



Working Paper no. 313

Bank capital channels in the monetary transmission mechanism

Bojan Markovic

November 2006

Bank of England

Bank capital channels in the monetary transmission mechanism

*Bojan Markovic**

Working Paper no. 313

* Bank of England. Email: bojan.markovic@bankofengland.co.uk.

The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England. I should like to thank an anonymous referee, Andrew Bailey, John Fender, Simon Hall, Glenn Hoggarth, Anton Muscatelli, Peter Sinclair, Gabriel Sterne, Balasz Vilagi and Jan Vlieghe very much for helpful comments and discussion. My gratitude also goes to seminar participants at the Royal Economic Society Easter School, the Bank of England, and the National Bank of Hungary. This paper was finalised on 26 June 2006.

The Bank of England's working paper series is externally refereed.

Information on the Bank's working paper series can be found at www.bankofengland.co.uk/publications/workingpapers/index.htm.

Publications Group, Bank of England, Threadneedle Street, London, EC2R 8AH; telephone +44 (0)20 7601 4030, fax +44 (0)20 7601 3298, email mapublications@bankofengland.co.uk.

Contents

Abstract	3
Summary	4
1 Introduction	6
2 Theoretical and empirical background and motivation	8
3 The modelling framework	12
4 Model parameterisation	21
5 Simulations	26
6 Concluding remarks	37
Appendix A: Households' optimisation problem	41
Appendix B: Banks and the financial contract	43
Appendix C: A log-linear version of the model	46
References	48

Abstract

Recent empirical evidence based on microdata panels indicates the importance of banks' balance sheets for the monetary transmission mechanism. This paper builds a dynamic general equilibrium model to analyse the macroeconomic consequences of changes in the cost of bank capital, and thus the cost of bank credit. The model includes the interaction between the supply side (banking sector) and the demand side (corporate sector) of the credit market.

The analysis suggests that bank capital channels may be an important part of the monetary transmission mechanism, particularly when there are large, direct shocks to banks' balance sheets. Such shocks could occur when there are structural changes that affect the banking system. The impulse responses are likely to be magnified due to the interaction between the supply and the demand sides of the credit market.

Key words: Banks, credit channel, credit market frictions, monetary transmission.

JEL classification: E32, E44, E50, C68.

Summary

Theory and empirical evidence suggest that the health and the behaviour of the banking sector can alter the way monetary policy affects inflation and output. Furthermore, a number of theoretical studies have suggested a potential role for bank capital regulation in determining bank lending decisions. Put simply, the transmission of monetary policy tightening through the banking sector is likely to be stronger when the level of bank capital approaches the minimum required by the regulator. This study assesses this ‘bank balance sheet channel’ using a theoretical model that extends the well-known Bernanke, Gertler and Gilchrist model of the corporate sector balance sheet channel.

The results suggest that monetary policy decisions can have a stronger effect in times when the health of the banking sector deteriorates. Banks may find it more costly to raise the fresh capital required to fulfil regulatory requirements. Moreover, the cost of raising fresh capital may rise further in economies where banks are not rated by external rating agencies, or where they disclose less information to the public, since in such circumstances potential bank shareholders may find it more costly to check the health of a particular bank. This higher cost of bank capital is further transferred to a higher cost of companies’ external borrowing through an increase in loan interest rates.

This study further suggests that the impact of monetary policy can be asymmetric. An increase in interest rates is likely to lead to a fall in the value of bank capital, thus increasing the likelihood of hitting the binding capital constraint. If the latter occurs, banks have either to raise fresh capital or to reduce their loan supply. In contrast, a fall in interest rates does not produce similar effects where the additional capital is in excess of regulatory requirement.

The importance of ‘the bank balance sheet channel’, modelled here, can therefore vary over time. First, the bank capital constraint is more likely to bind in times of contractions (ie rises in interest rates). Here a greater need for banks to raise fresh capital coincides with an increase in the cost of it. Furthermore, the importance of the channel increases at times when the health of both the banking and corporate sectors jointly deteriorates. In contractions, companies’ internal funds may dry up, and they have to rely more on external borrowing. The higher loan demand could lead to a binding bank capital constraint, which is exacerbated by the lower value of bank capital. Finally,

the relative importance of ‘the bank balance sheet channel’ is likely to increase in periods of occasional, but large, direct shocks to banks’ balance sheets. Such shocks may occur as a result of regulatory changes or structural reforms of the banking sector. Changes in the framework of bank capital regulation or an economy-wide write-off of non-performing loans are examples of such a situation.

There are a number of potential avenues for further work. Contemporary discussions about the new Basel proposals for international bank capital regulation and their potential impact on the effectiveness of monetary policy could be addressed in this framework. The analysis in this study does not however deal explicitly with the case of ‘credit rationing’, when banks limit their credit supply below the level of credit demand, given the same loan interest rate. In such a case the contractionary effect may be even stronger than the one proposed in this study.

1 Introduction

Empirical evidence suggests that the credit channel of the monetary transmission mechanism played a role in various economic episodes in a number of countries. Fisher (1933) argued that the Great Depression in the United States in the early 1930s was partly caused by the debt burden and financial distress associated with the deflation of the time. Bernanke and Lown (1992) and Ito and Nagataki Sasaki (1998) attributed the slow economic recovery after the 1990-91 recession in the United States partly to the heavy corporate debt burden and an undercapitalised banking system. Hall (2001) found that financial factors may have played a role in the depth and persistence of the UK recession of the early 1990s. The role of banks in the propagation of declines in real activity is considered important in other recent recessions – eg Texas 1985-87, New England 1991-92, the Nordic countries 1990-94, and in South East Asia 1997-98.⁽¹⁾ Recent studies (Deutsche Bundesbank (2002), Fukunaga (2002)) suggest a potential role for the credit channel in the current developments in Germany and Japan.

Models including credit market imperfections can be categorised as two distinct types: (1) bank balance sheet channel models, which focus on the supply side of the credit market (ie banks' balance sheets) and (2) corporate balance sheet (financial accelerator, or broad credit) channel models, which focus on the demand side of the credit market (ie corporates' balance sheets).

The general equilibrium literature has so far focused mainly on the demand side of the credit market. It models the financial accelerator⁽²⁾ working via corporates' balance sheets (Bernanke, Gertler and Gilchrist (1999), Kiyotaki and Moore (1997), and Carlstrom and Fuerst (1997), for example). It has also been applied to consumers' demand for credit (Aoki, Proudman and Vlieghe (2002)). Several recent papers have explored the issues of the financial accelerator within an open-economy context (Gilchrist, Hairault and Kempf (2002), Gertler, Gilchrist and Natalucci (2003), Paasche (2001), and Faia (2002), for example).

In contrast, little attention has been given to applying a general equilibrium approach to imperfections arising from the supply side of the credit market (banks' balance sheets), and their impact on the propagation of the business cycle. Empirical studies during the 1990s mostly failed

(1) Gertler, Gilchrist and Natalucci (2003) argue that the financial accelerator in conjunction with fixed exchange rate can fully account for the 14% drop in economic activity experienced by Korea during the 1997-98 episode.

(2) The financial accelerator is the mechanism by which credit markets play a role in the propagation of the business cycle.

to find evidence for the bank balance sheet channel. In part this was because the methodology was unsuitable insofar as it focused on aggregate data, which can be misleading.⁽³⁾ A new empirical approach based on microdata panels, employed in the recent series of papers published in Angeloni *et al* (2003),⁽⁴⁾ finds empirical evidence for the importance of banks' balance sheets in the monetary transmission mechanism in most euro-area countries. Moreover, microdata studies on individual loan agreements in the United States (Lown and Peristiani (1996), and Hubbard *et al* (2002)) have found that bank capital is important for banks' decisions on the loan interest rate in periods of crises. In order to address the theoretical gap that remains, the model constructed below incorporates bank balance sheet issues, in particular the bank capital channel, in a costly state verification model, first proposed in Townsend (1979), and later adapted in Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999). The model is calibrated to match some characteristics of the UK economy. It is a model of the external capitalisation, ie it assumes that, faced with a binding capital constraint, banks can raise fresh capital rapidly.⁽⁵⁾

For the purpose of understanding factors that drive the speed and the strength of the credit channel, and simulating policy, theoretical models should ideally (in no particular order): (a) be dynamic; (b) be general equilibrium models; (c) have a role for nominal and real variables; (d) feature an interaction between the supply and the demand side of the credit market; (e) have optimising agents; (f) have heterogeneous agents; and (g) be able to explain the (empirically observed) asymmetric effect of the credit channel. The model in this paper includes all, except (f) and partly (e). The model is based on a representative agent framework, and hence cannot serve to discuss the issue of heterogeneity. Moreover, in order to make the model tractable, banks are assumed to break even in each period, rather than to explicitly maximise profits. The later two assumptions are not necessarily inconsistent. The break-even assumption is compatible with a zero-profit condition, and the latter can be an outcome of an optimisation problem. For example, one could assume Bertrand-type competition among banks in the absence of fixed costs. The loan rates would be determined by costs, because any addition would lead to competitors undercutting the bank's offer. Alternatively, perfect contestability would imply that any chance that others can enter the market could force banks to cut their profits and justify the zero-profit condition. Finally,

(3) Aggregate numbers for credit can be misleading since funds do not flow freely from banks with excess capital to banks with capital shortages. Moreover, using aggregated data does not adequately control for loan demand, thus failing to isolate the loan supply effects (Oliner and Rudebusch (1996)).

(4) See Ehrmann *et al* (2003) for an overview.

(5) In reality, however, some banks may be unable to raise fresh capital rapidly, and thus would have to ration the credit. This model does not consider such a case.

although the zero-profit condition might be a strong assumption,⁽⁶⁾ it allows the model to be tractable analytically.

Three separate bank capital channels are modelled. The *default risk channel* arises from the possibility of banks defaulting on their capital. The channel exists in a steady state and varies in strength over the cycle. Its strength depends on the likelihood of firms defaulting on bank loans. The *adjustment cost channel* builds on the assumption of asymmetric information between banks and their shareholders, and the subsequent allocation cost necessary to reduce this asymmetry. A need to raise fresh capital rapidly sends a bad signal about the financial situation of a bank. New shareholders will invest in bank shares only after incurring search costs (checking the health of the particular bank before investing in bank shares, for example). This is a cost of adjusting the bank capital to the required level. The *capital loss channel* builds on the assumption that, during a recession, existing shareholders form an expectation of future capital losses. They come to anticipate a future fall in the value of bank capital.⁽⁷⁾ The more pronounced an expected fall in the value of bank capital is, the stronger the capital loss channel.⁽⁸⁾ All channels cause a variation in the expected return and thus a variation in the cost of bank capital.

The results suggest that, under a plausible parameterisation of the model, bank capital channels contribute significantly to the monetary transmission mechanism, together with the corporate balance sheet channel. The relative importance of bank capital channels is likely to increase in the event of large shocks to the value of bank capital. Such shocks might include the writing-off of non-performing loans from banks' balance sheets or a regulatory change that increases capital requirements. In such circumstances one can expect an interaction between the supply and the demand-side effects, and thus potentially larger shocks to the economy.

2 Theoretical and empirical background and motivation

The bank capital channel has received little attention in the literature. Previous literature modelling the impact of banks' balance sheets on the monetary transmission mechanism, has

(6) In reality, the asymmetric information could give incumbent banks an advantage and thus an opportunity for positive net profit.

(7) The trigger for this may be a bad signal about the bank's financial situation as in the case of an adjustment cost.

(8) This channel would not be effective if the strong efficient market hypothesis (by which all asset prices follow a random walk) holds. Various models, however, claim that this is not true for some long-term assets.

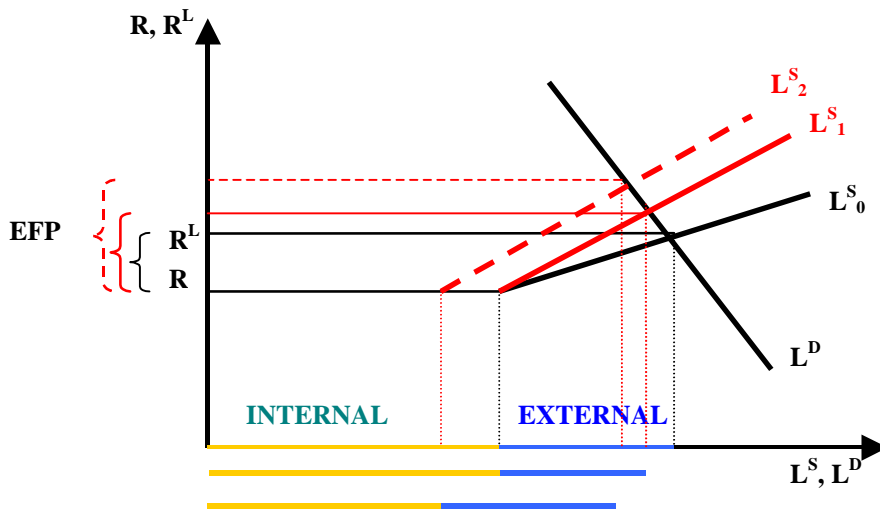
mainly focused on the deposit-reserves channel.⁽⁹⁾ The bank capital channel encompasses shocks to the cost or the value of bank capital that can affect bank lending. Monetary policy actions may lead to a change in the financial position of the banking sector, thus changing the preferences of its shareholders. A change in the financial position of the banking sector may arise due to changes in the riskiness of banks' assets, an expected change in the value of bank capital, or issues related to the capital regulation of the banking sector (eg a change in the bank capital requirement). Such changes can influence the cost of bank capital, and thus lending, and therefore generate the above effect. Empirical evidence provides support for the importance of bank capital for banking behaviour. Microdata studies based on individual loan agreements in the United States (Lown and Peristiani (1996), and Hubbard *et al* (2002)) have found that low-capitalised banks charge higher loan interest rates than well-capitalised banks in periods of crises. Markovic (2005), using a microdata panel approach, finds that well-capitalised banks extend more credit than low-capitalised banks following a monetary tightening in the United Kingdom. Furthermore, the value of bank capital may also fall due to a write-off of non-performing loans. For instance, at the end of 2002, Heizo Takenaka, Economics and Finance minister of Japan, announced a plan that aimed to halve the share of non-performing loans in the balance sheets of Japanese banks by mid-2005. Such a write-off of non-performing loans would lead to a fall in the value of bank capital, and may lead to a short-run decline in investment (Farrant *et al* (2003)). Finally, in some banking systems (German, for example), banks' balance sheets include a larger share of corporate equity holdings. Any change in the price of corporates' equity may have a direct effect on banks' profits, bank capital and consequently bank lending. By and large, any of the above-mentioned shocks can affect banks' balance sheets (the supply side of the credit market) and thus lending conditions via the bank capital channel.

The existence of a corporate balance sheet channel⁽¹⁰⁾ is also empirically supported. This channel addresses borrowers' rather than lenders' balance sheets. According to the broad credit channel, credit market imperfections are present in all credit markets, not only in the bank credit market. Hence, all external funds are more expensive than internal ones due to asymmetric information and the inability of lenders to monitor borrowers costlessly. This imperfection explains the existence of the external finance premium (EFP), which is the difference between costs of external and internal finance. In periods of recession, corporates' net worth falls and they have to rely more

(9) The deposit-reserves channel describes the change in the volume of bank lending as a result of a change in reserve requirements or the supply of deposits.

(10) In the previous literature, the channel is usually referred to as financial accelerator or broad credit channel.

Chart 1: The effect of an increase in the bank capital ratio on the credit market equilibrium



on higher-cost external funds. Nevertheless, at the same time the EFP increases, thus producing a further contractionary effect on spending. All shocks affecting corporates' net worth (eg interest rate or equity price shocks, and the multiplicity of underlying shocks that could generate either of these) affect the demand side of the credit market. The empirical evidence for the corporate balance sheet channel is extensive (eg Hubbard (1995), Oliner and Rudebusch (1996), Vermeulen (2000), Ashcraft and Campello (2002), Chatelain *et al* (2003)).

There are likely to be interactions between the supply and demand sides of the credit market, ie between the bank capital channel and the corporate balance sheet channel. An increase in the level of bank capital that banks desire, or are required to hold, raises the average cost of bank liabilities. This affects the supply side of the credit market. The higher cost is transferred to borrowers (although not one for one), and affects the rest of the economy further, via the interaction of the various markets in the economy. At the new higher cost of borrowing fewer investment projects are profitable and hence investment and real output are lower. Moreover, an increase in the EFP increases the average cost of funds by which firms finance their investments, and hence firms' profits and thus their net worth (internal funds) are likely to (temporarily) decline. The decline in their internal funds affects the demand side of the credit market.

The interaction between the supply and the demand side of the credit market is illustrated in Chart 1. Firms finance their investments using internal and external funds. The opportunity cost of internal funds is the risk-free interest rate R . The cost of external funds is the loan interest rate R^L .

The difference between the cost of external and internal funds is the EFP. The EFP depends on the firms' leverage ratio, ie the share of external funds in total funds. The higher the leverage ratio, the higher the exposure of the bank (ie the lower the collateralised part of the debt, since firms' internal funds act as collateral for the debt). Hence the cost of borrowing and the EFP are higher. The slope of the loan supply line (L_0^S) depends on banks' perception of the risk to the economy (the variance and the mean of shocks hitting the economy), and the auditing cost (the cost related to the retrieval of collateral). The higher the auditing cost and the perception of risk, the higher the EFP for the same leverage ratio. The slope additionally depends on the cost of bank capital, and its share in total bank liabilities. Related literature identifies agency cost, insolvency cost, lemons premia on new equity issues, and the tax advantage of debt, as some possible reasons for the empirically higher cost of bank capital compared to the cost of deposits. The higher the cost of bank capital, and thus the average cost of bank liabilities, the higher is the cost of bank credit, and thus the EFP.

A permanent increase in the level of bank capital that banks desire (or are required) to hold raises the average cost of bank liabilities, since the cost of bank capital is higher than the cost of deposits. In order to cover the higher average cost of bank liabilities (or to keep the same profit margin), banks have to increase their loan interest rate. On the graph, the loan supply pivots to L_1^S . An increase in the EFP increases the average cost of funds by which firms finance their investments, and hence firms' profits and thus their net worth (internal funds) are likely to decline temporarily. The temporary fall in internal funds is a temporary shock to the demand side of the credit market. On the graph, the loan supply line shifts to L_2^S . The credit market relates to the external funds (the blue line in Chart 1), not all funds. Hence, this movement actually corresponds with the rightwards movement in the loan demand line. The demand reaction leads to a further increase in the loan interest rate and the EFP. Consequently the level of investment, and thus real output, falls further.

A permanent unexpected increase in the bank capital ratio produces a permanent shock to the supply side of the credit market and a further temporary effect on the demand side of the credit market. In other words, it is likely that there is a continual interaction between the bank capital channel and the corporate balance sheet channel. Therefore, in order to look into issues related to the credit channel of the monetary transmission mechanism, we need a theoretical model that combines both credit channels. Existing models do not facilitate the analysis of such interactions

in the financial accelerator framework.⁽¹¹⁾ Below I attempt to build a dynamic general equilibrium model, which includes the interaction of the supply side (banking sector) and the demand side (corporate sector) of the credit market.

3 The modelling framework

The model extends the Bernanke, Gertler and Gilchrist (BGG (1999)) corporate balance sheet model to include issues related to banks' balance sheets. The optimisation problems that constitute the model are provided in appendices. In the main text I shall refer to the appendices that are novel in the context of the BGG model, whereas I shall only provide the main equations where necessary to clarify the discussion.

3.1 Summary of the BGG model

BGG develop a dynamic general equilibrium model with price rigidities. It aims to clarify the role of credit market frictions in the business cycle. The BGG model has several appealing features. First, it is a model of the corporate balance sheet channel, a transmission channel that has been empirically established. Second, it is a macro model with a theoretically appealing micro-foundation for a credit market imperfection. The micro-foundation is based on the costly state verification model (Townsend (1979)).⁽¹²⁾ Furthermore, the model is tractable and has proved to be useful in analysing monetary policy issues. Hall (2001) finds the model simulations robust and that they can reproduce the main stylised facts of the UK financial deterioration of the early 1990s. The model has been applied to the US (BGG (1999)) and the Japanese (Fukunaga (2002)) economies. Another appealing feature of the model is its system of staggered price adjustment (as in Calvo (1983)). This feature generates price persistence, and implies a short-run trade-off between output and inflation (see Walsh (1998)). It is appealing because it is micro-founded, and shows how the coefficient on output in the inflation equation depends on the frequency with which prices are adjusted.⁽¹³⁾ The model also includes money in the utility function, allowing monetary

(11) Two papers have focused on the bank capital channel - Van den Heuvel (2002) and Chami and Cosimano (2001). Both provide partial equilibrium models, and therefore do not allow for the interaction of various credit channels. A paper that combines the supply and the demand side of the credit market in a moral hazard framework similar to Chen (2001) is Meh and Moran (2004).

(12) The costly state verification model is further explained in Section 3.2.2.

(13) One should, however, note possible inconsistencies of the Calvo approach. The frequency of price changes is exogenous. Furthermore, a policy of certain, continuing disinflation is output-increasing according to Calvo's model. Both issues are counterintuitive and not robust (Mankiw (2000)). But, resolving these issues lies outside the scope of this study.

policy to affect the real economy.

The main contribution of the BGG model is the micro-foundation for the credit market imperfection, provided in the financial contract between financial intermediaries and firms. The optimisation problem of the financial contract is solved as a partial equilibrium problem and is then embedded in the general equilibrium framework. The financial contract is one period in length – it is negotiated at the beginning of a period and resolved by the end of the same period. This assumption allows BGG to separate the financial contract from the rest of the general equilibrium model. BGG therefore solve the contract as an incentive compatibility constraint *ex ante*, parametrically, with respect to variables, which are later determined by the entire general equilibrium model. This does not jeopardise the general equilibrium nature of the model. The financial contract may be considered within the general equilibrium framework as an asset that delivers distinctive outcomes in different states.

In the financial contract firms maximise profits subject to the risk-neutral⁽¹⁴⁾ financial intermediary's participation constraint (see Appendix B). The financial intermediary's participation constraint is a break-even constraint. The financial intermediary does not optimise over any objective function, but simply covers the cost of its deposit liabilities.⁽¹⁵⁾ Firms choose the level of capital, $Q_t K_{t+1}$, (with the shadow price of capital, Q , and the volume of capital, K) before the appearance of an idiosyncratic productivity disturbance, ω .⁽¹⁶⁾ The threshold level of such an idiosyncratic productivity disturbance, $\bar{\omega}$, indicates the ability of firms to repay loans, ie it divides the solvency and insolvency regions for firms. In the case of a good outcome, when $\omega \geq \bar{\omega}$, the financial intermediary will retrieve the full amount of loans with the loan interest rate. In a bad outcome, when $\omega < \bar{\omega}$, the financial intermediary will not be able to receive the full amount of loans, but will receive the firm's earnings, since the net worth of firms represents collateral. In order to retrieve collateral, the intermediary has to incur an auditing cost, μ_{ac} .

The auditing cost is the main reason for the accelerating effect of the corporate balance sheet

(14) Although the deposit providers (households) are risk-averse, the one-period nature of the contract will effectively make the financial intermediary risk-neutral, since it eliminates all aggregate uncertainty over the duration of the contract. For further explanation of this issue see Carlstrom and Fuerst (1997).

(15) In our extension the cost of liabilities includes both costs of deposits and bank capital. The break-even constraint indicates a zero-profit situation, which corresponds to a perfect competition assumption.

(16) The idiosyncratic productivity disturbance, ω , is i.i.d. across time and across firms. Although the financial intermediary does not know ω^j for each particular firm j , it knows the distribution of ω . The variable is log-normally distributed with variance σ and a mean of $-\frac{1}{2}\sigma$. Therefore, only the aggregate shocks are important in setting the external finance premium.

channel. The size of the accelerating effect depends on the leverage ratio $\frac{N}{QK}$.⁽¹⁷⁾ Equations (B-11) and (B-12) in Appendix B show that in the absence of the auditing cost, ie when $\mu_{ac} = 0$, the ratio, s , between the cost of external, R_{t+1}^K , and internal funds, R_t , takes the value of one. In such a case the costs of external and internal funds are equal, and no accelerating effect would arise. The accelerating effect arises due to the demand side of the credit market (corporates' balance sheets).

The BGG model is a useful tool for analysing monetary policy issues that incorporate the corporate balance sheet channel. Nevertheless, the model is not designed to address some important issues related to the banking sector. Although the financial intermediary exists in the model, it cannot be characterised as a bank. The function of the financial intermediary is to collect individual deposits, and channel them into loans, thus completely diversifying idiosyncratic risk. But, the intermediary is entirely deposit funded, and in every period the level of deposits equals the level of loans. There is no capital in the liability side of the intermediary's balance sheet. Consequently, we cannot explore shocks to bank capital, non-performing loans and other relevant issues related to the supply side of the credit market. Neither can we address issues related to the interaction between bank and corporate balance sheet channels.

The model constructed here allows for the existence of bank capital in banks' balance sheets, while keeping all of the main features of the BGG model. This should enable us to explore issues related to the supply side of the credit market, its interaction with the demand side of the credit market, and its consequences for the transmission mechanism.

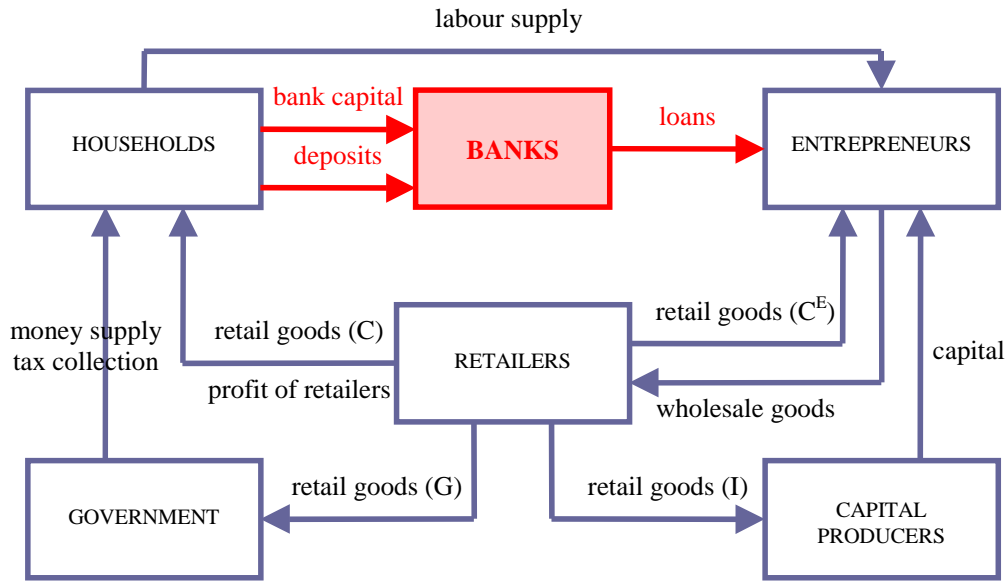
3.2 *The model*

There are six types of agents in this model: households, banks, entrepreneurs, capital producers, retailers, and government.

I utilise the modelling strategy employed in Carlstrom and Fuerst (1997) and BGG, and separate retailers from consumer goods producers (entrepreneurs) in order to introduce some nominal rigidity (price stickiness). The price stickiness is micro-founded following the Galí and Gertler (1999) extension to the Calvo (1983) model. The extension introduces an additional persistence into the basic Calvo model used in BGG. The Calvo approach requires monopolistic competition,

(17) In fact, this is the ratio of internal, N , to total finance, QK . Nevertheless, it mirrors the leverage ratio ie the ratio of external to total finance.

Chart 2: Structure of the model



but this complicates the solution of the financial contact between banks and entrepreneurs. In the monopolistically competitive environment, entrepreneurs are able to use their profit as a buffer against changes in the average cost of their funds. Consequently, the change in the EFP does not necessarily have an effect on investment. Although this situation may be robust, the problem is mathematically difficult to solve, and would not produce a neat solution.

In what follows I shall focus on the features which are novel compared with the existing literature in the area (BGG (1999), Carlstrom and Fuerst (1997), and Hall (2001), in particular). The novel features introduced in this paper relate to the households' optimisation problem and the financial contract between banks and entrepreneurs.

3.2.1 The households' optimisation problem⁽¹⁸⁾

Households are infinitely lived with preferences (see Appendix A) given by

$$E_t \sum_{k=0}^{\infty} \beta^k U \left(\ln C_{t+k}, \ln \frac{M_{t+k}}{P_{t+k}}, \ln(1 - H_{t+k}) \right)$$

where E_t denotes the expectations operator conditional on time t information, and $\beta \in (0, 1)$ is the discount factor. Each period risk-averse households maximise the discounted value of their

(18) The complete households' optimisation problem is given in Appendix A.

expected utility subject to the budget constraint

$$\begin{aligned}
C_{t+k} = & W_{t+k}H_{t+k} - T_{t+k} + \Pi_{t+k}^R + R_{t+k-1}D_{t+k} - D_{t+k+1} + \\
& (1 - \gamma_2)R_{t+k}^Z P_{t+k}^Z Z_{t+k} - P_{t+k}^Z Z_{t+k+1} - \frac{\gamma_1 (P_{t+k}^Z \Delta Z_{t+k+1})^2}{2 P_{t+k}^Z Z_{t+k}} \\
& + \frac{M_{t+k-1} - M_{t+k}}{P_{t+k}}
\end{aligned} \tag{1}$$

The budget constraint describes households' actions to purchase consumption goods, C , and receive profit, Π^R , from retailers, demand real money balances, $\frac{M}{P}$, rent their labour, H ,⁽¹⁹⁾ to entrepreneurs (firms producing goods) at a real wage, W . Each period, households allocate their real savings in deposits, D , on which they earn the risk-free interest rate, R , or new bank shares, Z , on which they acquire the gross real dividend rate, R^Z . Hence the total return from bank shares depends on the dividend rate and the change in the price of bank shares, P^Z . A no arbitrage condition implies that the expected returns on the two alternative assets are equal in equilibrium.

A specific feature of this optimisation problem is that investing in new bank shares attracts an adjustment cost. The adjustment cost may arise due to an information asymmetry between banks and their potential shareholders, and the subsequent allocation cost, which is necessary to reduce that asymmetry (eg a search cost due to checking the health of a bank before investing in bank shares).⁽²⁰⁾ Fees paid to credit rating agencies are an example of such costs. This cost is likely to be lower in economies where public disclosure of banks is higher. The size of the adjustment cost is represented by the parameter γ_1 . This cost is a dead-weight loss for society. We specify a quadratic form for the adjustment cost, therefore making it symmetric and proportional to the size of the adjustment.⁽²¹⁾

Another novel feature is the expectation of the default risk on bank capital, described by the parameter γ_2 . This parameter implies a differential between the cost of bank capital (the dividend

(19) The leisure endowment is normalised to unity. Hence $1 - H$ represents the leisure.

(20) One can argue that the bank, and not households, should bear this cost, but the assumption that households own banks implies the same macroeconomic consequences. It does not matter whether households bear the cost explicitly or implicitly via a capital loss from bank ownership.

(21) The information asymmetry justifies the symmetric cost. The cost of entering the stock market is likely to be proportional (eg brokers' commission). Furthermore, the new bank shares will not be sold to one agent, but are likely to be sold to more agents. Hence, the higher the relative size of the adjustment the higher the adjustment cost (eg search cost or insurance cost).

rate) and the cost of deposits (the risk-free interest rate) in the steady state. Other models (eg Van den Heuvel (2002)) usually assume a positive differential. We explain this by the default risk on bank capital.⁽²²⁾

Most of the first-order conditions from the household's optimisation problem are standard (see equations (A-3) to (A-6) in Appendix A). The non-standard arbitrage condition is the log-linear link between the return on bank capital and deposits (equation (A-10) in Appendix A).⁽²³⁾

$$E_t \left(\widehat{R}_{t+1}^Z \right) + E_t \left(\widehat{P}_{t+1}^Z - \widehat{P}_t^Z \right) = \widehat{R}_t + \gamma_1 \left(\widehat{Z}_{t+1} - \widehat{Z}_t \right) - \frac{\gamma_1}{R_0} E_t \left(\widehat{Z}_{t+2} - \widehat{Z}_{t+1} \right) + \frac{\gamma_2}{1 - \gamma_2} \widehat{\gamma}_{2t} \quad (2)$$

The equation delivers several interesting results. The left-hand side of the equation represents the required return on bank capital, which consists of the gross dividend rate, R^Z , and the expected capital gain, $\frac{P_{t+1}^Z}{P_t^Z}$ (with P^Z being the price of bank shares).⁽²⁴⁾ The right-hand side of the equation shows that the required return on bank capital depends on:

- the return on the alternative asset (risk-free deposits), which is the risk-free interest rate, R ;
- the adjustment cost, which depends on γ_1 , and the expected change in the volume of bank shares (with Z being the volume of bank shares);
- the probability of the bank defaulting on its capital, γ_2 .

The bank would be indifferent to having either deposits or bank capital in its liabilities only when there is no risk of default on bank capital, $\gamma_2 = 0$, no adjustment cost, $\gamma_1 = 0$ (the case of perfect information between banks and households), or expected capital gain or loss, $\Delta P_{t+1}^Z = 0$ (strong efficient market hypothesis (EMH) holds). In such a case there is no difference between the cost of bank capital and the cost of deposits, either in a steady state or over a cycle. Consequently the

(22) Berka and Zimmermann (2002), for example, explain the higher cost of bank capital relative to the cost of deposits by the higher exogenous volatility of the return on bank capital. Other explanations include a tax advantage of deposits over bank capital.

(23) In further text, $\widehat{\cdot}$ denotes deviations from the steady-state values, whereas subscript $_0$ denotes the steady-state values.

(24) Notice that this represents standard return to capital:

$$R_{t+1}^Z \frac{P_{t+1}^Z}{P_t^Z} = (1 + div_{t+1}) \frac{P_{t+1}^Z}{P_t^Z} = \frac{P_{t+1}^Z + div_{t+1} P_{t+1}^Z}{P_t^Z} = \frac{P_{t+1}^Z + DIV_{t+1}}{P_t^Z}.$$

bank capital requirement would never bind. Faced with the possibility of hitting its capital requirement, a bank would costlessly adjust the composition of its liability side. The Modigliani-Miller theorem would hold in such a case.

As mentioned above, in a steady state the dividend rate is higher than the risk-free interest rate due to a positive probability of default on bank capital – parameter γ_2 . From equation (A-9) in Appendix A, one can obtain the long-run link between the costs of bank capital and deposits ($\Delta P_0^Z = 1 \implies R_0^Z = R_0 \frac{1}{1-\gamma_2}$).

Equation (2) indicates three channels, which can cause a change in the wedge between the cost of bank capital (ie gross dividend payments⁽²⁵⁾), R^Z , and risk-free interest rate, R , in the short run:

(1) the capital loss channel; (2) the adjustment cost channel and (3) the default risk channel.

The capital loss channel arises owing to the expectations of a capital gain or loss from holding bank shares ($\frac{P_{t+1}^Z}{P_t^Z} < 0$). In a contraction, a bank needing to acquire fresh capital (in order to fulfil the capital requirement, for example), would send a bad signal about its financial situation to the market. Potential investors may anticipate a future fall in the price of bank shares. In such a case, a bank will be able to acquire fresh capital only if it offers higher dividends to potential investors.⁽²⁶⁾ The latter can also be explained intuitively as the bank needing to sell new shares at a discount, if it wants to raise fresh capital and thus fulfil its capital requirement. One has to bear in mind that this channel would not exist if the strong version of EMH (by which all asset prices follow a random walk) held. In such a case the price of bank shares would perfectly reflect the present discounted value of the stream of dividend payments, and there would be no expectation of any future capital gain or loss. Various models, however, claim that a strong EMH does not hold for some long-term assets.⁽²⁷⁾

A further channel that may cause an increase in the cost of bank capital during contraction is *the adjustment cost channel*. When the adjustment cost is positive ($\gamma_1 > 0$) the required return to

(25) From the banks' viewpoint, only gross dividend payments represent the cost of bank capital.

(26) Higher dividends have to be offered to existing investors too in order to make them interested in keeping bank shares.

(27) There is substantial evidence of over or underreaction of stock prices to earnings announcements (see DeBondt and Thaler (1985, 1987) for example). Furthermore, Shiller (1981) has found that fluctuations in stock prices may be much greater than is warranted by fluctuations in their fundamental values. Finally, Poterba and Summers (1989), and Lo and MacKinlay (1988) have found that stock returns display mean reversion: stocks with low returns today tend to have high returns in the future and *vice versa*.

bank capital is higher whenever there is a change in the current or expected level of bank capital. Potential new shareholders have to check the health of a bank before investing in its shares and thus suffer an adjustment cost. In such a case banks have to earn and pass on to shareholders higher profits: higher dividends at a given price of bank shares.⁽²⁸⁾

Finally, an increase in the cost of bank capital may occur due to *the default risk channel*. During periods of financial crises the behaviour of economic agents depends upon the default risks of firms and banks (see Hoggarth, Reidhill and Sinclair (2004)). The probability of default on bank capital, γ_2 , is higher in contraction periods.⁽²⁹⁾ Hence, in such periods bank shareholders may demand higher dividend rates to prevent them from selling bank shares.

Each of the above channels can cause an increase in the required dividend payments and thus the cost of bank capital, R^Z , during a contraction of the economy. I therefore call them bank capital channels. A rise in the cost of bank capital further increases the loan interest rate, set in the financial contracts between the bank and entrepreneurs.

3.2.2 Banks and the financial contract⁽³⁰⁾

The role of banks in the model is to collect deposits and lend their assets as loans to entrepreneurs. In order to operate, banks must raise bank capital in line with the regulatory capital requirement. Banks' balance sheets have the following structure:

Assets	Liabilities
Loans L	Deposits D
	Bank capital $P^Z Z$

In the model the price of loans is set in the financial contract between banks and entrepreneurs. The optimisation problem extends the costly state verification (CSV) model (Townsend (1979)).

(28) In practice, however, the dividend function typically displays heavy smoothing. To the extent that the dividend function is smooth, banks would be unable to raise the fresh capital rapidly.

(29) There is substantial evidence to suggest that macroeconomic conditions impact the probability of default. For a survey of the related literature see Allen and Saunders (2003).

(30) The complete financial contract problem is given in Appendix B.

According to the CSV model, if an entrepreneur defaults on a loan, he has an incentive to underreport the return to capital. In order to observe the actual return to capital, the bank has to incur auditing costs, which leads to an external finance premium (EFP). The auditing cost is a dead-weight loss and causes an accelerating effect through a corporate balance sheet channel. This mechanism is modelled in BGG (1999).

The EFP in this model may arise because of:

1. Asymmetric information between banks and entrepreneurs, reflecting an auditing cost, as in the BGG model.
2. Imperfect information for actual and potential bank shareholders about the bank's actions, creating bank capital channels (see Section 3.2.1).

The solution of the financial contract (see details in Appendix B) delivers the following equation for the EFP that illustrates two main reasons for the existence of the EFP in this model:

$$\frac{R_{t+1}^K}{R_t} = \Psi \left(\frac{N_{t+1}}{Q_t K_{t+1}} \right) \xi_t \quad (3)$$

The cost of firms' external finance is R^K , the risk-free interest rate, R , is the cost of firms' internal finance, $\frac{N}{QK}$ is the share of firms' internal finance in total funds⁽³¹⁾ (with internal funds, N , the shadow price of capital, Q , and the level of firms' capital, K). Parameter Ψ represents the sensitivity of the EFP, $\frac{R^K}{R}$, to the leverage ratio, and indicates the strength of the corporate balance sheet channel. This channel is modelled in BGG.

The additional channel in this model, arising from the bank's balance sheet, affects the EFP via variable ξ .⁽³²⁾ This variable is defined as the cost of bank liabilities above the risk-free interest rate, and has the following form:

$$\xi_t = 1 + \frac{R_{t+1}^Z - R_t}{R_t} \frac{P_{t+1}^Z Z_{t+1}}{L_{t+1}} \quad (4)$$

The additional cost depends positively on the ratio of a bank's capital to loans, $\frac{P^Z Z}{L}$ (with P^Z being the price and Z the volume of bank shares, and L the volume of loans extended to firms),

(31) The share of internal funds in the total mirrors the leverage ratio (the share of external in total funds).

(32) The function ξ is a definition that enables a neat derivation of the financial contract problem, and has a direct economic interpretation.

and the wedge between the cost of bank capital and the cost of deposits, $R^Z - R$. If the bank capital ratio increases, or if the cost of the bank capital increases relative to the cost of deposits, the size of the additional cost, ζ , also increases. The reasons for the change in the wedge between the costs of bank capital and deposits may arise due to default risk, adjustment cost or capital loss channels, and are explained in details in Section 3.2.1. If ζ increases, the bank can transfer the higher cost of its liabilities to entrepreneurs by increasing the external finance premium. This, in turn, causes a further fall in investment and thus in real output.

One should bear in mind that the bank capital is here defined as the multiple of the price of bank shares, P^Z , and their volume, Z . It is therefore equivalent to the market capitalisation of the bank, whenever the bank share prices are endogenously determined by market forces. The latter is the case in the capital loss channel. Using market capitalisation as a measure of bank capital can influence the procyclicality of the results, although the direction of the impact might go either way. The market capitalisation measure implies that banks would have to adjust their capital liabilities (raise the fresh capital) more frequently than otherwise. This measure therefore contributes to the adjustment cost channel, and raises the procyclicality of results. On the other hand, the market capitalisation requirement should afford better protection against default, and can thus reduce the risk of bank's default, which should have a countercyclical effect. If, however, we assume that bank capital is defined as a sum of items in banks' balance sheets, the capital loss channel would not exist.⁽³³⁾

4 Model parameterisation

The model is calibrated to match key structural features of the UK economy, and simulate policy shocks in order to explore the importance of these channels in the shock transmission. The parameters are chosen on the basis of actual data (historical averages and the most recent trends), and references from previous studies.

(33) Even in this case, though, the capital requirement may become binding. This would occur whenever the riskiness of bank portfolio increases (in recession, for example), as in reality the capital requirement is defined as the ratio between the bank capital and *risk-adjusted* assets.

4.1 *The financial position of the corporate sector*

The strength of the corporate balance sheet channel depends on the size of the auditing cost, μ_{ac} , the mean and variance of the idiosyncratic shock hitting the corporate sector, and the survival rate of entrepreneurs, γ .⁽³⁴⁾

The auditing cost is a key parameter that defines the strength of the corporate balance sheet channel. Equations (B-11) to (B-13) in Appendix B show that if there were no auditing costs, there would be no external finance premium, and thus no corporate balance sheet channel. Equation (B-2) in the same appendix indicates that the annual auditing cost, when incurred, is defined as a percentage of the value of state-dependent (not all) loans. In the good state – when firms are able to repay their loans completely – they have an incentive to underreport their return to capital (in order to keep a part of profit). In order to observe the firms' actual return to capital, banks incur an auditing cost. The auditing cost is therefore paid only on the fraction of failed loans.⁽³⁵⁾ It is calibrated at 0.12 in line with Hall (2001)⁽³⁶⁾ and Gertler, Gilchrist and Natalucci (2003).

The survival rate of businesses is calibrated at 0.975 per annum in line with BGG and Hall (2001). The mean and the variance of the idiosyncratic shock are set to match the following structural features of the UK economy given in Hall (2001): (1) an annualised business failure rate of the corporate sector of 3%; (2) the proportion of the capital stock that is financed using external funds of 50%; and (3) the annual external finance premium of 190 basis points. This determines the elasticity of the EFP to the leverage ratio, ψ , at 0.078.

4.2 *The financial position of the banking sector*

There are a number of parameters in the model that define the strength of the bank balance sheet channel. The prevailing bank capital ratio, and the equity risk premium in the banking sector,⁽³⁷⁾ determine the impact of the bank balance sheet composition on the steady-state variables of the

(34) See Carlstrom and Fuerst (1997) for details.

(35) The dissipative cost – the cost of selling off the collateral – can thus also be considered as a part of the auditing cost.

(36) Hall sets the size of the auditing cost at 0.12, compared to 0.10 set by BGG for the US. La Porta *et al* (1998, Table II) indicate that the rigour in carrying out laws related with creditor rights (enforcement) in the UK is lower compared to the US or Germany (8.6 in the UK, compared to 10.0 in the US and 9.2 in Germany). This justifies the higher auditing cost.

(37) The equity risk premium is defined as the wedge between the cost of bank capital and (assumed risk-free) deposits.

economy (see equation (4)). The bank capital ratio is calibrated at 12.6%.⁽³⁸⁾ One should bear in mind that the minimum Basel capital requirement is 8%.

For the calibration of the equity risk premium in the banking sector, estimates derived from a standard capital asset pricing model (CAPM) are employed. According to CAPM, the equity risk premium is related to the market risk. The market risk of a particular asset depends both on the risk of the market portfolio and the ratio of variance and covariance for the specific asset, β^c .⁽³⁹⁾ Dimson, Marsh and Staunton (2002) look at the real returns on UK equities, bonds and bills over the past century. They find annualised real returns of 5.8% on equities and 1% on bills. Aggregated data on the UK banking sector show that β^c for equities of the UK banks is very close to one during the 1990s.⁽⁴⁰⁾ Hence, I calibrate the equity risk premium in the banking sector at 4.8% per annum or 1.2% per quarter.⁽⁴¹⁾ This calibration is compatible with the expected risk of default on bank capital, γ_2 , of 1.18%.⁽⁴²⁾

Besides affecting the steady-state variables of the economy, the financial position of the banking sector also affects the dynamic response of the economy to various shocks through three additional channels – the default risk channel, the adjustment cost channel, and the capital loss channel.

The strength of the default risk channel depends on the calibration of the risk of banks defaulting on their capital, γ_2 . In the short run this risk is assumed to move in tandem with banks' credit exposure (the risk of corporate loan default), which is cyclical. The probability of loan default is

(38) The estimate is based on the average ratio of actual capital over risk-weighted assets (risk-asset ratio) in the UK banks in 2000 (Source: *Financial Stability Review*, December 2000, Table 11). The unweighted capital to asset ratio in the UK is somewhat lower - around 8%. Nevertheless, using the other number does not crucially change the model dynamics.

(39) The CAPM calculates the risk premium as $rp = \beta^c (r_j^m - r_j)$, where rp is the risk premium, β^c the ratio of variance and covariance for the specific asset, r_j^m the return on market portfolio (composite share index, for example), and r_j is the return on risk-free asset (government bonds, for example).

(40) Based on the database put together for Nier and Baumann (2002).

(41) Various studies suggest that the equity risk premium in the US declined over the past 30 years (Jagannathan *et al* (2000), and Siegel (1999) for example). To the extent that the similar process occurred in the UK, the risk premium may have fallen from the historical 4.8% level. The lower risk premium would somewhat moderate the simulated importance of the default risk channel, and thus the bank capital channel in this paper. The interaction with other channels implies that the effect of such moderation would be non-linear.

(42) This should not be taken as if there is 1% probability of UK banks not surviving in the following year. The treatment of the risk of bank default is stark in the model. There are several reasons why the default risk may be overstated. First, the calibrated equity risk premium is a complex function of variables and covariances, which are not explicitly modelled. Furthermore, the recovery rate of the failed banks may not be complete in the quarterly model (as is implicitly assumed here), indicating that the same equity risk premium can be compatible with the lower expected default risk. Finally, the Dimson *et al* (2002) study looks at data over the past century. One may argue that the risk premium in the UK has declined recently.

defined in the financial contract problem as the cumulative distribution, $F(\bar{\omega})$, of the idiosyncratic disturbance, ω , at its threshold value (see equation **(B-2)** in Appendix B). I further posit a functional form for the dynamic relationship between the probability of corporate loan default and the output, \hat{Y} , both defined as deviations from their steady-state values, as:

$$\hat{\gamma}_{2t} = \hat{F}(\bar{\omega})_t = \psi^{pbd} \hat{Y}_t \quad (5)$$

Using the calibration of the financial position of the corporate sector we obtain the elasticity of corporate default risk to output, ψ^{pbd} , of -15.2.⁽⁴³⁾ This means that γ_2 increases from a calibrated steady-state value of 1.18% to 1.36% in the event of a fall in output of 1% below its steady-state value.⁽⁴⁴⁾

The adjustment cost, $\frac{\gamma_1}{2}$, is calibrated at 0.15. This cost is caused by the information asymmetry between banks and their potential shareholders and hence its size is set roughly to match the assumed auditing cost that occurs due to the information asymmetry between banks and firms. BGG have argued that plausible values for the auditing cost fall in the region between 0 and 0.5. Gordy and Howells (2004) have stressed that, because of poor public disclosure banking sector is regarded as among the most difficult sectors for market participants to analyse. This suggests higher values for the adjustment cost in the banking sector. But one certainly expects this cost to be lower in healthier banking systems. Cecchetti (1999) has compared national banking systems using various measures, and found that the UK banking system is one of the healthiest. The adjustment cost is thus set in the lower bound of estimates. Nevertheless, in periods of banking crises, this cost may rise to values higher than calibrated here.

In order to model the capital loss channel, I define the functional form for the price of bank shares. Empirical evidence suggests that the price of bank shares moves broadly in line with the price of other firms' shares. The price of firms' shares in this model should be reflected in the value of entrepreneurs' net worth. Hence, the price of bank shares moves roughly in line with entrepreneurial net worth. Based on the restricted estimation of the relationship between the quarterly FT Banks and FTSE 100 indices during the past ten years, I define the following

(43) In calculating ψ^{pbd} we use the principle that steady states of both relevant variables, $F(\bar{\omega})$ and Y , are affected by a common variable, namely the size of the threshold value of an idiosyncratic disturbance, $\bar{\omega}$. The elasticity of corporate default risk to output is calculated as $\psi^{pbd} = \frac{\ln F(\bar{\omega})_{i+1} - \ln F(\bar{\omega})_i}{\ln Y_{i+1} - \ln Y_i}$ where i represents the steady-state value of $\bar{\omega}$ and $i + 1$ a limit change in the value of $\bar{\omega}$.

(44) Haldane, Hoggarth and Saporta (2001) find that banking crises are associated with periods of low output. See Allen and Saunders (2003) for further evidence on the impact of macroeconomic conditions on the probability of default.

functional form for the relationship between the expected price of bank shares, $E_t (P_{t+1}^Z)$, and the expected level of corporate net worth, $E_t (N_{t+1})$:

$$E_t (P_{t+1}^Z) = 0.22E_t (N_{t+1}) + 0.78P_t^Z$$

A potential drawback of this stylised equation is that the price of bank shares might be expected to be a jump variable, rather than one that evolves slowly. In such a case, the capital loss channel would not be effective.⁽⁴⁵⁾ But, in some circumstances the data seem to indicate sluggish changes in the price of bank shares.⁽⁴⁶⁾ That must be due to a series of unexpected shocks hitting the economy and may also be because of an information asymmetry that implies shareholders are unable to assess immediately the extent of a shock to bank capital.⁽⁴⁷⁾ The dissemination of the shock through the system may come slowly, and hence the price of bank shares may follow a smoothed path, as above.

4.3 Other parameters

The households' discount factor, β , is set at 0.992.⁽⁴⁸⁾ This implies a real risk-free interest rate of 3.3% per annum. The coefficient on leisure in households' utility function, ν , is set at 2.7 in line with most of the real business cycle literature. The latter ensures a matching of the steady-state fraction of time spent at work at the historical average of 0.30. It implies labour supply elasticity of 2.33. The coefficient of money in the utility function is determined to match the empirically observed ratio of money to annual nominal GDP at around 16% (following BGG).

The production function is assumed to be Cobb-Douglas with the capital share, α , of 0.330, a household labour share of 0.667, and entrepreneurial labour share of 0.003. The capital depreciation rate is set at 2.5% per quarter. The calibration of the model delivers shares of consumption (households' and entrepreneurs') in output of 59%, investment of 20%, and government expenditure of 20%.⁽⁴⁹⁾

(45) In a model with optimising banks where strong EMH holds, bank shares would be priced efficiently, and there would be no capital gain or loss.

(46) For example, the recent changes in Japan did not cause a sudden, but rather smoothed fall in the price of bank shares (Farrant *et al* (2003)). Moreover, in an empirical study Ito and Sasaki (1998) have found that, as Japanese stock prices fell at the beginning of the 1990s, bank capital gains and thus the level of bank capital also fell.

(47) For example, the fact that a bank records a certain share of bad loans at the moment of an unexpected adverse shock does not mean that the recorded share would not grow once the other linked firms and banks are hit by the shock. The shareholders are likely to learn about the linked effects slowly. Hence we may observe the series of unexpected shocks.

(48) Although Hall sets this parameter at 0.99, other studies set it a bit higher. For example, Millard and Wells (2003) set it at 0.997.

(49) The share of government expenditure in GDP is exogenously calibrated to match the UK data.

The probability of changing prices in period t , κ , is set at 0.25, which implies that on average retailers set prices once every four quarters. The fraction of rule-of-thumb (backward-looking) retailers, θ , is set at 0.25. The steady-state elasticity of the shadow price of capital, Q , to the ratio of investment to capital stock is set to 0.25, following BGG, Hall and Fukunaga. The parameters related to the law of motion of the productivity and government expenditure shocks (ρ^a and ρ^g) are set at 0.9 and 0.95, respectively.

5 Simulations

5.1 Impact of the bank capital channel in the long run

The introduction of the bank capital channel changes the steady-state variables in the model.

Table A: Long-run effects of the additional cost of bank capital

Parameter		Without BC	With BC	LR effect
Prob. of loan default	$F(\bar{\omega})$	4.05%	3.93%	
External finance premium	$R^K - R$	1.77%	1.89%	
Leverage ratio	$\frac{L}{QK}$	47.53%	47.30%	
Volume of loans	L	3.2201	3.1559	-2.0%
Corporate net worth	N	3.5544	3.5164	-1.1%
Investment	I	0.1694	0.1668	-1.5%
Output	Y	0.8467	0.8406	-0.7%
Consumption	C	0.4404	0.4393	-0.3%
Entrepr. consumption	C^e	0.0540	0.0534	-1.1%

Table A reveals that, in the long run, output and investment are lower when bank capital has a defined role in the transmission mechanism compared with the situation when it is not modelled. This is because of the higher cost of bank capital relative to the cost of (risk-free) deposits. Banks transfer this additional cost (arising from banks' balance sheets) to firms by setting a higher EFP than before. This happens despite the fall in the probability of loan default. The primary reason

for the fall in the probability of loan default is the fall in the leverage ratio. Firms hold a lower share of external in total finance, and hence are less likely to default on loans.

The introduction of the higher-cost bank capital in the bank's balance sheet has two opposing effects on the external finance premium. *The direct effect* is described in equation **(B-12)** in Appendix B. So long as the bank is able to transfer the higher cost of its capital to entrepreneurs, any exogenous increase in the bank's capital ratio or the bank equity risk premium increases the cost of bank loans and thus the EFP. *The indirect effect* arises due to a fall in loan demand in the face of an increase in the cost of loans.⁽⁵⁰⁾ This reduces entrepreneurs' leverage ratio, ie the ratio of their external to total finance (see equation **(B-13)** in Appendix B). In other words, since the EFP is higher, entrepreneurs will use less external finance. The lower volume of loans (external finance) reduces the risk of entrepreneurs not being able to repay their loan obligations, $F(\bar{\omega})$. The insolvency region for the entrepreneur (defined by $\bar{\omega}$) shrinks, and banks charge a lower loan rate. This will partly offset the initial rise in the EFP, and create a non-linear effect in the model. Under any plausible parameterisation though, the direct effect is stronger than the indirect effect.

An increase in the EFP causes a fall in the volume of loans and the leverage ratio. Since entrepreneurs have to achieve a higher return on capital in order to repay loans, fewer investment projects become viable. Consequently the steady-state levels of investment, and thus real output fall. But the deterioration of the steady-state levels is not substantial for the existing calibration. The estimated deterioration of output is about 0.7%.⁽⁵¹⁾

One should note that this analysis more or less corresponds to the effect of an exogenous increase in the bank capital ratio – due to an increase in bank capital requirements, for example. But there is a difference. An increase in the capital ratio is likely to reduce the bank default risk, γ_2 , and hence the risk premium banks pay on their capital, although this effect is not directly modelled. This would partially offset an increase in the EFP.

(50) This effect arises due to a general equilibrium modelling framework, and thus the endogenous loan demand.

(51) The calibration in the paper is consistent with the normal level of economic activity, not the situation of a financial crisis. In a recent empirical study Arnott and Bernstein (2002) have found the equity risk premium approached or exceeded 10% during the Great Depression, and war periods. The aggregated betas of the UK banking sector are also likely to vary over time. Both of these would push the equity risk premium in the banking sector far above the calibrated value.

The macroeconomic effects arising from an increase in the average cost of bank liabilities are different from those of an increase in either the auditing cost, μ_{ac} , or the steady-state real interest rate, R . Although an increase in the auditing cost leads to a fall in the leverage ratio, it also increases the cost of each individual default. So, even if the insolvency region for entrepreneurs shrinks, banks may be reluctant to charge the lower loan rate.⁽⁵²⁾ A rise in the steady-state real interest rate affects not only the contracting problem, but also households' optimal choice; if the real interest rate increases, households will save more and consume less, which will have a further effect on the time path of output, not included in this experiment.

5.2 Impact of the bank capital channel in the short run

Besides affecting the steady-state variables of the economy, the introduction of the bank balance sheet channel also affects the dynamic response of the economy to various shocks. In this section I analyse the effects of two shocks. The monetary transmission mechanism is usually analysed by exploring the economy's impulse responses to a policy innovation. Here the effects of shocks directly hitting the banking sector also need to be addressed.

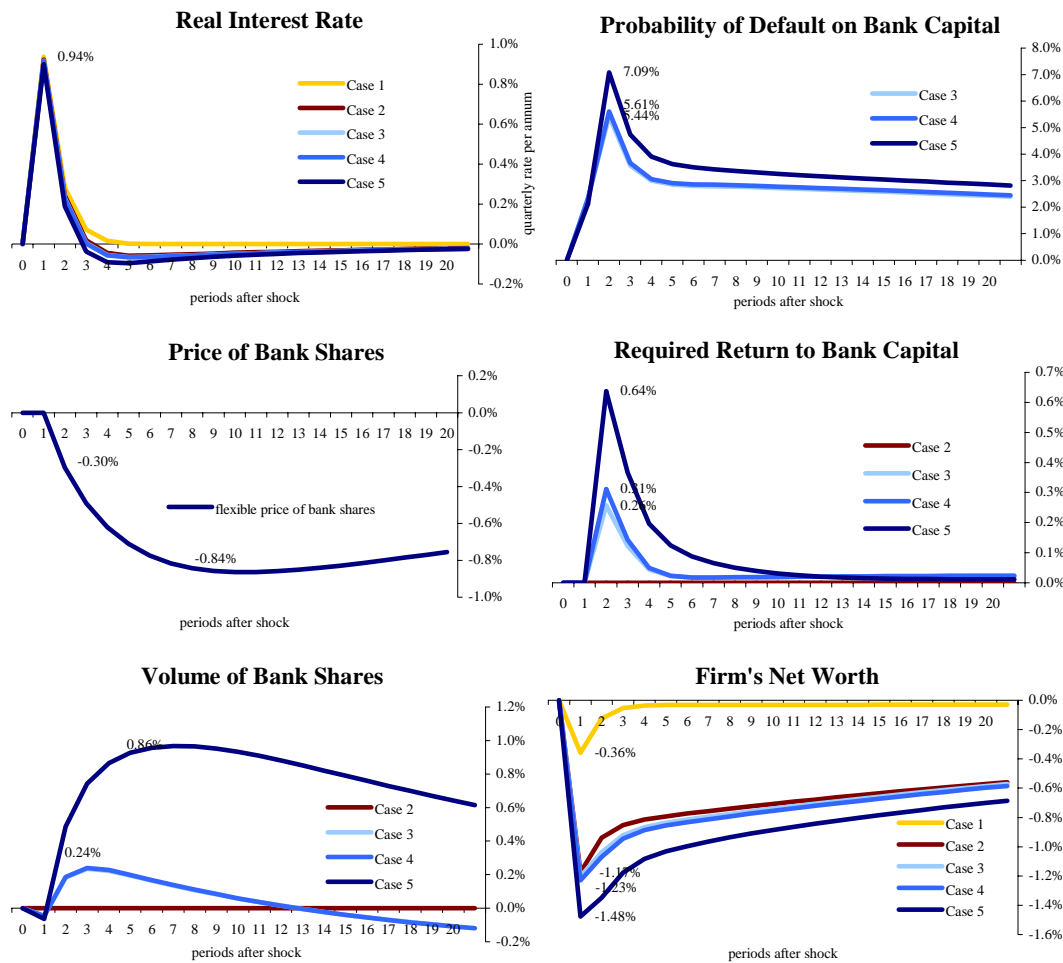
5.2.1 Policy innovation

In order to assess the importance of channels through which actions of policymakers affect the economy, simulations are conducted by progressively adding each of the credit channels to a model. The simulations embrace five different cases:

- Case 1 - no credit channels
- Case 2 - adding the corporate balance sheet channel
- Case 3 - adding the default risk channel
- Case 4 - adding the adjustment cost channel
- Case 5 - adding the capital loss channel

(52) See Hall and Vila Wetherilt (2002) for the detailed analysis of this effect within the BGG framework.

Chart 3: Impulse responses to a 1% temporary increase in policy rate *per annum*



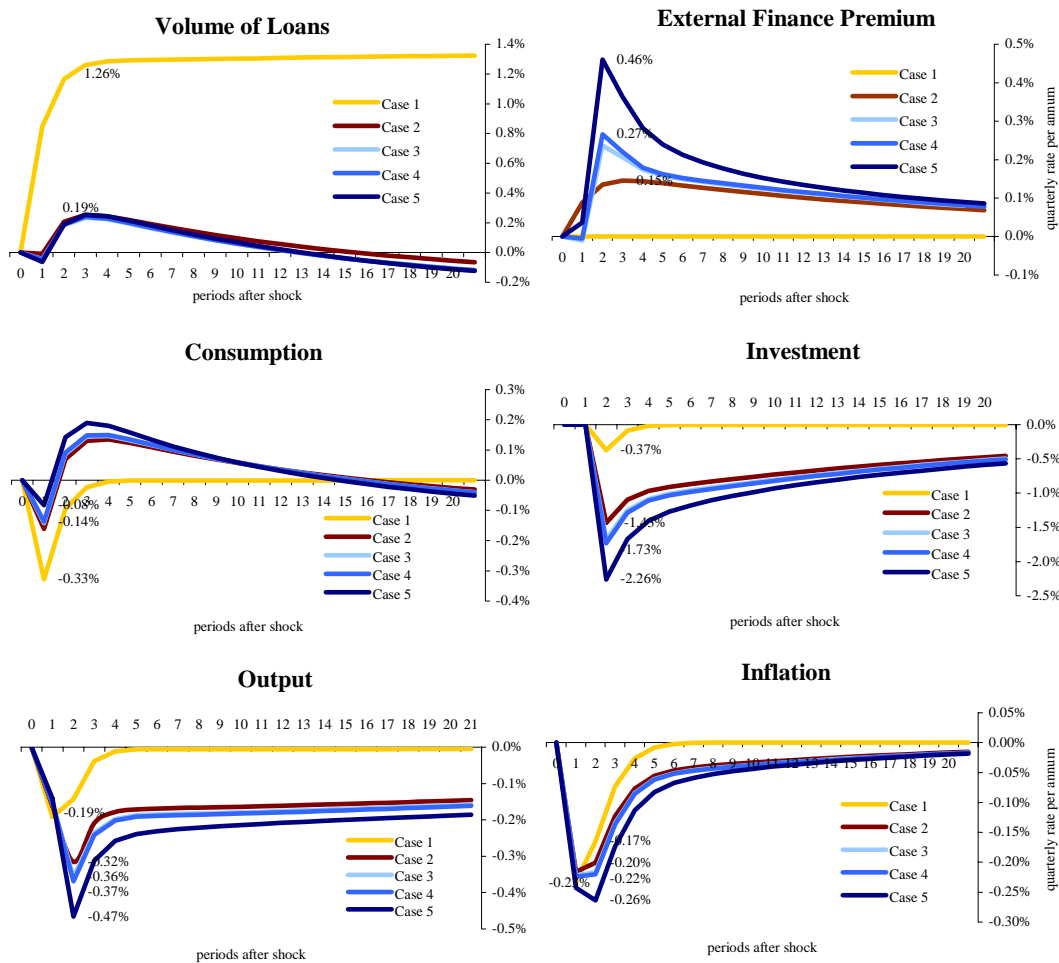
We simulate the impulse responses of the economy to a temporary (one quarter) increase in the policy rate of 1% per annum.⁽⁵³⁾ The policy rule used is an autoregressive forward-looking inflation rule.⁽⁵⁴⁾ This type of rule is used in BGG, and Clarida, Gali and Gertler (1999).

Charts 3 and 4 present the deviations of various variables in the model from their steady-state values. In the long run, all of these variables converge back to zero, ie their steady-state values, because the policy innovation is a temporary one. The model is very persistent and it takes a long time for steady-state convergence. Most of the interesting action, however, occurs at the beginning. Thus, the charts present only impulse responses for the first 20 periods.

(53) The simulations are conducted using Sparse Newton's solution method, and Stacked Newton's expectation algorithm.

(54) It is not to suggest that the UK authorities have ever followed such a rule: the choice is made for illustrative purposes.

Chart 4: Impulse responses to a 1% temporary increase in policy rate *per annum*



We can follow the main channels of the monetary transmission mechanism for the calibrated economy in Charts 3 and 4. The estimated fall in output due to the interest rate channel is 0.19%. As a result of the corporate balance sheet channel modelled in BGG, output falls further, reaching 0.32%. Each of the bank capital channels described in Section 3.2.1 further amplifies the output response. An estimated increase in bank default risk of 5.66%⁽⁵⁵⁾ increases the dividend rates banks have to pay on their capital by 0.26%. A need to meet the higher loan demand and thus raise fresh bank capital, triggers the adjustment cost channel, thus further increasing the required dividend rates to 0.31%. Finally the additional required dividend rates rise to 0.64% due to bank shareholders expecting a capital loss. A cumulative effect of the additional bank capital channels is for output to fall by 0.47%.

(55) This is a 5.66% deviation from the steady-state risk. In other words, the risk of a bank defaulting on its capital increases from 1.18% (steady-state calibration) to 1.25%.

Chart 5: Contribution of various channels to the output impulse response to a policy innovation

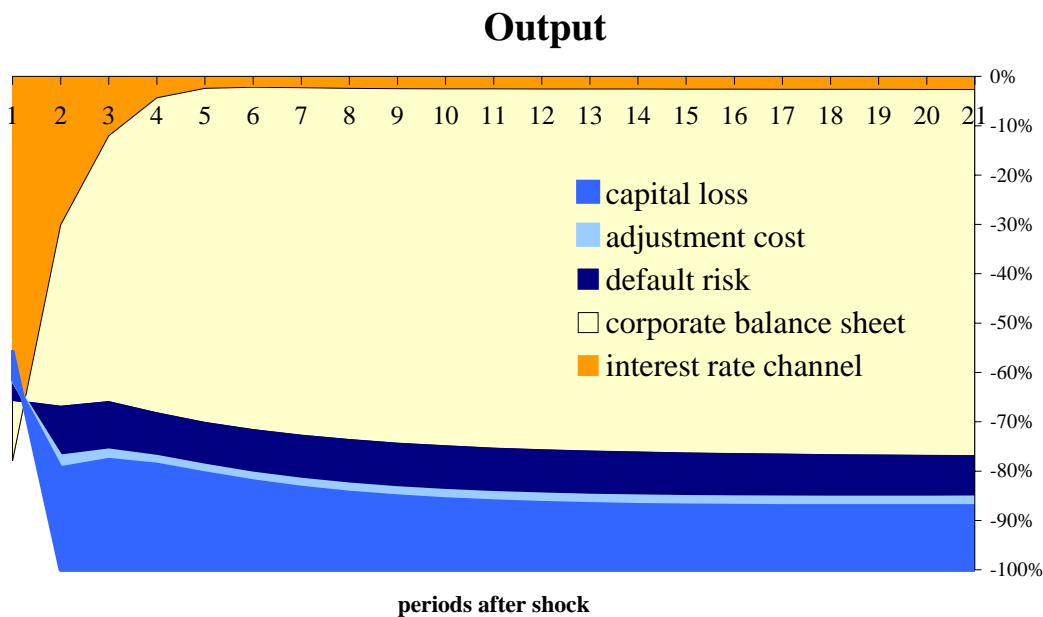
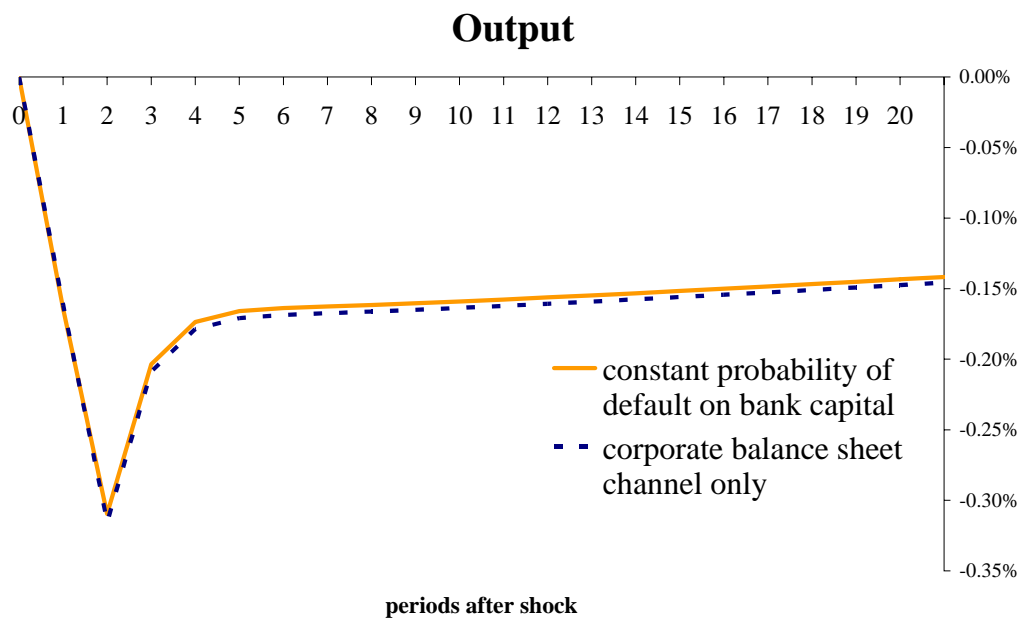


Chart 5 shows the contribution of various channels to the output impulse response over time. In the beginning the dominant channel is the interest rate channel. Immediately after the initial period, the corporate balance sheet channel becomes dominant. This channel adds a great persistence to the output reaction and the model in general. Bank capital channels accelerate the fall in output, especially in the second and third periods after the change in policy rate, when output reaches its low point. They jointly accelerate the fall in output by a further 50% below the previous response (the case without bank capital channels). The capital loss and the default risk channels are stronger than the adjustment cost channel. This is due to a rather modest change in the level of bank capital (0.24% in Case 4 when we add the adjustment cost channel).

The volume of loans temporarily increases after an unexpected policy tightening (see Chart 4). Firms borrow more in order to offset the decline in internally generated funds. Total finance for investment declines, however, because of the simultaneous increase in the EFP and thus the cost of loans. The increase in the volume of loans is short-lived and the trend reverses after roughly twelve quarters. The empirical evidence to support this is supplied in Gertler and Gilchrist (1994), who have conducted a VAR analysis and found that the volume of bank debt (ie firms' borrowing) tends to increase temporarily for large firms in response to a federal funds rate shock.⁽⁵⁶⁾

(56) The profile and size of the VAR response in Gertler and Gilchrist (1994) is quite similar to the one in Chart 4.

Chart 6: The effect of the introduction of the constant probability of banks defaulting on their capital for the output impulse response to a policy innovation



Furthermore, Dale and Haldane (1995) have set a VAR for the United Kingdom, and found that:

‘For corporates, the effect of an interest rate rise is to raise their borrowings in the short term...’ (Dale and Haldane (1995, page 1,620))⁽⁵⁷⁾

Chart 6 shows the impulse response of output to a policy innovation if we add an exogenous, constant bank default risk.⁽⁵⁸⁾ Although it leads to lower steady-state output, it does not amplify the time path of output. It rather makes the economy more resilient to an unexpected policy innovation, although the change is almost negligible in the existing calibration. The key reason for the smaller impact of the temporary policy innovation is a lower elasticity of the EFP to a change in the leverage ratio, ψ (0.0779 compared with 0.0782).⁽⁵⁹⁾ This occurs because firms have a lower leverage ratio (they are less indebted) and are therefore less affected by a tightening in monetary policy. Given firms are less indebted, any shock leading to a cut in investment revenues is less likely than before to lead to default on loans. Hence, in the event of an increase in official

(57) The same effect for the UK, but not for all other countries in the study, is found by Smart (2002).

(58) This implies a positive bank equity risk premium in the steady state, but no variations over the cycle.

(59) See equation (C-8) in Appendix C.

interest rates, banks tighten credit supply (raise loan rates) by less than would be the case if the corporate sector was more indebted.

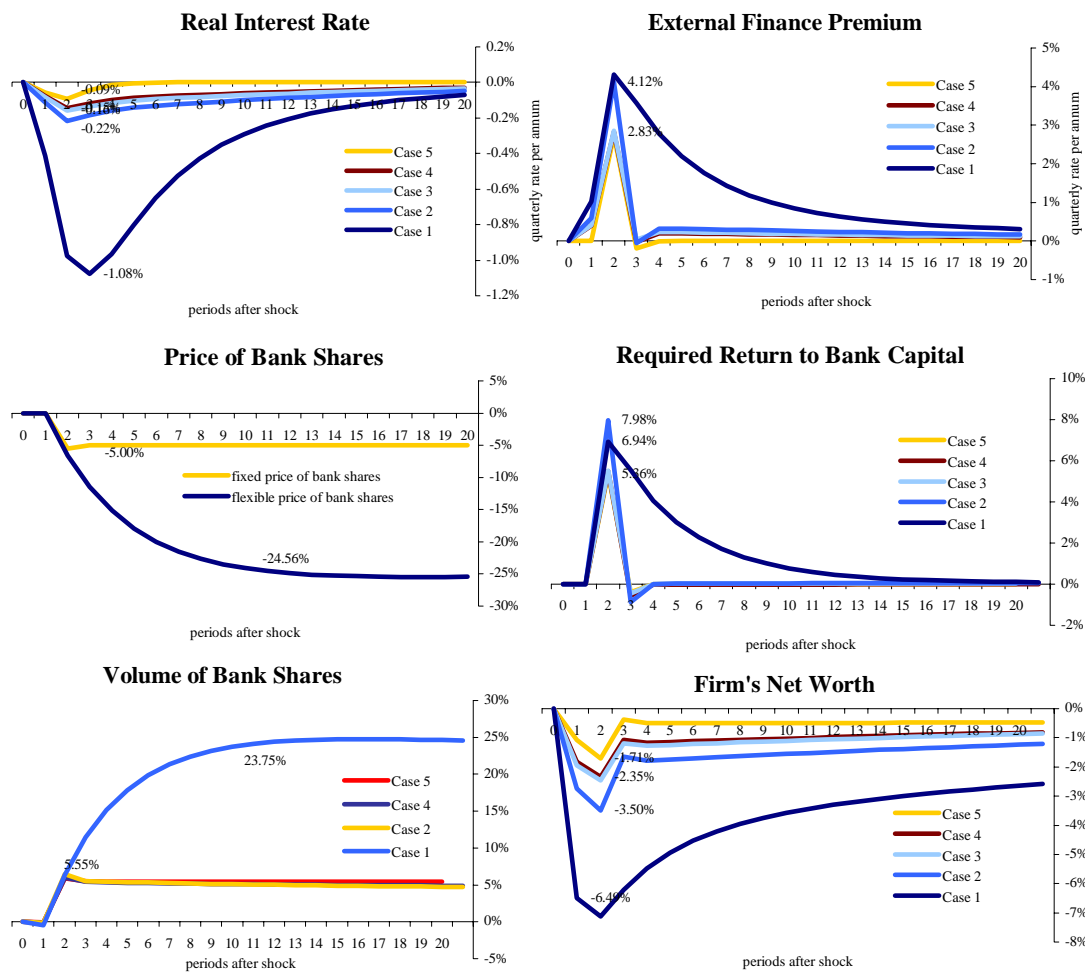
5.2.2 Shock to the value of the bank capital

Past evidence shows a record of occasional but large direct shocks to banks' balance sheets. Such shocks can deliver an immediate impact to the value of bank capital, and thus the price of bank shares. An example of such a shock is an economy-wide write-off of non-performing loans (see Farrant *et al* (2003)). The recognition of a bank's inability to recover the principal from non-performing loans implies that the banking sector was not as productive as balance sheets had previously indicated. This would likely trigger a permanent fall in the value of bank capital via a fall in the price of bank shares.

To assess the contribution of various credit channels (and thus the importance of the structure of the financial system) in the case of a direct shock to banks' balance sheets, I conduct simulations for five different cases:

- 'Case 1' - with all credit channels working (bank capital and corporate balance sheet channels)
- 'Case 2' - with the capital loss channel switched off. This is done by fixing the price of bank shares from the first period after the shock onwards. Adjustment cost and default risk channels, as well as the corporate balance sheet channel are operative in this case.
- 'Case 3' - with the adjustment cost channel switched off. This is done by setting the adjustment cost, $\frac{\gamma}{2}$, at zero. The only effective bank capital channel is the default risk channel.
- 'Case 4' - with the default risk channel switched off. This is done by setting ψ^{pbd} (the elasticity of the bank default risk to output) at zero. The only operative credit channel is the corporate balance sheet channel.
- 'Case 5' - with the corporate balance sheet channel switched off. This is done by setting ψ (the elasticity of the EFP to the leverage ratio) at zero. The impact occurs only via an initial change in the price of bank shares (the price of bank shares is fixed from a period after the shock) and the consequent change in the bank capital channel. We need the initial effect of the bank capital channel, since the shock is to banks' balance sheets. This is also the reason for a reversed order of cases compared to the previous section.

Chart 7: Impulse responses to a 5% fall in the value of bank capital



The economy's impulse responses are simulated for a permanent fall in the value of bank capital, via a fall in the price of bank shares of 5%. As in Section 5.2.1, it is assumed that banks are able to raise fresh capital in order to maintain their capital requirement.⁽⁶⁰⁾

An initial permanent fall in the value of bank capital of 5% transmits to the rest of the economy via channels described in Section 2. Charts 7 and 8 report impulse responses.

The most striking difference compared with the transmission of the policy innovation is a much enhanced level of the reaction in investment, output and inflation, when the capital loss channel is fully operative. The main reason is high persistence in the EFP, generated by sluggishness and a

(60) In other words, credit rationing is not considered in this model.

Chart 8: Impulse responses to a 5% fall in the value of bank capital

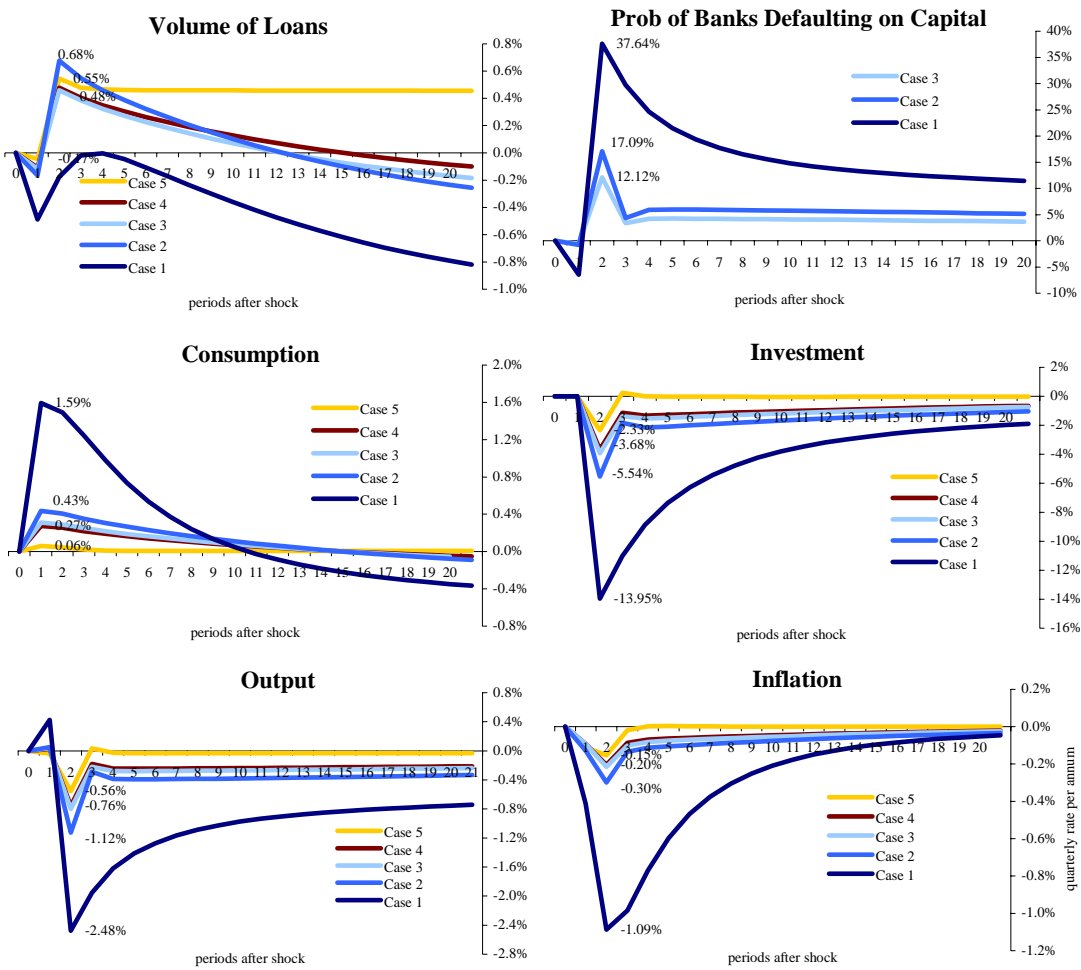
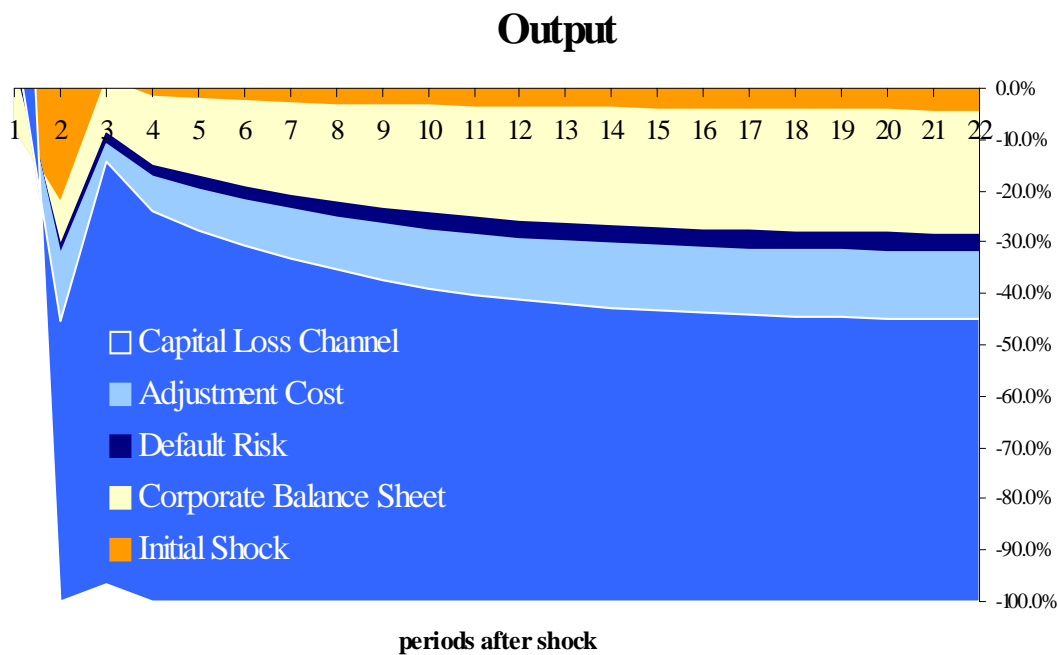


Chart 9: Contribution of various channels to the output impulse response to a shock to the value of bank capital

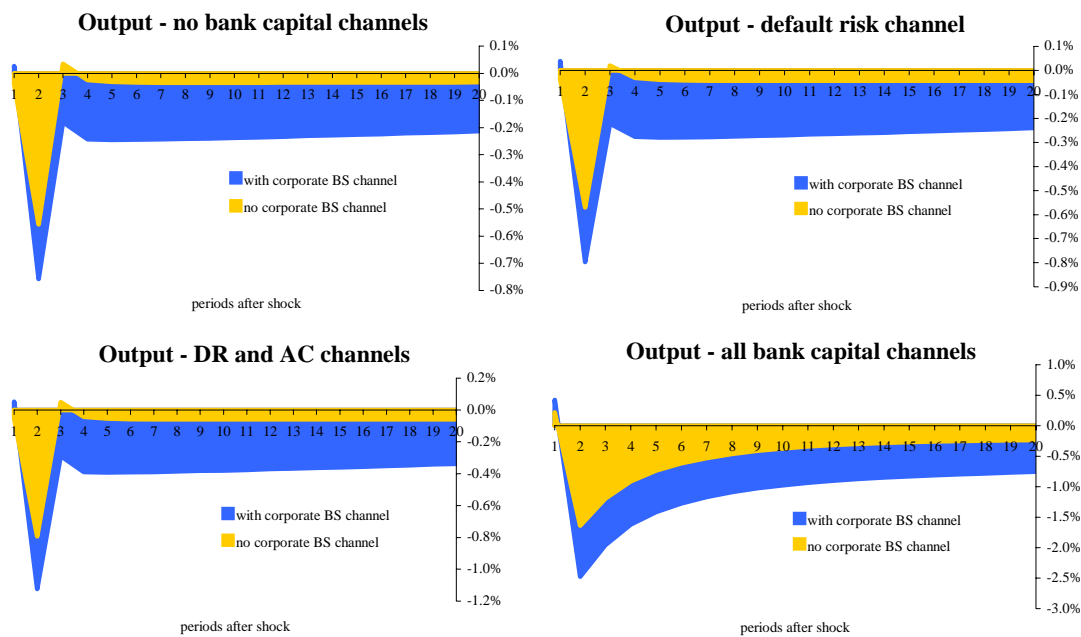


much higher long-run fall in bank share prices (24%). Hence, the adverse shocks to the banking system may have a much stronger effect in the case of a persistent expectation of losses from holding bank capital.

Chart 9 reveals that the adjustment cost channel is now much more important for the output response than in the case of a policy innovation. The estimated reaction of output is almost 50% stronger (1.12% compared with 0.76%) when the adjustment cost channel is operative. The main reason for the greater importance of the adjustment cost channel is the size and the nature of adjustment in the volume of bank shares. Banks have to raise up to 5.5% of fresh capital (as a percentage of their pre-existing capital) in the case of a big shock to the price of bank shares, whereas it was only 0.24% in the case of policy innovation. As mentioned earlier, the size of the adjustment cost depends on the structure and health of the banking sector, as well as banks' public disclosure. That would imply that the latter may become particularly important in the case of occasional but large shocks directly affecting banks' balance sheets.

Bank capital channels become more important than the corporate balance sheet channel when

Chart 10: Interaction between the supply and the demand-side effects of the credit market



direct shocks to banks' balance sheets are considered. Nevertheless, much of the additional effect of bank capital channels is due to their interaction with the corporate balance sheet channel (see discussion in Section 2). Chart 10 shows the much higher contribution of the corporate balance sheet channel compared with the one indicated in Chart 9. One can conclude that the interaction between the supply and the demand-side effects of the credit market can greatly amplify the effects of shocks to the economy.

6 Concluding remarks

Empirical studies suggest that issues related to the supply side of the credit market (banks' balance sheets) affect the monetary transmission mechanism. In order to analyse this impact a dynamic general equilibrium model is constructed to include the interaction between the supply side (banking sector) and the demand side (corporate sector) of the credit market. The bank capital channel arises due to asymmetric information between banks and their shareholders. The cyclical probability of banks defaulting on their capital triggers the default risk channel. The cyclical volume of bank shares produces an allocation cost, thus creating the adjustment cost channel. The cyclical price of bank shares creates the capital loss channel. All channels generate a rise in the required return to bank capital, and thus the cost of bank capital, during a contraction. The

higher cost of bank capital is transferred to firms via an increase in the external finance premium. At the new higher cost of borrowing, fewer investment projects are profitable and hence investment and real output are lower.

The results in Section 5.2 suggest that the bank capital channel may contribute to the monetary transmission mechanism, in addition to the corporate balance sheet channel. The contribution of the bank capital channel is likely to be stronger in economies with a higher steady-state probability of default on bank capital (higher bank bankruptcy rates, and in financial crises, for example). The stronger bank balance sheet channel should be observed in economies with greater information asymmetry. In economies where banks are not rated by external rating agencies, or they disclose less information to the public, potential bank shareholders suffer a higher search cost in order to check the health of a particular bank before investing in its shares. This increases the amplifying effect of the adjustment cost channel. The stronger bank capital channel should also be observed in economies where bank shares are not efficiently priced, or where the dissemination of shocks or information about shocks is slow. There, bank share prices adjust only gradually. For example, growth forecasts for Japan during the 1990s were consistently higher than actual growth. This suggests a slow dissemination of information about shocks. Such a situation corresponds to a series of unexpected shocks, thus creating a stronger capital loss channel.

The relative importance of the bank capital channel is likely to increase in periods of occasional, but large, direct shocks to banks' balance sheets. Such shocks may occur alongside structural reforms or regulatory changes or anything else that directly affects the value of bank capital. For example, a write-off of non-performing loans is likely to lead to a fall in the value of bank capital, therefore inducing or reinforcing the bank capital channel. A change in regulations that increases the bank capital requirements is likely to have similar consequences. The adverse impact of a structural reform or a regulatory change is likely to be stronger in economies with a potentially stronger bank capital channel.

The interaction between the supply and the demand side of the credit market is likely to greatly amplify the impulse responses. The effect of the corporate balance sheet channel increases due to its interaction with (additional) bank capital channels.

Further research could go in several directions. The model assumes that, faced with a binding

capital constraint, banks raise additional capital, thus overcoming the constraint and meeting the credit demand. In reality, banks can also limit the credit supply to below the level of the credit demand, given the same loan interest rate. This is a case of credit rationing. In such a case, the level of credit does not depend on firms' optimal choices, but rather on the available bank capital at the moment of a shock. Credit rationing may produce a stronger contractional effect, but it would be essential to analyse the issue further within the framework proposed.

This paper shows that inefficient pricing of bank shares has a potential to greatly amplify the effects of shocks, particularly direct shocks to bank balance sheets. This result pinpoints the need for modelling bank share prices, and for providing a micro-foundation for the deviation from the efficient market hypothesis. It would help provide a deeper insight into options for a policymaker to reduce this amplifying effect. In order to model bank share prices explicitly, the model would need to incorporate the bank optimisation problem. The tractable bank optimisation problem can be provided without necessarily jeopardising the assumed zero-profit condition.⁽⁶¹⁾ For example, perfect contestability or Bertrand-type competition should ensure that banks break even each period.

Another useful extension may be to introduce relationship lending and analyse how this might affect the monetary transmission mechanism. Close links between banks and firms, observed in Germany, are likely to affect lending policy and the strength of bank balance sheet channels, in general. The model in this paper assumes that deposits are risk-free. Although the existence of an explicit or implicit deposit insurance system may justify this assumption to a certain extent, the deposit insurance is almost never complete. In such cases the cost of bank liabilities would also depend on the wedge between the deposit and risk-free interest rates, and the volatility of this wedge over the cycle.

Addressing the heterogeneity issue may be a further extension. The above model is based on a representative agent framework. Introducing heterogeneity among banks, households, and firms would provide a further insight into the credit channel of the monetary transmission, and in particular its non-linear effects.⁽⁶²⁾ Heterogeneity among firms would permit the analysis of the

(61) Solving the costly state verification problem without the zero-profit condition is analytically very challenging, and may prove non-tractable.

(62) Heterogeneous financial agents are, for example, introduced in a framework by Goodhart *et al* (2003). This model is, however, a two-period model, aimed primarily for the analysis of financial fragility, rather than the monetary transmission mechanism.

trade credit channel to be explored. The trade credit channel can to a certain extent offset the effect of the bank credit channel, thus rendering the financial accelerator effect somewhat less important. Heterogeneity among banks would permit an analysis of the interbank credit market, which might render the effects of the bank capital channel somewhat less severe. Finally, heterogeneity among consumers (for example introducing rule-of-thumb consumers) should reduce the fraction of rational consumers, thus rendering the standard interest rate channel more persistent than one presented in this paper.

Finally, contemporary discussions about the new Basel proposals for the capital regulation of the banking sector can be assessed within this framework. By assessing credit risk more accurately this new proposal should contribute to the reduction of the default risk channel. But if it was to increase the cyclicity of the volume of bank shares, this would augment the adjustment cost channel and lead to an ambiguous overall effect.

Appendix A: Households' optimisation problem

Risk-averse households maximise their utility subject to a budget constraint:

$$\underset{C_t, D_{t+1}, Z_{t+1}, H_t, \frac{M_t}{P_t}}{MAX} E_t \sum_{k=0}^{\infty} \beta^k \left[\ln(C_{t+k}) + \varsigma \ln\left(\frac{M_{t+k}}{P_{t+k}}\right) + \nu \ln(1 - H_{t+k}) \right] \quad (\text{A-1})$$

subject to

$$\begin{aligned} C_{t+k} = & W_{t+k}H_{t+k} - T_{t+k} + \Pi_{t+k}^R + R_{t+k-1}D_{t+k} - D_{t+k+1} + \\ & (1 - \gamma_2)R_{t+k}^Z P_{t+k}^Z Z_{t+k} - P_{t+k}^Z Z_{t+k+1} - \frac{\gamma_1 (P_{t+k}^Z \Delta Z_{t+k+1})^2}{2 P_{t+k}^Z Z_{t+k}} \\ & + \frac{M_{t+k-1} - M_{t+k}}{P_{t+k}} \end{aligned} \quad (\text{A-2})$$

We use the following variables and parameters:

C	consumption	P^Z	price of bank shares
H	labour hours	W	real wage rate for household labour
$\frac{M}{P}$	real money balances	T	lump-sum tax
β	discount factor	Π^R	dividends received from ownership of retail firms
ς	coefficient on real money balances in the utility function	R^Z	gross real dividend rate
ν	coefficient on leisure in the utility function	R	gross real risk-free interest rate
D	deposits	$\frac{\gamma_1}{2}$	adjustment cost
Z	volume of bank shares	γ_2	probability of banks defaulting on their capital

First-order conditions

Over C_t

$$\lambda_{t+k} = \frac{\beta^k}{C_{t+k}} \quad (\text{A-3})$$

Over H_t

$$W_t \frac{1}{C_t} = \nu \frac{1}{1 - H_t} \quad (\text{A-4})$$

Over $\frac{M_t}{P_t}$

$$\frac{M_t}{P_t} \frac{1}{C_t} = \varsigma \left(\frac{R_{t+1}^N - 1}{R_{t+1}^N} \right)^{-1} \quad (\text{A-5})$$

Over D_{t+1}

$$\lambda_t = \beta R_t E_t (\lambda_{t+1}) \quad (\text{A-6})$$

Over Z_{t+1}

$$\lambda_t P_t^z \left[1 + \gamma_1 \left(\frac{Z_{t+1}}{Z_t} - 1 \right) \right] = \beta E_t \left\{ \lambda_{t+1} P_{t+1}^z \left[R_{t+1}^Z (1 - \gamma_2) + \frac{\gamma_1}{2} \left(\left(\frac{Z_{t+2}}{Z_{t+1}} \right)^2 - 1 \right) \right] \right\} \quad (\text{A-7})$$

Euler equation for consumption is obtained by combining equation (A-3) and equation (A-6):

$$\frac{1}{C_t} = \beta \frac{1}{C_{t+1}} R_t \quad (\text{A-8})$$

Link between the return on bank capital and the return on deposits – no arbitrage condition – is obtained by combining equations (A-6) and (A-7):

$$E_t \left\{ \lambda_{t+1} P_{t+1}^z \left[\begin{array}{c} R_{t+1}^Z (1 - \gamma_2) + \\ + \frac{\gamma_1}{2} \left(\left(\frac{Z_{t+2}}{Z_{t+1}} \right)^2 - 1 \right) \end{array} \right] \right\} = R_t E_t (\lambda_{t+1}) P_t^z \left[1 + \gamma_1 \left(\frac{Z_{t+1}}{Z_t} - 1 \right) \right] \quad (\text{A-9})$$

Log-linearisation around the steady state delivers the following relationship between return on bank capital and risk-free interest rate:

$$E_t \left(\widehat{R}_{t+1} \right) + E_t \left(\widehat{P}_{t+1}^z - \widehat{P}_t^z \right) = \widehat{R}_t + \gamma_1 \left(\widehat{Z}_{t+1} - \widehat{Z}_t \right) - \frac{\gamma_1}{R_0} E_t \left(\widehat{Z}_{t+2} - \widehat{Z}_{t+1} \right) + \frac{\gamma_2}{1 - \gamma_2} \widehat{\gamma}_{2t} \quad (\text{A-10})$$

Appendix B: Banks and the financial contract

In the financial contract the profit of risk-neutral entrepreneur is maximised subject to the bank's participation constraint.

$$MAX_{\bar{\omega}, K} E_t \left\{ \int_{\bar{\omega}^j}^{\infty} \omega R_{t+1}^K Q_t K_{t+1}^j dF(\omega) - [1 - F(\bar{\omega}^j)] (R_{t+1}^L)^j L_{t+1}^j \right\} \quad (\mathbf{B-1})$$

subject to lender's (bank's) participation constraint

$$\begin{aligned} & \underbrace{[1 - F(\bar{\omega}^j)] (R_{t+1}^L)^j L_{t+1}^j}_{\text{income from loans in good state}} + \underbrace{(1 - \mu_{ac}) \int_0^{\bar{\omega}^j} \omega R_{t+1}^K Q_t K_{t+1}^j dF(\omega)}_{\text{income from loans in bad state}} = \\ = & \underbrace{R_t D_{t+1}^j + R_{t+1}^Z P_{t+1}^Z Z_{t+1}^j}_{\text{cost of liabilities}} \end{aligned} \quad (\mathbf{B-2})$$

defining $\bar{\omega} R_{t+1}^K Q_t K_{t+1}^j = (R_{t+1}^L)^j L_{t+1}^j$ and $D_{t+1}^j + P_{t+1}^Z Z_{t+1}^j = L_{t+1}^j$

and

$$L_{t+1}^j = Q_t K_{t+1}^j - N_{t+1}^j \quad (\mathbf{B-3})$$

Variables and parameters

R^K	gross real return to capital	D	deposits
R	gross real risk-free interest rate	Z	bank shares
R^L	gross real loan interest rate	P^Z	price of bank shares
K	capital (QK are total funds invested by firms)	L	volume of loans (firms' external funds)
N	net worth of firms	μ_{ac}	auditing cost or expected default cost
Q	the price of an additional unit of capital in time t currency (Tobin's Q)		
γ	the rate of survival of entrepreneurs		
ω	an idiosyncratic productivity disturbance with log-normal prob. distribution $(\sigma^2, -\frac{1}{2}\sigma^2)$ over a set $(0, \infty)$		
$\bar{\omega}$	cut-off value of the idiosyncratic shock		

Solution for the contracting problem

By defining the leverage ratio⁽⁶³⁾ k :

$$k = \frac{QK}{N} \quad (\mathbf{B-4})$$

the ratio of costs of external and internal finance s :

$$s = \frac{R^K}{R} \quad (\mathbf{B-5})$$

and the additional cost of bank liabilities ξ :

$$\xi = 1 + \frac{R^Z - R}{R} \frac{P^Z Z}{L} \quad (\mathbf{B-6})$$

I can transform the financial contract into:

$$\underset{k, \bar{\omega}}{MAX} [1 - \Gamma(\bar{\omega})] sk \quad (\mathbf{B-7})$$

subject to the constraint

$$[\Gamma(\bar{\omega}) - \mu_{ac} G(\bar{\omega})] sk = (k - 1) \xi \quad (\mathbf{B-8})$$

where the expected share of firms' profits staying with the firm is $1 - \Gamma(\bar{\omega})$, and the expected share of profits going to the lender is $\Gamma(\bar{\omega}) - \mu_{ac} G(\bar{\omega})$.

$$\Gamma(\bar{\omega}) = \int_0^{\bar{\omega}} \omega f(\omega) d\omega + \bar{\omega} \int_{\bar{\omega}}^{\infty} f(\omega) d\omega \quad (\mathbf{B-9})$$

$$\mu_{ac} G(\bar{\omega}) = \mu_{ac} \int_0^{\bar{\omega}} \omega f(\omega) d\omega \quad (\mathbf{B-10})$$

First-order conditions

Over $\bar{\omega}$ ⁽⁶⁴⁾

$$\lambda = \frac{\Gamma'(\bar{\omega})}{\Gamma'(\bar{\omega}) - \mu_{ac} G'(\bar{\omega})} \quad (\mathbf{B-11})$$

Over k

$$s = \frac{\lambda \xi}{1 - \Gamma(\bar{\omega}) + \lambda [\Gamma(\bar{\omega}) - \mu_{ac} G(\bar{\omega})]} \quad (\mathbf{B-12})$$

Combining equations **(B-8)** and **(B-12)** I obtain:

$$k = \frac{\lambda \xi}{[1 - \Gamma(\bar{\omega})] s} \quad (\mathbf{B-13})$$

Notice that if $\mu_{ac} = 0$ then $\lambda = 1$ **(B-11)** and $s = 1$ **(B-12)**. In words – **if there were no auditing cost, there would be no external finance premium.** Notice that if the cost of bank capital equals

(63) In fact, this is the ratio of the total finance to the internal finance. But, it mirrors the leverage ratio ie the ratio of external finance to total finance.

(64) The cut-off value of the idiosyncratic shock, $\bar{\omega}$, divides solvency and insolvency regions for the firm (ie it enables the firm to pay back the loans in total). Only when $\omega > \bar{\omega}$ the firm earns some profit.

the cost of deposits ($R^Z = R$), or if the bank does not hold any capital ($\frac{P^Z Z}{L} = 0$), then $\zeta = 1$. In words – bank balance sheet composition would not affect the external finance premium, and the bank balance sheet channel would not exist.

From **(B-13)** I obtain:

$$\frac{QK}{N} = z \left(\frac{R}{R^K} \zeta \right) \quad (\text{B-14})$$

Inverting the above I obtain equation **(3)** from Section 3.2.2:

$$R_{t+1}^K = \Psi \left(\frac{N_{t+1}}{Q_t K_{t+1}} \right) R_t \zeta_t$$

with $\Psi'(\circ) < 0$.

The additional constraint affects the contracting problem, but also has a further effect since it changes all endogenous variables in the general equilibrium framework. Hence, I have to solve again for the new steady state, and this creates the non-linear effect.

The optimal cut-off point $\bar{\omega}$ is solved numerically by minimising the distance between the equation **(B-13)** and another link between k and s , which comes from the constraint on net worth accumulation and yields the following:⁽⁶⁵⁾

$$k^{def} = \frac{1}{\gamma [1 - \Gamma(\bar{\omega})] \frac{s}{\beta} + \frac{(1-a)(1-\Omega)}{a} \left[\frac{s}{\beta} - (1 - \delta) \right]} \quad (\text{B-15})$$

The optimal cut-off point $\bar{\omega}$ is an endogenous variable in the contracting problem, but an exogenous in the general equilibrium framework.

(65) See Hall and Vila Wetherilt (2002) for further explanation.

Appendix C: A log-linear version of the model

$$c_t = c_{t+1} - r_t \quad (\text{C-1})$$

$$h_t = \gamma_{hs} w_t - \gamma_{hs} c_t \quad (\text{C-2})$$

$$m_t - p_t = -\frac{1}{R_0^N - 1} r_t^n + c_t \quad (\text{C-3})$$

$$q_{t+1} = \phi i_{t+1} - \phi k_t \quad (\text{C-4})$$

$$r_t^k = (1 - \nu) (y_t - k_{t-1} + m c_t) + \nu q_t - q_{t-1} \quad (\text{C-5})$$

$$h_t = m c_t + y_t - w_t \quad (\text{C-6})$$

$$\pi_t = \frac{\beta(1 - \kappa)}{\phi^\pi} \pi_{t+1} + \frac{1 - \theta}{\phi^\pi} \pi_{t-1} + \frac{\theta \kappa (1 - \beta(1 - \kappa))}{\phi^\pi} m c_t \quad (\text{C-7})$$

$$r_{t+1}^k = r_t + \psi (q_t + k_{t+1} - n_{t+1}) + \zeta_t \quad (\text{C-8})$$

$$e f p_t = \frac{R_0^K}{R_0^K - R_0} r_{t+1}^k - \frac{R_0}{R_0^K - R_0} r_t \quad (\text{C-9})$$

$$y_t = \frac{C_0}{Y_0} c_t + \frac{C_0^e}{Y_0} c_t^e + \frac{I_0}{Y_0} i_t + \frac{G_0}{Y_0} g_t \quad (\text{C-10})$$

$$y_t = a_t + \alpha k_{t-1} + (1 - \alpha) \Omega h_t \quad (\text{C-11})$$

$$n_t = \chi (\phi^{lev} + 1) r_t^k - \chi \phi^{lev} r_{t-1} + [\chi \phi^{lev} \psi + \chi] n_{t-1} - \phi^{lev} \zeta_t - \chi \phi^{lev} \psi (q_{t-1} + k_{t-1}) + (1 - \chi) (y_t + m c_t) \quad (\text{C-12})$$

$$c_t^e = (\phi^{lev} + 1) r_t^k - \phi^{lev} r_t + (\phi^{lev} \psi + 1) n_t - \phi^{lev} \zeta_t - \phi^{lev} \psi (q_{t-1} + k_{t-1}) \quad (\text{C-13})$$

$$k_t = \delta i_{t-1} + (1 - \delta) k_{t-1} \quad (\text{C-14})$$

$$b_t = \frac{\phi^{lev} + 1}{\phi^{lev}} (q_t + k_t) + \frac{1}{\phi^{lev}} n_t \quad (\text{C-15})$$

$$\zeta_t = \gamma_1^\zeta (r_{t+1}^z - r_t) + \gamma_2^\zeta (p_t^z + z_t - b_t) \quad (\text{C-16})$$

$$r_{t+1}^z = r_t + p_t^z - p_{t+1}^z + \gamma_1 \left(1 + \frac{1}{R_0}\right) z_{t+1} - \gamma_1 z_t - \frac{\gamma_1}{R_0} z_{t+2} + \frac{\gamma_{2,0}}{1 - \gamma_{2,0}} \gamma_{2,t} \quad (\text{C-17})$$

$$p_{t+1}^z = \gamma^{pz} p_t^z + (1 - \gamma^{pz}) n_{t+1} \quad (\text{C-18})$$

$$\gamma_{2,t} = \psi^{pbd} y_t \quad (\text{C-19})$$

$$z_t = b_t - p_t^z \quad (\text{C-20})$$

$$r_t = r_t^n - \pi_{t+1} \quad (\text{C-21})$$

$$r_t^n = \rho^p r_{t-1}^n + (1 - \rho^p) \gamma_1^p \pi_{t+1} + \varepsilon_t^p \quad (\text{C-22})$$

$$a_t = \rho^a a_{t-1} + \varepsilon_t^a \quad (\text{C-23})$$

$$g_t = \rho^g g_{t-1} + \varepsilon_t^g \quad (\text{C-24})$$

With following parameters:

$$\gamma_{hs} = \frac{1 - H_0}{H_0} \quad (\text{C-25})$$

$$\nu = \frac{1 - \delta}{\alpha \frac{1}{X_0} \frac{Y_0}{K_0} + 1 - \delta} \quad (\text{C-26})$$

$$\chi = 1 - \frac{(1 - \alpha)(1 - \Omega) \frac{Y_0}{K_0} \frac{K_0}{N_0}}{X_0} \quad (\text{C-27})$$

$$\phi^\pi = 1 - \kappa + (1 - \theta) [1 - (1 - \kappa)(1 - \beta)] \quad (\text{C-28})$$

$$\phi^{lev} = \frac{K_0}{N_0} - 1 \quad (\text{C-29})$$

References

Allen, L and Saunders, A (2003), 'A survey of cyclical effects in credit risk measurement models', *Bank for International Settlements Working Paper no. 126*.

Angeloni, I, Kashyap, A, Mojon, B and Terlizzese, D (2003), 'Monetary policy transmission in the euro area: where do we stand?', in Angeloni, I, Kashyap, A and Mojon, B (eds), *Monetary policy transmission in the euro area*, pages 383-412.

Aoki, K, Proudman, J and Vlieghe, J (2002), 'House prices, consumption, and monetary policy: a financial accelerator approach', *Bank of England Working Paper no. 169*.

Arnott, R and Bernstein, P (2002), 'What risk premium is "normal"?' , *Financial Analysts Journal* 58 (2), March/April, pages 64-85.

Ashcraft, A B and Campello, M (2002), 'Borrowers' financial constraints and the transmission of monetary policy: evidence from financial conglomerates', *FRB of New York Staff Report no. 153*, August.

Berka, M and Zimmermann, C (2002), 'Basle Accord and financial intermediation: the impact of policy', paper presented at the Bank of England seminar series.

Bernanke, B, Gertler, M and Gilchrist, S (1999), 'The financial accelerator in a quantitative business cycle framework', in Taylor, J and Woodford, M (eds), *Handbook of macroeconomics*, pages 1,341-93.

Bernanke, B and Lown, C (1992), 'The credit crunch', *Brookings Papers on Economic Activity* 2, pages 205-39.

Calvo, G (1983), 'Staggered prices in a utility-maximising framework', *Journal of Monetary Economics* 12, pages 383-98.

Carlstrom, C and Fuerst, T (1997), 'Agency costs, net worth, and business fluctuations: a computable general equilibrium analysis', *American Economic Review* 87, December, pages 893-910.

Cecchetti, S (1999), 'Legal structure, financial structure, and the monetary policy transmission mechanism', *NBER Working Paper no. 7151*.

Chami, R and Cosimano, T (2001), 'Monetary policy with a touch of Basel', *International Monetary Fund Working Paper no. 01/151*.

Chatelain, J B, Generale, A, Hernando, I, Vermeulen, P and von Kalckreuth, U (2003), 'Firm investment and monetary policy transmission in the euro area', in Angeloni, I, Kashyap, A and Mojon, B (eds), *Monetary policy transmission in the euro area*, pages 133-61.

- Chen, N K (2001)**, ‘Bank net worth, asset prices, and economic activity’, *Journal of Monetary Economics* 48 (2), pages 415-36.
- Clarida, R, Gali, J and Gertler, M (1999)**, ‘The science of monetary policy: a new Keynesian perspective’, *Journal of Economic Literature* 42, pages 1,661-707.
- Dale, S and Haldane, A (1995)**, ‘Interest rates and the channels of monetary transmission: some sectoral estimates’, *European Economic Review* 39, pages 1,611-26.
- DeBondt, W and Thaler, R (1985)**, ‘Does the stock market overreact?’, *Journal of Finance* 40, pages 793-805.
- DeBondt, W and Thaler, R (1987)**, ‘Further evidence on investor overreaction and stock market seasonality’, *Journal of Finance* 42, pages 557-81.
- Deutsche Bundesbank (2002)**, ‘The development of bank lending to the private sector’, *Deutsche Bundesbank Monthly Report*, October, pages 34-46.
- Dimson, E, Marsh, P and Staunton, M (2002)**, ‘Long-run global capital market returns and risk premia’, paper available at <http://papers.ssrn.com>.
- Ehrmann, M, Gambacorta, L, Martinez-Pages, J, Sevestre, P and Worms, A (2003)**, ‘Financial systems and the role of banks in monetary policy transmission in the euro area’, in Angeloni, I, Kashyap, A and Mojon, B (eds), *Monetary policy transmission in the euro area*, pages 235-69.
- Faia, E (2002)**, ‘Monetary policy in a world with different financial systems’, *mimeo*.
- Farrant, K, Markovic, B and Sterne, G (2003)**, ‘The macroeconomic impact of revitalising the Japanese banking sector’, *Bank of England Quarterly Bulletin*, Winter, pages 439-51.
- Fisher, I (1933)**, ‘The debt-deflation theory of Great Depression’, *Econometrica* 1, pages 337-57.
- Fukunaga, I (2002)**, ‘Financial accelerator effects in Japan’s business cycle’, *Bank of Japan Working Paper no. 02-6*.
- Gali, J and Gertler, M (1999)**, ‘Inflation dynamics: a structural econometric analysis’, *Journal of Monetary Economics* 44, pages 195-222.
- Gertler, M and Gilchrist, S (1994)**, ‘Monetary policy, business cycles, and the behaviour of small manufacturing firms’, *Quarterly Journal of Economics* 109 (2), pages 309-40.
- Gertler, M, Gilchrist, S and Natalucci, F (2003)**, ‘External constraints on monetary policy and the financial accelerator’, paper presented at the conference ‘Asset prices, exchange rates, and monetary policy’, Stanford University, March 2003.
- Gilchrist, S, Hairault, J and Kempf, H (2002)**, ‘Monetary policy and the financial accelerator in a monetary union’, *European Central Bank Working Paper no. 175*.

Goodhart, C, Sunirand, P and Tsomocos, D (2003), 'A model to analyse financial fragility', *Oxford Financial Research Centre Working Paper 2003-FE-13*.

Gordy, M and Howells, B (2004), 'Procyclicality in Basel II: can we treat the disease without killing the patient?', paper presented at the conference 'Accounting, transparency, and bank stability', Bank for International Settlements, Basel, May.

Haldane, A, Hoggarth, G and Saporta, V (2001), 'Assessing financial system stability, efficiency and structure at the Bank of England', in BIS Papers No. 1 'Marrying the macro- and micro-prudential dimensions of financial stability', Bank for International Settlements, March, pages 138-59.

Hall, S (2001), 'Financial accelerator effects in UK business cycles', *Bank of England Working Paper no. 150*.

Hall, S and Vila Wetherilt, A (2002), 'The role of corporate balance sheets and bank lending policies in a financial accelerator framework', *Bank of England Working Paper no. 166*.

Hoggarth, G, Reidhill, J and Sinclair, P (2004), 'On the resolution of banking crises: theory and evidence', *Bank of England Working Paper no. 229*.

Hubbard, G (1995), 'Is there a credit channel for monetary policy?', *FRB of St Louis Review* 77 (3), May/June, pages 63-77.

Hubbard, G, Kuttner, K and Palia, D (2002), 'Are there "bank effects" in borrowers' costs of funds?: Evidence from a matched sample of borrowers and banks', *Journal of Business* 75 (4), pages 559-81.

Ito, T and Nagataki Sasaki, Y (1998), 'Impacts of the Basle capital standard on Japanese banks' behaviour', *NBER Working Paper no. 6730*.

Jagannathan, R, McGrattan, E and Scherbina, A (2000), 'The declining U.S. equity premium', *NBER Working Paper no. 8132*.

Kiyotaki, N and Moore, J (1997), 'Credit cycles', *Journal of Political Economy* 105, pages 211-48.

La Porta, R, Lopez-de-Silanes, F, Shleifer, A and Vishny, R W (1998), 'Law and finance', *Journal of Political Economy* 106, pages 1,114-55.

Lo, A and MacKinlay, C (1988), 'Stock market prices do not follow random walks: evidence from a simple specification test', *Review of Financial Studies* 1, pages 41-66.

Lown, C and Peristiani, S (1996), 'The behaviour of consumer loan rates during the 1990 credit slowdown', *Journal of Banking and Finance* 20, pages 1,673-94.

Mankiw, G (2000), 'The inexorable and mysterious trade-off between inflation and unemployment', paper presented as the Harry Johnson Lecture at the annual meeting of Royal Economic Society, August.

Markovic, B (2005), 'Essays on the credit channel of the monetary transmission mechanism', PhD thesis, The University of Birmingham.

Meh, C and Moran, K (2004), 'Bank capital, agency costs, and monetary policy', *Bank of Canada Working Paper 2004-6*.

Millard, S and Wells, S (2003), 'The role of asset prices in transmitting monetary and other shocks', *Bank of England Working Paper no. 188*.

Nier, E and Baumann, U (2002), 'Market discipline, disclosure, and moral hazard in banking', *EFA 2003 Annual Conference Paper no. 664*.

Oliner, S and Rudebusch, G (1996), 'Is there a broad credit channel for monetary policy?', *Federal Reserve Bank of San Francisco Economic Review*, Winter, pages 3-13.

Paasche, B (2001), 'Credit constraints and international financial crises', *Journal of Monetary Economics* 48, pages 623-50.

Poterba, J and Summers, L (1989), 'Mean reversion in stock prices: evidence and implications', *NBER Working Paper no. 2343*.

Shiller, R (1981), 'Do stock prices move too much to be justified by subsequent changes in dividends?', *American Economic Review* 71, pages 421-36.

Siegel, J (1999), 'The shrinking equity premium', *Journal of Portfolio Management*, Fall, pages 10-17.

Smant, D (2002), 'Bank credit in the transmission of monetary policy: a critical review of the issues and evidence', *mimeo*, Erasmus University Rotterdam.

Townsend, R (1979), 'Optimal contracts and competitive markets with costly state verification', *Journal of Economic Theory* 21, pages 265-93.

Van den Heuvel, S (2002), 'The bank capital channel of monetary policy', *mimeo*, University of Pennsylvania.

Vermeulen, P (2000), 'Business fixed investment: evidence of a financial accelerator in Europe', *European Central Bank Working Paper no. 37*.

Walsh, C E (1998), *Monetary theory and policy*, The MIT Press.