tendencies of banking, other authors argue that Basel II will contribute to a more stable financial system, and, while it may not attenuate normal swings in the business cycle, it will help avoiding the type of financial crises that occasionally have very large macroeconomic effects.

Counteracting the Likelihood of Procyclical Effects under Basel II

Although the debate on the potential procyclical effects of Basel II is still ongoing, the previous discussion made clear that the likelihood of those effects depends in large part on what else changes with the implementation of risk-based capital requirements

[22] See also Peura and Jokivuolle [76], who, using data on large banks in G10 countries, show that those banks tend to hold considerable buffer capital, and Stolz and Wedow [86], who suggest that bank capital buffers of German banks moved countercyclically during the 1993-2003 period.

under the new Basel Accord. Lowe [65] suggests three factors, which may attenuate the likelihood of the capital requirements procyclical effects under Basel II:

Improvements in credit risk management

The financial system should become less procyclical than in recent decades, if credit risk management, within financial institutions, improves. For instance, as credit quality problems should be recognized earlier in the business cycle, corrective actions can also be taken sooner, and problems can be solved earlier, decreasing the likelihood of financial instability. Besides, and as mentioned before, under Pillar 2, banks are required to follow the through-the-cycle approach analyzed above: in particular, banks are required to evaluate their risk bearing capacity with respect to scenarios which would particularly affect their credit exposures, and to draw on a longer time horizon in their assessment of the borrowers' credit risk under the IRB approach (Dierick *et al.* [40]).

Buffers over regulatory minimum

To avoid the procyclical effect of regulatory capital requirements, supervisors and markets should require, under Basel II, financial institutions to carry large enough capital buffers in good times to enable them to meet the higher requirements when times are not so good. In fact, the supervisor review process, which underlies the second pillar of Basel II, specifies that supervisors should expect banks to operate above the minimum regulatory capital ratios and should have the ability to require banks to hold capital buffers, which should in turn attenuate the potential procyclical effects of the new regulation.

Changes in supervisory practices

Basel II rules recognize that supervisors must assess whether a bank is adequately capitalized, even if it is meeting the Pillar 1 minimum capital requirements, taking into account external factors such as business cycle effects. Pillar 2 also establishes that banks must develop an internal capital adequacy assessment process (ICAAP), which should ensure that banks adequately identify and measure their risks, set adequate internal capital in relation to their risk profile and use sound risk management systems and develop them further. Supervisors are responsible for evaluating banks' ICAAP and for ensuring that the processes for developing those assessments are robust and satisfactory. Additionally, credit quality problems should become evident much earlier, not only because of better credit risk management practices, but also because of broader disclosure under Pillar 3. In this context, supervisors cannot ignore deteriorations in the quality of banks' portfolios, and should help to overcome the problems that arise when banks in very poor condition are allowed to continue operating.

Beyond these three factors, recognized by the last version of Basel II regulation, Gordy and Howells [46] also point out that, if the procyclicality hypothesis is still confirmed, there is room for some corrective measures within the IRB approach, by directly smoothing the output of the capital function. According to these authors, the new regulation addresses the potential procyclical effects essentially by (*i*) smoothing the inputs of the IRB capital function (*e.g.*, adopting through-the-cycle rating methodologies) and (*ii*) flattening the capital function in order to reduce its sensitivity to risk components (see Figure 1.1 above). However, these two solutions, by acting on the risk components or on the measure of potential loss, trigger a loss of transparency, since the calculated required capital does not properly represent actual risk (Pederzoli and Torricelli [72]). In this context, Gordy and Howells [46] show that a third solution - smoothing the IRB output - is less destructive to the information value of the capital ratio across banks and across time, when compared to the first solution, and is more effective in dampening procyclicality, when compared to the second solution. Gordy and Howells explain in the following way how this third solution could be implemented:

> "Let C_{it} denote the unsmoothed output from the IRB capital formula for bank i at time t, expressed as a percentage of portfolio book value, and let $\widehat{C}_{it}$ denote the corresponding regulatory minimum applied to the bank. At present, the New Accord sets $\widehat{C}_{it} = C_{it}$. One simple smoothing rule would specify $\widehat{C}_{it}$ as an autoregressive process that adjusts towards C_{it}, i.e.,
>
> $$\widehat{C}_{i,t} = \widehat{C}_{i,t-1} + \alpha(C_{i,t} - \widehat{C}_{i,t-1}).$$
>
> The current Accord can be represented in stylized fashion as setting $\alpha = 0$, whereas the New Accord sets $\alpha = 1$. An intermediate value of α would offer a compromise between the current Accord and New Accord in sensitivity to the business cycle." (Gordy and Howells [46], p. 397)

Table 1.2 summarizes other measures that have been proposed in the literature in order to dampen the potential procyclical effects of Basel II.

Kashyap and Stein [56] recognize that their corrective measure, by suggesting the reduction of capital requirements in bad times, may be naïve since it will "give regulators an excuse to engage in after-the-fact forbearance, with all the accompanying potential for various forms of regulatory moral hazard." However, these authors also mention that "if it really is the case that capital requirements need to come down, say, in a severe recessions, it is probably better to acknowledge this fact of life up front and to explicitly codify the magnitude of the adjustment. Such ex ante codification will, if anything, tend to reduce regulators' ex post discretion, thereby tempering moral hazard problems." (Kashyap and Stein [56], p. 28)

	Corrective Measure
Kashyap and Stein [55, 56]	Define a family of point-in-time risk curves, with each curve corresponding to different macroeconomic conditions.
Pederzoli and Torricelli [72]	Use the predictability view of the business cycle and a through-the-cycle logic in the rating assignment.
Pennacchi [75]	Combine a risk-based capital requirement with a risk-based deposit insurance: undercapitalized banks are required to partially adjust their capital ratio toward a target standard and pay a higher insurance premium appropriate with the capital ratio they choose.
Cecchetti and Li [29]	Central banks should react to the state of the banking system's balance sheet: the procyclical effect of prudential capital regulation can be counteracted and completely neutralized.

Table 1.2. Some alternative corrective measures to dampen the potential procyclical effects of Basel II

According to Pederzoli and Torricelli [72], Basel II, by requiring banks that adopt the IRB approach to follow a through-the-cycle rating system, may put the objective of increased risk-sensitivity of capital requirements at risk. However, if the business cycle effects are considered in a forward-looking perspective, both objectives - increased risk-sensitivity of capital requirements and business cycle effects neutralization - can be reconciled: the application of Pederzoli and Torricelli's measures to quarterly U.S. data over the forecasting period 1971-2002 show that the time varying capital requirements behave quite well in anticipating the business cycle, increasing (decreasing) in anticipation of recessions (expansions), and with a possible smoothing effect on the business cycle turning points.

Cecchetti and Li [29] suggest that, with the introduction of Basel II, the optimal monetary policy should move interest rates by more when the banking system is capital constrained, thus counteracting the procyclicality of capital regulation. Note, however, that Kishan and Opiela [58]'s results indicate that if Basel II creates more constrained banks during recessions and better capitalized banks during expansions, countercyclical policy may become more difficult: high-capital banks tend not to decrease loans in response to a contractionary monetary policy and, conversely, an expansionary monetary policy seems to have no stimulating effects on the loan growth of the low-capital banks. Therefore, Cecchetti and Li [29]'s proposal would be ineffective. Nonetheless, as Kishan and Opiela [58] also point out, changes introduced by Basel II will result in banks reallocating their capital and, consequently, adjusting the way they organize their balance sheets and the way they react to monetary policy shocks. In this context, it is not clear that the Kishan and Opiela's results are valid under Basel II: once more, extrapolations from the Basel I world to the Basel II world may not resist the Lucas' critique.

1.4 Concluding Remarks

Focusing on the relationship between bank capital requirements and the business cycle, we have brought together the theoretical literature related with the bank capital channel, which is based on the premise that the introduction of bank capital requirements limits banks' ability to supply loans, with the literature on the regulatory framework of capital requirements under the Basel Accords.

Most of the theoretical models analyzed predict that the introduction of bank capital requirements, for market or regulatory reasons, amplifies the effects of monetary and other exogenous shocks. This amplification effect usually rests on the argument that raising new capital can be difficult and costly for many banks, especially during economic downturns, thereby increasing the financing cost faced by firms that borrow from those banks. If firms are restricted to banks as sources of credit, this increase in the financing cost tends to affect negatively firms' investment and output.

In this context, the introduction of Basel II, whose implementation has started in January 2007, raised some concerns, by establishing that the amount of capital that a bank has to hold in its balance sheet depends on the riskiness of its portfolio. In particular, under Basel II, if the credit risk of banks' exposures increases during a recession, the risk weights used to compute capital requirements and, consequently, the minimum bank capital requirements will also increase. To the extent that it is difficult or costly to raise external capital in bad times, banks will be forced to cut back on their lending activity, thereby contributing to a worsening of the initial downturn. Consequently, Basel II may lead to a greater financial amplification of the business cycle than Basel I, counteracting capital regulation's goal to foster financial stability.

Our analysis shows that the existence and the strength of this amplification effect is still subject of much debate, and that additional measures, some of them already contemplated in the last version of the Basel II Accord, can be implemented to counteract this effect. In short, the procyclical effects of Basel II will depend on how the minimum capital requirements will react over the business cycle, which, in turn, will depend (*i*) on banks' customer portfolios, (*ii*) on the approach adopted by banks to compute their minimum capital requirements - the standardized or the IRB approach -, (*iii*) on the nature of the rating system used by banks - through-the-cycle or point-in-time rating systems -, (*iv*) on the view adopted concerning how credit risk evolves through time - the random walk or the predictability view, (*v*) on the capital buffers over the regulatory minimum held by the banking institutions, and (*vi*) on the market and supervisor intervention under Pillar 2 and 3.

In sum, this discussion shows that several theoretical studies predict that the introduction of capital requirements, that limits banks' ability to supply loans, accentuates the procyclical tendencies of banking, leading to amplified macroeconomic effects of monetary and other exogenous shocks (the bank capital channel). However, whether or not Basel II capital requirements will add to this amplification effect is still subject to much debate. Whereas some authors argue that the introduction the new bank capital requirements rules proposed by Basel II will accentuate this effect, by imposing countercyclical minimum capital requirements, other authors argue that Basel II will contribute to a more stable financial system, and, while it may not attenuate normal swings in the business cycle, it will help avoiding the type of financial crises that occasionally have very large macroeconomic effects. In fact, our analysis has not focused on questions such as whether bank regulation is itself optimal and what type of regulation is more appropriate to avoid financial crises. By bringing together the theoretical literature on the bank capital channel with the literature on the procyclical effects of Basel II, we tried instead to shed some light on how the introduction of the new banking system regulatory framework may potentially strengthen the propagation of exogenous shocks to the economy and, consequently, amplify business cycle fluctuations.

Chapter 2

Business Cycle and Bank Capital: Monetary Policy Transmission under the Basel Accords

2.1 Introduction

The precise mechanisms through which monetary policy affects real activity are not completely clarified. Some recent literature explores the possible explanation of monetary policy effects through financial imperfections. This essay fits in this line of research by centering its attention on how microeconomic structures, such as the bank funding structure and the relationship between the bank and the borrower, interact with macroeconomic business conditions. In particular, we contribute to clarify the role of bank capital and its regulatory environment in lending conditions and, consequently, in the transmission of monetary policy and in business cycle fluctuations.

An additional motivation lies in current changes in the regulatory environment. In fact, the study of bank capital - business cycle interactions is quite up to date, both at the academic and institutional level, due to the implications of the changeover from Basel I to Basel II bank capital requirements rules, whose implementation have begun in January 2007.[23]

[23] The relevant regulatory framework is determined by Basel I and Basel II, the Basel Accords of 1988 and 2004, respectively, detailed in Basel Committee on Banking Supervision [8, 9].

The existence of empirical evidence that the bank funding structure, or, more specifically, the bank capital, affects its supply of loans and, consequently, real activity, has motivated our modelization of the banking relationships in the context of a dynamic general equilibrium model.

First, one strand of this empirical literature indicates that lending growth after a monetary policy shock depends on the level of bank capital: using U.S. data from 1980 to 1995, Kishan and Opiela [57] predict that poorly capitalized banks experience more significant declines in their lending, following monetary contractions. Their results are in line with Van den Heuvel [93]'s, who, also using U.S. data, from 1969 until 1995, shows that the real effects of monetary policy are stronger when banks have low capital relative to the existing bank capital requirements: when a U.S. state's banking sector starts out with a low capital-asset ratio, subsequent output growth in that state is more sensitive to changes in the Federal funds rate and other indicators of monetary policy. After the implementation of Basel I and FDICIA (the Federal Deposit Insurance Corporation Improvement Act of 1991) in the U.S., the loan response by banks to monetary policy appears to be asymmetric, according to Kishan and Opiela [58]: a contractionary monetary policy decreases the loans of the small low-capital banks relative to high-capital banks, and an expansionary monetary policy is not able to increase the loan growth of the low-capital banks relative to the high-capital banks. Also in this line of research, Hubbard *et al.* [51] find that, even after controlling for information costs and borrower risk, the cost of borrowing from low-capital banks is higher than the cost of borrowing from well-capitalized banks; that is, capital positions of individual banks affect the interest rate at which their clients borrow.

Second, as mentioned by Van den Heuvel [92], the importance of bank capital on lending has increased since the implementation of Basel I, which, by imposing risk-based capital requirements, limits the ability of banks with a shortage of capital to supply loans. There is a considerable number of papers that test the hypothesis of a "credit crunch" - a significant leftward shift in the supply curve for bank loans - that may have occurred in the U.S. during the early 90s, simultaneously with the implementation of the new banking system regulation established by the Basel Accord. The idea behind those studies is that, given the common perception that bank capital is more costly than alternative funding sources (such as deposits), regulatory capital requirements can have real effects: in order to satisfy those requirements, banks may choose to reduce loans and, in such an event, some otherwise worthy borrowers cannot obtain them. The allocation of credit away from loans can, in turn, cause a significant reduction in macroeconomic activity, given that many borrowers cannot easily obtain substitute sources of funding in public markets. On this credit crunch literature, see, for instance, Bernanke and Lown [18], Peek and Rosengren [73, 74], and Sharpe [85] for a review.

Some studies in this literature are, however, quite skeptical about the role of the credit crunch in worsening the 1990 recession in the U.S. (*e.g.*, Bernanke and Lown [18]): they suggest that demand factors, including the weakened state of borrowers' balance sheet, were instead the major cause of the lending slowdown. In contrast, Peek and Rosengren [74], for instance, focusing on the strong downward pressure on capital positions of Japanese banks with branches in the U.S., identified an independent loan supply disruption and argued that this shock had substantial effects on real economic activity in the U.S.

This controversy illustrates one of the major difficulties of this type of analysis: it is hard to distinguish between movements in loan demand and movements in loan supply, especially because, as mentioned by Van den Heuvel [93], there is no interest rate summarizing the effective cost of financing, since this cost depends not only on the contractual interest rate, but also on collateral requirements, the extent of rationing, and other contractual features. Therefore, although there is some evidence that bank capital affects bank lending and, consequently, real activity, these studies are not completely successful in distinguishing shifts in loan demand from shifts in loan supply, leaving the question of the relative importance of different effects unanswered.

Our model contributes to evaluate the relative importance of these loan supply and demand effects, by bringing together, in a dynamic general equilibrium model, the borrowers' balance sheet channel developed by Bernanke *et al.* [17], with an additional channel working through bank capital, which also amplifies the real effects of exogenous nominal and real shocks. That is, taking the Bernanke *et al.*'s dynamic general equilibrium model as a starting point, we add banks that, due to the imposition of regulatory capital requirements, face financial frictions when raising funds.

This debate on the role of bank capital in business cycle fluctuations is quite relevant in the context of current implementation of Basel II. As detailed in Chapter 1, one of the central changes proposed by the new Basel Accord is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank must hold is determined, not only by the institutional nature of its borrowers (as in Basel I), but also by the riskiness of each particular borrower. Specifically, an increase in the credit risk of a given asset should lead to an increase in the amount of capital that a bank must hold against it. This has raised some concerns about the potential procyclical effects of Basel II: during a recession, for instance, if non-defaulted loans are considered riskier, banks will be required to hold more capital, or further reduce lending, thus exacerbating the economic downturn.

Theoretically, our model has been decisively motivated by Bernanke *et al.* [17]'s suggestion, in their concluding remarks, to introduce the specific role of banks in cyclical fluctuations. Although excluding some bank activities, for simplicity, our model explicitly assumes the role of banks in financing two entities in financial deficit (the public sector and nonfinancial firms) using the funds of households (the entity in financial surplus). We assume that banks are constrained by a risk-based capital ratio requirement according to which the ratio of bank capital to nonfinancial loans cannot fall below a regulatory minimum exogenously set. Banks are, thus, limited in their lending to nonfinancial firms by the amount of bank capital that households are willing to hold. Taking into account that bank capital is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion), we explore the additional channel through which the effects of exogenous shocks on real activity are amplified - the bank capital channel. The model is then extended in order to evaluate the impact of the bank capital channel under Basel I *versus* Basel II, thus aiming to shed additional light on the debate about the potential procyclical effects of Basel II.

Our work relates to the theoretical literature analyzed in Chapter 1 (Section 1.2), by accounting for the interactions between bank capital and macroeconomic conditions. We assume that banks issue capital to satisfy regulatory capital requirements (as Berka and Zimmermann [13], and Bolton and Freixas [21]) and that households' preferences for liquidity matter for banks' funding structure. By doing this, our model yields a liquidity premium effect on the external finance premium faced by firms, a mechanism through which bank capital affects the transmission of monetary policy to the real economy.[24] According to our results, this additional mechanism is responsible for a significant amplification of the immediate effects of a monetary policy shock, the more significant the closer the regulatory rules are to Basel II, rather than to Basel I.

This essay is organized as follows. After this introduction, Section 2.2 develops and calibrates a dynamic general equilibrium model, with particular attention to the banking relationships with entrepreneurs and households. Section 2.3 simulates a monetary policy shock under several variants of the model, in order to analyze the role of bank capital in the monetary policy transmission mechanism and the relative importance of demand and supply-of-loans effects. Section 2.4 extends the baseline model to evaluate and compare the magnitude of the demand and supply-of-loans effects under Basel I and Basel II. Conclusions are outlined in Section 2.5.

2.2 A Model with Bank Capital

In order to analyze the role of bank capital in the transmission mechanism of monetary policy, and, thus, in business cycle fluctuations, we develop a dynamic general equilibrium model, assuming five types of agents in the economy:

- Households, who work, consume and allocate their savings to bank deposits and bank capital;
- Entrepreneurs, who need external (bank) finance to buy capital, which is used in combination with hired labor to produce wholesale output;
- Banks, which, using the funds of households, finance and monitor (*ex post*) the entrepre-

[24] Our meaning of the bank capital channel, thus, differs from Van den Heuvel [92]'s, in which households and liquidity preferences and, thus, the liquidity premium effect, are absent.

neurs;

- Retailers, added in order to incorporate inertia in price setting;
- Government, which conducts both monetary and fiscal policy and regulates banks.

2.2.1 Entrepreneurs

The analysis of entrepreneurs' behavior follows closely the model of Bernanke, Gertler and Gilchrist [17], BGG hereafter.

In each period each entrepreneur buys the entire capital stock for his firm in order to, in combination with labor, produce output in the next period. More specifically, at time t, entrepreneur j purchases homogeneous capital for use at $t+1$, K_{t+1}^{j}. The return to capital is sensitive to both aggregate and idiosyncratic risk. The *ex post* gross return on capital for firm j is $\omega_{t+1}^{j}R_{t+1}^{K}$, where ω_{t+1}^{j} is an idiosyncratic disturbance to firms j's return and R_{t+1}^{K} is the *ex post* aggregate return to capital. The random variable ω^{j} is independently and identically distributed (i.i.d.) across time and across firms, with a continuous and once-differentiable cumulative distribution function (c.d.f.), $F(\omega)$, over a non-negative support, and $E\left(\omega^{j}\right)=1$.

At the end of period t, entrepreneur j has available net worth N_{t+1}^{j} which he uses to finance the acquisition of K_{t+1}^{j}. To finance the difference between his capital expenditures and his net worth, he must borrow an amount $L_{t+1}^{j}=Q_{t}K_{t+1}^{j}-N_{t+1}^{j}$, where Q_{t} represents the price paid per unit of capital at time t. Each entrepreneur then borrows from a financial intermediary (bank) which imposes a required return on lending between t and $t+1$, R_{t+1}^{F}. This relationship embodies an asymmetric information problem between each entrepreneur and the bank: only the entrepreneur observes costlessly the return of his project. The financial contract established between these two agents is, then, designed to minimize the expected agency costs. That is, as in BGG, we assume a costly state verification (CSV) problem, in which the bank must pay a monitoring cost in order to observe an individual borrower's realized return. This monitoring cost is assumed to equal a proportion μ of the realized gross payoff of the firm's capital:

$$\mu\omega_{t+1}^{j}R_{t+1}^{K}Q_{t}K_{t+1}^{j},$$

where $0<\mu<1$. The idiosyncratic disturbance ω_{t+1}^{j} is unknown to both the entrepreneur and the bank prior to the investment decision. That is, $Q_{t}K_{t+1}^{j}$and L_{t+1}^{j} are chosen prior to the realization of the idiosyncratic shock. After the investment decision is made, the bank can only observe ω_{t+1}^{j} by paying the monitoring cost.

Given $Q_{t}K_{t+1}^{j}$, L_{t+1}^{j} and R_{t+1}^{K}, the optimal contract is characterized by a gross non-default loan rate, Z_{t+1}^{j}, and a cutoff value $\overline{\omega}_{t+1}^{j}$, such that, if $\omega_{t+1}^{j}\geqslant\overline{\omega}_{t+1}^{j}$, the borrower pays the lender the amount $\overline{\omega}_{t+1}^{j}R_{t+1}^{K}Q_{t}K_{t+1}^{j}$ and keeps the remaining:

$$\left(\omega_{t+1}^{j}-\overline{\omega}_{t+1}^{j}\right)R_{t+1}^{K}Q_{t}K_{t+1}^{j}.$$

That is, $\overline{\omega}_{t+1}^{j}$ is defined by

$$\overline{\omega}_{t+1}^{j}R_{t+1}^{K}Q_{t}K_{t+1}^{j}=Z_{t+1}^{j}L_{t+1}^{j}. \tag{2.1}$$

If $\omega_{t+1}^{j}<\overline{\omega}_{t+1}^{j}$, the borrower receives nothing, while the bank monitors the borrower and receives $(1-\mu)\omega_{t+1}^{j}R_{t+1}^{K}Q_{t}K_{t+1}^{j}$.

In equilibrium, the contract guarantees the lender an expected gross return on the loan equal to the required return R_{t+1}^{F} (taken as given in the contracting problem). That is,

$$\begin{aligned}&\left[1-F(\overline{\omega}_{t+1}^{j})\right]Z_{t+1}^{j}L_{t+1}^{j}+(1-\mu)\int_{0}^{\overline{\omega}_{t+1}^{j}}\omega_{t+1}^{j}R_{t+1}^{K}Q_{t}K_{t+1}^{j}f(\omega)d\omega=\\=\;&R_{t+1}^{F}(Q_{t}K_{t+1}^{j}-N_{t+1}^{j}),\end{aligned} \tag{2.2}$$

where $f(\omega)$ is the probability density function (p.d.f.) of ω.

Combining equation (2.1) with equation (2.2) yields the following expression:

$$\left\{ \left[1 - F(\overline{\omega}^j_{t+1})\right] \overline{\omega}^j_{t+1} + (1-\mu) \int_0^{\overline{\omega}^j_{t+1}} \omega^j_{t+1} f(\omega) d\omega \right\} R^K_{t+1} Q_t K^j_{t+1} =$$
$$= \; R^F_{t+1}(Q_t K^j_{t+1} - N^j_{t+1}). \tag{2.3}$$

As shown by BGG, the bank's expected return reaches a maximum at an unique interior value of $\overline{\omega}^j_{t+1}$, $\overline{\omega}^{j^*}_{t+1}$, and equilibrium is characterized by $\overline{\omega}^j_{t+1}$ always below $\overline{\omega}^{j^*}_{t+1}$. Therefore, the hypothesis of an equilibrium with credit rationing is ruled out and the bank's expected return is always increasing in $\overline{\omega}^j_{t+1}$.

With aggregate uncertainty present, $\overline{\omega}^j_{t+1}$ depends on the *ex post* realization of R^K_{t+1}: conditional on the *ex post* realization of R^K_{t+1}, the borrower offers a state-contingent non-default payment that guarantees the lender a return equal in expected value to the required return R^F_{t+1}. Thus, condition (2.3) implies a set of restrictions, one for each realization of R^K_{t+1}.

The optimal contracting problem determines the division, between the borrower j and the bank, of the expected gross payoff to the firm's capital, $E_t\left(R^K_{t+1}\right) Q_t K^j_{t+1}$, where E_t denotes the expectation operator conditional on the information available at time t. The optimal contract results from the maximization of borrower's payoff, with respect to K^j_{t+1} and $\overline{\omega}^j_{t+1}$, subject to the set of state-contingent constraints implied by (2.3).

Let l_{t+1} represent $\frac{E_t\left(R^K_{t+1}\right)}{R^F_{t+1}}$, the expected discounted return to capital. Given $l_{t+1} > 1$, the first order conditions of the contracting problem yield the following relationship between $\frac{Q_t K^j_{t+1}}{N^j_{t+1}}$ and the expected discounted return to capital (see BGG for details):

$$\frac{Q_t K^j_{t+1}}{N^j_{t+1}} = \varphi\left(\frac{E_t\left(R^K_{t+1}\right)}{R^F_{t+1}}\right),$$

where $\varphi'(.) > 0$ and $\varphi(1) = 1$. Therefore, each borrower's capital expenditures are proportional to his net worth, with a proportionality factor that is increasing in the expected discounted return to capital. As mentioned by BGG, everything else equal, a rise in the expected discounted return to capital reduces the expected default probability. As a consequence, the entrepreneur can borrow more and expand the size of his firm. Since the expected default costs also increase as the ratio of borrowing to net worth increases, the entrepreneur cannot expand the size of his firm indefinitely.

Aggregating the preceding equation over firms we obtain[25]

$$\frac{Q_t K_{t+1}}{N_{t+1}} = \varphi \left(\frac{E_t \left(R^K_{t+1} \right)}{R^F_{t+1}} \right), \tag{2.4}$$

where K_{t+1} denotes the aggregate amount of capital purchased by all entrepreneurs at time t, and N_{t+1} the aggregate net worth of those agents.

Equivalently, equation (2.4) can be expressed as

$$\frac{E_t \left(R^K_{t+1} \right)}{R^F_{t+1}} = l \left(\frac{Q_t K_{t+1}}{N_{t+1}} \right), \tag{2.5}$$

where $l(.)$ is increasing in $\frac{Q_t K_{t+1}}{N_{t+1}}$ for $N_{t+1} < Q_t K_{t+1}$. Thus, in equilibrium, the expected discounted return to capital, $\frac{E_t\left(R^K_{t+1}\right)}{R^F_{t+1}}$, depends negatively on the share of the firms' capital expenditures that is financed by the entrepreneurs' net worth. As argued by Walentin [97], $l\left(\frac{Q_t K_{t+1}}{N_{t+1}}\right) R^F_{t+1}$ should be interpreted as the return on capital required by banks, in order to grant loans to the firms. Therefore, in an environment where entrepreneurs must borrow, under imperfect information, to buy capital, the expected discounted return to capital, $\frac{E_t\left(R^K_{t+1}\right)}{R^F_{t+1}}$, may be interpreted as an opportunity cost of being an entrepreneur, or, as in BGG's acceptation, as the *external finance premium* faced by entrepreneurs.

Entrepreneurial Net Worth

The net worth of entrepreneurs combines profits accumulated from previous capital investment with income from supplying labor. As a technical matter, it is necessary to start entrepreneurs off with some net worth in order to allow them to begin operations: as in BGG, we assume that, in addition to operating firms, entrepreneurs supplement their

[25] As mentioned by BGG, the assumption of constant returns to scale generates a proportional relationship between net worth and the capital demand at the firm level, with a factor of proportionality independent of firm's specific factors. This facilitates aggregation.

income by working. It is also assumed that the fraction of agents who are entrepreneurs remains constant.

Let V_t be the entrepreneurs' total equity (*i.e.*, wealth accumulated by entrepreneurs from operating firms). Then, normalizing the total entrepreneurial labor to one,

$$N_{t+1} = \gamma V_t + W_t^e, \tag{2.6}$$

where W_t^e is the entrepreneurial wage and γ is the probability that a entrepreneur survives to the next period. To avoid the possibility that entrepreneurs accumulate enough net worth to be fully self financed, it is assumed that those agents have finite horizons. The fraction of agents who are entrepreneurs is held constant by the birth of a new entrepreneur for each dying one.

Note that V_t can be expressed, in equilibrium, as

$$V_t = R_t^K Q_{t-1} K_t - R_t^F (Q_{t-1} K_t - N_t) - \mu \Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t, \tag{2.7}$$

where $\mu \Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t$ are the aggregate default monitoring costs with

$$\Theta(\overline{\omega}_t) \equiv \int_0^{\overline{\omega}_t} \omega_t^j f(\omega) d\omega.$$

Thus, combining equations (2.6) and (2.7), it is straightforward to conclude that N_{t+1} reflects the equity stake that entrepreneurs have in their firms, which in turn depends on firms' earnings net of interest payments to financial intermediaries.

Entrepreneurs who "die" in t are not allowed to buy capital and simply consume their residual equity $(1-\gamma)V_t$. That is,

$$C_t^e = (1-\gamma) V_t, \tag{2.8}$$

where C_t^e represents the total consumption of entrepreneurs who leave the market.

2.2.2 Banks

Financial intermediation, consisting of collecting funds from households and granting loans to entrepreneurs, is assured by banks. In this respect we depart from BGG by properly defining the financial intermediaries as banks and, consequently, specifying their behavior.

Banks are not subject to reserve requirements (for simplicity), but are legally subject to a risk-based regulatory capital requirement. In particular, banks must hold an amount of equity that covers at least a given percentage of loans, exogenously set by the regulator. We assume that only banks issue equity (as in Bolton and Freixas [21], for instance), on terms that depend on demand, *i.e.*, on households' willingness to hold capital in addition to deposits. Banks' assets comprise, not only loans to firms, but also government bonds, which have zero weight in the risk-based capital requirement since they bear no risk.

Another specificity of banks is the technology needed to monitor entrepreneurs. Since households do not have access to this technology, they delegate monitoring to banks, which undertake the costly state verification defined above. In this framework, each bank does not have any bargaining power in the relationship with the borrowing firm - the contract specifies the maximization of borrower's payoff subject to the constraint that the expected return to the bank covers only its opportunity cost of funds. In other words, we are assuming a competitive banking system (as in Berka and Zimmermann [13], for instance) with unrestricted entry, where each bank earns zero profits, in equilibrium.

In this context, we will now analyze the behavior of a representative bank which maximizes its expected profits, acting as a price (interest rate) taker in a competitive market. Its choice variables are loans, riskless government bonds, deposits and capital. Beside the capital requirements, we will also assume that the bank must buy deposit insurance. More specifically, the bank is subject to an insurance rate on deposits which depends negatively on the level of bank capital.[26]

[26] It should be noted, however, that we maintain BGG's hypothesis (for comparative purposes), in which lenders, by avoiding both idiosyncratic and aggregate risks, do not default. By holding a diversified portfolio of loans, banks guarantee idiosyncratic risk diversification. The aggregate risk that could be associated to deposits, is passed on to the entrepreneurs. As for bank capital, its risk is borne by the representative household which owns stocks on the bank. Bolton and Freixas [21], in a similar context of regulatory capital requirements, also consider perfectly diversified banks, which do not go bankrupt.

Finally, in line with the contract established between the representative bank and each entrepreneur, we assume that all bank's assets and liabilities have the same, one period, maturity.

Following Berka and Zimmermann [13]'s specification of deposit insurance cost, the bank's objective is then given by:

$$\max_{L_{t+1},B_{t+1},D_{t+1},S_{t+1}} \left(R^F_{t+1} L_{t+1} + R_{t+1} B_{t+1} - R^D_{t+1} D_{t+1} - E_t \left(R^S_{t+1} \right) S_{t+1} - \delta_e \frac{D_{t+1}}{S_{t+1}} D_{t+1} \right)$$

s.t.

$$L_{t+1} + B_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \tag{2.9}$$

$$\frac{S_{t+1}}{L_{t+1}} \geq \alpha_e \text{ (capital requirements)} \tag{2.10}$$

with $1 > \alpha_e > 0$ and $1 > \delta_e > 0$, and where

- L_{t+1} are the real loans granted to all firms from t to $t+1$;
- B_{t+1} are the real government bonds held by the bank from t to $t+1$;
- D_{t+1} are the real households' deposits;
- S_{t+1} is the real bank's capital;
- R^F_{t+1} is the required gross real return on loans between t and $t+1$;
- R_{t+1} is the gross real return on government bonds (B_{t+1});
- R^D_{t+1} is the gross real return on deposits (D_{t+1});
- $E_t \left(R^S_{t+1} \right)$ is the expected real return on bank capital (S_{t+1});
- $\delta_e \frac{D_{t+1}}{S_{t+1}}$ is the deposit insurance rate;
- α_e is the imposed level of capital requirements.

Note that R^F_{t+1} differs from the non-default lending rate (Z_{t+1}): as has been derived above (see equation 2.2), the difference between the two is due to the possibility of entrepreneur's default and to the existence of monitoring cost, which are taken into account in R^F_{t+1}. The rate of return on bank capital, R^S_{t+1}, is conditional on the realization of date $t+1$ state of nature whereas all the other rates of return are not (R^F_{t+1}, R_{t+1} and R^D_{t+1} are known in t).

The first order conditions of the interior solution (that is, the solution characterized by positive values of B_{t+1}, D_{t+1}, L_{t+1} and S_{t+1}) of this problem yield

$$\begin{aligned} R_{t+1} &= R^D_{t+1} + 2\delta_e \left(\frac{D_{t+1}}{S_{t+1}}\right), && (2.11) \\ R^F_{t+1} &= (1-\alpha_e)R_{t+1} + \alpha_e E_t\left(R^S_{t+1}\right) - \alpha_e\delta_e\left(\frac{D_{t+1}}{S_{t+1}}\right)^2, && (2.12) \end{aligned}$$

which satisfy the bank's zero profit condition. These two equations were obtained considering binding capital requirements, that is,

$$\frac{S_{t+1}}{L_{t+1}} = \alpha_e,$$

which, as we show below, proves indeed to be the case for reasonable values of the parameters.

Due to the introduction of binding capital requirements, the required return on lending, R^F_{t+1}, becomes dependent on a weighted average of the deposit return and the equity's expected return, whereas in BGG, R^F_{t+1} is equal to the riskless rate, R^D_{t+1}.

2.2.3 Households

The economy is composed of a continuum of infinitely lived identical risk averse households of length unity. Each household works, consumes, and invests its savings in assets which include deposits, that pay a real riskless rate of return between t and $t+1$ of R^D_{t+1}, and (risky) shares of ownership of banks in the economy, that pay R^S_{t+1}.

For simplicity, we assume a representative household's instantaneous utility function separable in consumption, liquidity (in the form of deposits) and leisure:

$$U_t = \frac{C_t^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{D_{t+1}{}^{1-\beta_0}}{1-\beta_0} + \alpha_1 \frac{(1-H_t^h)^{1-\beta_1}}{1-\beta_1},$$

where C_t denotes household real consumption, D_{t+1} the deposits (in real terms) held by the household from t to $t+1$ and H_t^h the household hours worked (as a fraction of total time endowment).

The real level of deposits is included in the instantaneous utility function to indicate the existence of liquidity services from wealth held in the form of that asset. That is, despite yielding a gross return of R^D, deposits also serve transaction needs since currency is absent from our model: we assume that deposits can be used in an almost money like fashion to simplify a variety of transactions. In short, we are assuming that, when compared to bank capital, deposits have an advantage in terms of liquidity, similarly to Poterba and Rotemberg [77] and, more recently, Van den Heuvel [94].

The representative household chooses consumption, leisure and portfolio to maximize the expected lifetime utility (appropriately discounted) subject to an intertemporal budget constraint that reflects intertemporal allocation possibilities. The household's problem is then given by

$$\max_{C_t, H_t^h, D_{t+1}, S_{t+1}} E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{(D_{t+k+1})^{1-\beta_0}}{1-\beta_0} + \alpha_1 \frac{(1-H_{t+k}^h)^{1-\beta_1}}{1-\beta_1} \right]$$
$$\text{s.t. } C_t = W_t^h H_t^h - T_t + \Pi_t + R_t^D D_t - D_{t+1} + R_t^S S_t - S_{t+1}, \tag{2.13}$$

where $0 < \beta < 1$ is the subjective discount factor, W_t^h is the real wage, T_t represents lump sum taxes, Π_t dividends received from ownership of imperfect competitive retail firms, and S_t the real bank capital held by the household from $t-1$ to t.

The first order conditions of (2.13) are the following three:

$$(C_t)^{-\sigma} = \beta R_{t+1}^D E_t \left[(C_{t+1})^{-\sigma} \right] + \alpha_0 D_{t+1}{}^{-\beta_0}, \tag{2.14}$$

which takes into account that the gross real rate of return on deposits, R_{t+1}^D, is certain at time t (is known ahead of time);

$$(C_t)^{-\sigma} = \beta \left\{ E_t \left(R^S_{t+1} \right) E_t \left[(C_{t+1})^{-\sigma} \right] + cov_t \left(R^S_{t+1}, (C_{t+1})^{-\sigma} \right) \right\}; \tag{2.15}$$

and the labor supply

$$\alpha_1 (1 - H^h_t)^{-\beta_1} = (C_t)^{-\sigma} W^h_t. \tag{2.16}$$

In this representation, the expected excess return on the risky asset (bank capital) is linked both to the risk and liquidity premium, since it depends, on the one hand, on the covariance between the aggregate consumption and bank capital's return and, on the other hand, on deposits liquidity.

2.2.4 Return on Bank Capital

Before proceeding we can now specify the return on bank capital. The bank capital requirement constraint establishes that the representative bank must issue an amount of capital which covers α_e times the value of loans. Loans are thus financed by bank capital and deposits, and households, in turn, allocate their savings to those two financial assets. A spread between the expected real return on bank capital and the real return on deposits is, then, justified by the liquidity services provided by deposits and by the riskless return on this asset, *i.e.*, $E_t(R^S_{t+1}) - R^D_{t+1} > 0$.

In addition, we assume that the expected real returns of bank capital and physical capital are equal:

$$E_t(R^S_{t+1}) = E_t(R^K_{t+1}). \tag{2.17}$$

Although physical capital is totally held by the entrepreneurs, if households could hold it, they would demand the same expected return on both physical and bank capital: since both returns are subject to the same aggregate risk and neither bank capital nor physical capital provide liquidity services to the household, equation (2.17) would correspond to the no-arbitrage condition.

2.2.5 General Equilibrium

Now, following the modeling strategy of BGG, we embed the solution of the partial equilibrium contracting problem within a dynamic new Keynesian general equilibrium model, also taking into account the results obtained in the household and the bank optimization problems.

As mentioned above, in each period t each entrepreneur j acquires physical capital, K_{t+1}^{j}, which is used in combination with hired labor to produce output in period $t+1$. Following BGG, we specify each entrepreneur's investment decisions, under adjustment costs, assuming that each entrepreneur j purchases the capital goods from some other competitive firms, producers of capital. More specifically, each entrepreneur sells his entire stock of capital at the end of each period t to the capital producing firms at price $\overline{Q}_t$. These firms also purchase raw output as an input, I_t (total investment expenditures), and combine it with the aggregate capital stock in the economy (K_t) to produce new capital goods via the production function $\Xi\left(\frac{I_t}{K_t}\right)K_t$, where $\Xi\left(.\right)$ is an increasing and concave function, with $\Xi\left(0\right)=0$. The function $\Xi\left(.\right)$ is concave in investment to capture the difficulty of quickly changing the level of capital installed in the firms (and is thus called the adjustment cost function). The new capital goods, jointly with the capital used to produce them, are then sold to each entrepreneur j at the price Q_t.[27]

In this context, the aggregate capital stock follows an intertemporal accumulation equation with external adjustment costs,

$$K_{t+1}=\Xi\left(\frac{I_t}{K_t}\right)K_t+(1-\delta)K_t, \tag{2.18}$$

where δ denotes the depreciation rate. The introduction of adjustment costs permits variation in the price of a unit of capital in terms of the numeraire good, Q_t, which, derived from the first order condition for investment for one of the capital producer firms mentioned above, is given by

[27] We ignore the "rental rate" $\left(\overline{Q}_t-Q_t\right)$, since in steady state $\overline{Q}=Q=1$ and around the steady state the difference between $\overline{Q}_t$ and Q_t is second order.

$$Q_t = \frac{1}{\Xi'\left(\frac{I_t}{K_t}\right)}, \tag{2.19}$$

The price of capital is, thus, an increasing function of the quantity invested.

Aggregate Production Function

The physical capital acquired at period t by each entrepreneur is then combined with labor to produce output in period $t+1$, by means of a constant returns to scale technology. This allows us to write the production function as an aggregate relationship:

$$Y_t = A_t K_t^{\alpha} H_t^{1-\alpha} \tag{2.20}$$

with $0 < \alpha < 1$ and where Y_t represents the aggregate output of wholesale goods, H_t the labor input and A_t an exogenous technology term.

The final output may then be either transformed into a single type of consumption good, invested, consumed by the government (G_t) or used in monitoring costs:

$$Y_t = C_t + C_t^e + I_t + G_t + \mu\Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t. \tag{2.21}$$

Entrepreneurs sell the output to retailers at a relative price of $\frac{1}{X_t}$, where X_t is the gross markup of retail goods over wholesale goods. Therefore, the expected gross return to holding a unit of capital from t to $t+1$ can be written as:

$$E_t\left(R_{t+1}^K\right) = E_t\left[\frac{\frac{1}{X_{t+1}}\alpha\frac{Y_{t+1}}{K_{t+1}} + Q_{t+1}(1-\delta)}{Q_t}\right], \tag{2.22}$$

where $\frac{1}{X_{t+1}}\alpha\frac{Y_{t+1}}{K_{t+1}}$ represents the rent paid to a unit of capital in $t+1$.

In turn, as already mentioned, the supply of investment capital is described by the return on physical capital the (representative) bank requires in order to grant loans to the firms (see equation 2.5 on page 44).

Concerning the labor input, it is assumed that $H_t = \left(H_t^h\right)^{\Omega} (H_t^e)^{1-\Omega}$, with $1 < \Omega < 0$, and where H_t^h represents the households labor, and H_t^e the entrepreneurial labor. Therefore, we can rewrite (2.20) as

$$Y_t = A_t K_t^{\alpha} \left[\left(H_t^h\right)^{\Omega} (H_t^e)^{1-\Omega}\right]^{1-\alpha}. \tag{2.23}$$

Equating marginal product with the wage, for each case, we obtain:

$$W_{t+1}^h = (1-\alpha)\Omega \frac{1}{X_{t+1}} \frac{Y_{t+1}}{H_{t+1}^h} \tag{2.24}$$

$$W_{t+1}^e = (1-\alpha)(1-\Omega) \frac{1}{X_{t+1}} \frac{Y_{t+1}}{H_{t+1}^e} \tag{2.25}$$

where W_{t+1}^h represents the real wage for households labor and W_{t+1}^e the real wage for entrepreneurial labor. As mentioned, and following BGG, we assume that entrepreneurs supply one unit of labor inelastically to the general labor market: $H_t^e = 1, \forall t$.

Now, taking into account equations (2.7), (2.20) and (2.25), we can rewrite (2.6) as

$$\begin{aligned} N_{t+1} = {} & \gamma \left[R_t^K Q_{t-1} K_t - R_t^F (Q_{t-1} K_t - N_t) - \mu \Theta(\overline{\omega}_t) R_t^K Q_{t-1} K_t\right] + \\ & + (1-\alpha)(1-\Omega) \frac{1}{X_t} A_t K_t^{\alpha} (H_t^h)^{\Omega(1-\alpha)}. \end{aligned} \tag{2.26}$$

The Retail Sector and Price Setting

To increase the empirical relevance of the model concerning price inertia, we introduce sticky prices in it using standard devices used in new-Keynesian research. Namely, we incorporate monopolistic competition and costs of adjusting nominal prices by distinguishing between entrepreneurs and retailers (since assuming that entrepreneurs are imperfect competitors would complicate aggregation): entrepreneurs produce wholesale goods in competitive markets, and then sell their output to retailers who are monopolistic competitors. Retailers do nothing other than buy goods from entrepreneurs, differentiate them (costlessly), and then resell them to households. They are included only in order to introduce price inertia in a tractable manner: following Calvo [23], it is assumed that the retailer is free to change its price in a given period only with probability $1 - \theta$ (with $0 < \theta < 1$). The profits from retail activity are rebated lump-sum to households (Π_t in the household's intertemporal budget constraint).[28]

Government

Government comprises the monetary, fiscal and regulatory authorities. We assume that conflicts between policies are internalized within the agent government, since we do not aim at exploring those differences.

Public expenditures, G_t, are financed by lump-sum taxes, T_t, and by issuing securities (government bonds, B_{t+1}):

$$G_t = B_{t+1} - B_t R_t + T_t + J_t,$$

where J_t represents other costs and revenues and includes the deposit insurance premium paid by the banks to the regulatory authority. In particular, the government adjusts the mix of financing between bonds issuance and lump-sum taxes to support an interest rate monetary policy rule, to be defined below. To implement its choice of the nominal interest rate, the government adjusts the supply of government bonds to satisfy the bank's demand for this asset.

2.2.6 The Linearized Model and Calibration

According to the model just described, and in the absence of exogenous shocks, the economy converges to a steady state growth path, along which all variables are constant over time (including prices, which implies a zero inflation rate in steady state).

To linearize the preceding equations, we use a first order Taylor series expansion around the steady state. Let the lower case letters denote the percentage deviation of each

[28] Detailed derivation, not presented here since it is standard in new Keynesian framework, is available upon request.

variable from its steady state level: $x_t = \ln\left(\frac{X_t}{X}\right)$, where X, without the time subscript, is the value of X_t in nonstochastic steady state.

The complete log-linearized model is provided in the appendix. Here we focus on the main equations necessary to clarify the results and discussion in the following sections.

Aggregate Demand

The aggregate demand is defined by equations (2.5), (2.8), (2.14), (2.15), (2.19), (2.21) and (2.22). The household's Euler equations (2.14) and (2.15) can be written in log-linear form as (assuming that $\sigma = \beta_0$):[29]

$$-\sigma c_t = -\sigma\beta R^D E_t\left(c_{t+1}\right) + \beta R^D r^D_{t+1} - \alpha_0\sigma\left(\frac{C}{D}\right)^{\sigma} d_{t+1}, \tag{2.27}$$

$$-\sigma c_t = -\sigma\beta R^K E_t\left(c_{t+1}\right) + \beta R^K E_t\left(r^K_{t+1}\right). \tag{2.28}$$

Recall that we assume that $E_t(R^S_{t+1}) = E_t(R^K_{t+1})$, as argued above.

In what concerns the relationship between the external finance premium and the ratio of capital expenditures to net worth, equation (2.5) - p. 44 - becomes, in the log-linearized version of the model,

$$E_t(r^K_{t+1}) - r^F_{t+1} = v(k_{t+1} + q_t - n_{t+1}), \tag{2.29}$$

where v is the steady state elasticity of $\frac{E_t(R^K_{t+1})}{R^F_{t+1}}$ with respect to $\frac{Q_t K_{t+1}}{N_{t+1}}$.

[29] We take a first-order Taylor approximation around the steady state ignoring the second order terms (or assuming that they are constant over time: $cov_t(.) = cov(.), \forall t$). Thus, the difference between $E_t\left(r^K_{t+1}\right)$ and r^D_{t+1} rests solely on liquidity.

Representative Bank

Equations (2.11), p. 48, and (2.12), p. 48, derived from the first order conditions of the bank's profit maximization problem, can be written in log-linear form as:

$$r_{t+1} = \frac{R^D}{R} r^D_{t+1} + \frac{2\delta_e \frac{D}{S}}{R}(d_{t+1} - s_{t+1}) \tag{2.30}$$

$$r^F_{t+1} = \alpha_e \frac{R^K}{R^F} E_t\left(r^K_{t+1}\right) + (1-\alpha_e)\frac{R}{R^F} r_{t+1} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F}(d_{t+1} - s_{t+1}). \tag{2.31}$$

The capital requirement constraint $S_{t+1} = \alpha_e(Q_t K_{t+1} - N_{t+1})$, turns into:

$$s_{t+1} = \frac{K}{L}\left(k_{t+1} + q_t\right) - \frac{N}{L} n_{t+1}. \tag{2.32}$$

Aggregate Supply and State Variables

The aggregate supply is defined by the aggregate production function (2.23), the labor market clearing condition - taking into account both equations (2.16) and (2.24) - and the Phillips curve (or the price adjustment equation) derived from the optimal price setting by the retail sector.

The transition for the two state variables, capital and net worth, is described by equations (2.18) and (2.26), respectively.

The log-linearized version of these equations is provided in the appendix.

Monetary Policy Rule

The interest rate rule is given by

$$r^n_{t+1} = \rho r^n_t + \varsigma \pi_{t-1} + \varepsilon^{r^n}_t \tag{2.33}$$

where $r^n_{t+1} \equiv r_{t+1} + E_t \pi_{t+1}$ is the nominal interest rate from t to $t+1$ (with $\pi_{t+1} \equiv p_{t+1} - p_t$) and $\varepsilon^{r^n}_t$ an i.i.d. disturbance at time t. As in BGG, we standardly assume that the current nominal interest rate responds to the lagged inflation rate and the lagged interest rate.

Calibration

We calibrate the model assuming that a period is a quarter. To evaluate the parameters and steady state (SS) variables common to the BGG's model, we followed these authors, focusing on U.S. data. See Table 2.2 in the appendix for details.

Other parameters and SS variables are specific to our model, namely, the ratio of loans to deposits in SS, the bank capital requirement and the deposit insurance costs parameters (α_e and δ_e, respectively) and the preference parameter, β_0.

To compute the SS ratio of loans to deposits, $\frac{L}{D}$, we use data on commercial and industrial (C&I) loans made by all U.S. commercial banks - provided by the Survey of Terms of Business Lending that is published by the Federal Reserve[30] - and data on the total loans and deposits at all U.S. commercial banks - available at the Federal Reserve Bank of St. Louis.[31]

To calibrate the deposit insurance parameter (δ_e) we followed Berka and Zimmermann [13]'s procedure, using U.S. data as of December 2006, from the Federal Deposit Insurance Corporation (FDIC).

Concerning the bank capital requirement, we set α_e equal to 0.08 based on the rules established by the Basel Accords - see Basel Committee on Banking Supervision [8, 9].

Finally, in calibrating the preference parameters, we assume, for simplicity, that $\sigma = \beta_0$. By that, we only need to compute the deposit to consumption ratio in steady state $\left(\frac{D}{C}\right)$ to solve the model, instead of defining both variables, C and D, separately. And, as in many business cycle models, including BGG, σ is set equal to 1 (log preferences).

For further details on the model's calibration see the appendix.

After log-linearizing the model, we applied the computational procedure used for solving linear rational expectations models developed by McCallum [67].

[30] Available at http://www.federalreserve.gov/releases/e2/.
[31] See http://research.stlouisfed.org/fred2/.

2.3 The Bank Capital Channel at Work

In order to analyze the role of bank capital in the transmission of monetary policy and, thus, in business cycle fluctuations, we present now some quantitative experiments focusing on the economy response to an unanticipated temporary negative monetary policy shock.

Concerning the channels through which monetary policy affects real activity, our model, derived above, brings together *(i)* the standard interest rate channel of monetary policy transmission - according to which an unanticipated increase in the nominal interest rate depresses the demand for physical capital, which, in turn, reduces investment and the price of capital; *(ii)* the borrowers' balance sheet channel; and *(iii)* the bank capital channel.

The borrowers' balance sheet channel predicts that the decline in asset prices (physical capital price in our model), due to a contractionary monetary policy, decreases borrowers' net worth, raising the external finance premium and, consequently, forcing down investment. This, in turn, will reduce asset prices and borrowers' net worth, further pushing down investment, and thus giving rise to the financial accelerator effect, which amplifies the impact of the monetary shock on borrowers' spending decisions. Finally, the bank capital channel, in contrast with the borrowers' balance sheet channel, works through the supply of funds side and is related to the introduction of the specific role of banks in cyclical fluctuations, as implied by our model.

2.3.1 Simulating the Amplification Effects of a Monetary Policy Shock

To analyze the bank capital channel, we begin by comparing the effects of a negative innovation in the nominal interest rate (which corresponds to an annual increase of 25 basis points) under three distinct hypotheses:

- Variant 1: Baseline model derived previously, assuming a risk-based capital ratio requirement of 8%;
- Variant 2: Model without capital requirements, *i.e.*, excluding the capital requirement con-

straint from the baseline model (equation 2.10);

- Variant 3: Model with no capital requirements nor financial accelerator, which is generated by fixing the external finance premium, in variant 2, at its steady state level. That is, under variant 3, the capital requirement constraint is absent from the model, and both the bank and each entrepreneur observe costlessly the return of the firm's project. This amounts to setting the parameter v, in the financial accelerator equation (2.29), to zero, since in the absence of capital market frictions the external finance premium should not respond to changes in the ratio of capital expenditures to net worth.

Figures 2.1 and 2.2 illustrate the impulse response functions of the relevant variables under these three variants (variant 1: solid line; variant 2: dashed line; and variant 3: dashed-dotted line), using the calibrated model economy with each period equivalent to a quarter and the variables expressed as percentage deviations from steady state values.

The increase in the nominal interest rate triggers an immediate decline in output, investment and consumption below their steady state values, after which the economy returns gradually to its steady state. As predicted by the Phillips curve in a sticky prices context, inflation also decreases in response to the output decline, and then gradually reverts to its stationary value. Inflation behavior, in turn, influences the nominal interest rate through the monetary policy rule - the monetary authority sets the nominal interest rate in response to lagged inflation and lagged nominal interest rate.

Figure 2.2 depicts the financial sector variables response. As in BGG, the external finance premium evolves countercyclically, increasing in response to the deterioration of entrepreneurs' financial position following the decline in assets prices. In fact, the financial accelerator effect of monetary policy (the borrowers' balance sheet channel), arising from the loan demand side and embedded within equation (2.29), is present in both variants 1 and 2. In line with the analysis in 2.2.1, above, this demand effect is based on the prediction that the external finance premium facing a borrower depends on the borrower's financial position - the greater the borrower's self-financing ratio is, the lower the external finance premium should be. Intuitively, a stronger financial position diminishes the expected monitoring costs that arise from the informational asymmetry between each entrepreneur and the bank.

However, it is notable that the impact of the monetary policy shock is stronger in the presence of capital requirements (that is, stronger in variant 1 than in variant 2). This amplification effect can be explained through the analysis of bank and household behavior, as follows.

Combining the log-linearized equations (2.30) and (2.31) which have been derived from the representative bank's profit maximization problem, it is straightforward to derive the following condition:

$$\begin{aligned} E_t(r^K_{t+1}) - r^F_{t+1} &= \left(1 - \alpha_e \frac{R^K}{R^F}\right) E_t(r^K_{t+1}) - (1-\alpha_e)\frac{R^D}{R^F} r^D_{t+1} - \\ &- \left[(1-\alpha_e)\frac{2\delta_e \frac{D}{S}}{R^F} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F}\right](d_{t+1} - s_{t+1}). \quad (2.34) \end{aligned}$$

Taking into account the steady state conditions and the calibration of the model, we conclude that $\left(1 - \alpha_e \frac{R^K}{R^F}\right) \simeq (1-\alpha_e)\frac{R^D}{R^F}$. More specifically, the difference between these two coefficients relies on the magnitude of the deposit insurance costs: when $\delta_e = 0.0000045$ and $\alpha_e = 0.08$, these coefficients take the values 0.9194 and 0.9193, respectively. Therefore, equation (2.34) may be rewritten as

$$\begin{aligned} E_t(r^K_{t+1}) - r^F_{t+1} &\simeq \left(1 - \alpha_e \frac{R^K}{R^F}\right) \left[E_t(r^K_{t+1}) - r^D_{t+1}\right] + \\ &+ \left[\frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F} - (1-\alpha_e)\frac{2\delta_e \frac{D}{S}}{R^F}\right](d_{t+1} - s_{t+1}). \quad (2.35) \end{aligned}$$

According to this expression, the external finance premium, $E_t(r^K_{t+1}) - r^F_{t+1}$, depends positively on $E_t(r^K_{t+1}) - r^D_{t+1}$, which we will refer to as the liquidity premium.[32] The external finance premium also depends on the deposit-bank capital ratio, $d_{t+1} - s_{t+1}$, through the deposit insurance costs, but this effect is relatively small and vanishes when

[32]Note that, since we use a first-order Taylor approximation around the steady state (ignoring the second order terms) to linearize the model, $E_t(r^K_{t+1}) - r^D_{t+1}$ is not the equity premium, defined as the extra return required by risk averse households to compensate for the covariance between equity returns and the stochastic discount factor. Instead, it reflects the liquidity advantage of deposits over bank capital, properly called liquidity premium.

we set δ_e equal to zero.[33] Therefore, we focus our attention now on the relationship between the liquidity premium and the external finance premium.

As illustrated in Figure 2.2, a contractionary monetary policy shock leads to an increase in the level of capital issued by the bank (s_{t+1}) in variant 1. This happens for two reasons: *(i)* the level of commercial and industrial (both uncollateralized) loans also increases - although entrepreneurs invest less $[\swarrow (Q_t K_{t+1})]$, the sharp decrease in their net worth $(\swarrow\swarrow N_{t+1})$ leads to an increase of $L_{t+1}(= Q_t K_{t+1} - N_{t+1})$ above its steady state level;[34] and *(ii)* as bank capital requirements are binding in variant 1, the bank may only grant more credit if it issues more capital. To hold more bank capital during the recession, households in turn require an increase in the liquidity premium, $E_t(r^K_{t+1}) - r^D_{t+1}$, since they must reduce the amount of deposits to attenuate the decline in consumption (in line with Gorton and Winton [47]'s model, for instance).

To clarify this last effect recall the log-linearized Euler equations (2.27) and (2.28) derived in Section 2.2. Combining these two equations, with the calibrated $\sigma = 1$, yields

$$\beta R^K E_t\left(r^K_{t+1}\right) - \beta R^D r^D_{t+1} = \left(R^K - R^D\right)\beta E_t\left(c_{t+1}\right) - \alpha_0 \frac{C}{D} d_{t+1} \tag{2.36}$$

where $\alpha_0 \frac{C}{D} > 0$, which confirms that the liquidity premium required by the households depends negatively on deposits (d_{t+1}).

In sum, after the contractionary monetary policy shock in variant 1, the level of loans can only increase above its steady state level if the bank issues more capital (due to the binding capital requirements). Households in turn require an increase in the liquidity premium to hold more bank capital and less deposits - note that, as illustrated in Figure 2.2, the liquidity premium under variant 1 increases with a simultaneous decrease in deposits' level and in the deposit-bank capital ratio. The larger the increase in the liquidity premium the larger will be the increase in the external finance premium (see equation 2.35):

[33] For example, in variant 1, the immediate change in deposit-bank capital ratio [second term on the right hand side of (2.35)] accounts for less than 1% of the change in the external finance premium. The absence of a significant impact is confirmed in an exercise, in the context of sensitivity analysis not reported here, where we compare different levels of capital requirements: choosing $\delta_e = 0.0000045$ (variant 1) or $\delta_e = 0$ leaves almost unchanged the impact of a decrease in α_e from 8% to 4%.

[34] See Gertler and Gilchrist [44] and Den Haan *et al.* [37] for some evidence on the increase of commercial and industrial loans after a contractionary monetary policy.

$$\swarrow d_{t+1} \Longrightarrow \nearrow \left[E_t(r^K_{t+1}) - r^D_{t+1}\right] \Longrightarrow \nearrow \left[E_t(r^K_{t+1}) - r^F_{t+1}\right].$$

The bank's balance sheet equilibrium is guaranteed by a reduction in bonds held by the bank.

We call the relationship between deposits and the external finance premium (through the liquidity premium), the *liquidity premium effect*. This effect is strictly related to the financial accelerator effect. That is, in variant 1 of the model, the external finance premium increases not only because the net worth of firms decreases (due to the decline in asset prices), but also because the liquidity premium required by the households increases (a cost that is passed on to firms):

$$\begin{array}{llcccc} \text{(A)} & \text{Liquidity Premium Effect:} & \Delta^- D & \Longrightarrow & \Delta^+ \frac{E_t R^K_{t+1}}{R^D_{t+1}} & \Longrightarrow \\ \text{(B)} & \text{Financial Accelerator Effect:} & \Delta^- Q & \Longrightarrow & \Delta^- \frac{N_{t+1}}{Q_t K_{t+1}} & \Longrightarrow \end{array} \quad \Delta^+ \frac{E_t R^K_{t+1}}{R^F_{t+1}}.$$

Comparing variants 1 and 2 further clarifies the liquidity premium effect. Although the variant 2 of the model assumes no regulatory capital requirements, the bank still issues some capital due to the deposit insurance rate, which depends negatively on the level of bank capital: in steady state, for instance, the bank sets an equity-loan ratio of 3.2%, approximately. However, and in contrast with variant 1, the negative monetary shock in variant 2 leads to a decrease in bank capital, since banks are no longer forced to issue equity to finance a given percentage of loans. As illustrated in Figure 2.2, after the negative shock both deposits and bank capital decrease in variant 2 (the increase in loans is compensated again by a decrease in bonds held by the bank), and the deposit-bank capital ratio increases (in contrast with variant 1).

Even though $d_{t+1} - s_{t+1}$ increases, in variant 2, the liquidity premium required by the households still rises after the shock, although less than in variant 1. This can again be explained through the analysis of equation (2.36) above, according to which the liquidity premium required by the households depends negatively on d_{t+1}. In variant 2, households reduce the amount of bank capital held after the shock, and, consequently, reduce the level of deposits to a smaller extent than in variant 1. Therefore, the increase in the liquidity premium is smaller than in variant 1, as predicted by equation (2.36). This, in turn, implies a smaller increase in the external finance premium through effect (A) above, reducing the effects of the exogenous shock on investment and output (see Figure 2.1).

We may then conclude that the introduction of regulatory capital requirements - in a model with bank capital, but where banks were not constrained by those requirements - amplifies the effects of monetary policy on real activity through the liquidity premium effect. Other experiments conducted by us, but not reported here, assuming different levels of risk-based capital requirements (α_e), show that the same conclusion applies to an exogenous increase in capital requirements imposed by the authorities (increase in α_e).

Finally, variant 3 excludes both the liquidity premium and the financial accelerator effects. As Figures 2.1 and 2.2 show, there are considerable differences between variants 1 and 2, on the one hand, and variant 3, on the other. The effects of a monetary policy shock are much weaker in variant 3. Concerning, for instance, the immediate effect on real output and inflation, output decreases 1.44% in variant 1 and only 0.52% in variant 3, while inflation decreases 0.52% and 0.18% in variants 1 and 3, respectively.[35]

BGG predict that the financial accelerator amplifies monetary shocks by about 50% (in terms of real output response). According to Quadrini [78], in his comment to Carlstrom and Fuerst [26], 50% is still relatively small: "Based on this result, it is hard to claim that financial frictions are the main mechanism through which monetary shocks get propagated in the economy. If we eliminate financial market frictions, the impact of monetary shocks will be reduced only by one third." (p. 31) Our model responds to this insufficiency. If we eliminate financial market frictions, that is, if we compare variant 3 with variants 1 and 2, the impact of the monetary shock is reduced by much more than one third: 63.63% and 56.84% from variants 1 and 2, respectively, to variant 3.

2.3.2 Decomposing the Amplification Effects

To confirm and then explain this discrepancy in the magnitude of results, we compare, in Figure 2.3, the effects of the negative innovation in the nominal interest rate under

[35]This difference in inflation response justifies the contrast in nominal interest rate behavior following the initial shock, shown in Figure 2.1.

variants 1, 3 and a BGG variant, that is, a variant derived as our baseline model but treating the bank as the financial intermediary in BGG's model, thus excluding bank capital and eliminating deposits from households' utility function.[36]

Variant 1 includes both the financial accelerator and the liquidity premium effects, variant BGG only comprises the financial accelerator effect and variant 3 excludes both effects (the external finance premium does not depart from its steady state value). Or, in other words, variant 1 comprises the effects arising from the loan demand side (due to the informational asymmetry between each entrepreneur and the bank, which gives rise to the financial accelerator effect) and the effects arising from the loan supply side (due to the presence of bank capital in the model, which gives rise to the liquidity premium effect); variant BGG, in turn, only comprises loan demand effects and variant 3 excludes both effects.

As illustrated in Figure 2.3, the real effects of monetary policy are in fact much stronger in variant 1 than in variant BGG: concerning real output, once more, whereas it initially decreases 1.44% in variant 1, it only decreases 0.685% in variant BGG. In other words, whereas the introduction of an informational asymmetry between each entrepreneur and the bank amplifies monetary shocks by about 30% in our model (variant BGG *vs* variant 3), the introduction of that same information asymmetry jointly with the imposition of bank capital minimum levels (through a deposit insurance rate and capital requirements) amplifies monetary shocks by significantly more than 100% (variant 1 *vs* variant 3).[37]

In variant 1 the external finance premium set by the bank must not only compensate the bank for the costs of mitigating incentive problems due to informational asymmetries (as in variant BGG), but also the return required by the households to hold bank capital. That is, the external finance premium, in variant 1, is not only influenced by the self financing ratio, $\frac{N_{t+1}}{Q_t K_{t+1}}$, but also by the liquidity premium required by the households,

[36] Although in BGG's original model, real money balances are included in the utility function, the results are similar to those obtained under the BGG variant: under interest rate targeting, money in the utility function yields a money demand equation, which "simply determines the path of the nominal money stock. To implement its choice of the nominal interest rate, the central bank adjusts the money stock to satisfy this equation." (Bernanke *et al.* [17], p. 1364).

[37] The behavior of the nominal interest rate after the initial period is, once more, justified by the response of inflation, which is much stronger in variant 1 than in variants 3 and BGG.

$\frac{E_t R^K_{t+1}}{R^D_{t+1}}$. Since the liquidity premium required by the households is countercyclical in variant 1 (see Figure 2.2), due to deposits response, the countercyclical movement in the external finance premium is exacerbated (see Figure 2.3: the external finance premium initially increases 0.066% in variant 1 *vs* 0.036% in variant BGG). This explains why real effects are much stronger in variant 1 than in variant BGG.

In sum, the amplification effects are much stronger in variant 1 (as well as in variant 2) than in variant BGG. The reason is summarized in Table 2.1: in addition to the borrowers' balance sheet channel of monetary policy transmission (also included in variant BGG), variants 1 and 2 comprise the *bank capital channel*, which, through the liquidity premium effect, further amplifies the monetary policy shock effects. In turn, the amplifying effects are somewhat stronger in variant 1 than in 2, since in variant 1 banks must issue more capital to comply with the binding capital requirements.

	Standard interest rate channel	Borrowers' balance sheet channel	Bank capital channel
		(amplifiers of monetary policy effects)	
Variant 1	✓	✓	✓
Variant 2	✓	✓	✓
Variant 3	✓		
Variant BGG	✓	✓	

Table 2.1. Monetary policy transmission channels

Our result of a much more powerful propagation than in BGG's model, is in line with Kocherlakota [60]'s argument - credit constraints can help to explain the properties of output fluctuations in the U.S., including the large movements in aggregate output. According to this author, these large movements cannot be explained by large shocks (those "are hard to find in the data," p. 3), but by mechanisms which transform "small, barely detectable, shocks to some or all parts of the economy into large, persistent, asymmetric movements in aggregate output."

As for persistence over time of the effects of the monetary policy shock, using the half-life (from the initial impact) criterion, as in Carlstrom and Fuerst [26], none of the amplification channels generate higher persistence: the output response, for instance, reaches half life between the second and the third quarters in variants 1, 2, 3 and BGG.

2.3.3 Confirming that Capital Requirements are Binding

As the results of our model rely on the assumption of binding capital requirements, we show now that, for reasonable values of the parameters, capital requirements are in fact binding in our model. In the absence of deposit insurance, this is straightforward to show: with no regulatory capital requirements nor deposit insurance, banks clearly prefer to finance loans with deposits, since, due to the liquidity premium, $R_{t+1}^{D} < E_t\left(R_{t+1}^{S}\right)$, that is, deposits are less expensive than bank capital. Therefore, there is no reason for banks to hold bank capital and, consequently, $S_{t+1} = 0$. If the capital requirement constraint is introduced, then banks should optimally set S_{t+1} at its minimum regulatory level.

When deposit insurance costs are introduced, the outcome depends on the value assumed for the deposit insurance costs parameter, δ_e, which enters the bank's profit function. In the absence of capital requirements and considering the calibrated value of δ_e (0.0000045, associated with an adequately capitalized bank belonging to the subgroup A, as defined by FDIC for the soundest financial institutions, as of December 2006), bank issues bank capital, in steady state, such that $S = 0.0317L$. That is, bank capital is set below the regulatory level. We also verify that bank capital remains always well below its minimum regulatory level, in the absence of regulatory capital requirements, when one of the following exogenous shocks is simulated: a contractionary or an expansionary monetary policy shock,[38] an expansionary or contractionary government expenditure shock, and an expansionary or contractionary technology shock. Therefore, when the regulatory capital constraint is introduced it will be binding: $S_{t+1} = 0.08L_{t+1}$.

Other experiments conducted by us, but not reported here, show that by considering binding capital requirements our model rules out the analysis of unsound financial institutions, as banks belonging to the subgroup C as defined by the FDIC, which consists of institutions that pose a substantial probability of loss to the deposit insurance fund, and, thus, face a higher δ_e. Excluding this hypothesis seems reasonable, in the context of our model, since a bank of type C will most probably face additional restrictions when issuing new capital, restrictions which we do not take into account.

[38] Corresponding, respectively, to an annual increase or decrease in the nominal interest rate of 25 basis points.

In addition, we have also performed the following sensitivity and robustness checks:

- Introducing a permanent technology shock and a temporary shock to government expenditures, as defined in the appendix;
- Removing the adjustment costs in the production of capital (which leads to a constant price of capital);
- Considering internal habit formation in consumption and modifying investment adjustment costs, making them directly dependent on changes in investment, as in Christiano *et al.* [32].

The results obtained indicate that the bank capital channel remains at work in all of the above experiments: the liquidity premium effect amplifies the effects of the exogenous shock considered. Besides, combining habit formation in consumption with Christiano *et al.*'s investment adjustment costs, generates more empirically consistent hump-shaped responses of investment, consumption and, consequently, output, to a negative innovation in the nominal interest rate.

2.4 The Liquidity Premium Amplification Effect: Basel I *vs* Basel II

The bank capital regulation framework of Basel I, established banks' obligation to continually meet a risk-based capital requirement. In short, under Basel I, each bank must maintain a total risk weighted capital ratio, defined as the ratio of bank capital to the bank's risk-weighted assets, of at least 8%. The weights for assets on the balance sheet depend, in turn, on the institutional nature of the borrower. For example, a zero weight is assigned to a government security issued in the OECD, meaning that the bank can finance such asset through deposits without adding any capital. Other three weights are permitted, all meant to reflect credit risk: 0.2 (*e.g.*, for interbank loans in OECD countries), 0.5 (*e.g.*, for loans fully secured by mortgages on residential property) and 1 (*e.g.*, for industrial and commercial loans).[39]

[39] See Basel Committee on Banking Supervision [8], for a detailed description of the rules introduced by Basel I, and Dewatripont and Tirole [38], for a short review.

As the same risk weight applies to all loans of each category ('one size fits all' approach), Basel I rules do not reflect the risk that each particular borrower poses to the bank. This has created the incentive for arbitrage activities: by moving low-risk instruments off balance sheet and retain only relatively high-risk instruments, banks were able to increase the risk to which they were exposed without increasing the amount of regulatory capital.

According to Jones [53], from a regulatory perspective, capital arbitrage has undermined the effectiveness of Basel I. At least for large banks, capital ratios under this framework are no longer reliable measures of capital adequacy: although for most banking organizations, neither public financial reports nor regulatory reports disclose sufficient information to measure the full extent of a bank's capital arbitrage activities, available evidence suggests that the volume of this type of activities is large and growing rapidly, especially among the largest banks. Furthermore, recent innovation in financial markets is making capital arbitrage more accessible to a much broader range of banks than in the past.

Basel II, aiming to further foster stability in the international banking system, addresses these shortcomings. One of the core changes proposed by Basel II is the increased sensitivity of a bank's capital requirement to the risk of its assets: the amount of capital that a bank has to hold against a given exposure becomes a function of the estimated credit risk of that exposure. Consequently, the constant risk weight of 100% for commercial and industrial (C&I) loans, for instance, is replaced by a variable weight, so that the C&I loans with a low credit rating and a high probability of default are thus assigned a high risk weight. That is, under Basel II, the risk weights used to compute banks' capital requirements are determined both by the category of borrower and by the riskiness of a particular borrower, thereby aiming to reduce regulatory capital arbitrage.[40]

The introduction of the new bank capital requirements rules may however accentuate the procyclical tendencies of banking, with potential macroeconomic consequences, as the countercyclical risk weights used to compute capital requirements may exacerbate the procyclical fluctuations in bank lending. Under Basel II, the co-movement of capital

[40] See Basel Committee on Banking Supervision [9] for details.

requirements and the business cycle could induce banks to further reduce lending during recessions due to high capital requirements.

The baseline model developed in Section 2.2 can be extended to compare the role of bank capital in the business cycle under Basel I *versus* Basel II. In fact, on the one hand, the capital requirements on that baseline version can be interpreted as a simplified Basel I rule: banks must hold an amount of equity of at least 8% of the amount of C&I loans, so that the same risk weight (100%) always applies to these loans, while government bonds, bearing no risk, have zero weight. On the other hand, by introducing, in the capital requirements constraint, risk weights that vary over the business cycle, the model can be extended in order to shed light on the potential procyclicality of Basel II. We proceed now in this direction.

Under Basel II rules, the risk weights in the capital requirements constraint depend on the estimated credit risk of each exposure. In our model, firms default on the loan if the idiosyncratic disturbance, ω^j_{t+1}, turns out to be smaller than the cutoff value $\overline{\omega}^j_{t+1}$. This cutoff value, in turn, depends positively on the ratio of capital expenditures to net worth, $\left(\frac{Q_t K^j_{t+1}}{N^j_{t+1}}\right)$, which, for simplicity, we refer to as the leverage ratio.[41] Therefore, the risk weights in the capital requirements constraint become a positive function of the leverage ratio.

Note that the optimal financial contract established between the bank and each entrepreneur yields a common cutoff value, $\overline{\omega}_{t+1}$, for all entrepreneurs. Combining equations (2.3) and (2.4) yields

$$\left\{\left[1 - F(\overline{\omega}^j_{t+1})\right]\overline{\omega}^j_{t+1} + (1-\mu)\int_0^{\overline{\omega}^j_{t+1}} \omega^j_{t+1} f(\omega)d\omega\right\} R^K_{t+1}\varphi\left(\frac{E_t(R^K_{t+1})}{R^F_{t+1}}\right) = $$
$$= R^F_{t+1}\left[\varphi\left(\frac{E_t(R^K_{t+1})}{R^F_{t+1}}\right) - 1\right].$$

The right hand side of the former equation is the same for all firms (it does not depend on j). Concerning the left hand side, it is straightforward to show that, for an interior solution

[41] Intuitively, everything else equal, higher leverage means higher exposure, implying a higher probability of default, which the bank translates into a higher cutoff value. The formal proof, similar to the one in BBG's Appendix A, is available upon request.

of $\overline{\omega}_{t+1}$, it is increasing in $\overline{\omega}^j_{t+1}$(formal proof available upon request). Therefore, there exists only one $\overline{\omega}^j_{t+1}$ that satisfies the former equation: $\overline{\omega}^j_{t+1} = \overline{\omega}_{t+1}, \forall j$. The intuition is that, facing a common discounted return, $\frac{E_t(R^K_{t+1})}{R^F_{t+1}}$, producers choose the same leverage ratio, leading to a common cutoff value; larger firms, rather than benefiting from lower interest rates, have, instead, access to larger amounts of credit.

Yet, the common cutoff value and, consequently, the credit risk, vary with the business cycle. This allows straightaway the analysis of the business cycle properties of Basel II, insulated from the effects of credit risk heterogeneity across firms.

According to the Internal Ratings Based (IRB) approach of Basel II, the estimated credit risk and, consequently, the risk weights used to compute capital requirements, are assumed to be a function of four parameters associated with each loan: the probability of default (PD), the loss given default (LGD), the exposure at default (EAD) and the loan's maturity (M). Banks adopting the advanced variant of the IRB approach are responsible for calculating all four of these parameters themselves, using their own internal rating models. Banks adopting the foundation variant of the IRB approach are only responsible for calculating the PD parameter, while the other three parameters are to be set by the regulatory authorities. As in Basel I, the ratio of bank capital to the risk-weighted assets must be at least 8%. The risk-weighted assets are, in turn, computed as follows.

1 The capital requirement for corporate exposures, under the assumption of one-year maturity, is given by[42]

$$CR = LGD \times \Phi\left[(1-\tau)^{-0.5} \times \ \Phi^{-1}(PD) + \left(\frac{\tau}{1-\tau}\right)^{0.5} \Phi^{-1}(0.999)\right] - PD \times LGD,$$

where $\Phi(.)$ denotes the cumulative distribution function for a standard normal random variable and τ represents the asset-value correlation which parameterizes dependence across borrowers and is assumed to be a decreasing function of the PD:

$$\tau = \frac{0.12 \times \ (1 - \exp(-50 \times PD))}{1 - \exp(-50)} + 0.24\left[1 - \frac{(1 - \exp(-50 \times PD))}{1 - \exp(-50)}\right].$$

2 According to the foundation variant of the IRB approach, the LGD is set to 0.45 to all corporate exposures. Basel II also establishes that the expected losses $PD \times LGD$ should

[42] See Basel Committee on Banking Supervision [9], paragraph 272, for details.

be covered with loss general provision. From the perspective of our work, provisions are treated as bank capital. Therefore, the capital requirement becomes

$$CR = 0.45 \times \Phi \left[(1-\tau)^{-0.5} \times \ \Phi^{-1}(PD) + \left(\frac{\tau}{1-\tau} \right)^{0.5} \Phi^{-1}(0.999) \right].$$

3 The risk-weighted assets are then given by $CR \times 12.5 \times EAD$.

Since all firms in our model have the same leverage ratio and, thus, the same probability of default (the same cutoff value $\overline{\omega}$), they are all assigned the same CR . The bank capital requirement constraint can thus be defined as

$$\frac{S_{t+1}}{CR_{t+1} \times 12.5 \times L_{t+1}} \geq 0.08 \Longleftrightarrow \frac{S_{t+1}}{CR^*_{t+1} \times L_{t+1}} \geq 0.08,$$

where L_{t+1} are the loans granted by the bank to all firms from t to $t+1$, S_{t+1} is the bank's capital and $CR^*_{t+1} = CR_{t+1} \times 12.5$.

By keeping track of how CR^* evolves over the business cycle, our model is able to give some insight into procyclicality of Basel II.

Note that under the foundation variant of the IRB approach of Basel II, CR^*_{t+1} only varies with PD_{t+1}. As mentioned, the probability of default on each loan in our model, $prob(\omega^j_{t+1} < \overline{\omega}_{t+1})$, depends positively on the cutoff value $\overline{\omega}_{t+1}$, which, in turn, depends positively on firm's leverage ratio, $\frac{Q_t K_{t+1}}{N_{t+1}}$. In sum, the higher the leverage ratio, the higher the probability of default, that is, the higher the credit risk. The optimal financial contract established between the bank and each entrepreneur can thus be used to derive a positive relationship between CR^*_{t+1} and $\frac{Q_t K_{t+1}}{N_{t+1}}$ as reported in Figure 2.6.

According to our simulations, this relationship can be approximated by the linear function

$$CR^*_{t+1} = a + b \frac{Q_t K_{t+1}}{N_{t+1}},$$

with $a = -1.6474$ and $b = 1.2371$. Consequently, the capital requirements constraint in the bank's objective, under Basel II, becomes:

$$\frac{S_{t+1}}{L_{t+1}} \geq 0.08\left(a + b\frac{Q_t K_{t+1}}{N_{t+1}}\right). \tag{2.37}$$

The calibrated model delivers, in steady state, a smaller minimum ratio of bank capital to loans than in Basel I (0.072 *vs* 0.08 under Basel I), which is in line with the results of Committee of European Banking Supervisors [33], for instance. Besides, the ratio of bank capital to bank loans, as defined by equation (2.37), fluctuates over the business cycle, in contrast with Basel I. Specifically, the higher the leverage ratio, the higher the fraction of loans which must be financed by bank capital.

The bank's objective is now given by:

$$\max_{L_{t+1},B_{t+1},D_{t+1},S_{t+1}} \left(R^F_{t+1}L_{t+1} + R_{t+1}B_{t+1} - R^D_{t+1}D_{t+1} - E_t\left(R^S_{t+1}\right)S_{t+1} - \delta_e\frac{D_{t+1}}{S_{t+1}}D_{t+1}\right)$$

s.t.

$$\begin{aligned} L_{t+1} + B_{t+1} &= D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \\ \frac{S_{t+1}}{L_{t+1}} &\geq 0.08\left(a + b\frac{Q_t K_{t+1}}{N_{t+1}}\right) \text{ (capital requirements)} \end{aligned} \tag{2.38}$$

Taking into account that the leverage ratio depends, in turn, on the loans granted to firms, since $L_{t+1} = Q_t K_{t+1} - N_{t+1}$, the capital requirement constraint in this problem can be rewritten as:

$$\frac{S_{t+1}}{L_{t+1}} \geq 0.08\left[a + b\left(\frac{L_{t+1}}{N_{t+1}} + 1\right)\right].$$

The first order conditions of the interior solution of problem (2.38) yield[43]

$$R_{t+1} = R^D_{t+1} + 2\delta_e\left(\frac{D_{t+1}}{S_{t+1}}\right), \tag{2.39}$$

[43]The two equations were derived considering binding capital requirements, since the analysis in 2.3.3 also applies here. In contrast with the bank's problem under Basel I, the bank's zero profit condition is not guaranteed here. Technically, we assume that profits are distributed to the households.

$$
\begin{aligned}
R^F_{t+1} \;=\; & \left[1 - 0.08\left(a - b + 2b\frac{Q_t K_{t+1}}{N_{t+1}}\right)\right] R_{t+1} + \\
& +0.08\left(a - b + 2b\frac{Q_t K_{t+1}}{N_{t+1}}\right) E_t\left(R^S_{t+1}\right) - \\
& -0.08\delta_e\left(a - b + 2b\frac{Q_t K_{t+1}}{N_{t+1}}\right)\left(\frac{D_{t+1}}{S_{t+1}}\right)^2 . \qquad (2.40)
\end{aligned}
$$

As in Basel I, the required return on lending, R^F_{t+1}, depends on a weighted average of the deposits' return and the bank capital's expected return. However, the weights depend now on firms' leverage. In particular, and taking into account the log-linearized version of equation (2.40) - see equation (2.42) in the appendix -, the higher the firms' leverage, that is, the higher the credit risk, the higher the required return on lending by banks.

To analyze the consequences on the business cycle of introducing Basel II rules, we compare the effects of a negative innovation in the nominal interest rate, corresponding to an annual increase of 25 basis points, under Basel I, that is, considering the model developed in Section 2.2, and Basel II. Figures 2.4 and 2.5 illustrate the impulse response functions of the relevant variables under the two hypotheses. The response of both economic and financial variables under Basel II is much more pronounced than in Basel I, thus supporting the procyclicality hypothesis of Basel II.

Recall that under Basel II, bank capital depends positively, not only on the level of loans, but also on the firms' leverage (see equation 2.37, above). Since both loans and firms' leverage tend to increase after the contractionary shock, for the same reasons described in Section 2.3, the response of bank capital is amplified under Basel II, as illustrated in Figure 2.5. As described in 2.3.1, to hold more bank capital during the recession, households require an increase in the liquidity premium, since they must reduce the amount of deposits held in order to attenuate the decline in consumption. In fact, Figure 2.5 shows that the amplified increase in bank capital after the shock, under Basel II, leads to an amplified decrease in deposits and, consequently, to a marked increase in the liquidity premium required by households.

As in the baseline model, the increase in the liquidity premium leads, in turn, to an increase in the external finance premium faced by firms: combining the log-linearized versions of equations (2.39) and (2.40) - see the appendix - yields

$$\begin{aligned} E_t\left(r_{t+1}^K\right) - r_{t+1}^F \;\simeq\; & \left(1 - 0.08 \times B\frac{R^K}{R^F}\right)\left[E_t(r_{t+1}^K) - r_{t+1}^D\right] + \\ & + \left[\frac{2 \times 0.08 B\delta_e \left(\frac{D}{S}\right)^2}{R^F} - (1 - 0.08B)\frac{2\delta_e \frac{D}{S}}{R^F}\right](d_{t+1} - s_{t+1}) - \\ & -0.08 \times 2b\frac{R^K - R - \delta_e\left(\frac{D}{S}\right)^2}{R^F}\frac{QK}{N} lev_{t+1} \end{aligned}$$

where $B = a - b + 2b\frac{QK}{N}$, and $lev_{t+1} = q_t + k_{t+1} - n_{t+1}$. According to this equation, the external finance premium, $E_t\left(r_{t+1}^K\right) - r_{t+1}^F$, depends on the liquidity premium, $E_t(r_{t+1}^K) - r_{t+1}^D$, on the deposit-bank capital ratio, $d_{t+1} - s_{t+1}$, and on firms' leverage, lev_{t+1}. Again, these two latter effects are relatively small when compared to the former one.[44]

In sum, our model predicts that after the contractionary shock banks must issue more capital under Basel II than under Basel I, since (*i*) the level of uncollateralized loans increases, (*ii*) firms' credit risk increases, and (*iii*) bank capital requirements are binding. In order to hold more bank capital, households require a higher increase in the liquidity premium, which, in turn, leads to a higher increase in the external finance premium faced by firms. Consequently, the liquidity premium effect which underlies the bank capital channel, detailed in 2.3.1, is stronger under Basel II, leading to more amplified responses of both economic and financial variables after the monetary shock.

This outcome supports the hypothesis, mentioned above in the introduction of this essay, that the application of the new bank capital requirements rules proposed by Basel II will accentuate the procyclical tendencies of banking, which may work against the main objective of Basel II of promoting the stability of the international banking system. In

[44] For instance, immediately after the negative shock, the equation above can be rewritten as:

$$\begin{aligned} E_t\left(r_{t+1}^K\right) - r_{t+1}^F \;&\simeq\; 0.82189\left[E_t(r_{t+1}^K) - r_{t+1}^D\right] + 0.00040\,(d_{t+1} - s_{t+1}) - 0.002926 lev_{t+1} \Longleftrightarrow \\ 0.13043 \;&\simeq\; 0.15063 + (-0.01255) - 0.00757 \end{aligned}$$

fact, the countercyclically risk weights used to compute capital requirements may lead banks to hold too much capital during downturns and less capital during upturns, when the danger of a systemic crises is larger, as argued by Daníelsson *et al.* [36].

2.5 Concluding Remarks

Focusing on how microeconomic structures - namely the bank funding structure and the relationship between the banks, entrepreneurs and households - interact with macroeconomic business conditions, we have built a bank capital channel into a general equilibrium model, and found that it amplifies the real effects of monetary policy shocks and business cycle fluctuations, through a liquidity premium effect. This effect is strictly related to the financial accelerator effect associated with the borrowers' balance sheet channel: when the liquidity premium and the financial accelerator effects are both present, the external finance premium responds not only to borrowers' financial position (as in Bernanke *et al.* [17]), but also to the liquidity premium required by households to hold bank capital. This exacerbates the (countercyclical) response of the external finance premium to a monetary policy shock, since the liquidity premium also moves countercyclically and influences positively the external finance premium.

The liquidity premium effect rests on the fact that bank capital (mandatory due to risk-based capital requirements) is more expensive to raise than deposits, due to households' preferences for liquidity, and that this difference tends to widen (narrow) during a recession (expansion): after a contractionary monetary policy shock, for instance, households tend to decrease the amount of deposits held to attenuate the decline in consumption; since we assume that deposits provide liquidity services, households, thus, require an increase in liquidity premium, that is, an increase in the difference between the expected return on bank capital (which is also owned by households, but which does not render any liquidity services) and the return on deposits. This cost is then passed on to firms by the bank through an increase of the external finance premium.

Concerning the magnitude of the amplification effects, our results indicate that if we bring together the bank capital with the borrowers' balance sheet channel, financial frictions do seem to be a very important mechanism through which monetary shocks get propagated in the economy and business cycle fluctuations are amplified. Actually, if, in addition to the informational asymmetry between each entrepreneur and his bank, we introduce in the model other financial frictions related to the imposition of regulatory bank capital minimum levels, the role of financial frictions in the mechanism through which monetary shocks are propagated in the economy becomes much more powerful than in Bernanke *et al.*'s model, in line with some arguments in related literature.

As the definition of bank capital minimum levels has been the focus of Basel I and Basel II, we have extended the model in order to compare a simplified version of these two regulatory frameworks, thereby contributing to the debate on the procyclicality of Basel II. We found that the liquidity premium effect amplifies business cycle fluctuations the more significantly the closer the regulatory rules are to Basel II, rather than to Basel I. For instance, in face of a contractionary shock, banks must issue more capital under Basel II than under Basel I. To absorb this additional capital, households require a higher increase in the liquidity premium, which, in turn, leads to a higher increase in the external finance premium faced by firms. This result implies that the application of the new bank capital requirements rules will accentuate the procyclical tendencies of banking, which conflicts with the main objective of Basel II of promoting the stability of the international banking system.

Economic policy conclusions should be drawn carefully, however, since the model simplifies and abstracts from many important features of the economy. Importantly, as the model is not designed to capture the effectiveness of Basel I and Basel II in preventing bank failure, conclusions regarding the ranking of the two frameworks are clearly out of its scope. As a matter of fact, our analysis has not been concerned with questions such as whether bank regulation is itself optimal and what type of regulation is more appropriate. We ignore risk and incentives that support capital adequacy regulation (as the social cost of bank failure) and, therefore, our analysis does not support any normative conclusions regarding bank-capital regulation.

So far, the value added by our work to the discussion of the role of financial imperfections in the monetary policy transmission mechanism and in business cycle fluctuations, and to the issue of procyclicality of Basel II, encourages to proceed this research. A promising direction is to build risk-sensitive capital requirements into a heterogeneous-agent general equilibrium model. This will allow a fuller account of Basel II rules, by considering that credit risk varies not only along the business cycle, but also across firms.

2.6 Appendix

The Linearized Model and Calibration

A. The Baseline Model

To linearize the model's equations, we use a first order Taylor series expansion around the steady state. Let the lower case letters denote the percentage deviation of each variable from its steady state level: $x_t = \ln\left(\frac{X_t}{X}\right)$, where X is the value of X_t in nonstochastic steady state.

Aggregate Demand

Starting by log-linearizing the Euler equations, equation (2.14) becomes (assuming that $\sigma = \beta_0$):

$$-\sigma c_t = -\sigma \beta R^D E_t\left(c_{t+1}\right) + \beta R^D r_{t+1}^D - \alpha_0 \sigma \left(\frac{C}{D}\right)^{\sigma} d_{t+1}.$$

Concerning equation (2.15), we take a first-order Taylor approximation around the steady state ignoring the second order terms (or assuming that they are constant over time: $cov_t(.) = cov(.), \forall t$) and obtain:

$$-\sigma c_t = -\sigma \beta R^K E_t\left(c_{t+1}\right) + \beta R^K E_t\left(r_{t+1}^K\right).$$

Concerning the entrepreneurs' consumption (equation 2.8), we follow BGG and assume in simulations that

$$c_t^e = n_{t+1}.$$

In turn, the aggregate resource constraint (2.21) becomes

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}i_t + \frac{C^e}{Y}c_t^e + \frac{G}{Y}g_t + \xi_t^y,$$

where

$$\xi_t^y = \frac{\mu\Theta(\overline{\omega})KR^K}{Y}\left[\ln\left(\frac{\mu\Theta(\overline{\omega}_t)Q_{t-1}K_tR_t^K}{\mu\Theta(\overline{\omega})KR^K}\right)\right].$$

This term (ξ_t^y) is ignored in the simulations. Note that $\frac{\mu\Theta(\overline{\omega})KR^K}{Y}$, the share of expected monitoring costs in output, is quite small (even smaller than $\frac{C^e}{Y}$).

In what concerns the relationship between the external finance premium and the ratio of capital expenditures to net worth, equation (2.5) can be written in log-linear form as

$$E_t(r_{t+1}^K) - r_{t+1}^F = v(k_{t+1} + q_t - n_{t+1}),$$

where v is the steady state elasticity of $\frac{E_t(R_{t+1}^K)}{R_{t+1}^F}$ with respect to $\frac{Q_tK_{t+1}}{N_{t+1}}$, *i.e.*, the steady state elasticity of the external finance premium with respect to the ratio of entrepreneurs' capital expenditures to net worth:

$$v = \frac{l'(\overline{\omega}_{SS})}{k'(\overline{\omega}_{SS})}\frac{k(\overline{\omega}_{SS})}{l(\overline{\omega}_{SS})}.$$

We follow Gertler *et al.* [45] to compute v.

Log-linearization of (2.19) implies that

$$q_t = \varphi\left(i_t - k_t\right),$$

where φ is the elasticity of the price of capital with respect to $\frac{I}{K}$: $\varphi = -\frac{\Xi''\left(\frac{I}{K}\right)}{\Xi'\left(\frac{I}{K}\right)}\frac{I}{K}$.

Log-linearization of (2.22), in turn, renders

$$r_t^K = (1-\varepsilon)(y_t - k_t - x_t) + \varepsilon q_t - q_{t-1}$$

with $\varepsilon = \frac{1-\delta}{(1-\delta)+\alpha\frac{Y}{XK}}$.

Aggregate Supply

In the log-linearized version of the model, equation (2.23) becomes

$$y_t = a_t + \alpha k_t + (1-\alpha)\Omega h_t^h,$$

and the labor market clearing condition, taking into account both equations (2.16) and (2.24), is given by

$$\left(1+\frac{1}{\eta}\right) h_t^h = y_t - x_t - \sigma c_t$$

where $\eta = \frac{\partial H^h}{\partial W^h}\frac{W^h}{H^h} = \frac{1}{\beta_1}\frac{1-H^h}{H^h}$.

Finally the Phillips curve (or the price adjustment equation) is given by

$$\pi_t = \beta E_t \pi_{t+1} - \kappa x_t,$$

where $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$, $\pi_t \equiv p_t - p_{t-1}$ is the rate of inflation from $t-1$ to t, $p_t = \ln\left(\frac{P_t}{P}\right)$, and P is the price index. This equation is derived from the optimal (staggered) price setting by the retail sector.

State Variables

Log-linearization of (2.26) implies that the entrepreneurs' net worth evolves according to (ignoring the monitoring costs):

$$\begin{aligned} n_{t+1} = {} & \gamma R^F n_t + \gamma R^F \left(1-\frac{K}{N}\right) r_t^F + \\ & + \left(\gamma\frac{K}{N}R^K\right) r_t^K + \gamma\frac{K}{N}\left(R^K - R^F\right) q_{t-1} + \\ & + \gamma\frac{K}{N}\left(R^K - R^F\right) k_t + (1-\alpha)(1-\Omega)\frac{Y}{N}\frac{1}{X}(y_t - x_t). \end{aligned}$$

Concerning the capital stock, the log-linearized version of (2.18) is

$$k_t = \delta i_{t-1} + (1-\delta) k_{t-1}.$$

Representative Bank

Equations (2.11) and (2.12) can be written in log-linear form as :

$$r_{t+1} = \frac{R^D}{R} r^D_{t+1} + \frac{2\delta_e \frac{D}{S}}{R}(d_{t+1} - s_{t+1})$$

$$r^F_{t+1} = \alpha_e \frac{R^K}{R^F} E_t \left(r^K_{t+1} \right) + (1-\alpha_e) \frac{R}{R^F} r_{t+1} - \frac{2\alpha_e \delta_e \left(\frac{D}{S}\right)^2}{R^F}(d_{t+1} - s_{t+1}).$$

The capital requirement constraint, $S_{t+1} = \alpha_e (Q_t K_{t+1} - N_{t+1})$, turns into:

$$s_{t+1} = \frac{K}{L}\left(k_{t+1} + q_t\right) - \frac{N}{L} n_{t+1}.$$

Monetary Policy Rule and Shock Processes

The interest rate rule is given by

$$r^n_{t+1} = \rho r^n_t + \varsigma \pi_{t-1} + \varepsilon^{r^n}_t$$

where $r^n_{t+1} \equiv r_{t+1} + E_t \pi_{t+1}$ is the nominal interest rate from t to $t+1$ (with $\pi_{t+1} \equiv p_{t+1} - p_t$) and $\varepsilon^{r^n}_t$ an i.i.d. disturbance at time t.

Concerning the exogenous disturbances to government spending and technology, they follow, as in BGG, stationary autoregressive processes:

$$\begin{aligned} g_t &= \rho_g g_{t-1} + \varepsilon^g_t \\ a_t &= \rho_a a_{t-1} + \varepsilon^a_t \end{aligned}$$

where ε^g_t and ε^a_t are i.i.d. disturbances.

B. The Log-linearized Equations of the Basel II Extension

By log-linearizing equations (2.39) and (2.40), derived from the bank's objective first order conditions, we get:

$$
\begin{aligned}
r_{t+1} &= \frac{R^D}{R} r^D_{t+1} + \frac{2\delta_e \frac{D}{S}}{R}(d_{t+1} - s_{t+1}) && (2.41)\\
r^F_{t+1} &= 0.08\left(a - b + 2b\frac{QK}{N}\right)\frac{R^K}{R^F}E_t\left(r^K_{t+1}\right) + \left[1 - 0.08\left(a - b + 2b\frac{QK}{N}\right)\right]\frac{R}{R^F}r_{t+1} - \\
&\quad -2\times 0.08\delta_e\left(a - b + 2b\frac{QK}{N}\right)\left(\frac{D}{S}\right)^2\frac{1}{R^F}(d_{t+1} - s_{t+1}) + \\
&\quad +0.08\times 2b\frac{R^K - R - \delta_e\left(\frac{D}{S}\right)^2}{R^F}\frac{QK}{N}lev_{t+1}, && (2.42)
\end{aligned}
$$

where $lev_{t+1} = q_t + k_{t+1} - n_{t+1}$.

Additionally, the log-linearized version of the binding capital constraint is

$$
s_{t+1} = \left(\frac{K}{L} + 0.08b\frac{L}{S}\frac{QK}{N}\right)(k_{t+1} + q_t) - \left(\frac{N}{L} + 0.08b\frac{L}{S}\frac{QK}{N}\right)n_{t+1}. \qquad (2.43)
$$

C. Calibration

To evaluate some of the model's parameters and variables in steady state (SS), we follow BGG, who, focusing on U.S. data, consider (recall that, according to our notation, a variable without the time subscript indicates its steady state value):

Entrepreneurial Consumption/Output in SS	$\frac{C^e}{Y}$	0.01
Government Expenditure/Output in SS	$\frac{G}{Y}$	0.2
Gross Markup of Retail Goods over the Wholesale Goods in SS	X	1.1
Price of Capital in SS	Q	1
Entrepreneurial Labor	H_t^e	1
Elasticity of the price of capital with respect to I/K	φ	0.25
Capital Share	α	0.35
Household Labor Share	$(1-\alpha)\Omega$	0.64
Labor Supply Elasticity	η	3
Depreciation Rate	δ	0.025
Interest Rate Smoothing	ρ	0.9
Coefficient on inflation in the interest rate rule	ς	0.11
Prob. that an entrepreneur survives to the next quarter	γ	0.9728
Probability of a firm does not change its price within a given period	θ	0.75
Serial correlation parameter for technology shock	ρ_a	1
Serial correlation parameter for gov. expend. shock	ρ_g	0.95
Standard Deviation of $\ln(\omega)$	$\sigma_{\ln\omega}$	0.28
Monitoring Costs Parameter	μ	0.12
Preference Parameter	σ	1
Preference Parameter	β_1	1

Table 2.2. Calibration I

Concerning the parameters related to the financial contract, we choose the same values as BGG for the probability that an entrepreneur survives to the next quarter ($\gamma = 0.9728$) and for the monitoring cost parameter ($\mu = 0.12$). For the standard deviation of $\ln(\omega)$, we assume that $\sigma_{\ln\omega} = 0.28$. According to Carlstrom and Fuerst [25], a standard deviation of ω of around 0.2 is comparable to the corresponding empirical standard deviation reported by Boyd and Smith [22]. These assumptions allowed us to approximate, with good accuracy, the three steady state outcomes pointed out by BGG: a financing premium of 2% per year; $\frac{K}{N} = 2$ (which implies a ratio of loans to capital expenditures, $\frac{L}{K}$, of 0.5) and an annualized business failure rate, $F(\overline{\omega}) = 3\%$.[45]

[45] Data for the U.S. on the financing premium is available at http://research.stlouisfed.org/fred2/, whereas data on the leverage ratio is available in Rajan and Zingales [79].

There are other parameters and variables in steady state which are specific to our model, namely:

Loans/Deposits in SS	$\frac{L}{D}$	0.75
Bank Capital Requirement	α_e	0.08
Deposit Insurance Costs Parameter (risk-sensitive dep. ins. rate)	δ_e	0.0000045
Preference Parameter	β_0	1

Table 2.3. Calibration II

$\frac{L}{D}$: In steady state, and according to the model, $L = K - N$, where L represents loans without collateral that are granted to entrepreneurs who buy capital to produce the final good. Therefore, real estate and consumer loans should not be included in L, as well as loans secured by collateral. In other words, L should only comprise commercial and industrial (C&I) loans which are not secured by collateral. The Survey of Terms of Business Lending, published by the Federal Reserve, provides data which allowed us to compute the amount of C&I loans not secured by collateral in percentage of all C&I loans (made by all U.S. commercial banks), in each quarter from 1997:2 to 2004:4:

$$\frac{L^{C\&I}_{WithoutCol}}{L^{C\&I}}.$$

Then, using the (U.S., quarterly) banking data, from 1997:2 to 2004:4, available at the Federal Reserve Bank of St. Louis (see http://research.stlouisfed.org/fred2/), on *(a)* the total loans at all commercial banks and *(b)* the deposits at all commercial banks, we computed the ratio (*a*)/(*b*), from which we could proceed, assuming

$$\frac{L^{Total}}{D^{Total}} = \frac{(a)}{(b)},$$

and

$$\frac{L^{C\&I}}{D^{C\&I}} = \frac{L^{Total}}{D^{Total}} \left(\equiv \frac{(a)}{(b)} \right),$$

where $D^{C\&I}$ denotes the deposits that are used in financing $L^{C\&I}_{WithoutCol}$, *i.e.*, the deposits relevant to our model.

Finally, we assumed that $\frac{L}{D}$ corresponds to the average value of

$$\frac{L^{C\&I}_{WithoutCol}}{D^{C\&I}} = \frac{L^{C\&I}_{WithoutCol}}{L^{C\&I}} \frac{L^{C\&I}}{D^{C\&I}} \simeq 0.75.$$

To calibrate the deposit insurance parameter (δ_e) we followed Berka and Zimmermann [13]'s procedure, using data from the Federal Deposit Insurance Corporation (FDIC)[46] as of December 2006 and assume that, in steady state, the representative bank of our model is an adequately capitalized bank belonging to the subgroup A, as defined by FDIC for the soundest financial institutions.[47] Therefore, the deposit insurance rate corresponds to 3 cents per \$100 of deposits in annual terms.[48] In quarterly terms, this means that

$$\delta_e \frac{D}{S} = 0.000075.$$

Since we are assuming that, in steady state, $\frac{L}{D} = 0.75$, and that $\frac{S}{L}$ is always equal to 0.08 (in the benchmark case),

$$\frac{D}{S} = 16.6(6) \Longrightarrow \delta_e = 0.0000045.$$

The other parameters and variables in steady state are set in the following way:

- v, $\frac{R^K}{R^F} = l$, $\frac{QK}{N}$, and Z follow from the computation of $\overline{\omega}$, which, according to the optimal financial contract established between the bank and each entrepreneur in steady state, must satisfy the following condition

  $$l(\overline{\omega}) - (1-\delta)\frac{1}{R^F} = \frac{\alpha}{(1-\alpha)(1-\Omega)}\left[\frac{1}{R^F}\frac{1}{LEV(\overline{\omega})} - \gamma l(\overline{\omega})(1-\Gamma(\overline{\omega}))\right],$$

  where $LEV = \frac{QK}{N}$ and $\Gamma(\overline{\omega}) \equiv \int_0^{\overline{\omega}} \omega^j f(\omega) d\omega + \overline{\omega} \int_{\overline{\omega}}^{\infty} f(\omega) d\omega$. Details on $\overline{\omega}$ and v computation are available upon request. See also Gertler *et al.* [45].

[46] Available at http://www.fdic.gov/deposit/insurance/risk/assesrte.html.

[47] See http://www.fdic.gov/deposit/insurance/risk/rrps_ovr.html.

[48] Be aware that the rates established by the FDIC changed in 2007.

- $\varepsilon = \frac{1-\delta}{(1-\delta)+\alpha\frac{Y}{XK}}$; $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

- The variables and parameters must satisfy the steady state equations derived from the model's FOC and optimization constraints.

- R represents the quarterly steady state real gross return on government bonds. Taking into account the first Euler equation (2.14) evaluated in steady state,

$$1 = \beta R^D + \alpha_0 \left(\frac{D}{C}\right)^{-\sigma}$$

and the relationship between R and R^D (see equation 2.11),

$$R = R^D + 2\delta_e \frac{D}{S},$$

we set the parameter α_0 to guarantee $R = 1.01$ in steady state (a value which is assumed by many other business cycle models, including BGG, for the riskless real rate of return, since it guarantees an average riskless interest rate of 4% per year), with $\frac{L}{D} = 0.75$.

Figures

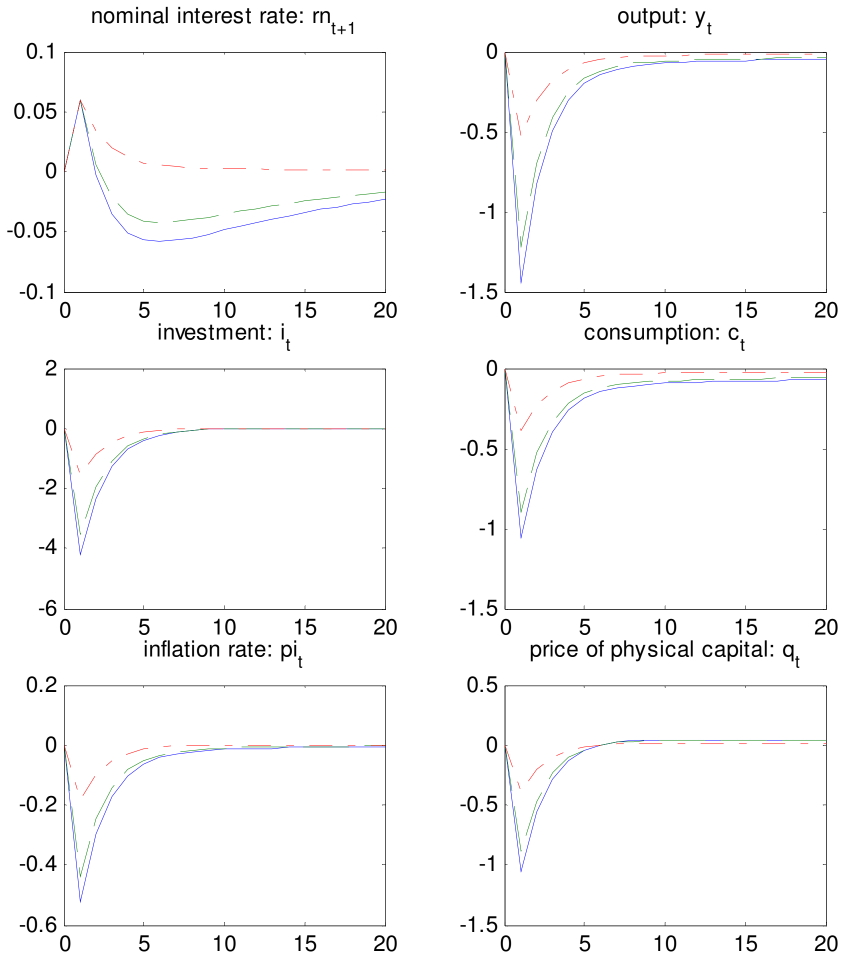

Figure 2.1. Response of economic activity to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant 2 (dashed line) - without capital requirements; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

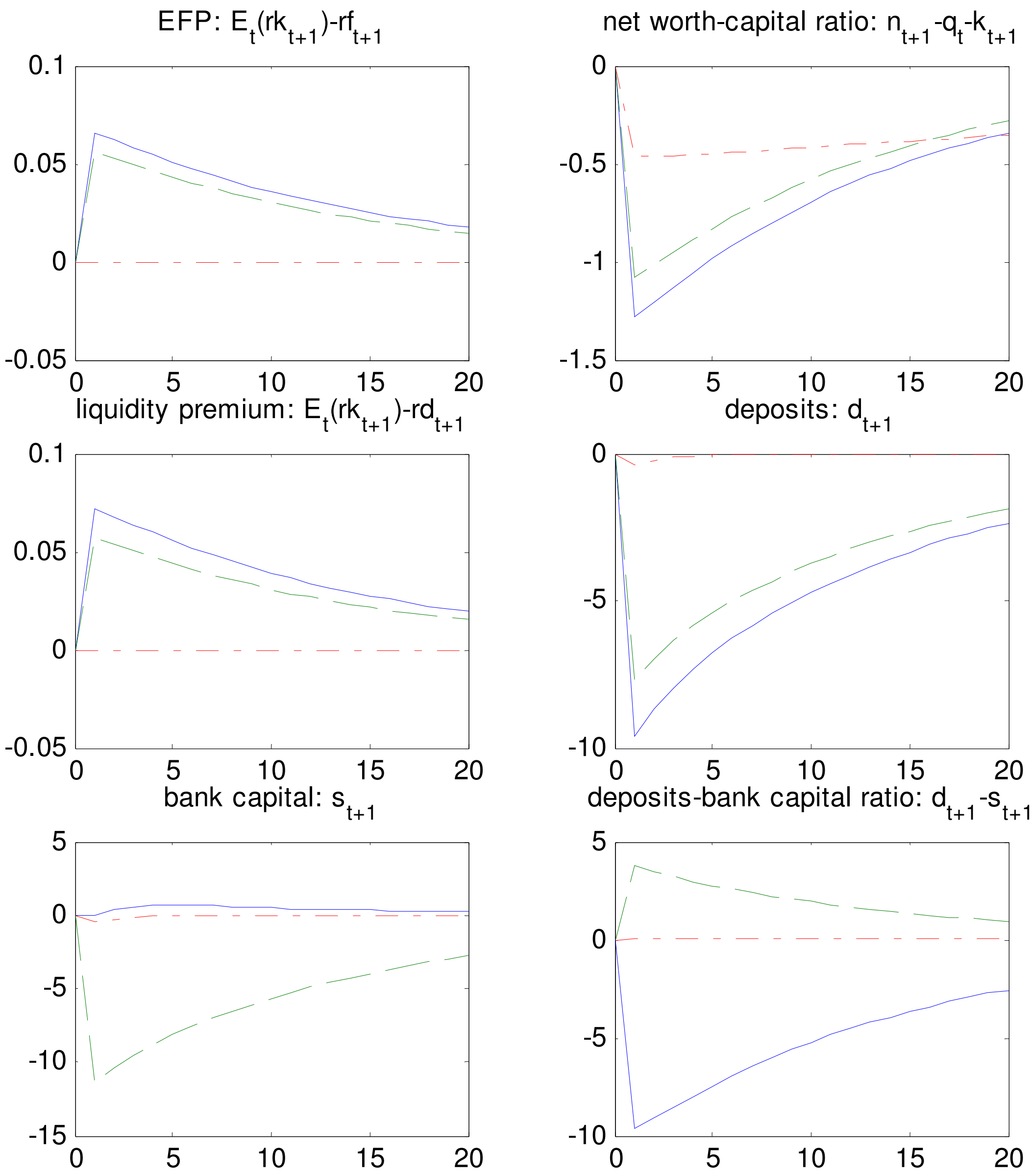

Figure 2.2. Response of financial variables to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant 2 (dashed line) - without capital requirements; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

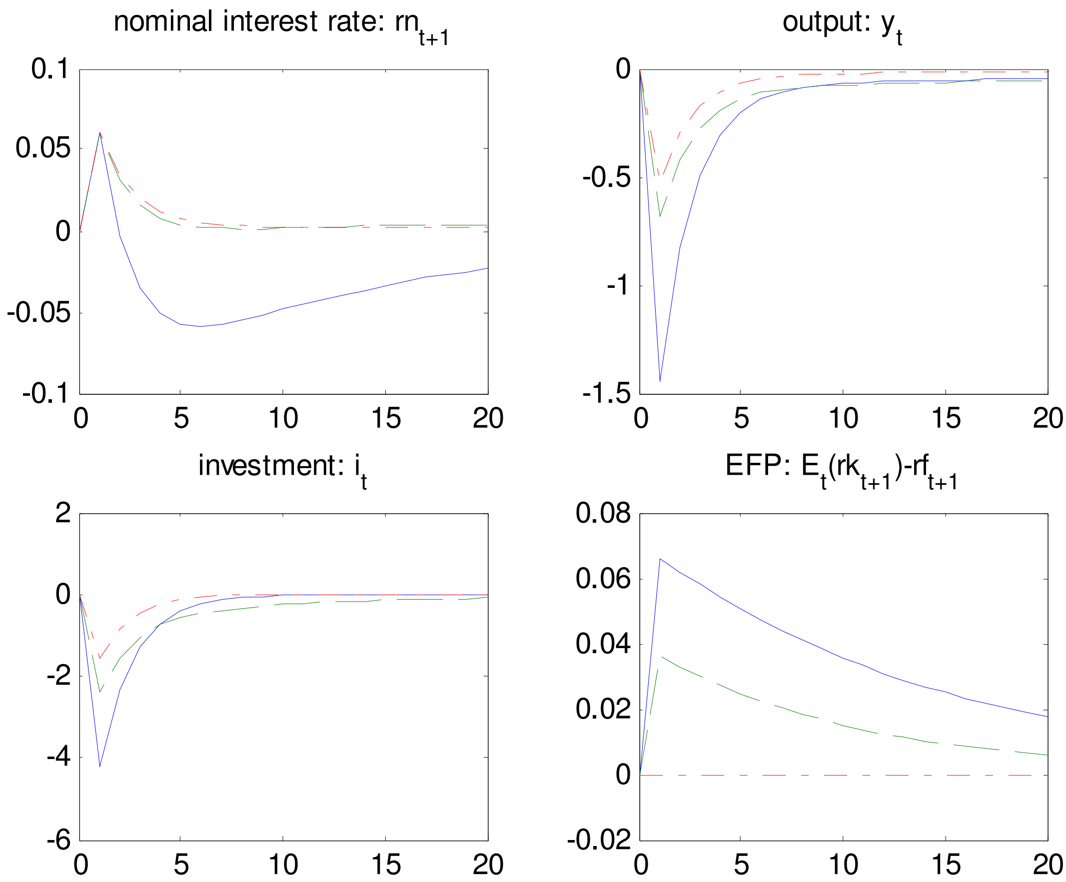

Figure 2.3. Response of economic activity to a negative monetary policy shock: variant 1 (solid line) - with capital requirements; variant BGG (dashed line) - based on BGG's model; variant 3 (dashed-dotted line) - with no capital requirements nor financial accelerator.

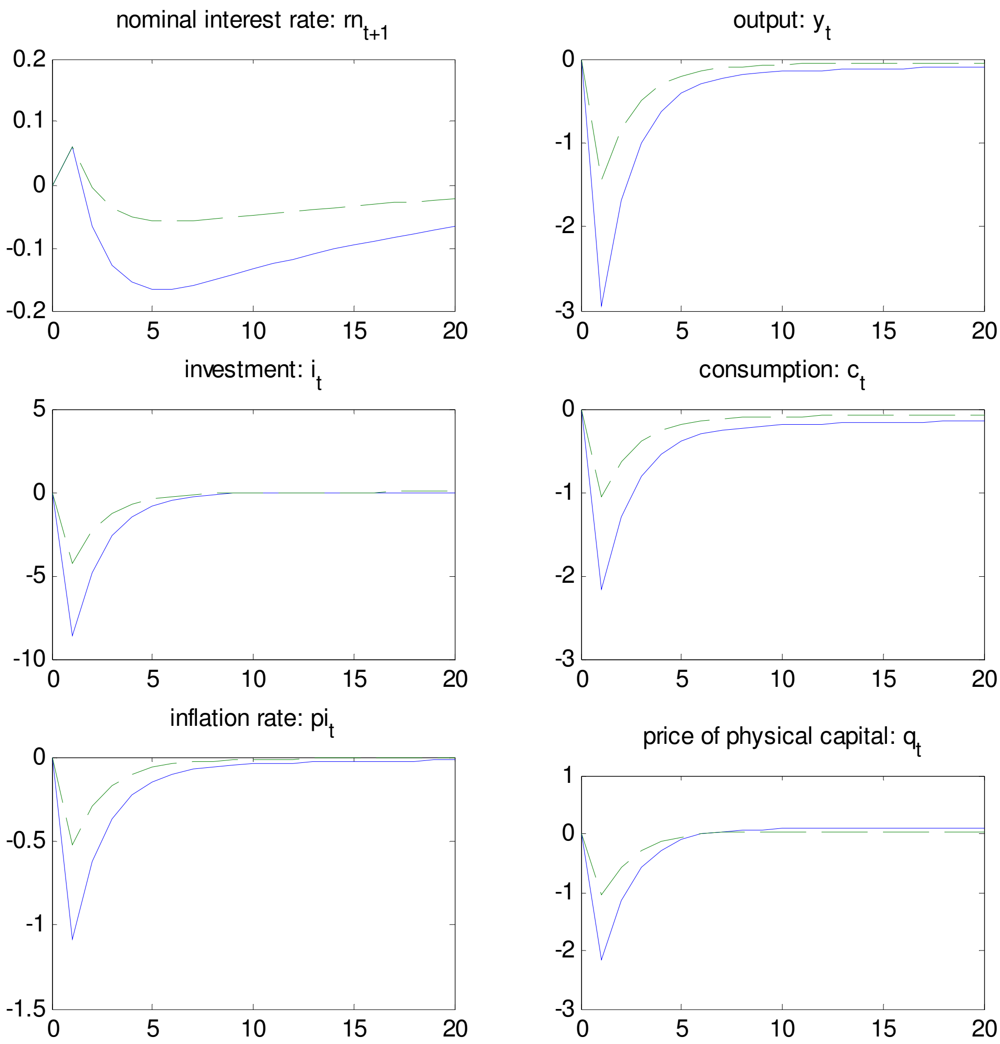

Figure 2.4. Response of economic activity to a negative monetary policy shock: Basel I - dashed line; Basel II - solid line.

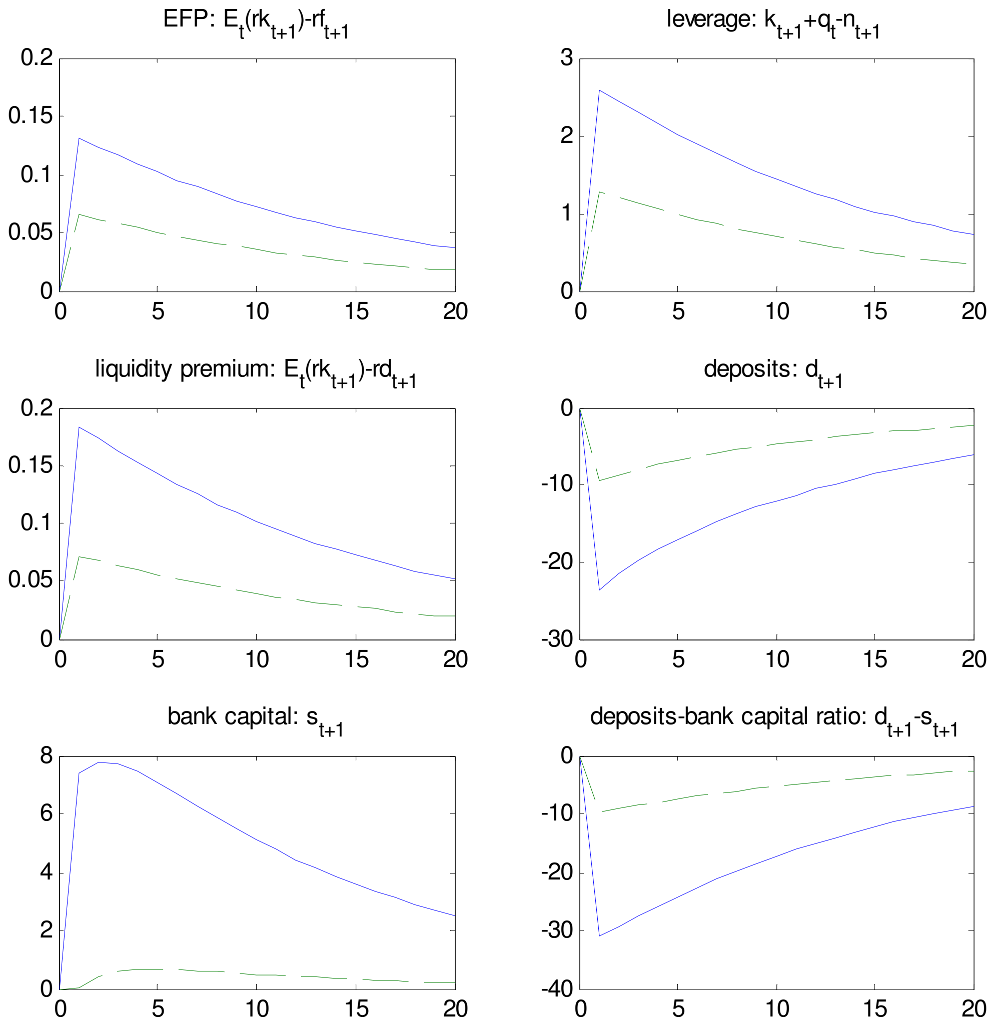

Figure 2.5. Response of financial variables to a negative monetary policy shock: Basel I - dashed line; Basel II - solid line.

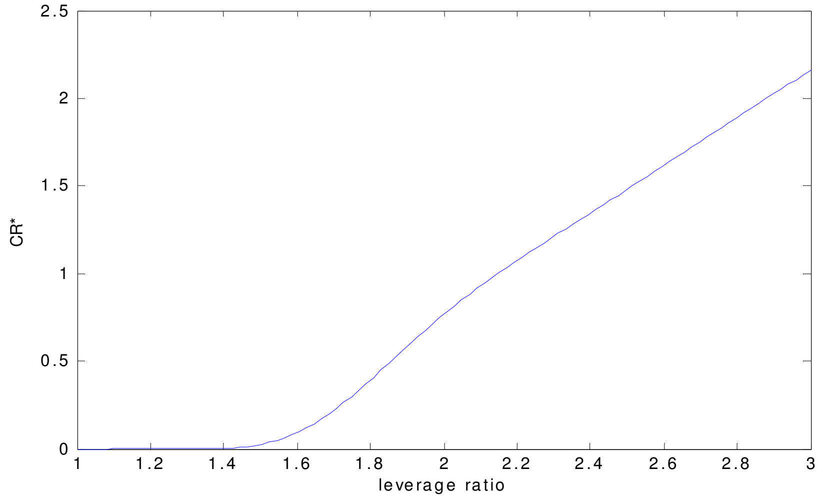

Figure 2.6. Relationship between the leverage ratio and the capital requirements weights, under Basel II, derived from the steady state optimal financial contract

Chapter 3

Basel II Capital Requirements, Firms' Heterogeneity and Macroeconomic Dynamics

3.1 Introduction

One of the most important changes underlying the new Basel Capital Accord (Basel II hereafter) - the increased sensitivity of a bank's capital requirement to the risk of its portfolio - has raised some concerns, at both academic and policy-making levels. In contrast with the bank capital regulation framework established by the Basel Accord of 1988 (Basel I hereafter), the risk weights used to compute bank capital requirements under Basel II are determined by both the institutional category and the riskiness of each particular borrower: the higher the credit risk of a given bank exposure, the higher the risk weight assigned to that exposure.[49] Consequently, if, during a recession, the non-defaulted bank borrowers are downgraded by the credit risk models in use, the minimum bank capital requirements will increase. The general concern is that, to the extent that it is difficult or costly for the bank to raise external capital in bad times, this co-movement in bank capital requirements and the business cycle may induce banks to further reduce lending during recessions, thereby amplifying the initial downturn. This potential procyclicality of Basel II may render more difficult for policy makers to maintain macroeconomic stability.

[49]Under Basel I only the borrower's institutional category is taken into account.

The present essay addresses this question in the context of a dynamic heterogeneous-agent model, in which firms differ in their access to bank credit depending on their financial position, that is, depending on their estimated credit risk. In particular, we aim to examine to what extent the changeover from Basel I to Basel II capital requirements rules may accentuate the procyclical tendencies of banking and, consequently, may amplify business cycle fluctuations, taking into account that under the new Basel Accord the minimum capital requirements depend on the credit risk of each particular bank exposure.

Some empirical papers, aiming to infer the potential procyclicality of Basel II, have also motivated our modelization of the bank-borrower relationship under the new regulatory framework in the context of a heterogeneous-agent model. Kashyap and Stein [56] simulate the degree of capital charge cyclicality that would have taken place over the four year interval 1998-2002 had the Basel II foundation Internal Ratings Based (IRB) approach been in use. The simulations, using data on the U.S., some European countries and the 'Rest of the World', suggest that Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges that may be - depending on a bank's customer mix and the credit-risk models that it uses - quite large. Altman *et al.* [4] point out that the procyclical effects of Basel II may be even more severe than expected if banks use their own estimates of loss given default to compute the capital requirements risk weights: low recovery rates when defaults are high will amplify cyclical effects, which will tend to be especially strong under the advanced IRB approach, where banks are free to estimate their own recovery rates and may tend to revise them downward when defaults increase and ratings worsen.

Concerning the standardized approach of Basel II, Carpenter *et al.* [27]'s estimates of how risk-weighted commercial and industrial loans might have evolved over the last three decades if banks had been using this approach, suggest very little cyclical impact compared to Basel I. That is, the variation in ratings over the business cycle would not have been substantial enough to imply much additional cyclicality under the standardized approach of the new accord when compared to Basel I. It is worth noting that under the standardized approach of Basel II, unrated firms are treated as in Basel I and the risk weights assigned to rated firms are based on ratings of external agencies, which usually follow a through-the-cycle approach to compute the default probability over the life of the loan, rating borrowers according to their ability to withstand a recession. In fact, and as the Catarineu-Rabell *et al.* [28]'s empirical study shows, the extent of additional procyclicality associated with Basel II will depend on the nature of the rating system used. According to this study, if banks use internal ratings close to those of the main rating agencies, the increase in capital requirements during a recession is quite small (around 15%). However, if banks choose an approach based on point-in-time rating systems, which assign ratings according to the ability of the borrowers to fulfil obligations over the credit horizon (typically one year), the increase in capital requirements during a recession will be much more pronounced (around 40% to 50%).

The procyclical effects of Basel II will also depend on the view adopted concerning how credit risk evolves over time. According to Segoviano and Lowe [84], for instance, one possible view is that the current performance of the economy can be taken as the best guess of its future performance (the random walk view). This view leads to risk being measured as low in an expansion and high in a recession, yielding to higher regulatory capital requirements in a downturn than in a boom. An alternative view suggests that the forces that drive economic booms often (although not always) sow the seeds of future economic downturns by generating imbalances in both real and financial sectors. Segoviano and Lowe argue that these imbalances increase risk by increasing uncertainty about the financial strength of individual borrowers, by making default probabilities more highly correlated and future collateral values more uncertain. The increase in defaults during a recession might thus be thought of as the materialization of risk built up during the boom. That is, this view - the predictability view - is consistent with the proposition that risk builds up in the boom but materializes in the downturn, and opens the possibility of measured credit risk being relatively high when times are good. In this context, Pederzoli and Torricelli [72]'s model, by considering the predictability view of the business cycle and a through-the-cycle logic in the rating assignment, is able to preserve the risk sensitivity of capital requirements and at the same time dampen Basel II procyclicality.

In sum, these and other empirical studies show that the procyclical effects of Basel II will depend on how the minimum capital requirements will react over the business cycle, which, in turn, depend (*i*) on banks' customer portfolios, (*ii*) on the approach adopted by banks to compute their minimum capital requirements - the standardized or the IRB approach -, (*iii*) on the nature of the rating system used - through-the-cycle or point-in-time rating systems -, (*iv*) on the view adopted concerning how credit risk evolves over time - the random walk or the predictability view, (*v*) on the capital buffers over the regulatory minimum held by the banking institutions, and (*vi*) on the market and supervisor intervention under Pillar 2 and 3 of Basel II.[50]

Our theoretical model contributes to evaluate the potential procyclical effects of Basel II and to what extent those effects might depend on banks' customer portfolios and on how borrowers' credit risk evolves over the business cycle. As in the model developed in Chapter 2, we take the Bernanke *et al.* [17]'s dynamic general equilibrium model as a starting point and we add banks that, due to the imposition of regulatory capital requirements, face financial frictions when raising funds. We depart, however, from these two models by properly considering that firms have different access to bank credit. Specifically, in the model of Bernanke *et al.* all firms are alike *ex ante*, except for the initial net worth. Aggregation is quite easy since all firms have the same ratio of capital expenditures to net worth and, thus, face the same external finance premium when borrowing from banks. Yet, and as mentioned by Bernanke *et al.*, there is in practice considerable heterogeneity among firms along many dimensions, in particular in access to credit. Our model attempts to fill this gap by considering firms with different levels of credit risk and, consequently, facing different conditions when borrowing from banks. Compared with the representative-firm, this heterogeneous-firm framework allows a more accurate inference of the potential procyclical effects of the changeover from Basel I to Basel II capital requirements: by introducing risk-sensitive capital requirements into a model with heterogeneous firms that differ on credit risk, we may properly analyze to what extent the riskiness of a bank's loan portfolio may accentuate the procyclical tendencies of banking under Basel II.

In this context, we first develop a heterogeneous-agent general equilibrium model in steady state, with uncertainty only at the firm level, assuming that banks finance nonfi-

[50] On this subject see also Carling *et al.* [24], Amato and Furfine [6] and Ayuso *et al.* [7], for instance.

nancial heterogeneous firms using the funds of a representative household. Firms have different access to credit depending on their estimated credit risk, which depends, in turn, on their leverage. We also assume that banks are constrained by a risk-based capital requirement according to which the ratio of bank capital to the risk-weighted nonfinancial loans cannot fall below 8%. Whereas under Basel I the capital requirements risk weights are constant and equal to one across all firms, under Basel II the risk weights depend positively on firms' credit risk. Note that in the stationary equilibrium the aggregate variables are constant over time, but firms are undergoing change both in size and in leverage. Therefore, the capital requirements risk weight assigned to each firm, under the new accord, also changes over time.

As in Chapter 2, banks are limited in their lending to nonfinancial firms by the amount of bank capital that households are willing to hold, which, due to households' preferences for liquidity, is more expensive to raise than deposits.

Our model evaluates the impact of the changeover from Basel I to Basel II capital requirements on the economy's aggregate variables in steady state and on the stationary distribution of firms over the state space. The firms' dynamics generated by the steady state model seem to be in line with the related literature. Besides, the effects of a permanent increase in the aggregate technology level on the stationary equilibrium indicate the existence of potential procyclical effects of Basel II.

We then simulate an aggregate technology shock, in order to properly assess those potential procyclical effects. Due to the large number of state variables considered, we adopt a partial equilibrium version of the steady state model, focusing on the bank-borrower relationship and in the absence of households. Assuming a countercyclical required return on bank capital, based on the robust results of Chapter 2, the model allows us to infer the importance of the banks' customer portfolios to the potential procyclicality of Basel II, which may be significant even when the perceived average credit risk decreases in bad times (as the predictability view suggests).

Related Theoretical Literature

Since the introduction of the first Basel Accord, some theoretical studies on the relationship between regulatory bank capital requirements and the business cycle have been developed, as analyzed in Chapter 1. However, only a few focused on the potential macroeconomic effects of Basel II.

Tanaka [88] extended a static IS-LM model, in the spirit of Bernanke and Blinder [15]'s work, to introduce the new capital requirements rules: the risk weights used to compute capital requirements become a function of the mean probability of borrower default over the business cycle. According to the model, an increase in the credit risk raises the probability that the bank faces a regulatory penalty, thus restricting bank's ability to lend. Therefore, if the credit risk varies with the business cycle, the new regulation may exacerbate macroeconomic fluctuations. The model also predicts that an expansionary monetary policy, under Basel II, may be less (more) effective during recessions (booms), when credit risk tends to be higher (lower). The intuition is that during a recession the bank's capital-to-asset ratio would be lower, for given levels of capital and loans, if the bank faces a relatively high level of credit risk. Hence, the bank's loans become more insensitive to an expansionary monetary policy, since a lower capital-to-asset ratio restricts banks' ability to increase its risky asset holdings.

Zicchino [100], aiming to capture the link between loan risk weights and borrowers' creditworthiness established in Basel II, introduces capital requirements risk weights that vary with macroeconomic conditions, in the theoretical partial equilibrium model of Chami and Cosimano [30]. In her model the capital requirements risk weights become a function of the macroeconomic activity, which, in turn, follows a first-order autoregressive stochastic process. Consequently, if banks face binding capital constraints, they will be able to increase their loan supply when times are good but they might be forced to reduce supply during a recession. Zicchino thus concludes that Basel II may lead to a greater reduction of credit following a negative macroeconomic shock: not only will loan demand fall during an economic downturn, but banks may be forced to reduce loan supply to satisfy tighter capital requirements. In order to avoid such an eventuality, supervisors should, according to Zicchino, encourage banks to build a capital buffer during expansions above the one banks would choose voluntarily.

In this context, the still preliminary work of Repullo and Suarez [82] considers the possibility that banks optimally choose to keep capital buffers, thus, counteracting the potential procyclicality of the new Basel Accord. The partial equilibrium model developed by these authors predicts that when the value of the on-going lending relationships is large enough and the cost of bank capital is not very large, banks optimally choose to keep capital buffers. However, the model also predicts that these capital buffers are insufficient to neutralize Basel II procyclicality: during a recession banks will significantly decrease the supply of credit to some of their dependent borrowers causing a credit crunch that would not occur under Basel I.

Our work differs from (and adds to) the existing literature by evaluating the potential procyclical effects of Basel II in the context of a heterogeneous-agent model: as one of the central changes of the new regulation is to introduce capital requirements risk weights that depend on the riskiness of each borrower, considering heterogeneous borrowers with different levels of credit risk and analyzing a bank's customer portfolio and how it varies with the business cycle is essential to capture some of the potential effects of the new Basel Accord.

This essay is organized as follows. After this introduction, Section 3.2 develops and calibrates a heterogeneous-agent general equilibrium model in steady state, with uncertainty only at the firm level. Three variants of the model are considered: the model assuming Basel II capital requirements rules, the model assuming Basel I capital requirements rules and the model without capital requirements. Section 3.3 simulates an aggregate technology shock under a partial equilibrium version of the model developed in the previous section, in which household are absent. In order to analyze the potential procyclical effects of Basel II, we compare the effects of the technology shock under the three variants of the model described above. Section 3.4 offers current conclusions and summarizes the state of this research project.

3.2 The Model in Steady State

In order to analyze the effects of the introduction of Basel II minimum capital requirements on cyclical fluctuations, we develop a dynamic general equilibrium model assuming three types of agents in the economy:

- Households, who consume and allocate their savings to bank deposits (which provide liquidity services) and bank capital;
- Entrepreneurs, who own firms that need external (bank) finance to buy capital and produce output;
- Banks, which, using the funds of households, finance and monitor (*ex post*) the entrepreneurs.

We first explore the model in steady state, that is, the model assuming no uncertainty over the aggregate state of the economy, even though there is uncertainty at the firm level. In steady state equilibrium, although firms are undergoing change, with some of them growing in size and others contracting, the aggregate variables are constant over time.

3.2.1 Entrepreneurs

At each point in time there is a continuum of heterogeneous firms, of total measure one, which have different access to credit depending on their financial position. In particular, each firm is characterized by *(i)* the amount of physical capital held to produce output, *(ii)* the price paid per unit of capital, *(iii)* its net worth and (*iv*) its idiosyncratic productivity.

In each period each entrepreneur buys the entire capital stock for his firm in order to produce output in the next period, according to the following production function:

$$Y_t^j = \omega_t^j A \left(K_t^j\right)^{\alpha}, \tag{3.1}$$

where K_t^j represents the homogeneous capital bought by each entrepreneur of type j at time $t-1$ and used in production at time t, A (> 0) represents a common and constant productivity factor and ω_t^j is an idiosyncratic disturbance to the production function, independently and identically distributed (i.i.d.) across time and across firms, with a continuous and once-differentiable cumulative distribution function (c.d.f.), $F(\omega)$, over a non-negative support. It is assumed that ω^j follows a log-normal distribution with $E\left(\omega^j\right) = 1$. In the steady state model, the only source of uncertainty for firms is the idiosyncratic shock.

The assumption of constant returns to scale, in the model of Bernanke, Gertler and Gilchrist [17] (BGG hereafter), is convenient for computational reasons since agency costs become independent of firm's size and a representative firm can be used. However, the implication that firm size does not matter is not appealing to our study. Besides, the convergence of the model to a steady state is not guaranteed if we assume a constant return to scale production function with no labor. In this context we consider, instead, decreasing returns to scale: $\alpha < 1$.

The entrepreneur's gross project output, at the end of each period, consists of the sum of his production revenues and the market value of his capital stock. Following Gertler *et al.* [45], we assume that the idiosyncratic shock affects both the production of new goods and the market value of capital. The shock ω_t^j may thus be considered a measure of the quality of entrepreneur's overall capital investment. Each entrepreneur's gross project output, at the end of time t, is then given by

$$\omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j(1-\delta)\omega_t^j K_t^j,$$

where δ is the depreciation rate and Q_t^j is the price, at the end of time t, of a unit of capital held by entrepreneurs of type j.[51]

Firms' Demand for Capital and the Cost of Funds

At the end of period t, each entrepreneur has available net worth N_{t+1}^j, which he then uses to finance his expenditures on capital goods: $Q_t^j K_{t+1}^j$. To finance the difference between capital expenditures and the net worth, each entrepreneur borrows an amount

[51] Q_t is in units of household consumption.

$L^j_{t+1} = Q^j_t K^j_{t+1} - N^j_{t+1}$ from the bank which, in turn, imposes a required return on lending, between t and $t+1$, of R^{Fj}_{t+1}.

Each entrepreneur's decision on how much capital to buy, K^j_{t+1}, depends both on the expected marginal return to capital and on the marginal financing cost.

The expected marginal return to capital at the end of time t, R^{Kj}_{t+1}, comprises both the expected marginal productivity of capital and the expected capital gains/losses:

$$R^{Kj}_{t+1} = \frac{A\alpha \left(K^j_{t+1}\right)^{\alpha-1} + E\left(Q^j_{t+1}\right)(1-\delta)}{Q^j_t}, \tag{3.2}$$

where $E[.]$ refers to expectations taken over the distribution of the idiosyncratic shock. We are excluding the possibility of arbitrage. Therefore, the expected return to capital may differ across firms.

The marginal cost of funds faced by a particular entrepreneur depends on the financial position of his firm, that is, depends on the ratio of firm's capital expenditures to net worth. As in Chapter 2 and in BGG, the relationship between the bank and each entrepreneur embodies an asymmetric information problem: only the entrepreneur observes costlessly the return of his project. That is, we assume a costly state verification framework, in which the bank must pay a monitoring cost in order to observe an individual borrower's realized return. This monitoring cost is assumed to equal a proportion μ of the entrepreneur's gross project output (net of unexpected capital gains/losses):

$$\mu\left[\omega^j_{t+1} A\left(K^j_{t+1}\right)^{\alpha} + E\left(Q^j_{t+1}\right)(1-\delta)\,\omega^j_{t+1} K^j_{t+1}\right],$$

where $0 < \mu < 1$.

At the end of time t, each entrepreneur (borrower) and the bank agree on a debt amount, L^j_{t+1}, and a borrowing rate, Z^j_{t+1}. At $t+1$, the entrepreneur defaults if his resources are not enough to pay back the amount due. That is, the entrepreneur defaults if ω^j_{t+1} is smaller than the default threshold, $\overline{\omega}^j_{t+1}$, defined by

$$\overline{\omega}^j_{t+1}\left[A\left(K^j_{t+1}\right)^{\alpha} + E\left(Q^j_{t+1}\right)(1-\delta)\,K^j_{t+1}\right] = Z^j_{t+1} L^j_{t+1}. \tag{3.3}$$

We assume that the unexpected capital gains/losses, when Q^j_{t+1} differs from $E\left(Q^j_{t+1}\right)$, are borne by the entrepreneur. This assumption simplifies the contracting problem.

If $\omega^j_{t+1} < \overline{\omega}^j_{t+1}$, the borrower defaults while the bank monitors the borrower and receives,

$$(1-\mu)\left[\omega^j_{t+1} A\left(K^j_{t+1}\right)^{\alpha} + E\left(Q^j_{t+1}\right)(1-\delta)\,\omega^j_{t+1} K^j_{t+1}\right].$$

If $\omega^j_{t+1} \geq \overline{\omega}^j_{t+1}$, the borrower pays the lender the amount $Z^j_{t+1} L^j_{t+1}$ and keeps the remaining.

The contract guarantees the bank an expected gross return on the loan equal to the required return R^{Fj}_{t+1} (taken as given in the contracting problem). That is, the loan contract established between each borrower and the bank must satisfy

$$\begin{gathered}\left[1-F\left(\overline{\omega}^j_{t+1}\right)\right] Z^j_{t+1}\left(Q^j_t K^j_{t+1} - N^j_{t+1}\right) + \\ +(1-\mu)\int_0^{\overline{\omega}^j_{t+1}} \left[\omega^j_{t+1} A\left(K^j_{t+1}\right)^{\alpha} + E\left(Q^j_{t+1}\right)(1-\delta)\,\omega^j_{t+1} K^j_{t+1}\right] f(\omega)d\omega = \\ = R^{Fj}_{t+1}(Q^j_t K^j_{t+1} - N^j_{t+1}).\end{gathered}$$

where $f(\omega)$ is the probability density function (p.d.f.) of ω. Combining the former equation with equation (3.3) yields

$$\begin{aligned}&\left[\Gamma\left(\overline{\omega}^j_{t+1}\right) - \mu\Theta\left(\overline{\omega}^j_{t+1}\right)\right]\left[A\left(K^j_{t+1}\right)^{\alpha} + E\left(Q^j_{t+1}\right)(1-\delta)\,K^j_{t+1}\right] = \\ &= R^{Fj}_{t+1}(Q^j_t K^j_{t+1} - N^j_{t+1})\end{aligned} \tag{3.4}$$

where $\Gamma\left(\overline{\omega}^j_{t+1}\right)$is the expected gross share of profit going to the lender,

$$\Gamma\left(\overline{\omega}^j_{t+1}\right) \equiv \int_0^{\overline{\omega}^j_{t+1}} \omega^j_{t+1} f(\omega)d\omega + \overline{\omega}^j_{t+1}\int_{\overline{\omega}^j_{t+1}}^{\infty} f(\omega)d\omega$$

and $\mu\Theta(\overline{\omega}_{t+1})$ the expected monitoring costs,

$$\mu\Theta(\overline{\omega}^j_{t+1}) \equiv \mu \int_0^{\overline{\omega}^j_{t+1}} \omega^j_{t+1} f(\omega) d\omega.$$

Therefore, $\Gamma\left(\overline{\omega}^j_{t+1}\right) - \mu\Theta\left(\overline{\omega}^j_{t+1}\right)$ represents the net share of profits going to the lender and $\left[1 - \Gamma\left(\overline{\omega}^j_{t+1}\right)\right]$ the share going to the entrepreneur (where, by definition, $\Gamma\left(\overline{\omega}^j_{t+1}\right)$ satisfies $0 < \Gamma\left(\overline{\omega}^j_{t+1}\right) < 1$).

The optimal contracting problem determines the division of the expected gross project output, $A\left(K^j_{t+1}\right)^\alpha + E\left(Q^j_{t+1}\right)(1-\delta) K^j_{t+1}$, between the borrower and the lender. The optimal contract results from the maximization of borrower's expected payoff, with respect to K^j_{t+1} and $\overline{\omega}^j_{t+1}$, subject to (3.4):

$$\begin{aligned} &\max_{K^j_{t+1}, \overline{\omega}^j_{t+1}} \left[1 - \Gamma\left(\overline{\omega}^j_{t+1}\right)\right] \left[A\left(K^j_{t+1}\right)^\alpha + E\left(Q^j_{t+1}\right)(1-\delta) K^j_{t+1}\right] \\ &\text{s.t.} \\ &\left[\Gamma(\overline{\omega}^j_{t+1}) - \mu\Theta(\overline{\omega}^j_{t+1})\right] \left[A\left(K^j_{t+1}\right)^\alpha + E\left(Q^j_{t+1}\right)(1-\delta) K^j_{t+1}\right] = R^{Fj}_{t+1}(Q^j_t K^j_{t+1} - N^j_{t+1}). \end{aligned} \tag{3.5}$$

The first order conditions of this contracting problem yield, in turn, the following equations (see Appendix A for details):

$$\begin{aligned} &\frac{\Gamma'\left(\overline{\omega}^j_{t+1}\right)}{\Gamma'(\overline{\omega}^j_{t+1}) - \mu\Theta'(\overline{\omega}^j_{t+1})} \left\{ \left[\Gamma(\overline{\omega}^j_{t+1}) - \mu\Theta(\overline{\omega}^j_{t+1})\right] A\left(K^j_{t+1}\right)^{\alpha-1} (1-\alpha)(\alpha-1) \frac{1}{R^{Fj}_{t+1} Q^j_t} \right\} + \\ + \quad &\left[1 - \Gamma\left(\overline{\omega}^j_{t+1}\right)\right] l^j_{t+1} - \frac{\Gamma'\left(\overline{\omega}^j_{t+1}\right)}{\Gamma'(\overline{\omega}^j_{t+1}) - \mu\Theta'(\overline{\omega}^j_{t+1})} \frac{1}{k^j_{t+1}} + \\ &+ \left[1 - \Gamma\left(\overline{\omega}^j_{t+1}\right)\right] \alpha(1-\alpha) A\left(K^j_{t+1}\right)^{\alpha-1} \frac{1}{R^{Fj}_{t+1} Q^j_t} = 0 \end{aligned} \tag{3.6}$$

and

$$\begin{aligned} &\left[\Gamma(\overline{\omega}^j_{t+1}) - \mu\Theta(\overline{\omega}^j_{t+1})\right] l^j_{t+1} + \left[\Gamma(\overline{\omega}^j_{t+1}) - \mu\Theta(\overline{\omega}^j_{t+1})\right] (1-\alpha) A\left(K^j_{t+1}\right)^{\alpha-1} \frac{1}{R^{Fj}_{t+1} Q^j_t} - \\ &-1 + \frac{1}{k^j_{t+1}} = 0 \end{aligned} \tag{3.7}$$

where $l_{t+1}^{j} \equiv \frac{R_{t+1}^{Kj}}{R_{t+1}^{Fj}}$ (external finance premium faced by firms of type j) and $k_{t+1}^{j} \equiv \frac{Q_t^j K_{t+1}^j}{N_{t+1}^j}$ (ratio of capital expenditures to net worth of type j firms). As we assume decreasing returns to scale, and in contrast with BGG and Chapter 2, the cutoff value $\overline{\omega}$ varies with firms' type: borrowers have different ratios of capital expenditures to net worth and, consequently, different cutoff values for ω and different access to credit. Besides, the first order conditions (FOCs) are more complex: whereas in BGG and Chapter 2 the only unknown variables were the threshold value, $\overline{\omega}_{t+1}^{j}$, the external finance premium and the ratio of capital expenditures to net worth, now the FOCs also depend on the capital stock, K_{t+1}^{j}, on the price of capital, Q_t^j, on the required return on lending by the bank, R_{t+1}^{Fj}, and on the common productivity factor, A (which is constant in the steady state model, but will vary when we introduce an aggregate productivity shock in the next section). Nevertheless, and in line with BGG, our simulations predict that, for a given price of capital and level of net worth, the external finance premium faced by leveraged firms increases with the capital stock. Figure 3.1 illustrates this relationship using the contract calibrated as described below, in 3.2.5. Besides, as in BGG, this figure also shows that an increase in firm's net worth improves firm's financial position causing a rightward shift in the external-finance-premium curve: an increase in net worth relative to the capital stock reduces the firm's expected default probability and, consequently, the external finance premium.

See Appendix A for the assumptions made in order to solve numerically equations (3.6) and (3.7).

Entrepreneurial Net Worth

As a technical matter, it is necessary to start entrepreneurs off with some net worth in order to allow them to begin operations. We assume that, in each period, each entrepreneur is endowed with a small endowment, W^e. The net worth of entrepreneurs thus combines profits accumulated from previous capital investment and the endowment W^e.

To avoid the possibility that the entrepreneurial sector accumulates enough net worth to be fully self-financed, we assume that each entrepreneur consumes, in every period, a constant fraction $(1-\gamma)$ of his resources.[52] Therefore, the net worth (N^j_{t+1}) and consumption (C^{ej}_t) of each entrepreneur of type j, at the end of time t, are defined as follows.[53]

a) If $\omega^j_t \geq \overline{\omega}^j_t$, the borrower pays the lender the amount

$$Z^j_t L^j_t = \overline{\omega}^j_t \left[A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) K^j_t \right]$$

and keeps the remaining:

$$\begin{aligned} N^j_{t+1} &= \gamma \Big\{ \omega^j_t A \left(K^j_t \right)^\alpha + Q^j_t (1-\delta) \omega^j_t K^j_t + W^e - \\ &\quad - \overline{\omega}^j_t \left[A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) K^j_t \right] \Big\} \qquad (3.8) \\ C^{ej}_t &= (1-\gamma) \Big\{ \omega^j_t A \left(K^j_t \right)^\alpha + Q^j_t (1-\delta) \omega^j_t K^j_t + W^e - \\ &\quad - \overline{\omega}^j_t \left[A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) K^j_t \right] \Big\}. \qquad (3.9) \end{aligned}$$

b) If $\omega^j_t < \overline{\omega}^j_t$, the borrower pays the lender the amount $\omega^j_t A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) \omega^j_t K^j_t$:

$$\begin{aligned} N^j_{t+1} &= \gamma \Big\{ \omega^j_t A \left(K^j_t \right)^\alpha + Q^j_t (1-\delta) \omega^j_t K^j_t + W^e - \\ &\quad - \left[\omega^j_t A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) \omega^j_t K^j_t \right] \Big\} \qquad (3.10) \\ C^{ej}_t &= (1-\gamma) \Big\{ \omega^j_t A \left(K^j_t \right)^\alpha + Q^j_t (1-\delta) \omega^j_t K^j_t + W^e - \\ &\quad - \left[\omega^j_t A \left(K^j_t \right)^\alpha + E \left(Q^j_t \right) (1-\delta) \omega^j_t K^j_t \right] \Big\}. \qquad (3.11) \end{aligned}$$

Capital Producers

Following the models developed in Chapter 2 and in BGG, we specify each entrepreneur's investment decisions under external capital adjustment costs. We depart, however,

[52] Alternatively, we could assume that agents had finite horizons. We did not pursue this hypothesis for simplicity, avoiding the exit and entry of firms. However, we intend to further research on this issue and introduce in the model exiting firms and the creation of new ones.

[53] As a technical matter, under both hypotheses a) and b) we consider that $N^j_{t+1} \geqslant \gamma W^e$. Therefore, if, for instance, $Q^j_t < E\left(Q^j_t\right)$ under b), we assume that the entrepreneur pays the bank $\omega^j_t A \left(K^j_t\right)^\alpha + Q^j_t(1-\delta)\omega^j_t K^j_t$ and keeps the remaining (γW^e).

from those models by introducing a specific capital producer for each entrepreneur. In particular, an entrepreneur of type j sells his entire stock of capital, K_t^j, at the end of each period t to the capital producing firm associated with his firm. This capital producer also purchases raw output as an input and combines it with K_t^j to produce new capital goods via the production function $\Xi\left(\frac{I_t^j}{K_t^j}\right)K_t^j$, where $\Xi(.)$ is an increasing and concave function, with $\Xi(0) = 0$, and I_t^j represents the investment at time t of the entrepreneur of type j. The new capital goods, jointly with the capital used to produce them, are then sold to the entrepreneur at the price Q_t^j. The capital stock of each firm of type j thus evolves according to:

$$K_{t+1}^j = \Xi\left(\frac{I_t^j}{K_t^j}\right)K_t^j + (1-\delta)K_t^j, \tag{3.12}$$

and the FOC for investment for the capital producers yields

$$Q_t^j = \frac{1}{\Xi'\left(\frac{I_t^j}{K_t^j}\right)}. \tag{3.13}$$

We assume that the capital adjustment cost function $\Xi(.)$ takes the following form (similar to the function used by Jermann [52] and Boldrin *et al.* [20]):

$$\Xi(.) = \left[a_1\frac{\varphi+1}{\varphi}\left(\frac{I_t^j}{K_t^j}\right)\right]^{\frac{\varphi}{\varphi+1}} \tag{3.14}$$

where φ (> 0) is the elasticity of the ratio of investment (measured in units of capital) to the capital stock with respect to the price of capital and a_1 is a constant. Therefore, equation (3.13) can be rewritten as

$$Q_t^j = \frac{1}{a_1}\left(\frac{K_{t+1}^j - (1-\delta)K_t^j}{K_t^j}\right)^{\frac{1}{\varphi}}. \tag{3.15}$$

Note that Q_t^j is set after the realization of the idiosyncratic shock at the beginning of time t (see Figure 3.2).

3.2.2 Banks

Financial intermediation, consisting of collecting funds from households (deposits and bank capital) and granting loans to the entrepreneurs, is assured by banks, which are legally subject to a risk-based regulatory capital requirement. The asset side of a bank's balance sheet includes loans granted to firms, whereas the liability side comprises deposits and bank capital. In line with the contract established between the representative bank and each entrepreneur, banks' assets and liabilities have the same, one period, maturity.

Following a simplified version of Basel II capital requirements rules, banks are required to hold at least a minimum amount of bank capital, determined by amount of loans granted to firms and by the credit risk of banks' loan portfolios. That is, we assume that the minimum amount of bank capital that each bank has to hold depends on the estimated credit risk of its loan portfolio, as specified by the following equation

$$S_{t+1} \geqslant 0.08 \int \alpha_{e_{t+1}}^j L_{t+1}^j d\Upsilon_{t+1},$$

where

- S_{t+1} is the bank capital issued by the bank and held by households between t and $t{+}1$;
- L_{t+1}^j is the loan granted, at the end of time t, to firms of type j;
- $\alpha_{e_{t+1}}^j$ is the credit risk weight associated with type j firms, at the end of time t;
- Υ_{t+1} is the distribution of firms over the state space (N, K, Q, ω), at the end of time t.

Under Basel I, $\alpha_{e_{t+1}}^j$ is constant and equal to one across all commercial and industrial loans ($\alpha_{e_{t+1}}^j = 1, \forall\ t,\ j$). Under Basel II, the risk weights in the capital requirements constraint depend positively on the estimated credit risk of each exposure. According to our model, firms default on the loan if the idiosyncratic disturbance, ω_{t+1}^j, turns out to be smaller than the cutoff value $\overline{\omega}^j_{t+1}$. Therefore, the higher the cutoff value, the higher the probability of default, $prob(\omega^j_{t+1} < \overline{\omega}^j_{t+1})$. The risk weights, under Basel II, should thus depend positively on the cutoff value, $\overline{\omega}^j_{t+1}$.

Figure 3.3, derived from our simulations of the model, shows that the financial contract delivers a positive relationship between $\overline{\omega}^j_{t+1}$ and the ratio of capital expenditures to net worth, k^j_{t+1}. Therefore, firms' credit risk and, consequently, Basel II risk weights $\left(\alpha^j_{e_{t+1}}\right)$ depend positively on firms' ratio of capital expenditures to net worth (k^j_{t+1}). In this context, we assume that the risk weights depend positively and linearly on k, as specified by the following equations:

$$\begin{aligned} \alpha^j_{e_{t+1}} &= a + bk^j_{t+1}, \text{ if } k^j_{t+1} > -\frac{a}{b}; \\ \alpha^j_{e_{t+1}} &= 0, \text{ if } k^j_{t+1} \leqslant -\frac{a}{b}, \end{aligned} \tag{3.16}$$

where a and b are constants and $b > 0$.

For simplicity, we assume that banks are allowed to issue bank capital at any time, on terms that also depend on households' willingness to hold bank capital in addition to deposits. Since bank capital is more expensive to raise than deposits, due to households' preference for liquidity (as shown below in 3.2.3), the capital requirement constraint is always binding:

$$S_{t+1} = 0.08 \int \alpha^j_{e_{t+1}} L^j_{t+1} d\Upsilon_{t+1}.$$

We will now analyze the behavior of a representative bank which maximizes its expected profits, acting as a price (interest rate) taker in a competitive market. Its choice variables are loans, deposits and bank capital. The bank's objective is then given by:

$$
\begin{aligned}
&\max_{L^j_{t+1}, D_{t+1}, S_{t+1}} \left[\int R^{Fj}_{t+1} L^j_{t+1} d\Upsilon_{t+1}\right] - R^D_{t+1} D_{t+1} - R^S_{t+1} S_{t+1} \\
&\text{s.t.} \\
&\int L^j_{t+1} d\Upsilon_{t+1} = D_{t+1} + S_{t+1} \text{ (balance sheet constraint)} \\
&\frac{S_{t+1}}{\int \alpha^j_{e_{t+1}} L^j_{t+1} d\Upsilon_{t+1}} = 0.08 \text{ (binding capital requirements),}
\end{aligned}
\tag{3.17}
$$

where:

- D_{t+1} are the households' deposits from t to $t+1$;
- R^{Fj}_{t+1} is the required return on loans granted by the bank to firms of type j, between t and $t+1$;
- R^D_{t+1} is the gross return on deposits;
- R^S_{t+1} is the gross return on bank capital.

This specification facilitates the comparison between Basel I and Basel II regulatory frameworks:

a) Under Basel II,

$$
\alpha^j_{e_{t+1}} = a + bk^j_{t+1} \Leftrightarrow \alpha^j_{e_{t+1}} = a + b\frac{Q^j_t K^j_{t+1}}{N^j_{t+1}} \Leftrightarrow \alpha^j_{e_{t+1}} = a + b\left(\frac{L^j_{t+1}}{N^j_{t+1}} + 1\right).
$$

Therefore, taking into account that k^j_{t+1} depends on the loan granted to the firm, since $L^j_{t+1} = Q^j_t K^j_{t+1} - N^j_{t+1}$ and $k^j_{t+1} = \frac{Q^j_t K^j_{t+1}}{N^j_{t+1}}$, the capital requirements constraint in the bank's objective can be rewritten as

$$
S_{t+1} = 0.08 \int \left[a + b\left(\frac{L^j_{t+1}}{N^j_{t+1}} + 1\right)\right] L^j_{t+1} d\Upsilon_{t+1},
$$

and the FOCs of the interior solution of problem (3.17) yield

$$R_{t+1}^{Fj} = \left[1 - 0.08\left(a - b + 2bk_{t+1}^{j}\right)\right] R_{t+1}^{D} + 0.08\left(a - b + 2bk_{t+1}^{j}\right) R_{t+1}^{S}. \tag{3.18}$$

The required return on loans granted by the bank to firms of type j, R_{t+1}^{Fj}, is, thus, a weighted average of the gross return on deposits and the gross return on bank capital. The weights depend on firms' type: the higher the ratio of capital expenditures to net worth (that is, the higher the credit risk of the firm), the higher the weight associated with R_{t+1}^{S}, since a larger fraction of loans must be financed with bank capital.

b) Under Basel I, $\alpha_{e_{t+1}}^{j} = 1, \forall j, t$, and the FOCs of the interior solution of problem (3.17) yield

$$R_{t+1}^{Fj} = (1 - 0.08)R_{t+1}^{D} + 0.08R_{t+1}^{S}, \forall j. \tag{3.19}$$

The required return on loans granted by the bank to firms of type j, is again a weighted average of the gross return on deposits and the gross return on bank capital. However, the weights are now constant and do not depend on firms' type, that is, all firms face the same required return on lending.

In contrast with the bank's problem under Basel I, the bank's zero profit condition is not guaranteed in a). Technically, we assume that profits are distributed to the households.

We also build a third variant of the model assuming no regulatory capital requirements at all. In this case, and since bank capital is more expensive to raise than deposits, the bank finances all loans with deposits: $S_{t+1} = 0$ and $R_{t+1}^{Fj} = R_{t+1}^{D}$, for any j.

3.2.3 Households

The economy is composed of a continuum of infinitely lived identical risk averse households of length unity. Each household consumes and allocates its savings to assets which include deposits, that pay a riskless rate of return between t and $t+1$ of R_{t+1}^{D}, and shares of ownership of banks in the economy, that pay R_{t+1}^{S}. For simplicity, labor is absent from our model. The representative household's instantaneous utility function is separable in consumption and liquidity (in the form of deposits) and given by:

$$U(C_t, D_{t+1}) = \frac{{C_t}^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{{D_{t+1}}^{1-\beta_0}}{1-\beta_0}, \tag{3.20}$$

where C_t denotes household consumption at time t and D_{t+1} the deposits held by the household from t to $t+1$.

As in Chapter 2, the level of deposits is included in the instantaneous utility function to indicate the existence of liquidity services from wealth held in the form of that asset. In short, we are assuming that deposits have an advantage in terms of liquidity when compared to bank capital. See Chapter 2 for details.

The representative household chooses consumption and its portfolio to maximize the expected lifetime utility (appropriately discounted) subject to an intertemporal budget constraint that reflects intertemporal allocation possibilities. The household's optimization problem is then given by

$$\begin{aligned} &\max_{C_t, D_{t+1}, S_{t+1}} E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{(C_{t+k})^{1-\sigma}}{1-\sigma} + \alpha_0 \frac{(D_{t+k+1})^{1-\beta_0}}{1-\beta_0} \right] \\ &\text{s.t.} \\ &C_t \;=\; R_t^D D_t - D_{t+1} + R_t^S S_t - S_{t+1} + \Pi_t^B, \end{aligned} \tag{3.21}$$

where $\beta \in (0,1)$ is the subjective discount factor and Π_t^B are dividends paid by the bank, under Basel II.[54]

The FOCs with respect to D_{t+1} and S_{t+1} are the following:

$$(C_t)^{-\sigma} = \beta R_{t+1}^D E_t \left[(C_{t+1})^{-\sigma} \right] + \alpha_0 {D_{t+1}}^{-\beta_0},$$
$$(C_t)^{-\sigma} = \beta \left\{ E_t \left[R_{t+1}^S (C_{t+1})^{-\sigma} \right] \right\}.$$

In steady state there is no aggregate uncertainty and $C_t = C_{t+1} = C$. Therefore, assuming $\sigma = \beta_0$, the FOCs become,

[54] Under Basel I, $\Pi_t^B = 0$.

$$1 = \beta R^D + \alpha_0 \left(\frac{C}{D}\right)^{\sigma}, \quad (3.22)$$

$$1 = \beta R^S. \quad (3.23)$$

Since $\alpha_0 \left(\frac{C}{D}\right)^{\sigma}$ is strictly positive, R^S exceeds R^D, that is, the representative household, due to its preferences for liquidity, requires a liquidity premium, $R^S - R^D$, in order to hold bank capital in its portfolio.

As mentioned, we also considered a variant of the model in which banks do not face regulatory capital requirements and, thus, optimally choose to finance all the loans with deposits. In this case, households allocate all their savings to deposits and there is no bank capital in the model. Therefore, we set α_0 equal to zero and the Euler equation becomes

$$1 = \beta R^D.$$

3.2.4 Equilibrium

A stationary equilibrium for this economy consists of:[55]

- Decision rules $C = C(D, S; \Upsilon)$, $D = D(D, S; \Upsilon)$, $S = S(D, S; \Upsilon)$ for the representative household;
- A decision rule $K' = K(K, Q, N, \omega)$ for firms;
- A law of motion for firms' net worth, $N' = N(K, Q, N, \omega)$;
- A decision rule $Q' = Q(K, Q, N, \omega)$ for the representative capital producer associated with each firm, producer of manufactured goods;
- Equilibrium prices (R^K, R^F), for each type of firm, and (R^D, R^S);
- A stationary distribution $\Upsilon(K, Q, N, \omega)$;

  Such that

[55] A variable with the superscript $'$ refers to its end-of-period value. To simplify the notation we now drop the j superscript.

- The consumer decision rules solve problem (3.21);
- $K' = K(K, Q, N, \omega)$ satisfies equation (3.2) and solves the contract problem (3.5);
- $N' = N(K, Q, N, \omega)$ satisfies equations (3.8) and (3.10);
- $Q' = Q(K, Q, N, \omega)$ satisfies equations (3.12) and (3.13);
- The required return on lending by the bank, R^F, satisfies equation (3.18), under Basel II (or equation 3.19, under Basel I);
- The bank's balance sheet and the capital requirements constraint are satisfied:

$$\int L' d\Upsilon = D + S$$
$$\frac{S}{\int (\alpha_e L')\, d\Upsilon} = 0.08;$$

- The markets clear:

$$\begin{aligned}\int L' d\Upsilon &= \int (Q'K' - N')\, d\Upsilon \\ Y + W^e + \int [Q'(1-\delta)\omega K]\, d\Upsilon &= \\ &= C + C^e + \left[\int (Q'K')\, d\Upsilon\right] + \text{Monitoring Costs,} \end{aligned} \tag{3.24}$$

where Y denotes the aggregate output and C^e the aggregate entrepreneurial consumption.[56]

- The stationary distribution $\Upsilon(K, Q, N, \omega)$ is consistent with $K(K, Q, N, \omega)$, $N(K, Q, N, \omega)$, $Q(K, Q, N, \omega)$ and the distribution of the idiosyncratic shock.

3.2.5 Calibration

We calibrate the model assuming that a period is a quarter. Some of the parameters were calibrated as in Chapter 2: see Table 3.1.

[56]Equation (3.24) is derived in Appendix B.

Depreciation rate	δ	0.025
Monitoring costs parameter	μ	0.12
Preference parameter	σ	1
Preference parameter	β_0	1
Discount factor	β	0.9818

Table 3.1. Parameters values I

The parameter φ in equation (3.15) is set to 0.25, in line with Jermann [52]. The coefficient associated with deposits in the utility function (3.20), α_0, is set such that, in steady state and under Basel I, $R^D = 1.01(01)$, as assumed by many other business cycle models, including BGG, for the riskless real rate of return, since it guarantees an average riskless interest rate of 4% per year.

We consider a higher standard deviation of $\ln(\omega)$ - which enters the financial contract - than in Chapter 2, because with the former value and under decreasing returns to scale we did not guarantee that all leveraged firms (those with $k > 1$) face an external finance premium, $\frac{R^K}{R^F}$, higher than 1 (see Table 3.2).

Entrepreneurs' endowment	W^e	1
Capital adjustment costs parameter	a_1	$3.90625e - 007$
Fraction of wealth consumed by each entrepreneur	$1 - \gamma$	0.5
Aggregate productivity factor	A	0.1
Production function parameter	α	0.9
Standard Deviation of $\ln(\omega)$	$\sigma_{\ln \omega}$	0.6
Utility function parameter	α_0	0.5086
Parameter of capital requirements' risk weights under Basel II	a	-1
Parameter of capital requirements' risk weights under Basel II	b	1

Table 3.2. Parameters values II

The remaining parameters, also reported in Table 3.2, satisfy the following requirements:

(*i*) The fraction of wealth consumed by each entrepreneur at the end each period, $1 - \gamma$, the common productivity factor A and the parameter α in the production function (3.1) are set such that, in steady state:

- The fraction of self-financed firms is small (around 9% in steady state), as our model focuses on the behavior of leveraged firms;
- The firms' stationary distribution over net worth (size) is skewed to the right, that is,

is skewed toward small firms, which, according to Cooley and Quadrini [34, 35], is an empirical regularity of the data;

- The average leverage ratio, measured by the average ratio of loans to capital expenditures, is close to 0.5, as the data reproduced in Rajan and Zingales [79] points out.

(*ii*) The entrepreneurs' endowment, W^e, is set to $\frac{NVec(1)}{\gamma}$, where $NVec(1)$ represents the first grid point in the state space of firms' net worth.[57] This variable's law of motion, defined in 3.2.1, guarantees that each firm's net worth does not take values below γW^e : $N_{t+1}^j \geqslant \gamma W^e$.

(*iii*) The capital adjustment costs parameter a_1 in equation (3.15) is set such that when this equation in considered in aggregate terms with $\varphi = 0.25$ and $\delta = 0.025$, Q_t equals one in steady state.

(*iv*) The parameters underlying the relationship between the capital requirements risk weight (α_e) and the ratio of firm's capital expenditures to net worth (k) under Basel II - see equation (3.16), above - were calibrated such that a zero risk weight is assigned to firms with $k = 1$ and a maximum risk weight of 2 is assigned to firms with $k = 3$. Specifically, we assume, in our simulations, that all firms with $k > 3$ are assigned the maximum level of α_e $(= 2)$. This is in line with the assumptions made concerning the financial contract established between the bank and each entrepreneur (see the computational procedure described in Appendix C, step 8), and avoids unrealistic values of α_e (based on Figure 1.1 in Chapter 1).

We then solve numerically the model, for the steady state, using the computational procedure described in Appendix C.

3.2.6 Results

Before introducing an aggregate shock in the model to test the potential procyclical effects of Basel II, we now describe the firms' dynamics generated by the model in steady state. Three variants of the model are considered:

- Variant 1: the model assuming Basel II capital requirements rules;

[57] As detailed in Appendix C, to solve the model we discretize the state space of firms' net worth.

- Variant 2: the model assuming Basel I capital requirements rules;
- Variant 3: the model without capital requirements, *i.e.*, excluding the capital requirements constraint from the model.

The steady state values of some key variables of the model are reported in Table 3.3. Comparing variant 3 with variants 1 and 2 allow us to conclude that the introduction of regulatory capital requirements has a negative effect on capital accumulation and, consequently, on firms' production - the steady state output in variant 1 (2) is 3.7% (1.9%) smaller than in variant 3. In both variants 1 and 2, banks are required to finance a fraction of loans with bank capital, which is more expensive to raise than deposits, due to households' preferences for liquidity ($R^S > R^D$). This additional cost is passed on to firms through an increase in the required return on lending, R^F. The total amount of loans granted to firms, and, consequently, firms' capital accumulation and output are thus smaller in variants 1 and 2.

	Variant 1 (Basel II)	**Variant 2** (Basel I)	**Variant 3** (No Capital Req.)
Aggregate Output	0.2288	0.2329	0.2375
Aggregate Capital Stock	2.5290	2.5801	2.6362
Aggregate Net Worth	1.2848	1.2923	1.3034
Average Leverage Ratio (borrowers)	0.5399	0.5448	0.5503
Average Ratio of Cap. Expend. to Net Worth	2.8915	2.9463	3.0073
Aggregate Loans	1.3327	1.3709	1.4157
% of Borrowers	0.9161	0.9172	0.9186
R^D	1.0092	1.01(01)	1.01(01)
R^S	1.0185	1.0185	–
Average R^F (borrowers)	1.0113	1.0108	1.01(01)
Average Capital Requirements Risk Weight	1.4296	1.0000	–
Aggregate Bank Capital/Aggregate Loans	0.1307	0.0800	–

Table 3.3. Key variables of the model in steady state

Table 3.3 also indicates that firms' size, proxied by firms' net worth, is smaller in variants 1 and 2. However, the differences across the three variants of the model are less significant with respect to this variable, when compared, for instance, with differences in output or in the capital stock: net worth in variant 1 (2) is 1.4% (0.9%) smaller than in variant 3. Figures 3.4 and 3.5, which plot the distribution of firms over net worth and capital stock, support this result. Figure 3.4, in particular, shows that the distribution of firms over net worth is, in fact, quite similar across the three variants of the model. Differences are, however, evident concerning the distribution over capital stock: Figure 3.5 confirms that the introduction of regulatory capital requirements has a negative effect on capital accumulation and shows that this negative effect is stronger under Basel II.

Figure 3.6, which plots the joint distribution of firms over net worth and capital stock under Basel II regulatory capital requirements, jointly with Figures 3.4 and 3.5, also allow us to conclude that the stationary distribution, under the three variants of the model, is characterized by small and leveraged firms: having access to bank credit, firms are able to accumulate a significant amount of capital when compared to their size.[58]

As analyzed in 3.2.2, for a given amount of loans, the minimum amount of capital that banks must hold, in variant 1, is increasing in the capital requirements risk weights, which depend positively on the borrowers' credit risk (proxied by the ratio of firms' capital expenditures to net worth). In variant 2, in turn, the risk weights are constant and equal to one across all firms. The last two rows of Table 3.3 show that the average capital requirements risk weight in variant 1 is higher than in variant 2, leading, in turn, to a higher ratio of bank capital to loans, despite the decrease in borrowers' average leverage ratio with the changeover from Basel I to Basel II capital requirements rules. That is, the stationary distribution of firms in this economy seems to be characterized by somehow highly leveraged firms, thereby leading to a relatively high level of average credit risk in steady state. Consequently, under Basel II, the representative bank must finance a higher proportion of loans with bank capital. As bank capital is more expensive to raise than deposits, the financing cost faced by firms is higher under Basel II, leading to smaller steady state values of aggregate loans, capital accumulation, and, consequently, aggregate output.[59]

[58]Recall that the model was calibrated in order to generate a firms' stationary distribution over net worth skewed toward small firms, which, according to Cooley and Quadrini [34, 35], is an empirical regularity of the data.

[59]The aggregate amount of loans and the aggregate capital stock in variant 1 are (respectively) 2.8% and 2% smaller than in variant 2.

Firms' Dynamics in Steady State

Figures 3.7 to 3.9 describe firms' dynamics generated by the calibrated steady state model. It is straightforward to conclude that, except for the required return on lending (R^F) and the capital requirements risk weights, and despite the differences across the three variants of the model reported in Table 3.3, firms' dynamics, in steady state, do not vary significantly across variants 1, 2 and 3 (Basel II, Basel I and No Capital Requirements, respectively).

Figure 3.7 reports typical decision rules for net worth (N) and physical capital (K). We conclude that, for a given value of capital expenditures, N_{t+1} (firms' net worth at the end of time t) is increasing in both N_t and the idiosyncratic shock, ω_t. Concerning the capital stock, and due to the introduction of capital adjustment costs in the model, this variable changes gradually and, consequently, its decision rule is very close to the 45^o line. The capital stock at the end of time t, K_{t+1}, also increases with the idiosyncratic shock, but this effect is imperceptible in the figure. As expected (see equation 3.15), for a given value of N_t and Q_{t-1}, the price of capital at time t (Q_t) is decreasing in K_t and increasing in the idiosyncratic shock.[60]

Figures 3.7 (d), 3.8 and 3.9 report some unconditional moments, computed by averaging some key variables of the model according to the firms' stationary distribution Υ. The key properties of firms' behavior, which are in line with Cooley and Quadrini [34]'s results, can be summarized as follows:

1. Small firms take on more debt: small firms borrow more and are more leveraged;

2. Small firms face higher probability of default (proxied by the default threshold, $\overline{\omega}$);

3. Small firms face a higher external finance premium (and a higher required return on lending, under Basel II);

4. Small firms grow faster (see Figure 3.9, d).

Figures 3.7 (d) and 3.8 (a and b) show that, although capital expenditures increase with firms' size (as measured by firms' net worth), small firms take on more debt: small

[60]For simplicity, and since the decision rule for Q does not vary significantly across the three variants of the model, we only plot this decision rule under Basel I.

firms borrow more and, consequently, have higher ratios of capital expenditures to net worth. As depicted by Figure 3.7 (d), firms' capital expenditures increase with firms' size but at a slower pace than the net worth. Consequently, the amount of uncollateralized loans is smaller for large firms.

A higher ratio of capital expenditures to net worth translates into a higher expected probability of default, as predicted by the contract established between each firm and the bank. Actually, Figure 3.8 (c) shows that small firms face, on average, higher probability of default (proxied by the default threshold, $\overline{\omega}$). Consequently, the capital requirements risk weights in variant 1 are, on average, higher for those firms, as they have higher credit risk - see Figure 3.8 (d). Finally, small firms, having higher probability of default, face higher external finance premia, as illustrated by Figure 3.9 (a). As mentioned, the magnitude of these effects (except for the capital requirements risk weights) is very similar across the three variants of the model.

Figure 3.9 also reports the relationship between the required return on lending by the bank, R^F, and the ratio of capital expenditures to net worth, k. In variant 1, and in contrast with the other two variants of the model, R^F increases with k. Recall that under Basel II the required return on a loan granted to a particular firm is a weighted average of the return on deposits, R^D, and the return on bank capital, R^S (with $R^S > R^D$, due to households' preferences for liquidity). The weights depend, in turn, on the firm's credit risk (proxied by the firm's ratio of capital expenditures to net worth, k). Everything else equal, the higher the firm's leverage, the higher the fraction of bank loans that must be financed with bank capital and, thus, the higher the weight associated with R^S and the higher the financing cost, R^F. Since small firms, in our model, are more leveraged, they face a higher R^F. That is, R^F increases with k and, consequently, decreases, on average, with firms' size.

Indeed, and as Figure 3.8 (d) illustrates, small firms face higher capital requirements risk weights in variant 1 and, consequently, face a higher required return on lending, R^F. In variant 2, in turn, the required return on lending by the bank does not depend on firms' type (see equation 3.19), thus being independent of firms' leverage and firms' size. Figure 3.9 (b) also allow us to conclude that only the less leveraged firms (those with a ratio of capital expenditures to net worth smaller than 2, approximately) benefit with the changeover from Basel I to Basel II rules: the required return on lending is smaller for those firms under the latter regulatory framework. The distribution of firms across their leverage is thus essential to evaluate the effects of the introduction of Basel II rules, as will become clearer in Section 3.3.[61]

Changing the Common Productivity Factor in the Steady State Model

Following the same computational procedure described in Appendix C, we solved the model for the steady state, assuming now a higher value for the common productivity factor: $A = 0.101$ (which corresponds to an increase of 1%). Table 3.4 shows the new steady state values of the same variables reported in Table 3.3.

	Variant 1 (Basel II)	**Variant 2** (Basel I)	**Variant 3** (No Capital Req.)
Aggregate Output	0.2388	0.2416	0.2451
Aggregate Capital Stock	2.6236	2.6579	2.7006
Aggregate Net Worth	1.3048	1.3097	1.3181
Average Leverage Ratio (borrowers)	0.5494	0.5527	0.5567
Average Ratio of Cap. Expend. to Net Worth	2.9941	3.0351	3.0811
Aggregate Loans	1.4081	1.4363	1.4703
% of Borrowers	0.9185	0.9193	0.9203
R^D	1.0088	1.0099	1.01(01)
R^S	1.0185	1.0185	–
Average R^F (borrowers)	1.0111	1.0106	1.01(01)
Average Capital Requirements Risk Weight	1.4484	1.0000	–
Aggregate Bank Capital/Aggregate Loans	0.1320	0.0800	–

Table 3.4. Key variables of the model in steady state with A = 0.101

By comparing the two tables we find that, as expected, a higher common productivity factor leads to a higher level of aggregate steady state output (which increased by 4.4%, 3.7% and 3.2%, in variant 1, 2 and 3, respectively). The increase in output is due, not only to the higher common productivity factor, which enters the production function of every firm, but also to the positive effect of A on capital accumulation (as also reported

[61]Note that the required return on lending faced by even less leveraged firms (firms with $k < 1.5$, approximately) is smaller in variant 1 (Basel II) than in variant 3 (model with no capital requirements), since, according to our simulations, the steady state return on deposits, R^D, is also smaller in variant 1 (see Table 3.3). This is in line with the results obtained in Chapter 2.

in Table 3.4). Figure 3.10 confirms this result, showing that a higher level of A implies a clear rightward shift of the stationary distribution of firms across the capital stock.[62]

The steady state firms' aggregate net worth also increases with A, but at a smaller extent than the aggregate capital expenditures. Therefore, firms become more leveraged, on average, in the new steady state: the average leverage ratio increases by 1.76%, 1.46% and 1.16% in variants 1, 2, and 3, respectively. Figure 3.11 supports this result (in variant 1):[63] given firms' size (N), an increase in A triggers higher capital expenditures by firms (see panel a). Since net worth is less sensitive to the common productivity factor, the average ratio of capital expenditures to net worth is higher in the new steady state for each level of N (see panel c).

The preceding results can be explained through the analysis of household and bank behavior, as follows. As reported in Table 3.4, the return on deposits, in both variants 1 and 2, is smaller in the new steady state:[64] the increase in A leads to an increase in the steady state ratio of household's consumption to deposits and, consequently, to a decrease in R^D (see equation 3.22 in 3.2.3). Therefore, the required return on lending by the bank, R^F, is also smaller in both variants (see Figure 3.11 e and Table 3.4).[65] A smaller cost of financing leads, in turn, to a higher amount of loans granted to firms, stimulating capital accumulation. The decrease in R^D and the consequent increase in aggregate loans, capital accumulation and output, are stronger in variant 1 than in variant 2, indicating the existence of potentially stronger procyclical effects associated with Basel II capital requirements.

We may summarize the following conclusions from the steady state model:

• The introduction of regulatory capital requirements has a negative effect on steady state aggregate output: the financing cost is higher, on average, in the presence of capital requirements, leading to a smaller aggregate amount of loans granted to firms which, in turn, has a negative effect on firms' capital accumulation and output;

[62]The distribution of firms in variant 3 is not shown for simplicity.

[63]For simplicity, we omit the firms' dynamics in the other two variants of the model.

[64]Since the discount factor, β, doesn't change with A, R^S (in variants 1 and 2) and R^D (in variant 3) are the same as in the previous steady state.

[65]Under Basel II, the effect of the decrease in R^D exceeds the effect of the increase in the average risk weight associated with R^S (caused by the increase in the average leverage ratio).

• In a steady state equilibrium characterized by a significant fraction of high credit risk firms, the former effect is stronger under Basel II capital requirements;

• The financing cost faced by small firms is higher, under Basel II, due to banks' perception that these firms are riskier and, hence, carry higher capital requirements than under Basel I;

• A higher common productivity factor has positive effects on steady state aggregate output, especially under the new regulatory framework, indicating the existence of potentially stronger procyclical effects.

3.3 Introducing an Aggregate Technology Shock

We now introduce an aggregate technology shock in the model in order to analyze the effects on cyclical fluctuations of the changeover from Basel I to Basel II capital requirements rules. In particular, we aim to compare the impact of an aggregate technology shock across the three variants of the model developed in the previous section.

Recall the common productivity factor A, that enters each firm's production function - see equation (3.1). In contrast with the previous section, where A was assumed to be constant, we now introduce a temporary negative aggregate productivity shock, which leads to a 1% decrease in A, at the beginning of period 1. The common productivity factor then gradually converges to its steady state value following the autoregressive process:

$$A_t = (1 - \rho_a)A + \rho_a A_{t-1}, \tag{3.25}$$

with $\rho_a = 0.75$ and $t = 1, 2, ...T$.

It is well known that introducing an aggregate shock into a dynamic heterogeneous-agent model is not an easy computational task, since, by assuming a continuum of agents, the state of the economy, at any point in time, is an infinite-dimensional object. Specifically, in order to be able to forecast prices (interest rates) accurately, agents need to keep track of the evolution of the distribution Υ_{t+1}, which is an infinite dimensional object. One approach that renders these models computable was developed by Krusell and Smith

[63], who consider that agents only use a finite number of statistical moments, derived from the distribution, to predict future prices.[66]

The large number of individual state variables considered in our model (the capital stock, the price of capital and firms net worth) renders this methodology quite difficult to use. Besides, in order to analyze the consequences of the introduction of Basel II capital requirements, we are interested in keeping track of the evolution of firms' distribution over their ratio of capital expenditures to net worth (which proxies for firms' probability of default and, thus, determines the capital requirements risk weights used under the new Basel Accord).

In this context, we followed an alternative procedure, based on Mendoza *et al.* [69], to analyze the effects of the aggregate technology shock.[67] In contrast with Section 3.2, and due to the large number of state variables in the model, we consider a partial equilibrium framework, in which households are absent. In particular, we assume that both the return on deposits (R^D) and the return on bank capital (R^S) are exogenously set at their steady state values and do not change over the business cycle. Alternatively, we can interpret this economy as a small open economy, which takes interest rates as given.

Following Mendoza *et al.*, after solving the model for the steady state, we choose a number of transition periods, T, taking into account the path of the common productivity factor A, given by equation (3.25). Assuming an initial shock of -1%, the common productivity factor takes approximately 110 quarters to return to its steady state value. We thus consider $T = 110$. Using the FOCs and the law of motion for the net worth, derived in Section 3.2 and properly modified in order to account for the aggregate productivity shock, we solve for the optimal choices backward, starting from T and taking into account that both A and the decision rules at $T + 1$ are equivalent to those derived in the steady state model. This procedure allow us to compute the optimal decision rules at $t = T, T - 1, ..., 2, 1$, which can then be used to find the sequence of firms' distributions over the state space (N, K, Q, ω) at each point in time and to compute the aggregate variables of the model.

[66]In particular, Krusell and Smith used the mean and the standard deviation of the distribution.

[67]The model developed by these authors does not consider an aggregate shock, but analyzes the transitional dynamics between two different steady states. We adjust their procedure in order to account for an aggregate shock.

3.3.1 Results

We begin by comparing the effects of the negative technology shock, described above, under the three distinct hypotheses: variant 1 - the model assuming Basel II capital requirements rules; variant 2 - the model assuming Basel I capital requirements rules; variant 3 - the model without capital requirements.

Figures 3.12 and 3.13 illustrate the impulse response functions of the relevant aggregate variables of the model under these three variants, using the calibrated model economy, with each period equivalent to a quarter and the variables expressed as percentage deviations from their steady state values.

The decrease in the common productivity factor A triggers an immediate decline in output below its steady state value, after which it returns gradually to its steady state. Due to the introduction of capital adjustment costs, the capital stock response is moderate, first decreasing and then gradually reverting to its steady state value. Therefore, and since labor is absent from our model, the response of output is essentially determined by the common productivity factor in the first periods after the shock.[68]

As in Chapter 2, the average price of physical capital, the aggregate capital expenditures and the aggregate firms' net worth are all procyclical. However, as the decrease in capital expenditures (QK) is more amplified than the decrease in net worth (N), firms' demand for uncollateralized loans ($QK - N$) also decreases after the shock, as Figure 3.12 (f) shows. That is, in contrast with Chapter 2, the decline in asset prices (Q) after the shock has a stronger effect on capital expenditures than on net worth.

As described in Section 3.2, under Basel I capital requirements, the amount of bank capital held by the bank depends positively on the amount of loans granted to the firms:

$$S_{t+1} = 0.08 \int L^j_{t+1} d\Upsilon_{t+1} \Leftrightarrow S_{t+1} = 0.08 L_{t+1}.$$

[68] A very simple growth accounting exercise shows that, in the second quarter after the shock, the capital stock explains around 0.14% of output (both variables expressed as percentage deviations from their steady state values), in all variants of the model. The role of capital then gradually increases, reaching 50% after 20 quarters (approximately). These values are not very different from those derived from the model developed in Chapter 2.

Therefore, the decrease in aggregate loans after the shock leads, necessarily, to a decrease in bank capital (see Figure 3.13, a). Under Basel II, in turn, the minimum amount of bank capital that a bank must hold depends both on the total amount of loans granted by the bank and on the credit risk of its loan portfolio:

$$S_{t+1} = 0.08 \int \alpha^j_{e_{t+1}} L^j_{t+1} d\Upsilon_{t+1}, \text{ with } \alpha^j_{e_{t+1}} = a + bk^j_{t+1}.$$

As detailed in Section 3.2, firms' credit risk is proxied by the ratio of capital expenditures to net worth. Figure 3.13 (b) shows that the average value of this ratio decreases with the negative technology shock, since the amount of loans granted to firms also decreases.[69] This effect is supported by the results obtained in 3.2.6, according to which a permanent decrease in the common productivity factor, leads to a decrease in the steady state leverage ratio. Therefore, bank capital should not only be procyclical in variant 1, since both loans and the average ratio of capital expenditures to net worth decrease, but should also decrease by a larger extent than aggregate loans, after the shock.

However, as depicted by Figure 3.13, despite the decrease in bank capital under Basel II, the average ratio of bank capital to loans $\left(\frac{S}{L}\right)$ increases, immediately after the shock, then decreasing below its steady state level, in the second quarter, and gradually reverting towards its equilibrium level from below after the fourth quarter. The average capital requirements risk weight (α_e) and the average required return on lending by the bank (R^F) follow the same path, in variant 1. The analysis of the technology shock effects on the distribution of firms over their ratio of capital expenditures to net worth (k) can be useful to understand this result.

Figure 3.14 illustrates the impulse response functions, to the negative technology shock, of the fraction of firms in each of the following categories:

[69]This result seems to be in line with the 'predictability view', analyzed in the introduction of this chapter, which opens the possibility of measured credit risk being relatively low (high) during recessions (expansions).

- Self-financed firms: $0 < k^j \leq 1$;
- Firms with $1 < k^j \leq 2$;
- Firms with $2 < k^j \leq 3$;
- Firms with $3 < k^j \leq 4$;
- Firms with $k^j > 4$.

According to our computational procedure (see Appendix C), all firms with $k^j > 3$ face the same α_e^j and R^{Fj} - see Figure 3.13 (h) and Figure 3.9 (b), respectively. That is, we assume that highly leveraged firms are treated equally by the bank (have the same perceived credit risk, face the same required return on lending, the same default threshold and the same external finance premium).[70] Figure 3.14 indicates that the decrease in the average ratio of capital expenditures to net worth, in variants 1 and 2, is mainly driven by a decrease in the fraction of highly leveraged firms in the economy (firms with $k^j > 4$). Figure 3.14 also suggests that, immediately after the shock, some of those firms move to the preceding category ($3 < k^j \leq 4$). This relocation affects negatively the average value of k, helping to explain the decrease in this variable after the shock, but does not affect the average capital requirements risk weight (α_e) and the average cost of financing (R^F).[71] In addition, firms with k^j between 1 and 2, in steady state, and which migrated to the two subsequent categories after the shock, as Figure 3.14 suggests, justify the initial increase in α_e and R^F. The increase in α_e explains, in turn, the increase in the average ratio of bank capital to loans in variant 1, as implied by the capital requirements constraint.

In sum, although the average ratio of capital expenditures to net worth decreases, our computational procedure yields an increase in the average credit risk immediately after the shock, due to the shift in the distribution of firms over k. This explains why the ratio of bank capital to loans increased in the first quarter. Figure 3.14 illustrates that, in the second quarter after the shock, the fraction of firms with $1 < k^j \leq 2$ and $2 < k^j \leq 3$ increased and the fraction of firms with $3 < k^j \leq 4$ and $k^j > 4$ decreased, leading, simultaneously, to a decrease in k and in the perceived average credit risk. Consequently α_e, $\frac{S}{L}$ and R^F also decreased (see Figure 3.13, c to e).

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[70] Thus avoiding unrealistically high firm's probability of default and external finance premium.

[71] Since both the return on deposits (R^D) and the return on bank capital (R^S) are fixed, the required return on lending by the bank (R^F) is fixed in variant 2 and only responds to changes in the ratio of capital expenditures to net worth in variant 1. See equations (3.18) and (3.19) in Section 3.2.

Concerning the variables that enter the financial contract established between the bank and each firm, Figure 3.13 allows us to conclude that the impulse response functions of the average default threshold ($\overline{\omega}$) and the average external finance premium (EFP) resemble that of the average capital requirements risk weight in variant 1, due, once more, to the response of firms' distribution over k to the technology shock. There is, however, an additional effect influencing the relationship between k, $\overline{\omega}$ and the EFP outside the steady state: in contrast with BGG, the common productivity factor, A, enters the FOCs derived from the contracting problem under decreasing returns to scale (see equations 3.6 and 3.7, in 3.2.1). According to our simulations, a decrease in A triggers, everything else constant (including k), an increase in the default threshold (that is, a higher firm's expected probability of default), and an increase in the EFP faced by each firm. Therefore, the technology shock has two distinct effects which render the results derived from the contract outside the steady state more difficult to interpret:

$$\Delta^{-}A \Rightarrow \begin{cases} \Delta^{-}k \;\Rightarrow\; \Delta^{-}\overline{\omega} \;\Rightarrow\; \Delta^{-}EFP \\ \Delta^{+}\overline{\omega} \;\Rightarrow\; \Delta^{+}EFP \end{cases}$$

Concerning the potential procyclical effects of Basel II, we conclude that the impulse response functions are very similar across the three variants of the model, contradicting the procyclicality hypothesis. In fact, only α_e, $\frac{S}{L}$ and, consequently, R^F have a noticeably different behavior in variant 1. However, as we are assuming that both the return on deposits and the return on bank capital are constant, R^F deviation from its steady state value is not sufficient to generate significantly different responses of the remaining variables of the model under Basel II.

Actually, the procyclical effects of bank capital requirements, both in the model developed in Chapter 2 and in some studies discussed in Chapter 1, are associated with some specific cost in raising bank capital (*e.g.*, the liquidity premium required by the households in order to hold bank capital, and which increases during recessions, or the information dilution costs introduced by Bolton and Freixas [21]).[72] In the present work we assume,

[72] See also Markovic [66], who developed a theoretical model that accounts for three distinct bank capital channels that trigger an increase in the required return on bank capital by shareholders, and thus an increase in the cost of bank capital, during an economic downturn.

thus far, that the return on bank capital required by the representative household, in order to hold this asset in its portfolio, is constant throughout the business cycle, that is, is the same during upturns and downturns, and does not vary with the changeover from Basel I to Basel II bank capital requirements rules. Thus, since the exogenous shock we introduced in the model is not sufficient to cause a major change in firms' distribution over their leverage, it is not surprising that an aggregate shock does not render significantly different effects across the three variants of the model.

Therefore, based on the results obtained in Chapter 2, we consider now that, immediately after the negative technology shock, the cost of bank capital increases: during a downturn, the representative household demands a higher return on bank capital, R^S, in order to hold this asset and attenuate the decrease in consumption. Also based on the model developed in Chapter 2, we assume that after the decrease in the common productivity shock, R^S increases by 0.5%, gradually converging to its steady state value according to the following autoregressive process:

$$R_{t+1}^S = (1 - \rho_a)R^S + \rho_a R_t^S,$$

with $\rho_a = 0.75$ and $t = 1, 2, ...T$. In contrast with the previous chapter, we assume that the response of R^S is the same under Basel II and Basel I (that is, the increase in the liquidity premium is the same in both variants 1 and 2). Since bank capital is absent in variant 3, the results presented here, concerning this variant of the model, are the same as those reported in Figures 3.12 and 3.13.

The Effects of a Technology Shock Assuming a Countercyclical Required Return on Bank Capital

Figures 3.15 and 3.16 show the impulse response functions of the model's relevant aggregate variables under the three variants of the model, assuming that, immediately after the technology shock, the required return on bank capital increases and then gradually converges to its steady state. As explained before, the response of output, in our model, is mainly driven by the common productivity factor in the first quarters after the shock.

Therefore, the impulse response functions of aggregate output are initially very similar across the three variants of the model. However, Figures 3.15 and 3.16 also show that the impact of the technology shock on the remaining economic and financial variables is visibly stronger in the presence of regulatory capital requirements: as in the preceding experiment, in which R^S was assumed to be constant, the aggregate capital stock and its average price, the firms' net worth, the aggregate amount of loans and the average ratio of capital expenditures to net worth are all procyclical, but the effects of the technology shock on these variables are clearly amplified when capital requirements are introduced in the model. Concerning, for instance, the immediate effect on aggregate loans and capital expenditures, the first variable decreases 0.57% in variant 1, 0.32% in variant 2, and only 0.19% in variant 3, while capital expenditures decrease 0.49%, 0.31% and 0.19% in variants 1, 2 and 3, respectively. Put differently, if we eliminate capital requirements from the model, that is, if we compare variant 3 with variants 1 and 2, the immediate impact of the technology shock on aggregate loans is reduced by 67.28% and 42.59% from variants 1 and 2, respectively, to variant 3. The same exercise focusing on the aggregate capital expenditures leads to a reduction of 61.21% and 37.92% from variants 1 and 2, respectively, to variant 3.[73] It is straightforward to conclude that this amplification effect is stronger in variant 1, supporting the procyclicality hypothesis underlying the changeover from Basel I to Basel II capital requirements rules: if we compare variant 2 with variant 1, the immediate impact of the technology shock on aggregate loans and aggregate capital expenditures is reduced by 43.01% and 37.51%, respectively, from variant 1 to variant 2.

Due to the adjustment in the distribution of firms over k, the average capital requirements risk weight in variant 1, the average default threshold and the average external finance premium increase, immediately after the shock, despite the decline in the average ratio of capital expenditures to net worth: as before, the decrease in this ratio is mainly driven by a shift of highly leveraged firms (with $k^j > 4$) towards the preceding category ($2 < k^j \leq 3$) - see Figure 3.17. This figure also shows that the adjustments in firms' dis-

[73]When the role of capital in explaining the output response to the technology shock becomes more significant, the differences in the output impulse response functions across the three variants of the model emerge. For instance, in the 15^{th} quarter after the shock, if we eliminate capital requirements from the model, that is, if we compare variant 3 with variants 1 and 2, the impact of the technology shock in output is reduced by 20.39% and 9.09% from variants 1 and 2, respectively, to variant 3.

tribution over the ratio of capital expenditures to net worth are more amplified in variant 1 than in variant 2.

Given the imposed increase in the return on bank capital required by the households after the negative technology shock, this amplification effect can be explained through the analysis of bank behavior, as follows. In contrast with the previous experiment, and as depicted by Figure 3.16 (f), the average required return on lending by the bank, R^F, in variant 1 does not follow the same path as the average capital requirements risk weight (see panel e). Recall that, in both variant 1 and variant 2, R^F is a weighted average of the return on deposits and the return on bank capital. As derived in 3.2.2, under Basel I the weights are constant,

$$R_{t+1}^{Fj} = (1 - 0.08)R_{t+1}^{D} + 0.08R_{t+1}^{S}, \forall j,$$

whereas under Basel II the weights depend on firm's leverage,

$$R_{t+1}^{Fj} = \left[1 - 0.08\left(a - b + 2bk_{t+1}^{j}\right)\right] R_{t+1}^{D} + 0.08\left(a - b + 2bk_{t+1}^{j}\right) R_{t+1}^{S}.$$

Figure 3.16 (a and f) shows that, as predicted by the first equation, R^F, in variant 2, follows very closely the return on bank capital. In contrast with the previous experiment, we assume that households require an increase in the return of bank capital in order to hold this asset in their portfolios after the negative technology shock. This cost is then passed on to firms by the bank through an increase in the required return on lending, R^F. The consequent decline in the aggregate amount of loans granted to firms and in firms' capital expenditures, under Basel I, is thus more amplified than in the case when R^S was assumed to be constant.

In variant 1, in turn, R^F depends both on firms' credit risk and R^S. Figure 3.16 (f) shows that the response of R^F is much stronger under this variant of the model than under variant 2. Two effects contribute to this more amplified response.

First, and as in the previous experiment, the adjustment in firms' distribution over k, immediately after the shock, affects positively R^F (taking into account the assumption that all firms with $k^j \geq 3$ are treated equally by the bank). However, by comparing Figure 3.13 (e) with Figure 3.16 (f), it is straightforward to conclude that, immediately after the shock, the increase in R^F, under Basel II, is much more amplified in the second experiment. Besides, and in contrast with the previous case, R^F remains above its steady state value during the subsequent periods. This can be explained through a second effect associated with the economy's initial distribution of firms over k, as follows.

As we mentioned in 3.2.6, the stationary equilibrium of this economy is characterized by a large fraction of highly leveraged firms. Consequently, the steady state average level of credit risk is relatively high, leading to a higher steady state ratio of bank capital to loans under Basel II than under Basel I. As also analyzed in 3.2.6, only the less leveraged firms benefit with the changeover from Basel I to Basel II. Besides, as predicted by the second equation above, the higher the leverage of the firm, the more sensitive is R^{Fj} to a change in R^S. In particular, assuming a 0.5% increase in R^S, and for given values of k^j and R^D, only the firms with $k^j < 1.87$ benefit with the introduction of Basel II regulation:[74] the increase in the financing cost after the shock is smaller for those firms, under the new regulatory framework. For the remaining firms, Basel I would be preferable.

Therefore, since this economy is characterized by a large fraction of highly leveraged firms in steady state, and since those are the firms which lose with the introduction of Basel II, the increase in the average financing cost is more amplified in variant 1 than in variant 2: for those highly leveraged firms, the increase of the required return on lending after the exogenous shock is stronger under Basel II than under Basel I.[75]

Actually, this second effect is much stronger than the previous one, which was also present in the preceding experiment: even in the second quarter after the shock, when the average capital requirements risk weight decreases below its steady state value - indicating a decrease in the average level of credit risk in the economy, due to the adjustment in firms' distribution over k -, the average required return on lending remains well above its equilibrium level, in contrast with the previous experiment (see Figure 3.16, e and f).

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[74]This result takes into account that the steady state level of R^D is smaller under Basel II than under Basel I.

[75]And the decrease in the average leverage ratio is not sufficient to offset this effect.

Finally, since the required return on lending by the bank increases more in variant 1 than in variant 2, the decrease in the aggregate amount of loans granted to firms, and, consequently, in firms' capital expenditures is more amplified in the former variant.[76]

In sum, the introduction of a countercyclical required return on bank capital leads to a stronger response of the economy to a technology shock when capital requirements are considered in the model, especially under the Basel II regulatory framework.

We may then conclude that, to the extent that it is costly to raise or hold bank capital in bad times and the representative bank's loan portfolio is characterized by a significant fraction of highly leveraged firms, the introduction of the new bank capital requirements rules proposed by Basel II may accentuate the procyclical tendencies of banking, with macroeconomic consequences. The Basel II procyclical effect should be greater, the greater the fraction of firms who begin with relatively high leverage ratios, that is, with relatively high credit risk. The distribution of firms over their leverage ratio, which in our model proxies for the credit risk, is therefore crucial to understand the potential procyclical effects of the new bank capital requirements rules.

3.3.2 Some Additional Experiments

Mimicking a Monetary Policy Shock

Although the model developed in this chapter does not contemplate a central bank and a monetary policy rule, in contrast with the model developed in Chapter 2, we may still capture some potential effects of a negative monetary policy shock, assuming that this shock translates into an exogenous increase in the return on deposits, R^D (in line with Meh and Moran [68], for instance). Specifically, we now introduce an exogenous shock that leads to a 0.1% increase in R^D, which then gradually converges to its steady state value following the autoregressive process:

[76] In contrast with Chapter 2, this amplification effect does not depend on the amplitude of the liquidity premium's response: recall that we are assuming here that the increase in R^S is the same under both Basel I and Basel II.

$$R^D_{t+1} = (1 - \rho_a)R^D + \rho_a R^D_t,$$

with $\rho_a = 0.75$ and $t = 1, 2, ...T$.

For the same motive pointed out in 3.3.1, we also assume that, after the negative monetary policy shock, households require an increase in the return on bank capital, R^S, in order to hold this asset in their portfolios. In particular we consider that, simultaneously with the increase in R^D, R^S increases by 0.5%, gradually converging to its steady state value according to the same autoregressive process followed by R^D. Consequently, the liquidity premium, $R^S - R^D$, increases after the shock, as in Chapter 2.

Figure 3.18 reports the impulse response functions of some key variables of the model under variants 1 and 2.[77] The response of both economic and financial variables in variant 1 is more pronounced than in variant 2, thus supporting again the procyclicality hypothesis of Basel II. In this case, aggregate output follows very closely the response of physical capital, as the common productivity factor is assumed to stay constant (see panel b). Since we are assuming an increase in the liquidity premium required by the households after the shock and since the economy is characterized by a large fraction of highly leveraged firms, the rise in the financing cost is more amplified under Basel II, leading to a stronger decrease in the amount of loans granted to firms and, consequently, to a stronger decrease in firms' capital expenditures and output, after the shock. Once more, the decrease in the average leverage ratio, after the negative monetary policy shock, is not sufficient to offset the effect associated with the high sensitivity of the high leverage firms' financing cost to changes in the required return on bank capital, R^S.

In sum, as long as the increase in R^S is sufficiently higher than the increase in R^D, that is, as long as the liquidity premium increases significantly after the negative monetary policy shock (see panel h), the procyclical tendencies of banking are accentuated under the new Basel Accord.[78]

[77]We omit variant 3, for simplicity.

[78]Even considering that the increase in the liquidity premium is the same under Basel I and Basel II, in contrast with Chapter 2.

We also tested the effects of the negative technology shock analyzed in 3.3.1 assuming that, after the shock, households require, not only an increase in the return on bank capital, but also an increase in the return on deposits, R^D.[79] In particular we assume that after the decrease in the common productivity shock, R^D increases by 0.1% in the three variants of the model, gradually converging to its steady state value according to the same autoregressive process followed by R^S. The results, not reported here, do not change significantly: the responses of the model's key variables to the technology shock are stronger in all the variants of the model when compared to the results reported in 3.3.1, but the amplification effect, associated with the introduction of Basel II capital requirements, remains valid, as long as the increase in R^S is significantly higher than the increase in R^D, as we assume in our experiments.

Increasing the Upper Limit of k

As analyzed in 3.3.1, the assumption that the representative bank treats all firms with $k^j \geqslant 3$ equally, affects the response of the economy to the negative technology shock. Here we test the effects of increasing this upper limit from 3 to 4. That is, we recalibrate the parameters underlying the relationship between the capital requirements risk weights (α_e) and firms' ratio of capital expenditures to net worth (k) - see equation 3.16 in Section 3.2 - such that a zero risk weight is assigned to firms with $k = 1$ and a maximum risk weight of 2.4 is assigned to firms with $k = 4$. Besides, we consider, in the computational procedure, maximum values for the external finance premium and for the default threshold value (derived from the optimal contracting problem FOCs when $k = 4$), and assume that those values hold for all firms with $k \geq 4$. We then solve the new calibrated steady state model, considering both Basel I and Basel II capital requirements, and analyze the effects of a negative technology shock assuming a countercyclical return on bank capital, as before.

The amplification effect underlying the Basel II capital requirements remains at work in this new context: the economy is characterized by a large fraction of highly leveraged

[79] In fact, the results obtained in Section 3.2 indicate that R^D varies negatively with A in both variants 1 and 2 (see the effects of an increase in A in the general equilibrium steady state model).

firms in steady state and, consequently, the required return on lending by the bank increases more, after the shock, under Basel II than under Basel I (despite the decrease in the average ratio of capital expenditures to net worth). Therefore, the decrease in aggregate loans and in firms' capital expenditures is more amplified under the new regulatory framework. It is worthwhile to mention that, as before, the decrease in the average ratio of capital expenditures to net worth, immediately after the shock, is mainly driven by a decrease in the fraction of highly leveraged firms in the economy (firms with $k^j > 4$) which move to the preceding category ($3 < k^j \leq 4$). However, as we assume here a higher value for the upper limit of k, the average capital requirement risk weight (α_e), the average default threshold ($\overline{\omega}$) and the average external finance premium (l) follow the same path of the average ratio of capital expenditures to net worth (k), in contrast with the previous experiments.

3.4 Concluding Remarks

As argued by Lowe [65], Allen and Saunders [3] and Amato and Furfine [6], the banking sector is intrinsically procyclical, regardless of the design of capital requirements. Indeed, in the presence of financial market frictions, concerns about loan quality and repayment probability lead banks to decrease lending in bad times, exacerbating the economic slowdown, as firms and individuals that cannot easily substitute bank loans with alternative sources of funding decrease their investment activity. In good times, in turn, banks tend to increase lending, possibly exacerbating the initial boom. Despite the widely recognized effort of the new Basel Accord to deal with the shortcomings of the previous accord, some concerns have been raised that Basel II may accentuate the procyclical tendencies of banking, with potential macroeconomic consequences.

Focusing on the relationship between the banking sector and credit constrained firms, this last essay provides a framework which can be used to evaluate the potential procyclical effects of Basel II, by introducing a simplified version of the new capital requirements rules into a heterogeneous-agent model, in which firms have different access to bank credit depending on their financial position and, consequently, on their credit risk. It thus allows a fuller account of Basel II rules than the model developed in Chapter 2, by considering that credit risk varies, not only along the business cycle, but also across firms.

The general equilibrium model in steady state illustrates that the introduction of regulatory capital requirements under both Basel I and Basel II has a negative effect on the economy's aggregate output. As households require a liquidity premium to hold bank capital in their portfolios, this asset is more costly to raise than deposits, as in Chapter 2. The introduction of regulatory capital requirements, by forcing banks to finance a fraction of loans with bank capital, thus increases the banks' loan funding cost and, consequently, banks' lending rates, thereby leading to a lower aggregate amount of loans granted to firms and, thus, to lower physical capital accumulation and output. This result should, however, be cautiously interpreted, bearing in mind that the model abstracts from some positive features of banking regulation, which may counteract the aforementioned effect. We ignore, for instance, the role of bank capital regulation in avoiding financial crises, which certainly affects the macroeconomic equilibrium.

In a stationary equilibrium characterized by a significant fraction of high credit risk firms, the former effect is stronger under Basel II than under Basel I. As the minimum capital requirements, under Basel II, become a function of each borrower perceived credit risk, banks with a relatively high risk asset portfolio will have to finance a higher fraction of loans with bank capital than under Basel I. Again, the resulting additional cost faced by those banks under the new accord is passed on to borrowers through an increase in the firms' financing costs, leading to a decrease in the average leverage ratio and exacerbating the negative effects of the introduction of regulatory capital requirements on physical capital accumulation and output. This result is in line with one of the outcomes of a very recent paper by Zhu [99], according to which the impact of the changeover from Basel I to Basel II capital requirements may differ substantially across banks depending on the risk profile of their loan portfolios: according to the model developed by Zhu, Basel II will lead to a higher ratio of bank capital to loans for small and also more risky banks. Nevertheless, we should bear in mind that, due to the focus on business cycle implications, our model leaves out some positive effects and externalities which should emerge with the introduction of Basel II and which should positively affect the steady state equilibrium, counterbalancing our result.

The model developed in Chapter 3 allow us to conclude that the small (and also more leveraged) firms are the ones that will lose more with the introduction of the new risk-sensitive capital requirements, supporting the concerns that have been raised that the new regulation may raise the financing costs of small and medium-sized enterprises - due to banks' perception that these firms are riskier - and the special treatment given to these firms by the last version of Basel II. We also found that a permanent increase in the technology level has positive effects on steady state aggregate output, especially under Basel II, indicating the existence of potentially stronger procyclical effects under the new regulatory framework.

To the extent that it is more costly to hold bank capital in bad times and that the representative bank's loan portfolio is characterized by a significant fraction of highly leveraged firms, the introduction of an aggregate technology shock into a partial equilibrium version of the former heterogeneous-agent model supports the former outcome, that is, supports the Basel II procyclicality hypothesis. By considering that the liquidity premium required by the households moves countercyclically (based on Chapter 2 results) and it is, therefore, more costly for the bank to raise bank capital during an economic downturn, the introduction of Basel II capital requirements exacerbates the (countercyclical) response of the firms' financing cost to an aggregate technology shock, leading to a more amplified decrease in firms' physical capital accumulation and output.

This amplification effect rests, not only on the countercyclical liquidity premium, as in Chapter 2, but also on the risk profile of the bank's loan portfolio. The model predicts that the financing cost of highly leveraged firms is very sensitive to changes in the required return on bank capital. As the economy's stationary equilibrium is characterized by a significant fraction of this type of firms, yielding a minimum ratio of bank capital to loans higher under Basel II than under Basel I, the average financing cost faced by firms responds more strongly to the aggregate technology shock under Basel II, leading to more amplified effects on capital accumulation and output. We may thus conclude that, according to the model developed in Chapter 3, the amplification effect underlying Basel

II tends to hold in an economy characterized by a significant fraction of small firms, which usually cannot easily substitute bank loans with alternative sources of funding and have higher perceived credit risk than large firms.

This result supports Kashyap and Stein [56]'s argument that Basel II capital requirements have the potential to create an amount of additional cyclicality in capital charges that may be quite large, depending on a bank's customer mix. The Basel II procyclical effect should be greater, the greater the fraction of firms who begin with relatively high leverage ratios, that is, with relatively high credit risk. The distribution of firms over their leverage ratio, which in the model proxies for the credit risk, is therefore crucial to evaluate the potential procyclical effects of the new bank capital requirements rules. Besides, the Basel II procyclicality hypothesis holds even if the predictability view - which considers the possibility of measured credit risk being relatively high (low) when times are good (bad) - is confirmed. That is, the decrease in the average leverage ratio, that follows the negative aggregate shock in the model economy, is not sufficient to offset the amplification effect. Therefore, the adoption of the predictability view of the business cycle may thus not be sufficient to counteract the procyclical effects of Basel II, depending on the bank's customer mix and on how costly it is for banks to hold bank capital during a recession.

A clear lesson to be drawn is that the potential procyclical and across firms effects should be taken into account when designing a bank capital regulatory framework. Although not analyzed in this work, we believe that a well regulated, sounder and less prone to systemic risk banking system improves the financing of efficient firms across the economy. But it is no less true, as our work implies, that overregulation, leading to large and procyclical capital requirements, may counteract those positive aspects and, on top of that, may impose a stronger penalization to the financing of smaller and more leveraged firms, which, in many instances, coincide with the more dynamic and innovative segments of the economy.

Overall, the theoretical models developed in Chapters 2 and 3 predict that the introduction of regulatory bank capital requirements tends to amplify the effects of technology and monetary and fiscal policy shocks in the economy, taking into account that raising bank capital is costly, especially during economic downturns. Chapter 2 builds a bank capital channel into a dynamic general equilibrium model, and finds that it amplifies the real effects of monetary policy shocks and business cycle fluctuations, through a liquidity premium effect. Thus, introducing bank capital seems to enhance the role of financial frictions in the propagation of shocks, in line with the arguments in related literature. Chapter 3, by embedding the bank-borrower relationship into a heterogeneous-agent model, shows that the amplification effects may be stronger under Basel II capital requirements, supporting the Basel II procyclicality hypothesis, depending on the banks' customer portfolios. That is, even if the new Basel Accord may be more effective than the previous one in reducing the riskiness of the banking sector, it may accentuate the procyclical tendencies of the banking sector and, consequently, amplify the business cycle fluctuations.

However, none of the models was designed to capture the effectiveness of Basel I and Basel II in preventing bank failure. Economic policy conclusions should thus be drawn carefully. As mentioned throughout the dissertation, our analysis has not been concerned with questions such as whether bank regulation is itself optimal. We abstract from risk and incentives that support the introduction of regulatory capital requirements and, therefore, our analysis does not support any normative conclusions regarding bank-capital regulation.

Nevertheless, it will be possible to capture, in future work, some of the positive externalities associated with banking regulation - in systemic risk prevention, for instance - and analyze to what extent those effects may counteract the main results of Chapters 2 and 3.

Another positive way forward will be to introduce the aggregate technology shock considered in Chapter 3 in a general equilibrium heterogeneous-agent model, which will allow the endogenous derivation of the behavior of the required return on bank capital by the households throughout the business cycle. As mentioned, we did not pursue this methodology here due to the large number of state variables considered, which renders the model developed in Chapter 3 very slow to converge. One way to overcome this technical difficulty is to abstract from the external adjustment costs in physical capital accumulation, as the financial accelerator effect of Bernanke *et al.* [17] seems to be of second-order importance when the focus is on evaluating the procyclical effects of Basel II *vs* Basel I in the context of the model in Chapter 3. In fact, and in contrast with the model developed in Chapter 2, the amplification effect of Basel II in Chapter 3 rests exclusively on loan supply effects, being independent of the financial accelerator effect associated with the borrowers' balance sheet channel.

Further research could also introduce entry and exit of firms in the heterogeneous-agent model. This should avoid the possibility that the entrepreneurial sector accumulates enough net worth to be fully self-financed and permit to abandon the assumption that each entrepreneur consumes, in every period, a constant fraction of his resources. Finally, it may prove interesting to give more emphasis to the role of households' consumption, in which case labor should be introduced in the framework developed in chapter 3.

3.5 Appendices

Appendix A: Optimal Contracting Problem

Following BGG, and in order to solve equations (3.6) and (3.7) derived from the FOCs of the contracting problem, we made the following assumptions (to simplify the notation we now drop the j superscript):

Assumptions

$$\ln(\omega) \sim N\left(-0.5\sigma^2_{\ln\omega}, \sigma^2_{\ln\omega}\right).$$

Therefore, $E(\omega) = 1$ and

$$E(\omega|\omega \geqslant \overline{\omega}) = \frac{1 - \Phi(z - \sigma_{\ln\omega})}{1 - \Phi(z)},$$

where $\Phi(.)$ is the c.d.f. of the standard normal, $\phi(.)$ is the p.d.f. of the standard normal, and z is related to $\overline{\omega}$ through

$$z \equiv \frac{\ln(\overline{\omega}) + 0.5\sigma^2_{\ln\omega}}{\sigma_{\ln\omega}}.$$

Let

$$y = z - \sigma_{\ln\omega} \equiv \frac{\ln(\overline{\omega}) - 0.5\sigma^2_{\ln\omega}}{\sigma_{\ln\omega}}.$$

Under these assumptions it is straightforward to compute:

1. The expected gross share of profit going to the lender, $\Gamma(\overline{\omega})$

By definition,

$$\Gamma(\overline{\omega}) \equiv \int_0^{\overline{\omega}} \omega f(\omega) d\omega + \overline{\omega} \int_{\overline{\omega}}^{\infty} f(\omega) d\omega = E(\omega|\omega < \overline{\omega}) \Pr(\omega < \overline{\omega}) + \overline{\omega} \Pr(\omega \geqslant \overline{\omega}).$$

Therefore,

$$1-\Gamma\left(\overline{\omega}\right)=1-E(\omega|\omega<\overline{\omega})\Pr(\omega<\overline{\omega})-\overline{\omega}\Pr(\omega\geqslant\overline{\omega}).$$

Since,

$$E(\omega)=1\iff E(\omega|\omega<\overline{\omega})\Pr(\omega<\overline{\omega})+E(\omega|\omega\geqslant\overline{\omega})\Pr(\omega\geqslant\overline{\omega})=1\iff$$
$$\iff E(\omega|\omega<\overline{\omega})\Pr(\omega<\overline{\omega})=1-E(\omega|\omega\geqslant\overline{\omega})\Pr(\omega\geqslant\overline{\omega}),$$

$1-\Gamma\left(\overline{\omega}\right)$ and $\Gamma\left(\overline{\omega}\right)$ can be rewritten as

$$\begin{gathered}1-\Gamma\left(\overline{\omega}\right)=1-1+E(\omega|\omega\geqslant\overline{\omega})\Pr(\omega\geqslant\overline{\omega})-\overline{\omega}\Pr(\omega\geqslant\overline{\omega})=\\=\left[E(\omega|\omega\geqslant\overline{\omega})-\overline{\omega}\right]\Pr(\omega\geqslant\overline{\omega})=\left[\frac{1-\Phi(z-\sigma_{\ln\omega})}{1-\Phi(z)}-\overline{\omega}\right]\left[1-\Phi(z)\right];\\\Gamma\left(\overline{\omega}\right)=\Phi(z-\sigma_{\ln\omega})+\overline{\omega}\left[1-\Phi(z)\right]=\Phi(y)+\overline{\omega}\left[1-\Phi(z)\right].\end{gathered}$$

2. $\Theta\left(\overline{\omega}\right)$

$$\begin{gathered}\Theta\left(\overline{\omega}\right)=\int_0^{\overline{\omega}}\omega f(\omega)d\omega=1-E(\omega|\omega\geqslant\overline{\omega})\Pr(\omega\geqslant\overline{\omega})=\\=1-\frac{1-\Phi(z-\sigma_{\ln\omega})}{1-\Phi(z)}\left[1-\Phi(z)\right]=\Phi(z-\sigma_{\ln\omega})=\Phi(y).\end{gathered}$$

3. $\Gamma'\left(\overline{\omega}\right)$

$$\begin{aligned}\Gamma'\left(\overline{\omega}\right)&=\frac{1}{\overline{\omega}\sigma_{\ln\omega}}\phi(z-\sigma_{\ln\omega})+1-\Phi(z)-\frac{1}{\sigma_{\ln\omega}}\phi(z)=\\&=\frac{1}{\overline{\omega}\sigma_{\ln\omega}}\phi(y)+1-\Phi(z)-\frac{1}{\sigma_{\ln\omega}}\phi(z).\end{aligned}$$

4. $\Theta'\left(\overline{\omega}\right)$

$$\Theta'\left(\overline{\omega}\right)=\frac{1}{\overline{\omega}\sigma_{\ln\omega}}\phi(z-\sigma_{\ln\omega})=\frac{1}{\overline{\omega}\sigma_{\ln\omega}}\phi(y).$$

As derived in Section 3.2, the contracting problem, which determines the division of the expected gross project output $A\left(K_{t+1}^{j}\right)^{\alpha}+E\left(Q_{t+1}^{j}\right)(1-\delta)K_{t+1}^{j}$ between the borrower and the lender (ignoring the covariance between Q_{t+1}^{j} and ω_{t+1}^{j}), may be written as:

$$
\begin{aligned}
&\max_{K_{t+1}^{j},\overline{\omega}_{t+1}^{j}} \left[1-\Gamma\left(\overline{\omega}_{t+1}^{j}\right)\right]\left[A\left(K_{t+1}^{j}\right)^{\alpha}+E\left(Q_{t+1}^{j}\right)(1-\delta)K_{t+1}^{j}\right]\\
&s.t.\\
&\left[\Gamma(\overline{\omega}_{t+1}^{j})-\mu\Theta(\overline{\omega}_{t+1}^{j})\right]\left[A\left(K_{t+1}^{j}\right)^{\alpha}+E\left(Q_{t+1}^{j}\right)(1-\delta)K_{t+1}^{j}\right]=R_{t+1}^{Fj}(Q_{t}^{j}K_{t+1}^{j}-N_{t+1}^{j}).
\end{aligned}
$$

Taking equation (3.2) into account, the expected gross project output can be rewritten as

$$
A\left(K_{t+1}^{j}\right)^{\alpha}+E\left(Q_{t+1}^{j}\right)(1-\delta)K_{t+1}^{j}=R_{t+1}^{Kj}Q_{t}^{j}K_{t+1}^{j}+(1-\alpha)A\left(K_{t+1}^{j}\right)^{\alpha}
$$

and the contract problem becomes

$$
\begin{aligned}
&\max_{K_{t+1}^{j},\overline{\omega}_{t+1}^{j}} \left[1-\Gamma\left(\overline{\omega}_{t+1}^{j}\right)\right]\left[R_{t+1}^{Kj}Q_{t}^{j}K_{t+1}^{j}+(1-\alpha)A\left(K_{t+1}^{j}\right)^{\alpha}\right]\\
&s.t.\\
&\left[\Gamma(\overline{\omega}_{t+1}^{j})-\mu\Theta(\overline{\omega}_{t+1}^{j})\right]\left[R_{t+1}^{Kj}Q_{t}^{j}K_{t+1}^{j}+(1-\alpha)A\left(K_{t+1}^{j}\right)^{\alpha}\right]=R_{t+1}^{Fj}(Q_{t}^{j}K_{t+1}^{j}-N_{t+1}^{j}).
\end{aligned}
$$

Solving the contract, with respect to K_{t+1}^{j} and $\overline{\omega}_{t+1}^{j}$, renders the following FOCs:

$$
\begin{aligned}
K_{t+1}^{j} \quad &: \quad \left[1-\Gamma\left(\overline{\omega}_{t+1}^{j}\right)\right]\left[R_{t+1}^{Kj}Q_{t}^{j}+(1-\alpha)\alpha A\left(K_{t+1}^{j}\right)^{\alpha-1}\right]+\\
&\quad +\lambda^{j}\left\{\left[\Gamma(\overline{\omega}_{t+1}^{j})-\mu\Theta(\overline{\omega}_{t+1}^{j})\right]\left[R_{t+1}^{Kj}Q_{t}^{j}+(1-\alpha)\alpha A\left(K_{t+1}^{j}\right)^{\alpha-1}\right]-R_{t+1}^{Fj}Q_{t}^{j}\right\} \;=0;\\
\overline{\omega}_{t+1}^{j} \quad &: \quad \Gamma'\left(\overline{\omega}_{t+1}^{j}\right)-\lambda^{j}\left[\Gamma'\left(\overline{\omega}_{t+1}^{j}\right)-\mu\Theta'\left(\overline{\omega}_{t+1}^{j}\right)\right]=0;\\
\lambda^{j} \quad &: \quad \left[\Gamma(\overline{\omega}_{t+1}^{j})-\mu\Theta(\overline{\omega}_{t+1}^{j})\right]\left[R_{t+1}^{Kj}Q_{t}^{j}K_{t+1}^{j}+(1-\alpha)A\left(K_{t+1}^{j}\right)^{\alpha}\right]-R_{t+1}^{Fj}(Q_{t}^{j}K_{t+1}^{j}-N_{t+1}^{j})=0
\end{aligned}
$$

where λ^{j} is the Lagrange multiplier associated with the constraint that the bank earns its required rate of return in expectation. These FOCs yield, in turn, equations (3.6) and (3.7) in 3.2.1.

Appendix B: Aggregate Consistency Condition

To derive the aggregate consistency condition - equation (3.24) in 3.2.4 - we first compute the total amount of assets held by each entrepreneur, at the end of time t.

Entrepreneurs that do not default at time t

For this type of entrepreneurs, the amount of assets held, at the end of time t, is given by

$$\mathcal{W}_{t+1}^{j} = \omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j + W^e.$$

Entrepreneurs' assets, in turn, are allocated to consumption, to the payment to the bank and to net worth, that is,

$$\omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j + W^e = C_t^{ej} + \overline{\omega}_t^j\left[A\left(K_t^j\right)^{\alpha} + E\left(Q_t^j\right)(1-\delta)K_t^j\right] + N_{t+1}^j.$$

If $\omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j < \overline{\omega}_t^j\left[A\left(K_t^j\right)^{\alpha} + E\left(Q_t^j\right)(1-\delta)K_t^j\right]$,we assume that the entrepreneur pays the bank $\omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j$ and keeps the remaining (W^e).

Net worth is then used to buy capital ($Q_t^j K_{t+1}^j$). Since $N_{t+1}^j < Q_t^j K_{t+1}^j$ the entrepreneur must borrow to buy capital: $N_{t+1}^j + L_{t+1}^j = Q_t^j K_{t+1}^j$.

We may then conclude that,

- if $\omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j \geq \overline{\omega}_t^j\left[A\left(K_t^j\right)^{\alpha} + E\left(Q_t^j\right)(1-\delta)K_t^j\right]$

$$\begin{aligned} &\omega_t^j A\left(K_t^j\right)^{\alpha} + Q_t^j(1-\delta)\omega_t^j K_t^j + W^e = \\ &= C_t^{ej} + \overline{\omega}_t^j\left[A\left(K_t^j\right)^{\alpha} + E\left(Q_t^j\right)(1-\delta)K_t^j\right] + Q_t^j K_{t+1}^j - L_{t+1}^j; \end{aligned} \tag{3.26}$$

- otherwise

$$\omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)\omega_t^j K_t^j + W^e = \\ = C_t^{ej} + \omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)\omega_t^j K_t^j + Q_t^j K_{t+1}^j - L_{t+1}^j. \quad (3.27)$$

Entrepreneurs that default at time t

As above, for this type of entrepreneurs, the amount of assets held, at the end of time t, is given by

$$\mathcal{W}_{t+1}^j = \omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)\omega_t^j K_t^j + W^e.$$

Entrepreneurs' assets are allocated to consumption, to the payment to the bank and to net worth:

$$\omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)\omega_t^j K_t^j + W^e = C_t^{ej} + \omega_t^j \left[A \left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right] + N_{t+1}^j.$$

If $Q_t^j < E\left(Q_t^j\right)$, we assume that the entrepreneur pays the bank

$$\omega_t^j \left[A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)K_t^j\right]$$

and keeps the remaining (W^e).

Net worth is then used to buy capital ($Q_t^j K_{t+1}^j$). Since $N_{t+1}^j < Q_t^j K_{t+1}^j$ the entrepreneur must borrow to buy capital: $N_{t+1}^j + L_{t+1}^j = Q_t^j K_{t+1}^j$.

In this context,

- if $Q_t^j \geq E\left(Q_t^j\right)$

$$\omega_t^j A \left(K_t^j\right)^\alpha + Q_t^j (1-\delta)\omega_t^j K_t^j + W^e = \\ = C_t^{ej} + \omega_t^j \left[A \left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right] + Q_t^j K_{t+1}^j - L_{t+1}^j; \quad (3.28)$$

- otherwise

$$
\begin{aligned}
&\omega_t^j A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)\omega_t^j K_t^j + W^e = \\
&= C_t^{ej} + \omega_t^j\left[A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)K_t^j\right] + Q_t^j K_{t+1}^j - L_{t+1}^j.
\end{aligned} \tag{3.29}
$$

Aggregate consistency condition

Aggregating equations (3.26), (3.27), (3.28) and (3.29) over firms, we get[80]

$$
\begin{aligned}
&Y_t + W^e + \left[\int Q_t^j(1-\delta)\omega_t^j K_t^j d\Upsilon_{t+1}\right] = \\
&= C_t^e + \left[\int Q_t^j K_{t+1}^j d\Upsilon_{t+1}\right] - L_{t+1} + \text{Bank Revenues}_t,
\end{aligned} \tag{3.30}
$$

where Υ_{t+1} is the distribution of firms over the state space (N, K, Q, ω) at the end of time t, $Y_t = \int \omega_t^j A\left(K_t^j\right)^\alpha d\Upsilon_{t+1}$, $C_t^e = \int C_t^{ej} d\Upsilon_{t+1}$, $L_{t+1} = \int L_{t+1}^j d\Upsilon_{t+1}$ and

$$
\begin{aligned}
\text{Bank Revenues}_t \;=\; &\int_{j\in A} \overline{\omega}_t^j\left[A\left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right] d\Upsilon_{t+1} + \\
&\int_{j\in B} \omega_t^j\left[A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)K_t^j\right] d\Upsilon_{t+1} + \\
&\int_{j\in C} \omega_t^j\left[A\left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right] d\Upsilon_{t+1} + \\
&\int_{j\in D} \omega_t^j\left[A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)K_t^j\right] d\Upsilon_{t+1},
\end{aligned}
$$

with A = set of borrowers that do not default and for which

$$
\omega_t^j A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)\omega_t^j K_t^j \geq \overline{\omega}_t^j\left[A\left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right],
$$

[80] Recall that we are assuming a continuum of firms, producers of manufactured goods, of total measure one.

B = set of borrowers that do not default and for which

$$\omega_t^j A\left(K_t^j\right)^\alpha + Q_t^j(1-\delta)\omega_t^j K_t^j < \overline{\omega}_t^j\left[A\left(K_t^j\right)^\alpha + E\left(Q_t^j\right)(1-\delta)K_t^j\right],$$

C = set of borrowers that default and for which

$$Q_t^j \geq E\left(Q_t^j\right),$$

D = set of borrowers that default and for which

$$Q_t^j < E\left(Q_t^j\right).$$

The realized bank's profits are, in turn, given by

$$\Pi_t^B = \text{Bank Revenues}_t - R_t^D D_t - R_t^S S_t - \text{MonitoringCosts}_t.$$

Rearranging the preceding equation we get

$$\begin{gathered}\text{Bank Revenues}_t = \\ = \Pi_t^B + R_t^D D_t + R_t^S S_t + \text{MonitoringCosts}_t.\end{gathered}$$

Substituting this last expression into equation (3.30) yields

$$\begin{gathered}Y_t + W^e + \left[\int Q_t^j(1-\delta)\omega_t^j K_t^j d\Upsilon_{t+1}\right] = \\ = C_t^e + \left[\int Q_t^j K_{t+1}^j d\Upsilon_{t+1}\right] - L_{t+1} + \Pi_t^B + R_t^D D_t + R_t^S S_t + \text{MonitoringCosts}_t.\end{gathered}$$

Finally, using the bank's balance sheet constraint,

$$L_{t+1} = D_{t+1} + S_{t+1}$$

and the household's budget constraint,

$$C_t = R_t^D D_t - D_{t+1} + R_t^S S_t - S_{t+1} + \Pi_t^B$$

we get equation (3.24):

$$Y_t + W^e + \int Q_t^j (1-\delta)\omega_t^j K_t^j d\Upsilon_{t+1} = C_t + C_t^e + \int Q_t^j K_{t+1}^j d\Upsilon_{t+1} + \text{MonitoringCosts}_t.$$

Appendix C: Computational Procedure[81]

1 Choose a discrete grid of points in the (K, N, Q) state plane: $KVec$, $NVec$ and $QVec$. We consider 30 grid points for K from $[0.5, 30]$, 30 grid points for N from $[0.5, 30]$ and 10 grid points for Q from $[0.5, 1.75]$.

2 Create a discrete grid for the idiosyncratic shock ω and compute the probability associated with the realization of each value in the grid.
Note that ω is an idiosyncratic disturbance to the capital return of type j firms, independently and identically distributed (i.i.d.) across time and across firms, and follows a log-normal distribution with $E(\omega) = 1$. To approximate this distribution we proceed as follows:
a) Create a grid for ω: $grid\omega$ (with size $n\omega = 18$ from $[0.1, 3.25]$);
b) Compute the lognormal cumulative distribution function ($cum\omega$), considering the calibrated value for the standard deviation of $\ln(\omega)$, $SD[\ln(\omega)]$, and taking into account that $E(\omega) = 1$;
c) To discretize $cum\omega$ and compute the probabilities associated with each ω, we first create another grid (ωVec), with the same size of $grid\omega$, and whose points are placed in between the points of $grid\omega$ according to the following procedure:

$$\omega Vec(1) = grid\omega(1),$$
$$\omega Vec(i) = grid\omega(i-1) + \frac{grid\omega(i) - grid\omega(i-1)}{2}, \text{ for } i = 2, 3, ...n\omega.$$

[81] To simplify the notation we now drop the j superscript.

We then compute the probabilities associated with each grid point of ωVec as follows:

$$prob\omega(1) = 0;$$

$$prob\omega(i) = cum\omega(i) - cum\omega(i-1), \text{ for } i = 2, 3, ...n\omega;$$

Note: since $prob\omega(1) = 0$, the first grid point is ignored in simulations.

3 Using the grids defined in step 1, compute $k_t = \frac{Q_{t-1}K_t}{N_t}$, the ratio of capital expenditures to net worth at the end of time $t-1$. This procedure may generate firms whose capital expenditures are less than their net worth ($k_t < 1$), that is, firms that don't need external funds to finance their capital expenditures. The model's calibration guarantees that the fraction of this type of firm is relatively small.

4 Compute, for each type of firm, the bank capital requirements weight α_{e_t} (equal to one, under Basel I, or dependent on the ratio of firms' capital expenditures to net worth, under Basel II, as depicted by equation 3.16). As mentioned in 3.2.5, we assume, under Basel II, that all firms with $k > 3$ are assigned the maximum level of α_e $(= 2)$, which is in line with the assumptions made concerning the contract established between the bank and each entrepreneur (see step 8, below) and avoids unrealistic values of α_e. Self-financed firms, in turn, are assigned α_{e_t} equal to zero.

5 Given the calibrated discount factor, compute the steady state value of R^S, the return on bank capital, using equation (3.23).

6 Guess an initial steady state value for R^D, the return on deposits (constant in steady state).

7 Compute the required return on lending by the bank to each type of firm, R_t^F, as implied by the FOCs of the bank's optimization problem. Here we must also take into account the existence of self-financed firms ($k_t < 1$). In particular, this possibility modifies the bank's optimization problem: we assume that when firm's net worth exceeds its capital expenditures, the entrepreneur deposits the difference in the bank and receives, in the next period, $(N - QK)\, R^D$, where R^D is the return on deposits. Therefore, financial intermediation consists now in collecting funds from households $(D{+}S)$ and self-

financed entrepreneurs (D^e) and granting loans to the leveraged entrepreneurs (L). The bank's objective is then given by:

$$\max_{L^j_{t+1}, D_{t+1}, D^e_{t+1}, S_{t+1}} \left[\int_{j\in B} R^{Fj}_{t+1} L^j_{t+1} d\Upsilon_{t+1} \right] - R^D_{t+1}\left(D_{t+1} + D^e_{t+1}\right) - R^S_{t+1} S_{t+1}$$

$$\text{s.t.} \int_{j\in B} L^j_{t+1} d\Upsilon_{t+1} = D_{t+1} + D^e_{t+1} + S_{t+1} \text{ (balance sheet constraint)}$$

$$\frac{S_{t+1}}{\int_{j\in B} \alpha^j_{e_{t+1}} L^j_{t+1} d\Upsilon_{t+1}} = 0.08 \text{ (binding capital requirements)},$$

where D^e_{t+1} represents the deposits held by the self-financed entrepreneurs, from t to $t+1$,

$$D^e_{t+1} = \int_{j\in D} \left(N^j_{t+1} - Q^j_t K^j_{t+1}\right) d\Upsilon_{t+1},$$

B is the set of entrepreneurs that borrow from the bank and D is the set of self-financed entrepreneurs. The FOCs of this problem lead to the same results obtained in 3.2.2.

8 Compute, for each k_t, the associated external finance premium required by the bank $\left(l_t \equiv R^K_t / R^F_t\right)$ and the cutoff value for the idiosyncratic risk ($\overline{\omega}_t$), using the FOCs of the optimal contractual arrangement problem between each firm and the bank;
There are two technical difficulties which we must deal with.
First, although the contractual problem is defined for firms with $k_t > 1$, the grids defined in step 1 allow for self-financed firms (with $k_t \leq 1$), that is, firms with $N_t - Q_{t-1}K_t \geq 0$. For those firms, and since they don't need to borrow from the bank to buy capital, we assume $\overline{\omega}_t = 0$ (there is no risk of default) and $l_t = 1$ (there is no external finance premium required by the bank);
Second, the grids defined in step 1 also allow for highly leveraged firms. Consequently, the FOCs of the optimal contractual arrangement problem yield very high values of l_t for those firms. To avoid these unrealistic values, we define maximum values for l_t and for $\overline{\omega}_t$ (derived from the optimal contracting problem FOCs when $k = \overline{k}$), and assume that those values hold for all firms with $k \geq \overline{k}$ (we consider $\overline{k} = 3$). In sum, we are assuming

that the bank treats equally all the firms with $k \geqslant \overline{k}$.

Note that the former steps 4, 7 and 8 are required to compute $\overline{\omega}_t$, derived from the contract between the bank and each entrepreneur at the end of time $t-1$, which, in turn, enters the law of motion of the entrepreneur's net worth (see equation 3.8).

9 Guess an initial value of R^K_{t+1} for each type of firm in the state space (N, Q, K, ω).

10 Compute the decision rule for the capital stock, $K_{t+1} = K(K_t, Q_{t-1}, N_t, \omega_t)$, and for the price of capital, $Q_t = Q(K_t, Q_{t-1}, N_t, \omega_t)$:

a) Recall equation (3.2), which defines the expected marginal return to capital,

$$R^K_{t+1} = \frac{A\alpha\left(K_{t+1}\right)^{\alpha-1} + E\left(Q_{t+1}\right)(1-\delta)}{Q_t},$$

and let $g(.) = A\alpha\left(K_{t+1}\right)^{\alpha-1} + E\left(Q_{t+1}\right)(1-\delta)$. Therefore, taking equation (3.2) into account yields, $g(.) = R^K_{t+1}Q_t$.

b) Guess initial values of $g(.)$, for each point in the state space (N, Q, K, ω);

c) Use stepwise linear interpolation to compute $g(.)$ for values of (N, Q, K, ω) outside the grid;

d) Solve equation

$$R^K_{t+1}Q_t = g(.),$$

taking into account that

$$Q_t = \frac{1}{a_1}\left(\frac{K_{t+1} - (1-\delta)K_t}{K_t}\right)^{\frac{1}{\varphi}}.$$

This process allow us to compute the decision rule for capital, $K_{t+1} = K(K_t, Q_{t-1}, N_t, \omega_t)$;

e) Update the guess for $g(.)$,

$$g(.) = A\alpha\left(K_{t+1}\right)^{\alpha-1} + E\left(Q_{t+1}\right)(1-\delta)$$

where $K_{t+1} = K(K_t, Q_{t-1}, N_t, \omega_t)$, $Q_{t+1} = \frac{1}{a_1}\left(\frac{K_{t+2}-(1-\delta)K_{t+1}}{K_{t+1}}\right)^{\frac{1}{\varphi}}$ and $K_{t+2} = K(K_{t+1}, Q_t, N_{t+1}, \omega_{t+1})$. Go back to step 10.c) until convergence;

f) Compute the decision rule $Q_t = Q(K_t, Q_{t-1}, N_t, \omega_t)$, from the FOC derived from the capital producers optimization problem:

$$Q_t = \frac{1}{a_1}\left(\frac{K_{t+1}-(1-\delta)K_t}{K_t}\right)^{\frac{1}{\varphi}},$$

with $K_{t+1} = K(K_t, Q_{t-1}, N_t, \omega_t)$;

11 Compute the law of motion for the net worth $N_{t+1} = N(K_t, Q_{t-1}, N_t, \omega_t)$, as defined by equations (3.8) and (3.10).

Taking into account the assumptions described above (see step 7), the net worth of each self-financed entrepreneur combines profits accumulated from previous capital investment, the endowment W^e and the return on deposits:

$$N^j_{t+1} = \gamma\left\{\omega^j_t A\left(K^j_t\right)^\alpha + Q^j_t(1-\delta)\omega^j_t K^j_t + W^e + (N^j_t - Q^j_{t-1}K^j_t)R^D\right\}.$$

12 Update the guess for R^K_{t+1}:

a) Using the decision rules for Q and K and the law of motion for N, compute

$$k_{t+1}(K_t, Q_{t-1}, N_t, \omega_t) = \frac{Q_t K_{t+1}}{N_{t+1}};$$

b) Following the procedure described in steps 4 and 7, compute, for each type of firm, $\alpha_{e_{t+1}}$ and R^F_{t+1};

c) Compute l_{t+1} and $\overline{\omega}_{t+1}$, following the procedure described in step 8;

d) Update the guess for $R^K_{t+1} : R^K_{t+1} = l_{t+1} \times R^F_{t+1}$. Go back to step 10 - considering the last update for $g(.)$, computed in step 10. e), as the initial guess in step 10. c) - until convergence.

13 Using the decision rules for K and Q, the law of motion for N, and the distribution of ω (defined in step 2), find the steady state distribution of firms over the state space (K, Q, N, ω):

a) Guess an initial distribution Υ_t, such that $\sum\limits_{K_t, Q_{t-1}, N_t, \omega_t} \Upsilon_t(K_t, Q_{t-1}, N_t, \omega_t) = 1$;

b) Compute the distribution of next period:

$$\Upsilon_{t+1}(K_{t+1}, Q_t, N_{t+1}, \omega_{t+1}) =$$
$$= \sum_{K_t, Q_{t-1}, N_t, \omega_t} \left[\mathcal{I}^K(K_t, Q_{t-1}, N_t, \omega_t, K_{t+1}) \mathcal{I}^N(K_t, Q_{t-1}, N_t, \omega_t, N_{t+1}) \right.$$
$$\left. \mathcal{I}^Q(K_t, Q_{t-1}, N_t, \omega_t, Q_t) \Pr(\omega_{t+1}) \Upsilon_t(K_t, Q_{t-1}, N_t, \omega_t) \right],$$

where $\Pr(\omega_{t+1})$ is the probability of realization of ω at time $t+1$ and $\mathcal{I}^K$, $\mathcal{I}^N$ and $\mathcal{I}^Q$ are the following indicator functions:

$$\begin{aligned}
\mathcal{I}^K(K_t, Q_{t-1}, N_t, \omega_t, K_{t+1}) &= \begin{cases} 1, \text{if} & K_{t+1} = K(K_t, Q_{t-1}, N_t, \omega_t) \\ 0, & \text{otherwise} \end{cases}; \\
\mathcal{I}^N(K_t, Q_{t-1}, N_t, \omega_t, N_{t+1}) &= \begin{cases} 1, \text{if} & N_{t+1} = N(K_t, Q_{t-1}, N_t, \omega_t) \\ 0, & \text{otherwise} \end{cases}; \\
\mathcal{I}^Q(K_t, Q_{t-1}, N_t, \omega_t, Q_t) &= \begin{cases} 1, \text{if} & Q_t = Q(K_t, Q_{t-1}, N_t, \omega_t) \\ 0, & \text{otherwise} \end{cases};
\end{aligned}$$

c) Iterate until convergence, that is, until $\Upsilon_\tau(.) = \Upsilon_{\tau+1}(.)$.

After computing the stationary distribution of firms, it is straightforward to compute the aggregate level of capital, output, firms' net worth, entrepreneurial consumption, loans, deposits and bank capital.

14 Compute bank's demand for the household's deposits: $D = \int L^j d\Upsilon - D^e - S$, with $S = 0.08 \int (\alpha_e^j L^j)\, d\Upsilon$.

15 Compute the amount of deposits held by the representative household:

a) Compute household's consumption using the aggregate consistency condition (3.24):[82]

$$C_t = Y_t + W^e + \int \left[Q_t^j (1-\delta) \omega_t^j K_t^j \right] d\Upsilon_{t+1} - C_t^e - \int Q_t^j K_{t+1}^j d\Upsilon_{t+1} - \text{MonitoringCosts}_t$$

b) Compute the amount of deposits held by the representative household using the Euler equation evaluated in steady state (equation 3.22):

$$D = \frac{\alpha_0 C}{1 - \beta R^D}.$$

16 Update the guess for R^D, such that the bank's demand for the household's deposits equals

[82]The introduction of self-financed firms does not change this condition. Detailed derivation, similar to the one in Appendix B, is available upon request.

the amount of deposits held by the representative household. Go back to step 7 until convergence.

Figures

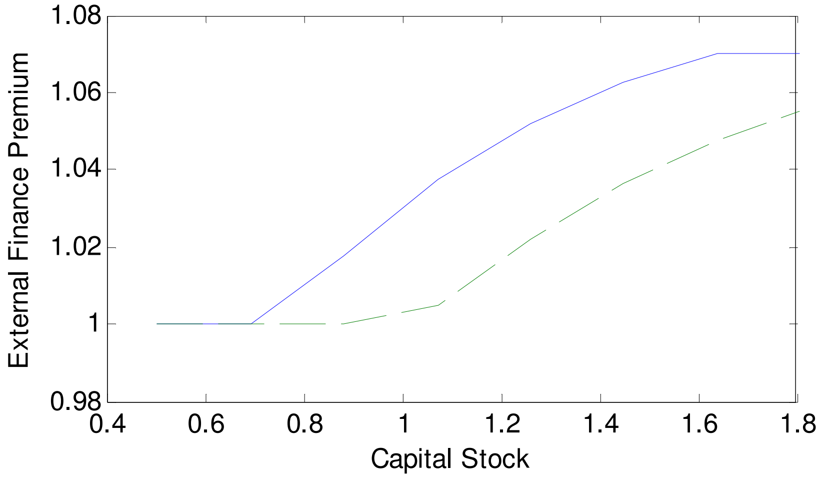

Figure 3.1. The relationship between the capital stock and the external finance premium. Solid line: Net Worth = 0.5; Dashed line: Net Worth = 0.7.

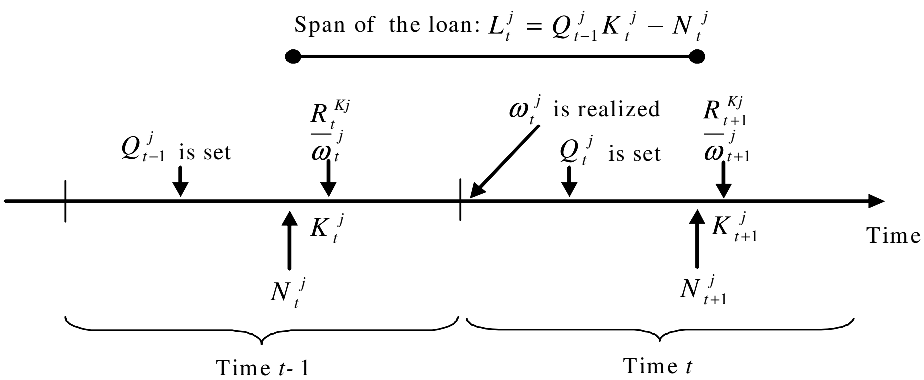

Figure 3.2. Sequence of Events.

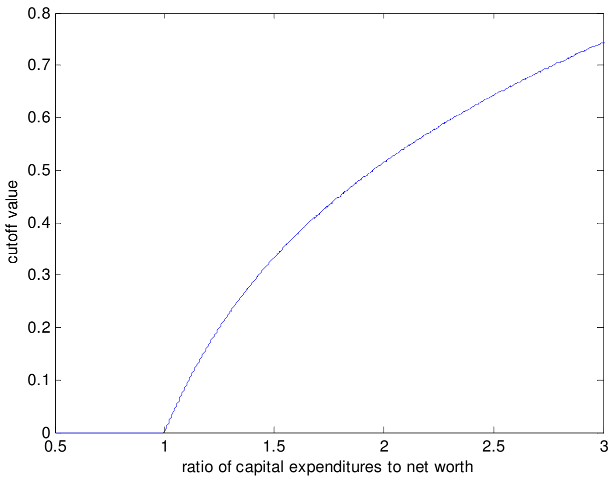

Figure 3.3. The relationship between the ratio of firm's capital expenditures to net worth $\left(k_{t+1}^{j}\right)$ and the cutoff value $\left(\overline{\omega}_{t+1}^{j}\right)$ derived from the financial contract under decreasing returns to scale.

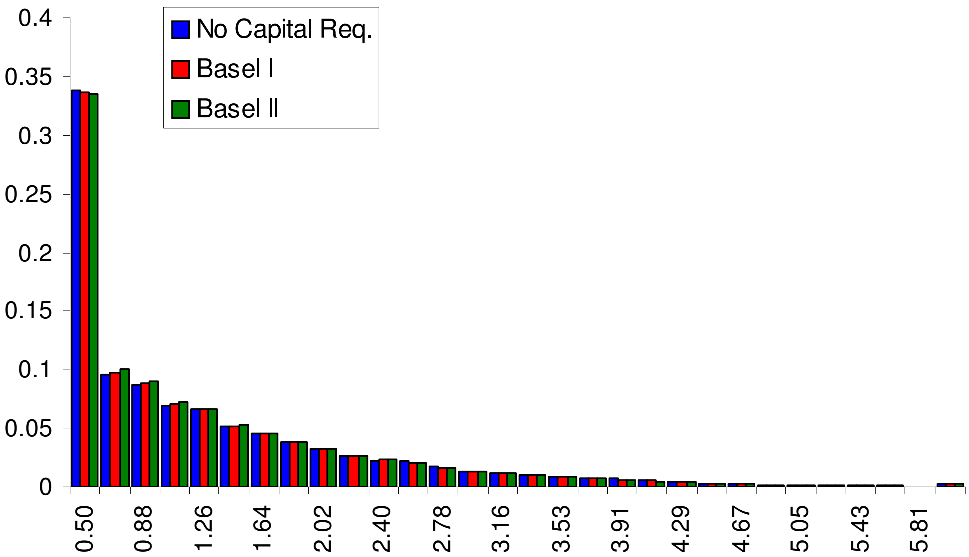

Figure 3.4. Stationary distribution of firms over net worth.

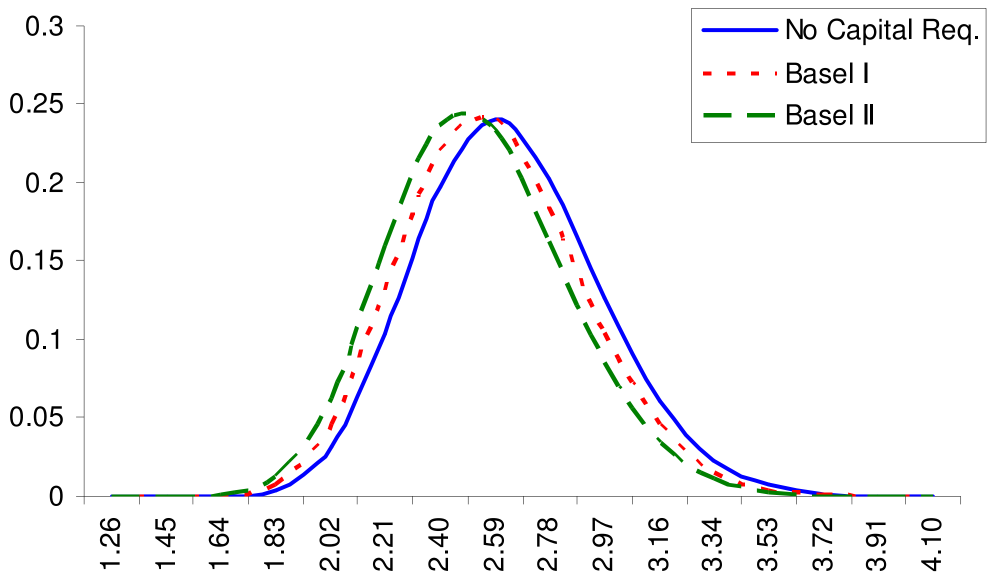

Figure 3.5. Stationary distribution of firms over capital stock.

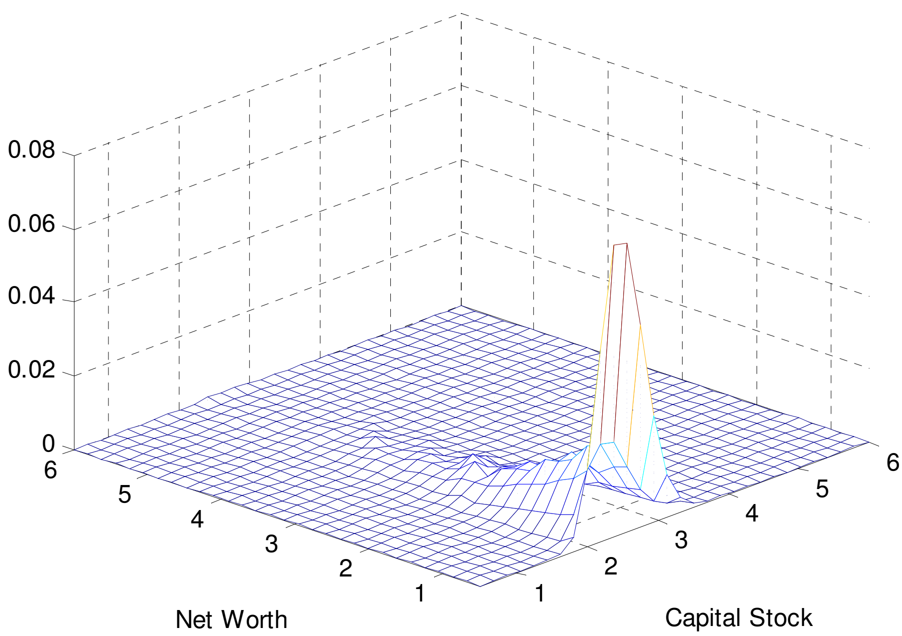

Figure 3.6. Joint stationary distribution of firms over net worth and capital stock in variant 1 (Basel II capital requirements).

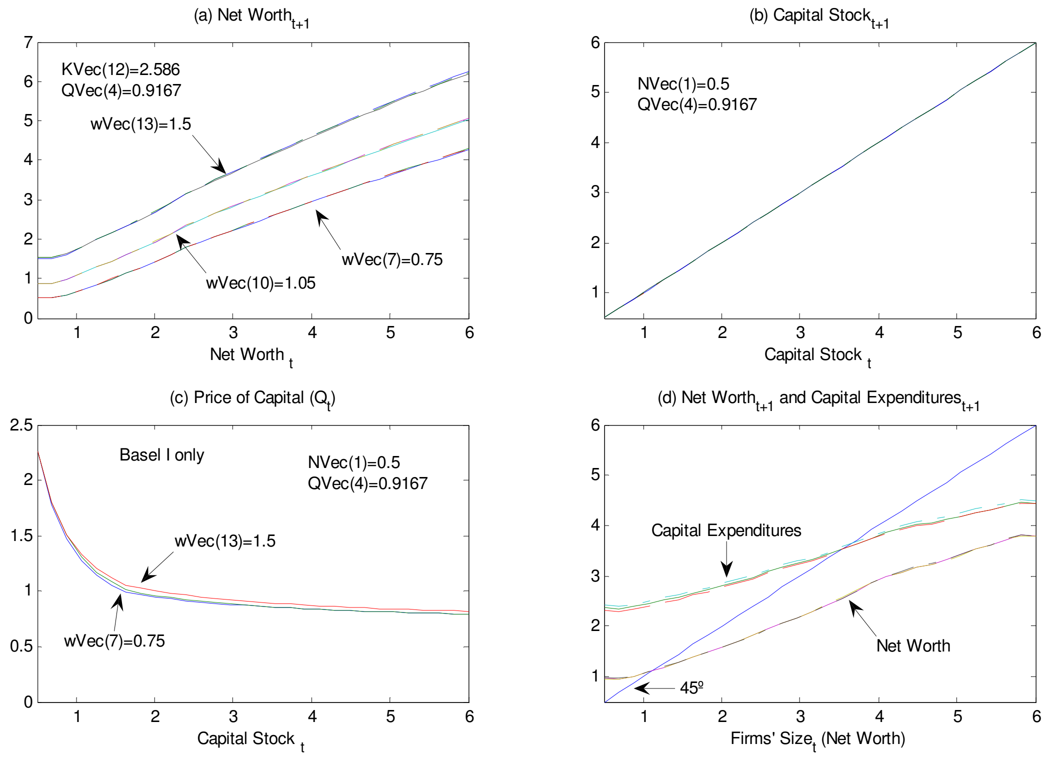

Figure 3.7. Firms' Dynamics in Steady State I - variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

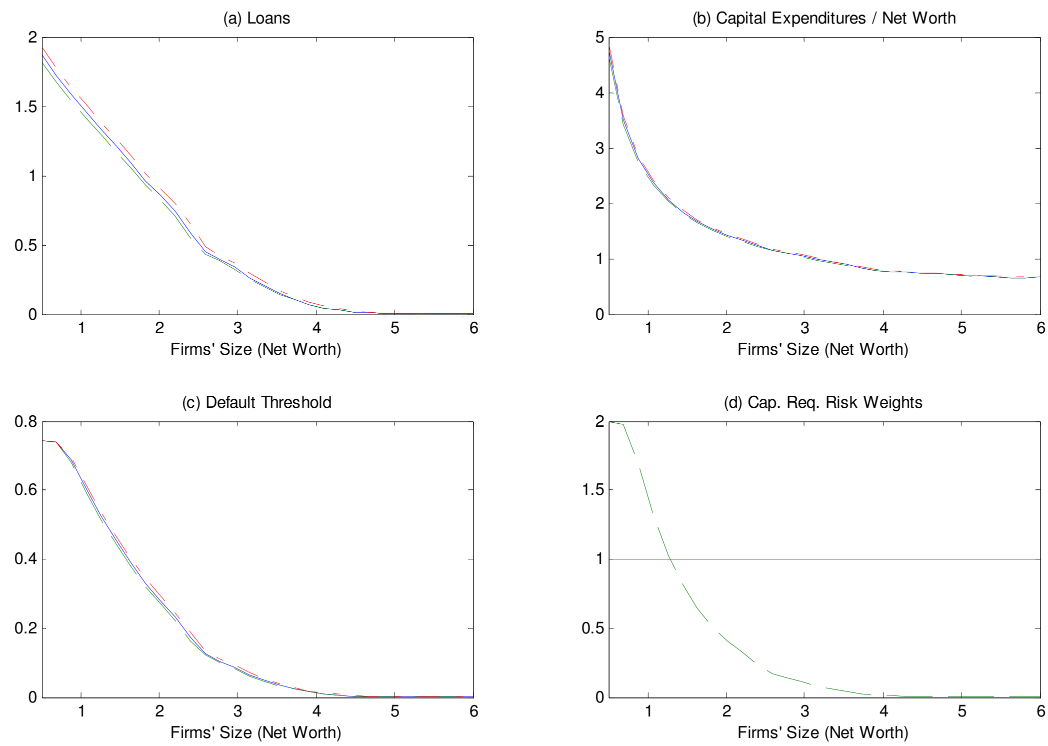

Figure 3.8. Firms' Dynamics in Steady State II - variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

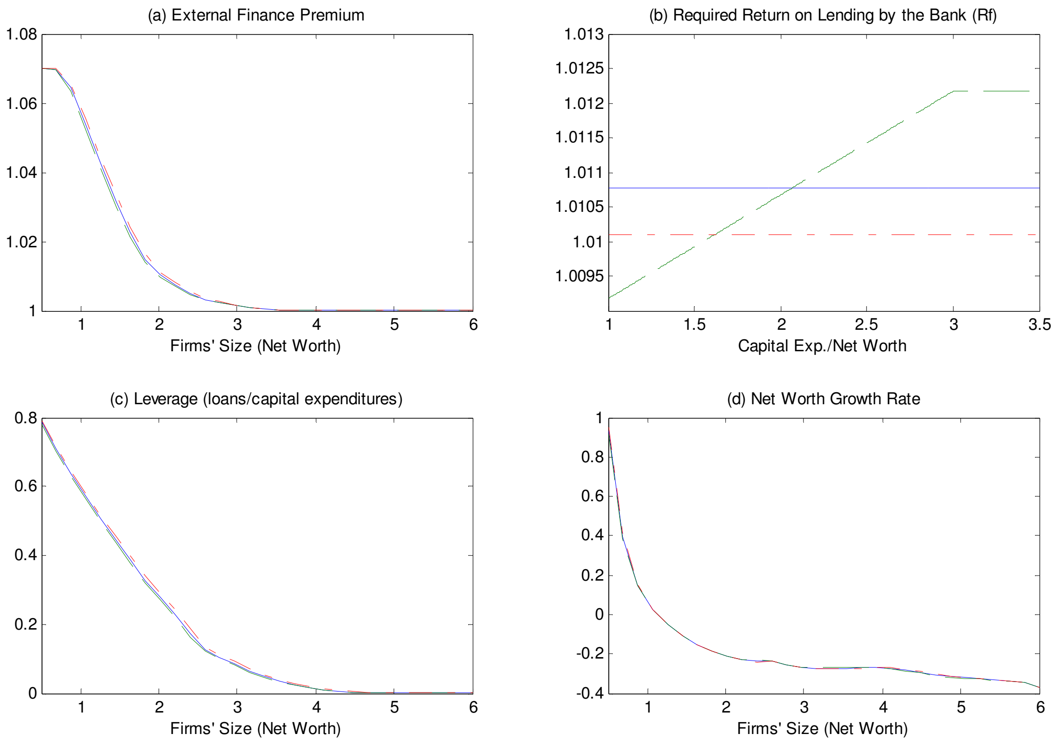

Figure 3.9. Firms' Dynamics in Steady State III - variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

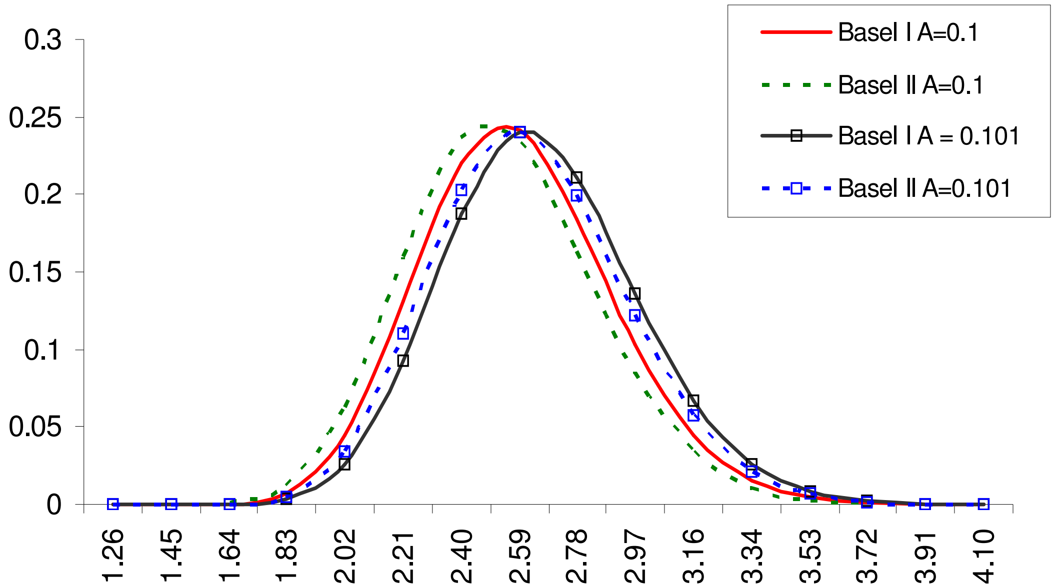

Figure 3.10. Stationary distribution of firms over capital stock: $A = 0.1$ *vs* $A = 0.101$.

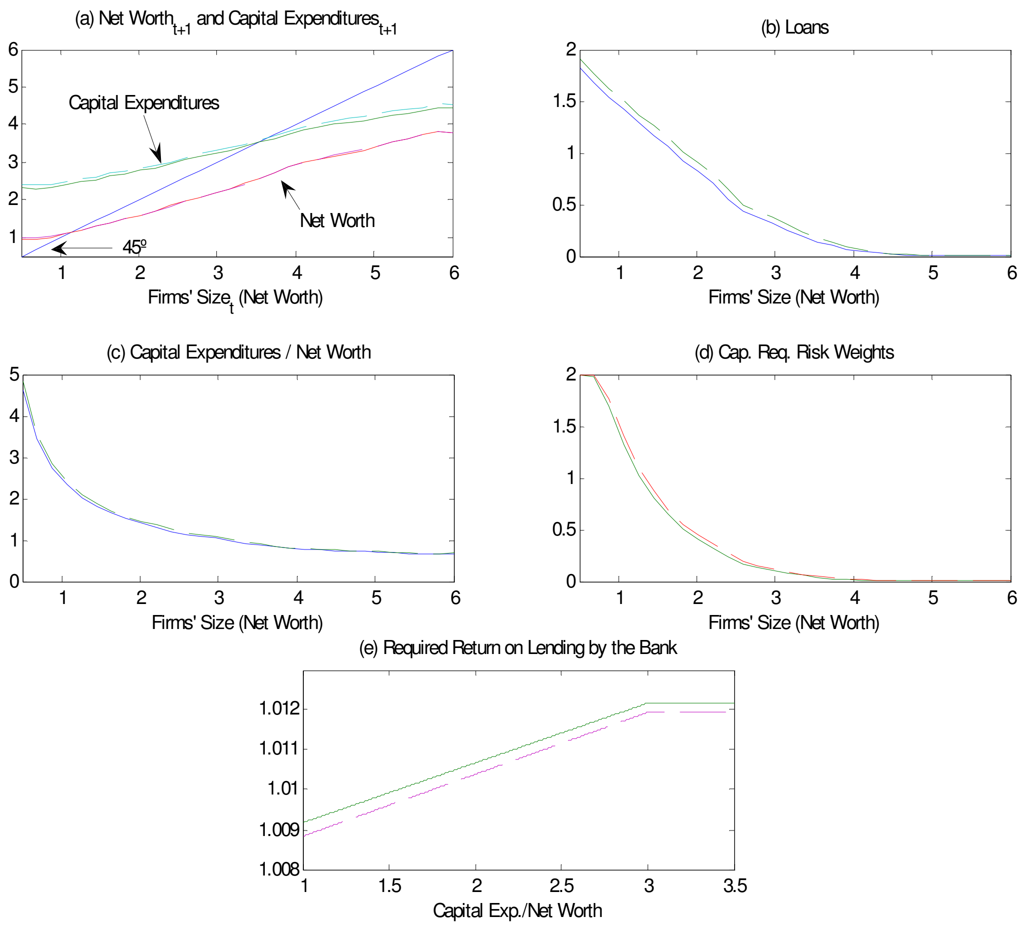

Figure 3.11. Firms' Dynamics in variant 1 (Basel II capital requirements): $A = 0.1$ (solid line) *vs* $A = 0.101$ (dashed line).

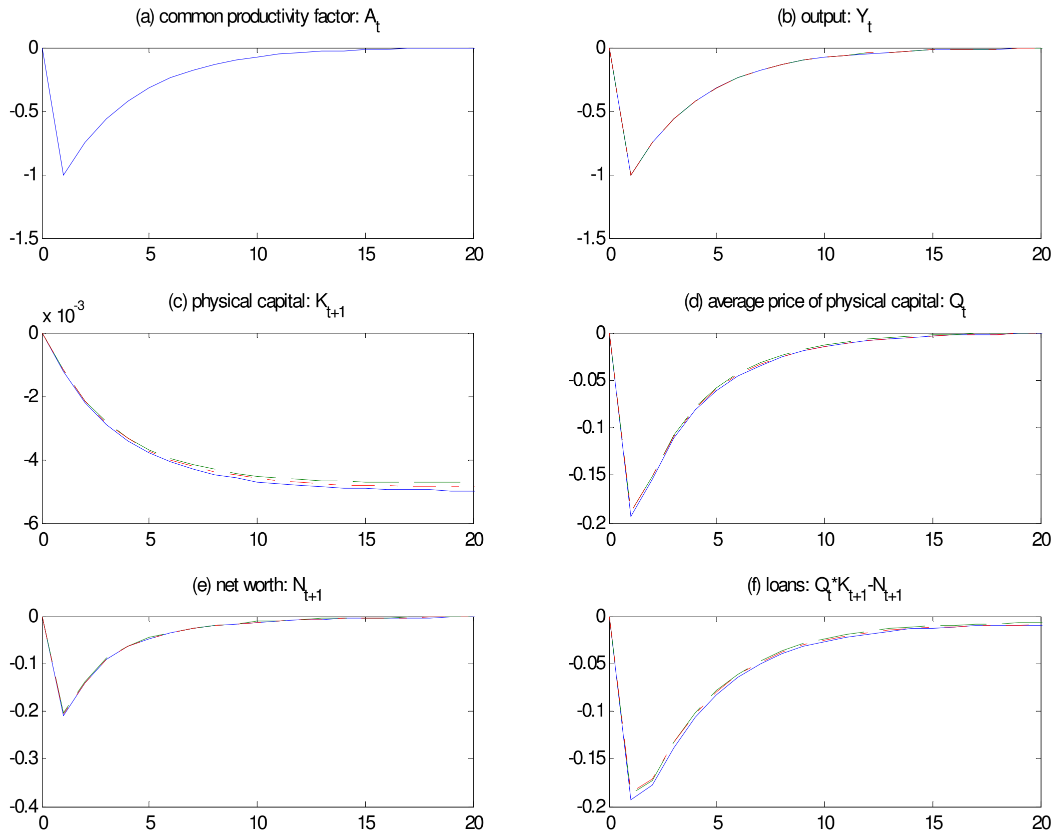

Figure 3.12. Response of economic activity to a negative technology shock: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

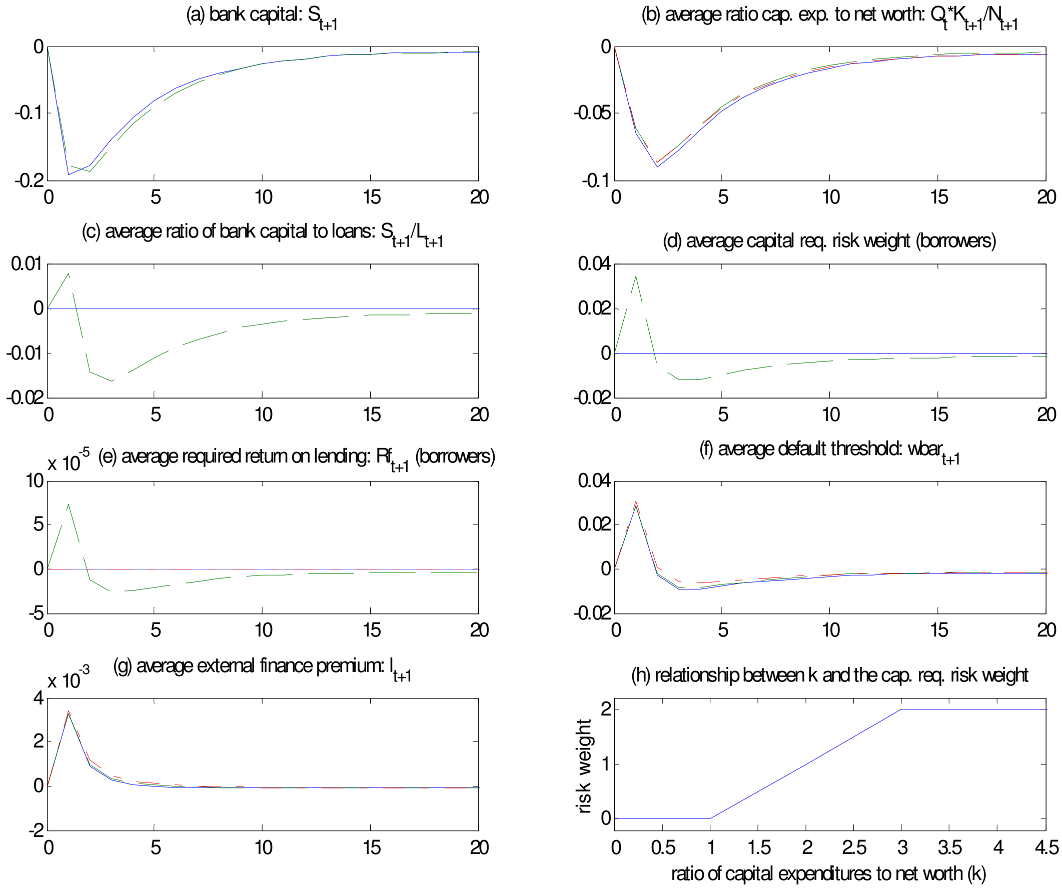

Figure 3.13. Response of financial variables to a negative technology shock: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

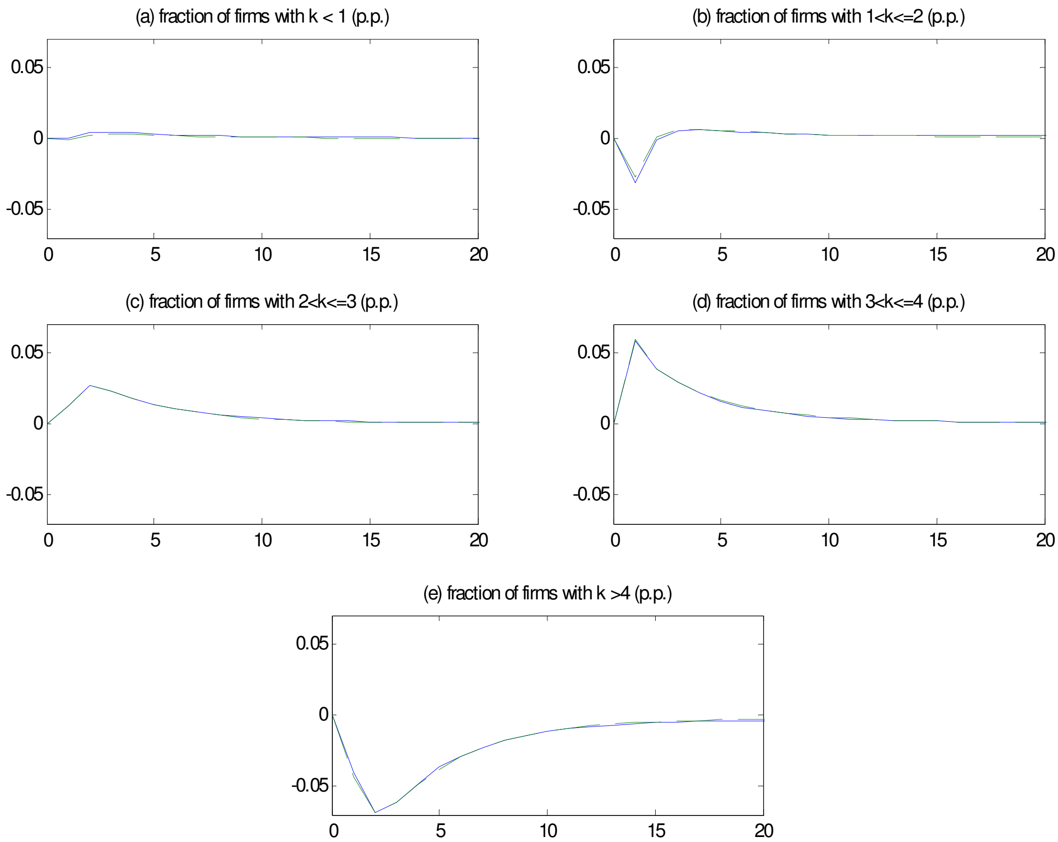

Figure 3.14. Response (in percentage points) of firms' distribution over the ratio of capital expenditures to net worth to a negative technology shock: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements.

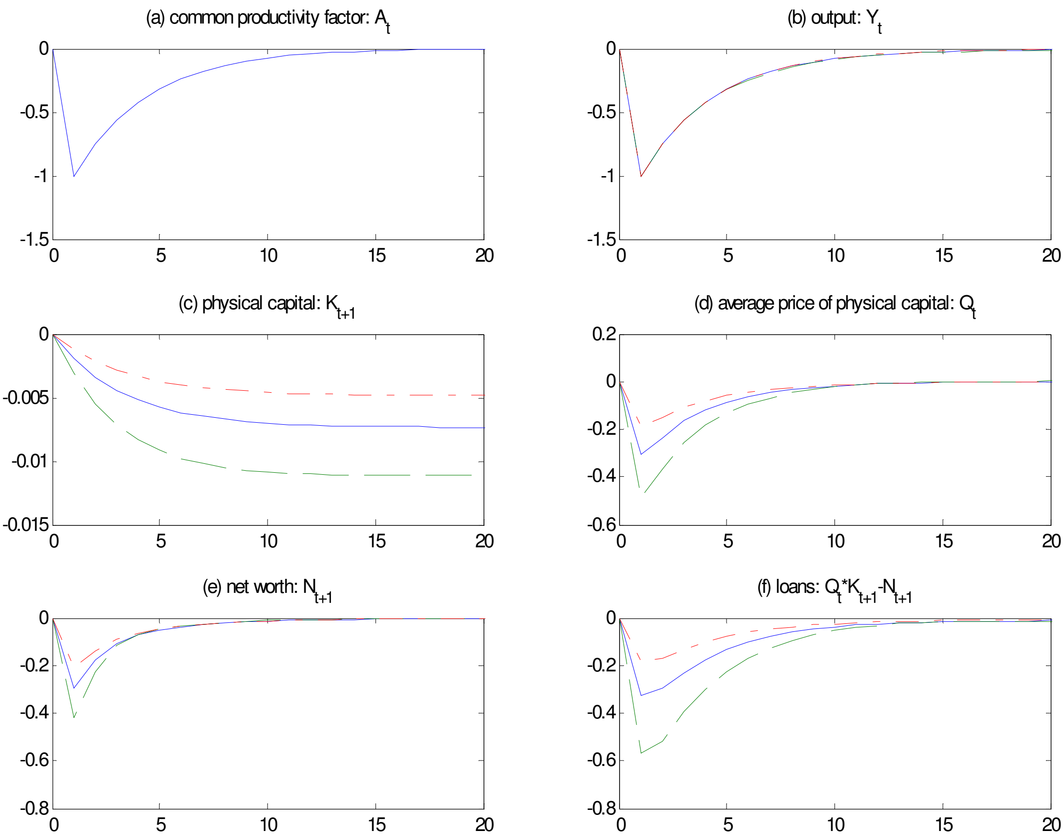

Figure 3.15. Response of economic activity to a negative technology shock and increase in R^S: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

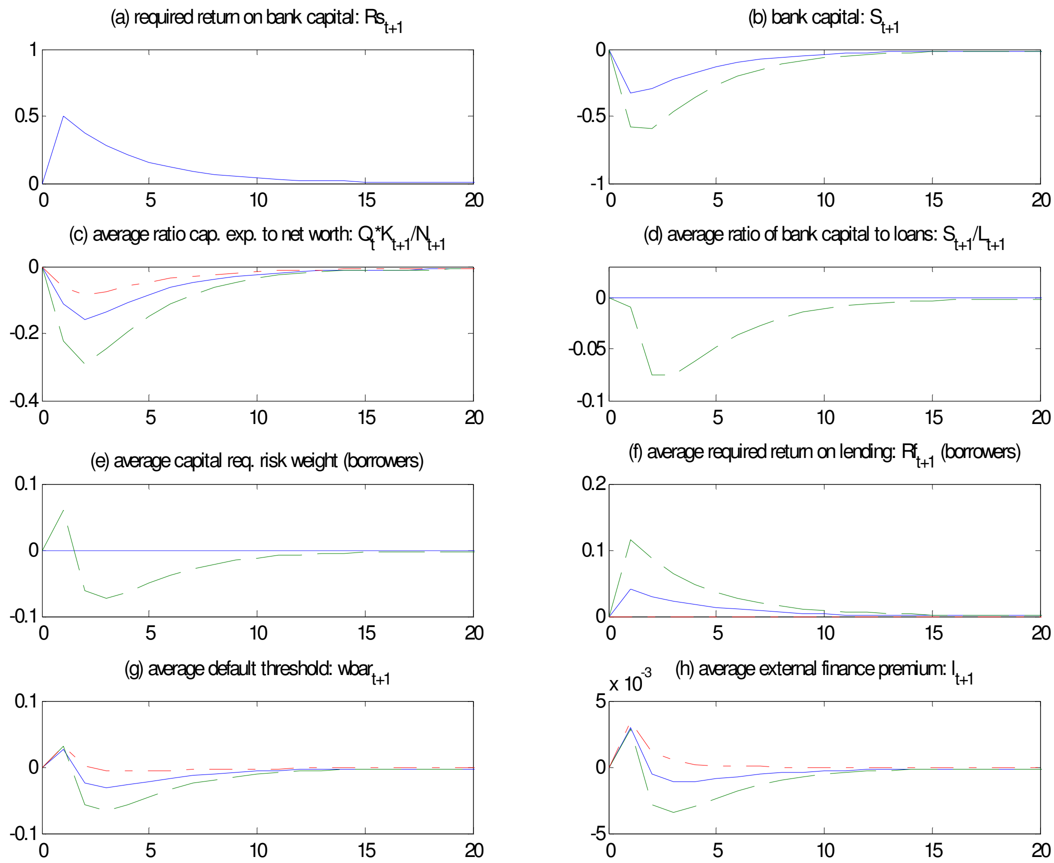

Figure 3.16. Response of financial variables to a negative technology shock and increase in R^S: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements; variant 3 (dashed-dotted line) - no capital requirements.

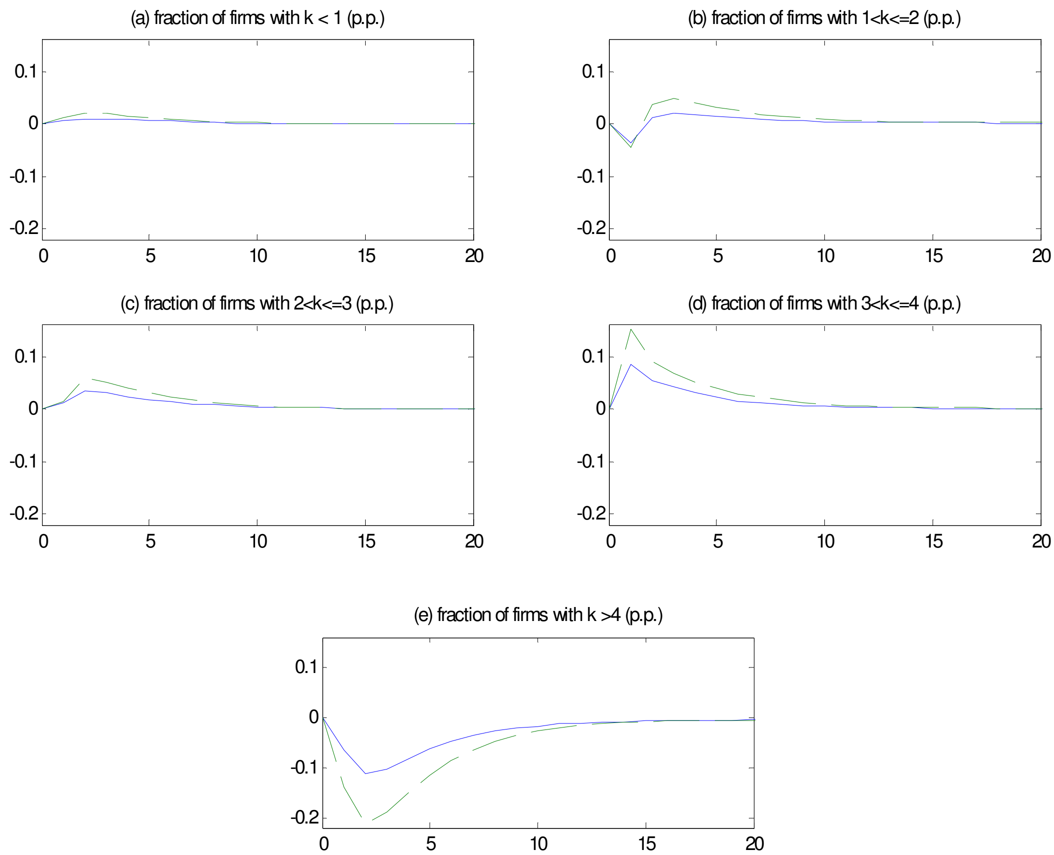

Figure 3.17. Response (in percentage points) of firms' distribution over the ratio of capital expenditures to net worth to a negative technology shock and increase in R^S: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements.

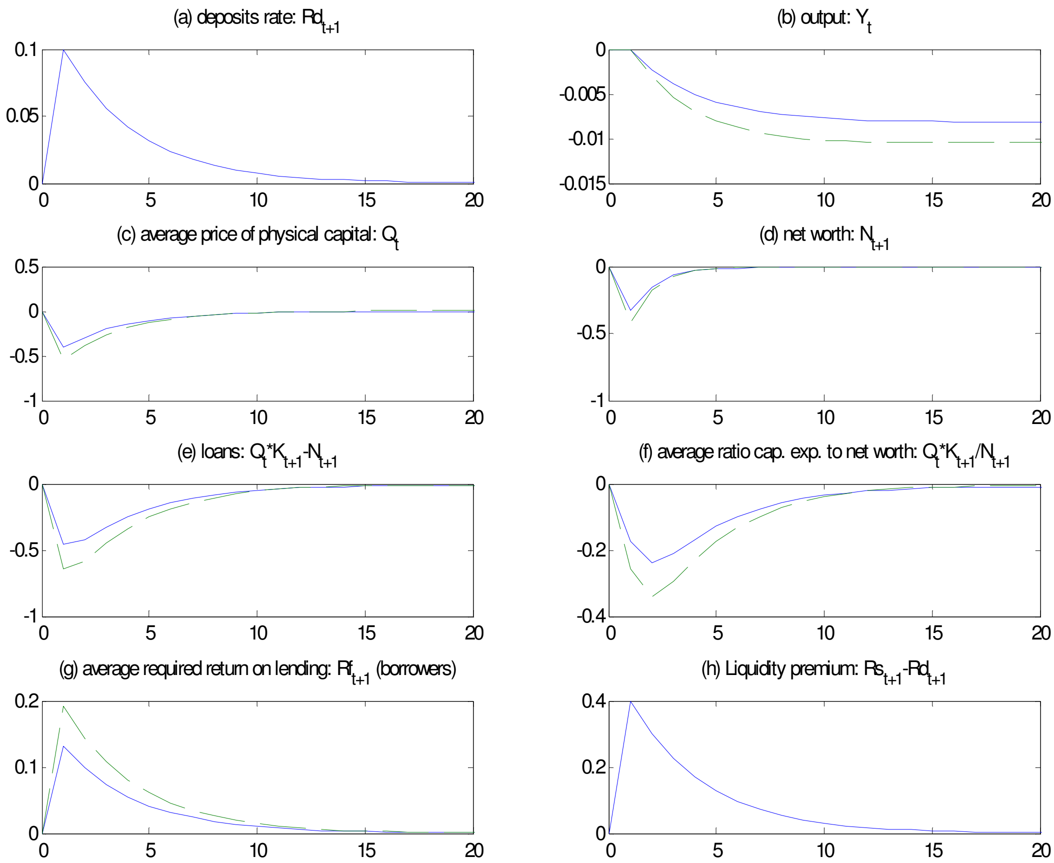

Figure 3.18. Response of economic activity to a negative monetary policy shock and increase in R^S: variant 1 (dashed line) - Basel II capital requirements; variant 2 (solid line) - Basel I capital requirements.

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