Bank capital channels in the monetary transmission mechanism

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Abstract

Recent empirical evidence based on micro-data pannels 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 of one sort or another that affect the banking system. The impulse responses are likely to be magnified due to the interaction between the supply and the demand side of the credit market.

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

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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 - e.g. 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 (i.e. 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 (i.e. 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 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 micro-data 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, micro-data studies on individual loan agreements in the US (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

[1] Gertler, Gilchrist and Natalucci (2003) argue that the financial accelerator in conjuction with fixed exchange rate can fully account for the 14% drop in economic activity experienced by Korea during the 1997-1998 episode.

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

[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.

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, i.e. 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 what policy makers can do to alter the credit channel effects, 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 maximise profits.

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.[6] The more pronounced an expected fall in the value of bank capital is, the stronger the capital loss channel.[7] 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

[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.

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

[7] 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.

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 literature. Previous literature modelling the impact of banks' balance sheets on the monetary transmission mechanism, has mainly focused on the deposit-reserves channel.[8] 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 (e.g. 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. Micro-data studies based on individual loan agreements in the US (Lown and Peristiani (1996), and Hubbard et al. (2002)) have found that low-capitalised banks change higher loan interest rates than well-capitalised banks in periods of crises. Markovic (2004), using a micro-data panel approach, has found that well-capitalised banks extend more credit than low-capitalised banks following a monetary tightening in the UK. 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 aims 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[9] is also empirically supported. This channel addresses borrowers' rather than lenders' balance sheets.

[8] 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.

[9] In the previous literature, the channel is usually reffered to as the financial accelerator or the broad credit channel.

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 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 (e.g. 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 (e.g. 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, i.e. 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 Figure 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, i.e. the share of external funds in total funds. The higher the leverage ratio, the higher the exposure of the bank (i.e. 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 premium 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

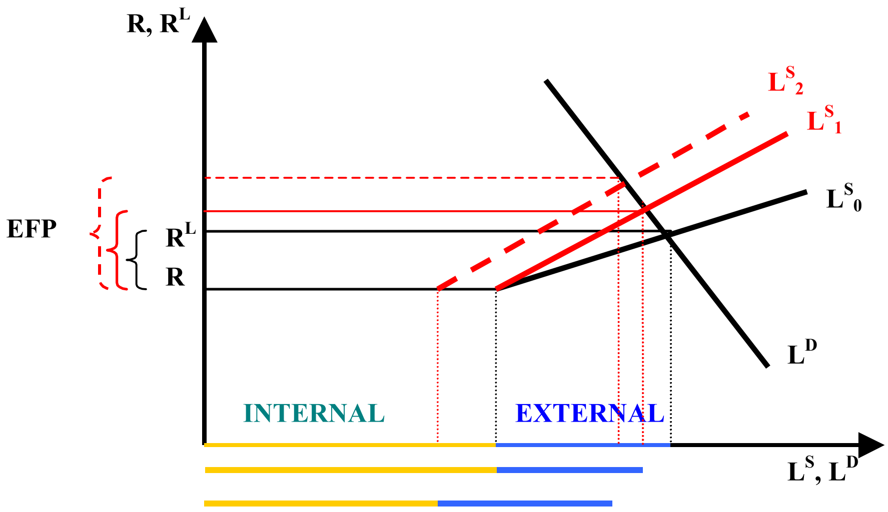

Figure 1: The effect of an increase in the bank capital ratio on the credit market equilibrium

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 Figure 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 freamework.[10] Below

[10] 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

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, and are novel in the context of the BGG model, are provided in appendices. In the main text I shall refer to the appendices, whereas only providing the main equations 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. Firstly, it is a model of the corporate balance sheet channel, a transmission channel that has been empirically established. Secondly, 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)).[11] 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.[12] The model also includes money in the utility function, allowing monetary 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

side of the credit market in a moral hazard framework similar to Chen (2001) is Meh and Moran (2003).

[11] The costly state verification model is further explained in Section 3.2.2.

[12] One should, however, note possible inconsistences 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 is out of the scope of this study.

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[13] 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.[14] 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.[15] The threshold level of such an idiosyncratic productivity disturbance, $\overline{\omega}$, indicates the ability of firms to repay loans, i.e. it divides the solvency and insolvency regions for firms. In the case of a good outcome, when $\omega \geqslant \overline{\omega}$, the financial intermediary will retrieve the full amount of loans with the loan interest rate. In a bad outcome, when $\omega < \overline{\omega}$, 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 channel. The size of the accelerating effect depends on the leverage ratio $\frac{N}{QK}$.[16] Equations 26 and 27 in Appendix B show that in the absence of the auditing cost, i.e. when $\mu_{ac} = 0$, the ratio, s, between the cost of external, R^K_{t+1}, 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

[13] 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).

[14] 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.

[15] 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.

[16] In fact, this is the ratio of internal, N, to total finance, QK. Nevertheless, it mirrors the leverage ratio i.e. the ratio of external to total finance.

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
- 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 the nominal rigidity, i.e. the price stickiness. The price stickiness is micro-founded following the Gali 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, 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.

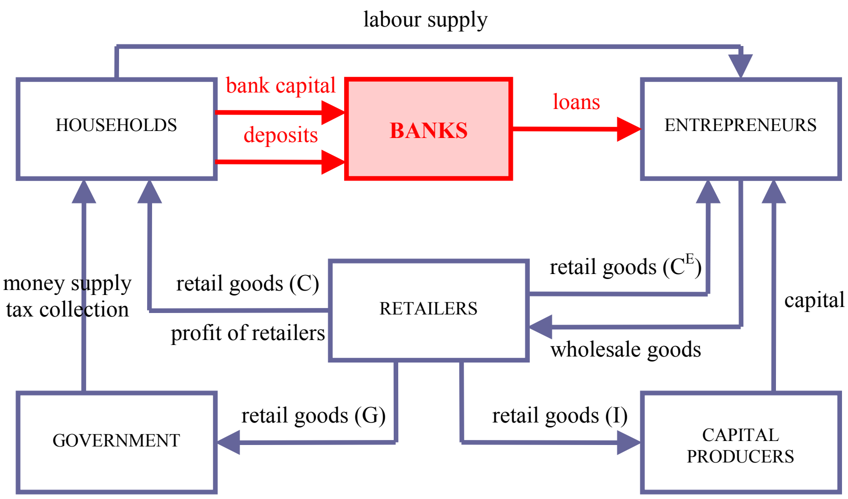

Figure 2: Structure of the model

3.2.1 Households' optimisation problem[17]

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 expected utility subject to the budget constraint

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

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,[18] 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,

[17] The complete households' optimisation problem is given in Appendix A.
[18] The leisure endownment is normalised to unity. Hence $1 - H$ represents the leisure.

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, necessary to reduce that asymmetry (e.g. a search cost due to checking the health of a bank before investing in bank shares).[19] 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. I specify the quadratic form for the adjustment cost, therefore making it symmetric and proportional to the size of the adjustment.[20]

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 rate) and the cost of deposits (the risk-free interest rate) in the steady state. Other models (e.g. Van den Heuvel, 2002) usually assume a positive differential. I explain this by the default risk on bank capital.[21]

Most of the first order conditions from the household's optimisation problem are standard (see Equations 8 to 11 in Appendix A). The non-standard arbitrage condition is the log-linear link between the return on bank capital and deposits (Equation 15 in Appendix A).[22]

$$\begin{aligned} E_t\left(\widehat{R^Z}_{t+1}\right)+E_t\left(\widehat{P^Z}_{t+1}-\widehat{P^Z}_t\right) &= \widehat{R}_t+\gamma_1\left(\widehat{Z}_{t+1}-\widehat{Z}_t\right)- \\ & \frac{\gamma_1}{R_0}E_t\left(\widehat{Z}_{t+2}-\widehat{Z}_{t+1}\right)+\frac{\gamma_{2_0}}{1-\gamma_{2_0}}\widehat{\gamma_2}_t \quad (2) \end{aligned}$$

The equation delivers several interesting results. The left-hand side of the equation represents the required return on bank capital, which consists of the

[19] 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.

[20] The information asymmetry justifies the symmetric cost. The cost of entering the stock market is likely to be proportional (e.g. brokers' commision). 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 (e.g. search cost or insurance cost).

[21] Berka and Zimmerman (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.

[22] In further text, $\widehat{}$ denotes deviations from the steady-state values, whereas subscript $_0$ denotes the steady-state values.

gross dividend rate, R^Z, and the expected capital gain, $\frac{P^Z_{t+1}}{P^Z_t}$ (with P^Z being the price of bank shares).[23] 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, $\Delta P^Z_{t+1} = 0$ (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 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 14 in Appendix A, one can obtain the long-run link between the costs of bank capital and deposits ($\Delta P^Z_0 = 1 \Longrightarrow R^Z_0 = R_0 \frac{1}{1-\gamma_2}$).

Equation 2 indicates three channels, which can cause a change in the wedge between the cost of bank capital (i.e. gross dividend payments[24]), 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 ($\frac{P^Z_{t+1}}{P^Z_t} < 0$). 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.[25] 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

[23] Notice that this represents standard return to capital: $R^Z_{t+1} \frac{P^Z_{t+1}}{P^Z_t} = (1 + div_{t+1}) \frac{P^Z_{t+1}}{P^Z_t} = \frac{P^Z_{t+1} + div_{t+1} P^Z_{t+1}}{P^Z_t} = \frac{P^Z_{t+1} + DIV_{t+1}}{P^Z_t}$.

[24] From the banks' viewpoint, only gross dividend payments represent the cost of the bank capital.

[25] Higher dividends have to be offered to existing investors too in order to make them interested in keeping bank shares.

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.

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 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.

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.[26] 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[27]

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)). 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

[26] 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).

[27] The complete financial contract problem is given in Appendix B.

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 between potential bank shareholders and the bank, 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:

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

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[28] (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.[29] This variable is defined as the cost of bank liabilities above the risk-free interest rate, and has the following form:

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

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), 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, ξ, 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 ξ 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.

[28] The share of internal funds in the total mirrors the leverage ratio (the share of external in total funds).

[29] Function ξ is a definition that enables the neat derivation of the financial contract problem, and has an economic meaning.

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.

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.[30] The auditing cost is calibrated at 0.12 in line with Hall (2001)[31] and Gertler, Gilchrist and Natalucci (2003), and the survival rate of businesses 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,[32] determine the impact of the bank balance sheet composition on the steady-state variables of the economy (see Equation 4). The bank capital ratio is calibrated at 12.6%.[33] 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,

[30] See Carlstrom and Fuerst (1997) for details.

[31] 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 rigor 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.

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

[33] 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.

β^c.[34] In a recent study, Dimson, Marsh and Staunton (2002) look at the real returns on the 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.[35] Hence, I calibrate the equity risk premium in the banking sector at 4.8% per annum or 1.2% per quarter. This calibration is compatible with the expected risk of default on bank capital, γ_2, of 1.18%.[36]

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 defined in the financial contract problem as the cumulative distribution, $F(\overline{\omega})$, of the idiosyncratic disturbance, ω, at its threshold value (see Equation 17 in Appendix B). I further posit a functional form for the dynamic relationship between the probability of corporate loan default and the output, $\widehat{Y}$, both defined as deviations from their steady-state values, as:

$$\widehat{\gamma_{2t}} = \widehat{F}(\overline{\omega})_t = \psi^{pbd}\widehat{Y}_t \quad (5)$$

Using the calibration of the financial position of the corporate sector I obtain the elasticity of corporate default risk to output, ψ^{pbd}, of -15.2.[37] 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.[38]

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

[35] Based on the database put together for Nier and Baumann (2004).

[36] 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 explicitely modelled. Furthermore, the recovery rate of the failed banks may not be complete in the quarterly model (as it 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 has declined in recent period in the UK.

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

[38] 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.

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 FTBanks and FTSE100 indexes during the past ten years, I define the following functional form for the relationship between the expected price of bank shares, $E_t\left(P_{t+1}^Z\right)$, and the expected level of corporate net worth, $E_t\left(N_{t+1}\right)$:

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

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.[39] But, in some circumstances the data seem to indicate sluggish changes in the price of bank shares.[40] 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 immediately assess the extent of a shock to bank capital.[41] 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.

[39] 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.

[40] 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 bank capital also fell.

[41] 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.

4.3 Other parameters

The households' discount factor, β, is set at 0.992.[42] This implies the 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 0.33, 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 the shares of consumption (households' and entrepreneurs') in output of 59%, investment of 20%, and government expenditure of 20%.[43]

The probability of changing prices in t period, 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 ($\rho^a$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 1 Long-run effects of the additional cost of bank capital

Parameter		without BC	with BC	LR effect
prob. of loan default	$F(\overline{\omega})$	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%

[42] 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.

[43] The share of government expenditure in GDP is exogenously calibrated to match the UK data.

Table 1 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.[44]

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 27 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.[45] This reduces entrepreneurs' leverage ratio, i.e. the ratio of their external to total finance (see equation 28 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, $F(\overline{\omega})$. The insolvency region for the entrepreneur (defined by $\overline{\omega}$) 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%.[46]

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.

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

[44] The reason for the fall in the probability of loan default is in fact the fall in the ratio of external to total finance. The fall in the probability of loan default partially offsets the initial rise in the EFP, that occurs due to tighter credit conditions. But this second-round effect is subdued to the initial effect.

[45] This effect arises due to a general equilibrium modelling framework, and thus the endogenous loan demand.

[46] 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.

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.[47] 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 present 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 policy makers affect economy, simulations are conducted by progressively adding each of the credit channels to a model. The simulations are conducted for 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

I simulate the impulse responses of the economy to a temporary (one quarter) increase in the policy rate of 1% per annum.[48] The policy rule used is an autoregressive forward-looking inflation rule. This type of rule is used in BGG, and Clarida, Gali and Gertler (1999).

Figures 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, i.e. 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

[47] See Hall and Vila-Wetherilt (2002) for the detailed analysis of this effect within the BGG framework.

[48] The simulations are conducted using Sparse Newton's solution method, and Stacked Newton's expectation algorithm.

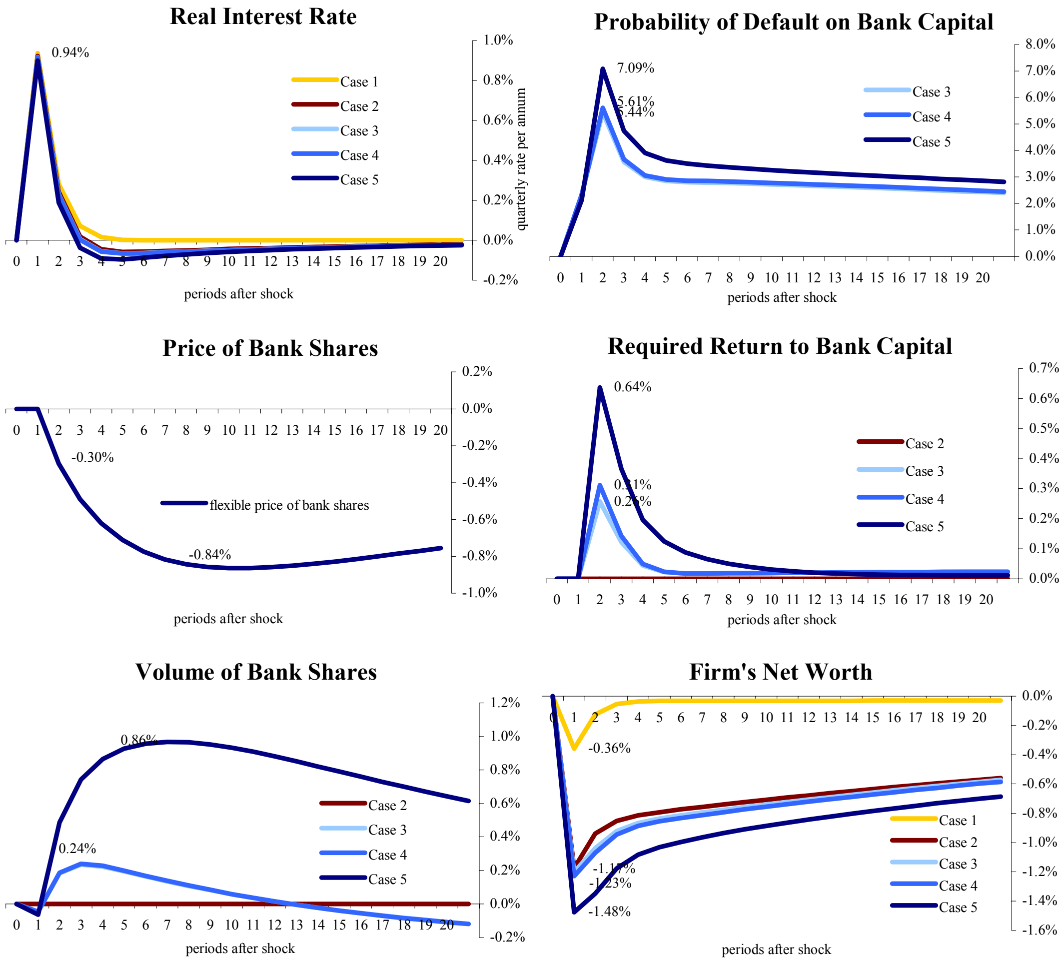

Figure 3: Impulse responses to a 1% temporary increase in policy rate p.a.

convergence. Most of the interesting action, however, occurs at the beginning. Thus, the figures present only impulse responses for the first 20 periods.

One can follow the main channels of the monetary transmission mechanism for the calibrated economy in Figures 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%[49] increases the dividend rates banks have to pay on their capital by 0.26%. A need to fulfil 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%.

Figure 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 I add the adjustment cost channel).

The volume of loans temporarily increases after an unexpected policy tightening (see Figure 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 a number of periods. 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 (i.e. firms' borrowing) tends to increase temporarily for large firms in response to a federal funds rate shock.[50] Furthermore, Dale and Haldane (1995) have set a VAR for the UK, 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), p.1620)

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

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

[50] The profile and size of the VAR response in Gertler and Gilchrist (1994) is in fact quite similar to the one in Figure 4.

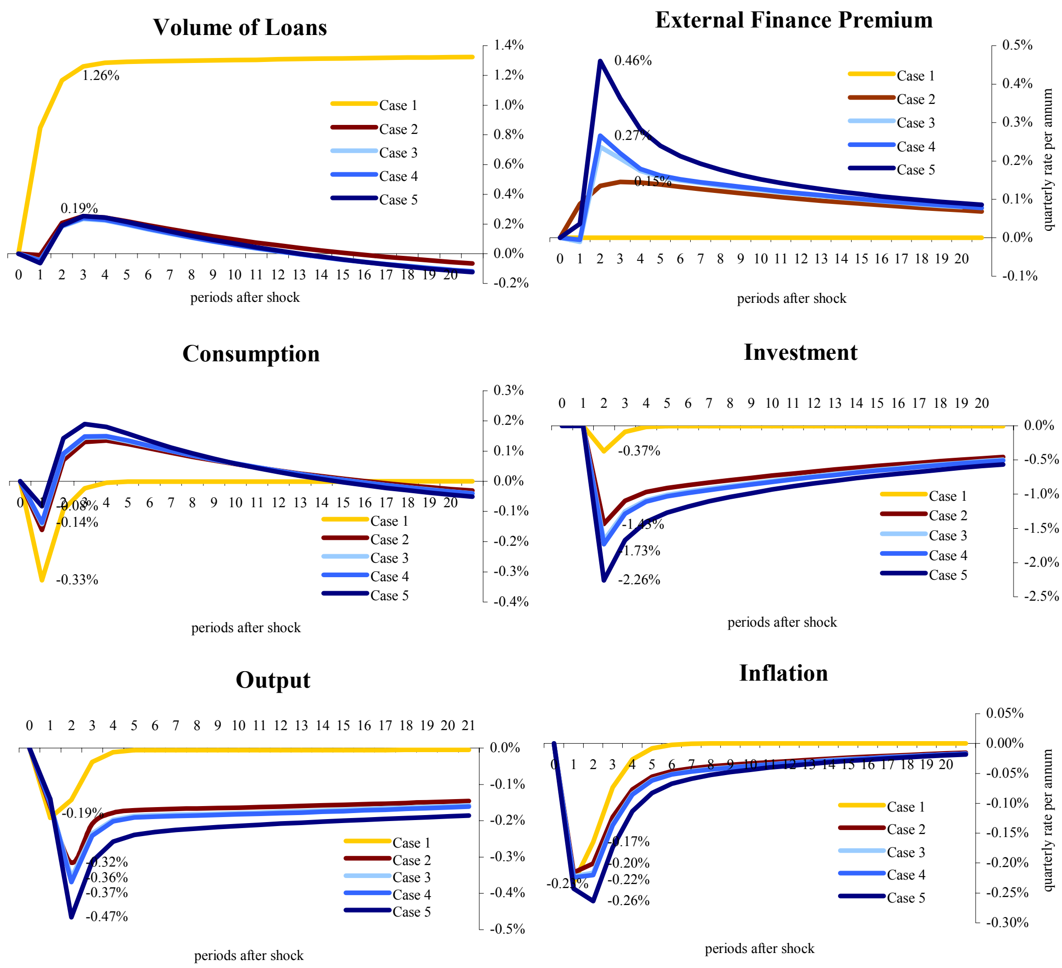

Figure 4: Impulse responses to a 1% temporary increase in policy rate p.a.

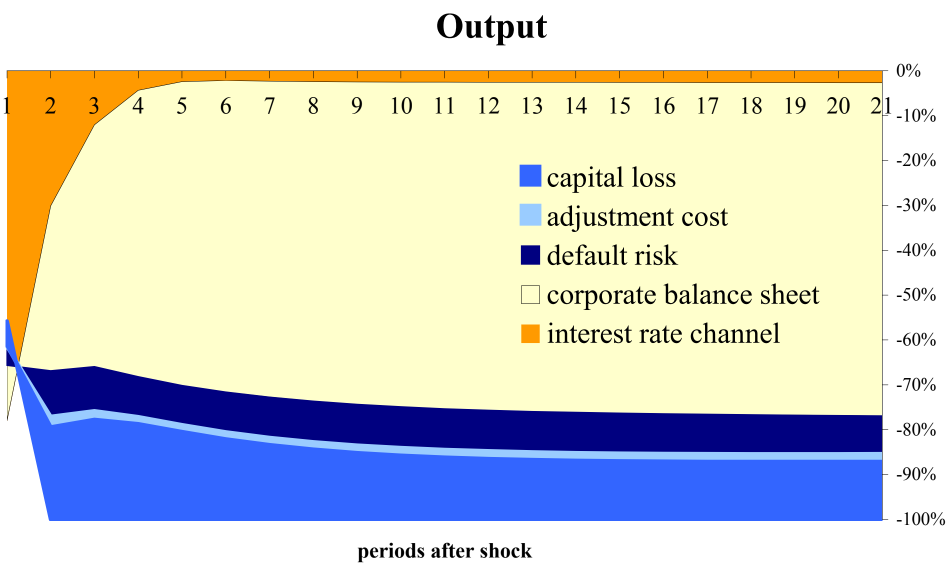

Figure 5: Contribution of various channels to the output impulse response to a policy innovation

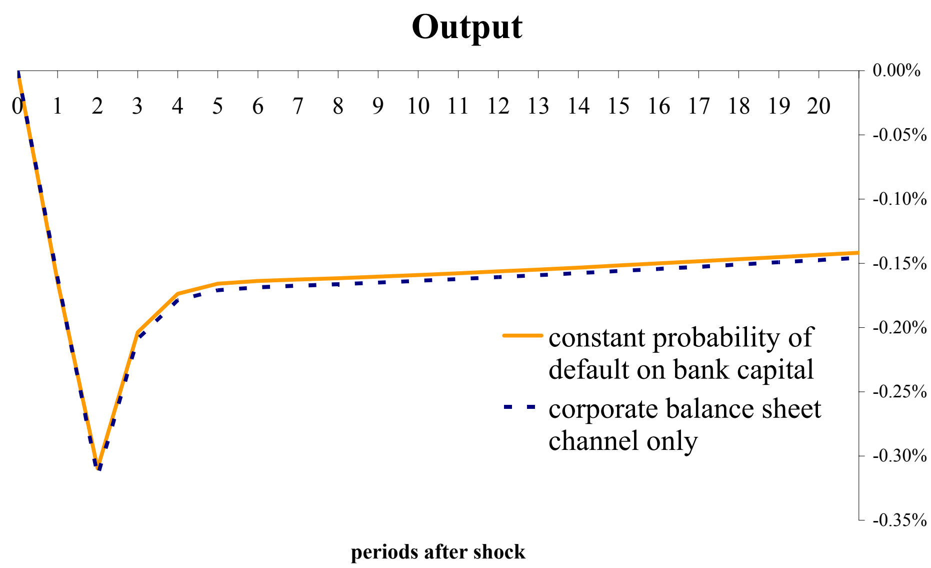

Figure 6: The effect of the introduction of the constant probability of banks defaulting on their capital for the output impulse response to a policy innovation

Figure 6 shows the impulse response of output to a policy innovation if I add an exogenous, constant bank default risk.[51] 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).[52] 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 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. 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 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, $\frac{\gamma_1}{2}$, 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.

[51] This implies a positive bank equity risk premium in the steady state, but no variations over the cycle.
[52] See Equation 38 in Appendix C.

- '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. I 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.

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 the capital requirement.[53]

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. Figures 7 and 8 report impulse responses.

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

Figure 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 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). Figure 10 shows the much higher contribution of the corporate balance sheet channel compared with the one indicated in Figure 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.

[53]In other words, credit rationing is not considered in this model.

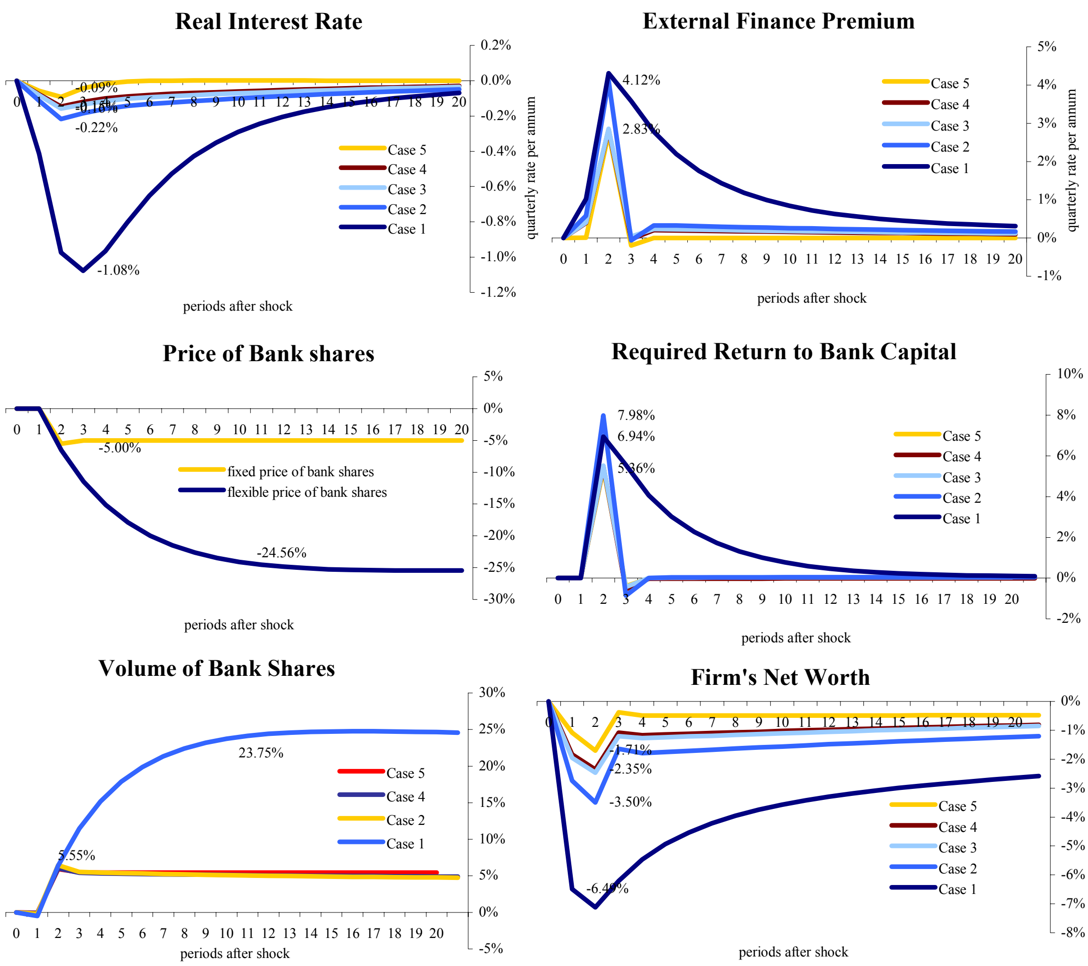

Figure 7: Impulse responses to a 5% fall in the value of bank capital

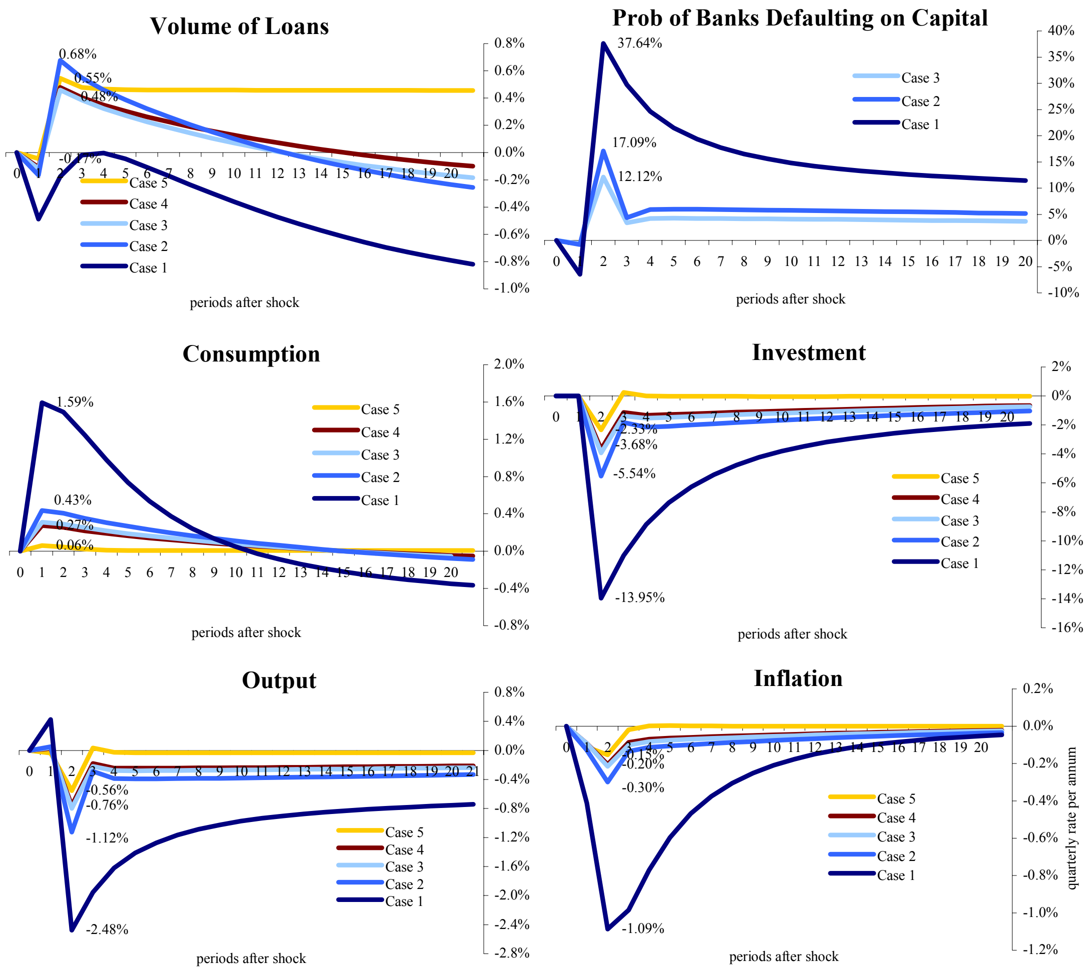

Figure 8: Impulse responses to a 5% fall in the value of bank capital

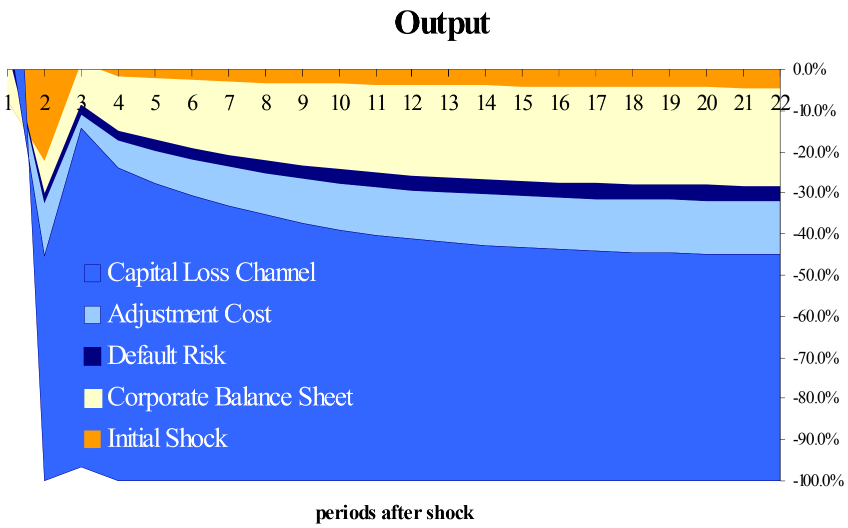

Figure 9: Contribution of various channels to the output impulse response to a shock to the value of bank capital

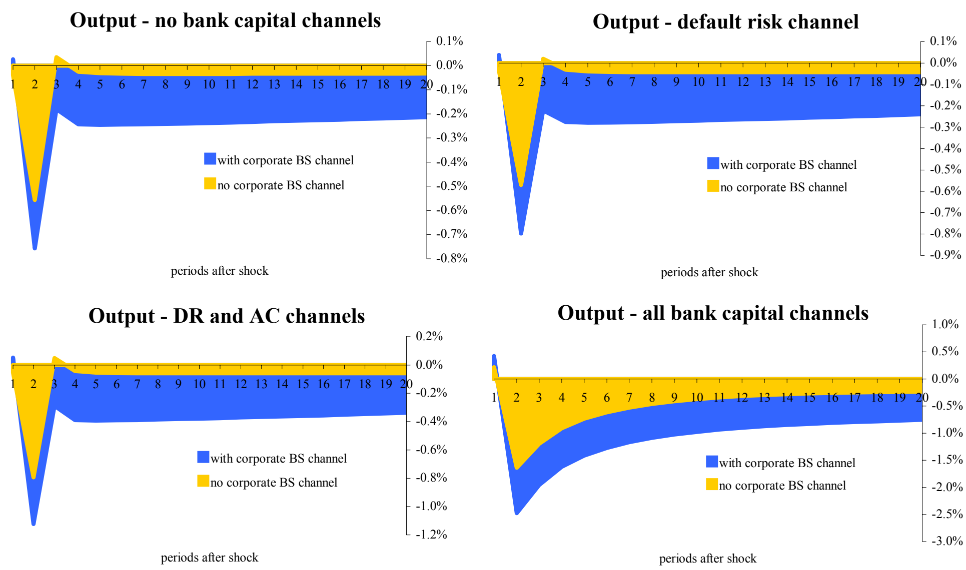

Figure 10: Interaction between the supply and the demand side effects of the credit market

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 cyclicality of the 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 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 contactionary 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 microfoundation for the deviation from the efficient market hypothesis. It would help provide a deeper insight into options for a policy maker to reduce this amplifying effect.

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. This 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.

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 erosion of the default risk channel. But if it was to increase the cyclicality of the volume of bank shares, this would augment the adjustment cost channel and lead to an ambiguous overall effect.

A Households' optimisation problem

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

$$\underset{C_t, D_{t+1}, Z_{t+1}, H_t, \frac{M_t}{P_t}}{MAX} E_t \sum_{k=0}^{\infty} \beta^k \left[\ln(C_{t+k}) + \varsigma \ln\left(\frac{M_{t+k}}{P_{t+k}}\right) + \nu \ln(1 - H_{t+k}) \right] \quad (6)$$

subject to

$$
\begin{aligned}
C_{t+k} \quad = \quad & W_{t+k}H_{t+k} - T_{t+k} + \Pi^{R}_{t+k} + R_{t+k-1}D_{t+k} - D_{t+k+1} + \\
& (1-\gamma_2)R^{Z}_{t+k}P^{Z}_{t+k}Z_{t+k} - P^{Z}_{t+k}Z_{t+k+1} - \frac{\gamma_1}{2}\frac{(P^{Z}_{t+k}\Delta Z_{t+k+1})^2}{P^{Z}_{t+k}Z_{t+k}} \\
& + \frac{M_{t+k-1} - M_{t+k}}{P_{t+k}}
\end{aligned}
\tag{7}
$$

I use the following variables and parameters
C - consumption
H - labour hours
$\frac{M}{P}$ - real money balances
β - households' discount factor
ς - coefficient on real money balances in the utility function
ν - coefficient on leisure in the utility function
D - deposits
Z - volume of bank shares
P^Z - price of bank shares
W - real wage rate for household labour
T - lump-sum tax
Π^R - dividends received from ownership of retail firms
R^Z - gross real dividend rate
R^N - gross nominal risk-free interest rate
R - gross real risk-free interest rate
$\frac{\gamma_1}{2}$ - adjustment cost
γ_2 - probability of banks defaulting on their capital

A.0.3 First order conditions

Over C_t

$$\lambda_t = \frac{1}{C_t} \tag{8}$$

Over H_t

$$W_t \frac{1}{C_t} = \nu \frac{1}{1-H_t} \tag{9}$$

Over $\frac{M_t}{P_t}$

$$\frac{M_t}{P_t}\frac{1}{C_t} = \varsigma \left(\frac{R^{N}_{t+1} - 1}{R^{N}_{t+1}}\right)^{-1} \tag{10}$$

Over D_{t+1}

$$\lambda_t = \beta R_t E_t(\lambda_{t+1}) \tag{11}$$

Over Z_{t+1}

$$\lambda_t P_t^z \left[1+\gamma_1\left(\frac{Z_{t+1}}{Z_t}-1\right)\right] = \beta E_t\left\{\lambda_{t+1}P_{t+1}^z\left[R_{t+1}^Z\left(1-\gamma_2\right)+\frac{\gamma_1}{2}\left(\left(\frac{Z_{t+2}}{Z_{t+1}}\right)^2-1\right)\right]\right\} \tag{12}$$

Euler equation for consumption - combining equation 8 and equation 11

$$\frac{1}{C_t}=\beta\frac{1}{C_{t+1}}R_t \tag{13}$$

Link between the return on bank capital and the return on deposits - 'no arbitrage condition' obtained by combining equations 11 and 12

$$E_t\left\{\lambda_{t+1}P_{t+1}^Z\left[\begin{array}{c} R_{t+1}^Z\left(1-\gamma_2\right)+ \\ +\frac{\gamma_1}{2}\left(\left(\frac{Z_{t+2}}{Z_{t+1}}\right)^2-1\right)\end{array}\right]\right\} = R_t E_t\left(\lambda_{t+1}\right)P_t^Z\left[1+\gamma_1\left(\frac{Z_{t+1}}{Z_t}-1\right)\right] \tag{14}$$

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

$$E_t\left(\widehat{R^Z}_{t+1}\right)+E_t\left(\widehat{P^Z}_{t+1}-\widehat{P^Z}_t\right)=\widehat{R}_t+\gamma_1\left(\widehat{Z}_{t+1}-\widehat{Z}_t\right)-\frac{\gamma_1}{R_0}E_t\left(\widehat{Z}_{t+2}-\widehat{Z}_{t+1}\right)+\frac{\gamma_{2_0}}{1-\gamma_{2_0}}\widehat{\gamma_{2t}} \tag{15}$$

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.

$$\underset{\overline{\omega},K}{MAX}E_t\left\{\int_{\overline{\omega}^j}^{\infty}\omega R_{t+1}^K Q_t K_{t+1}^j dF(\omega)-\left[1-F(\overline{\omega}^j)\right]\left(R_{t+1}^L\right)^j L_{t+1}^j\right\} \tag{16}$$

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

$$\begin{aligned} &\underbrace{\left[1-F(\overline{\omega}^j)\right]\left(R_{t+1}^L\right)^j L_{t+1}^j}_{\text{income from loans in good state}}+\underbrace{(1-\mu_{ac})\int_0^{\overline{\omega}^j}\omega R_{t+1}^K Q_t K_{t+1}^j dF(\omega)=}_{\text{income from loans in bad state}} \\ =\; &\underbrace{R_t D_{t+1}^j+R_{t+1}^Z P_{t+1}^Z Z_{t+1}^j}_{\text{cost of liabilities}} \end{aligned} \tag{17}$$

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

$$L_{t+1}^{j} = Q_t K_{t+1}^{j} - N_{t+1}^{j} \tag{18}$$

I use the following variables and parameters:

ω - an idiosyncratic productivity disturbance with log-normal probability distribution, $(\sigma^2, -\frac{1}{2}\sigma^2)$, over a set $(0, \infty)$

$\overline{\omega}$ - cut-off value of the idiosyncratic shock, which divides solvency and insolvency regions for the firm (i.e. which enables the firm to pay back the loans in total). Only when $\omega > \overline{\omega}$ a firm earns some profit.

R^K - gross real return to capital

R - gross real risk-free interest rate

R^L - gross real loan interest rate

Q - the price of an additional unit of capital in time t currency (Tobin's Q)

K - capital (QK are total funds invested by firms)

N - net worth of firms

D - deposits

Z - bank shares

P^Z - price of bank shares

L - volume of loans (firms' external funds)

μ_{ac} - auditing cost or expected default cost

γ - natural turnover of firms (the rate of survival of entrepreneurs)

B.0.4 Solution for the contracting problem

By defining the leverage ratio[54] k

$$k = \frac{QK}{N} \tag{19}$$

the ratio of costs of external and internal finance s

$$s = \frac{R^K}{R} \tag{20}$$

and the additional cost of bank liabilities above the risk-free interest rate ξ

$$\xi = 1 + \frac{R^Z - R}{R} \frac{P^Z Z}{L} \tag{21}$$

I can transform the financial contract into:

$$\underset{k,\overline{\omega}}{MAX} \left[1 - \Gamma\left(\overline{\omega}\right)\right] sk \tag{22}$$

subject to the constraint

$$\left[\Gamma\left(\overline{\omega}\right) - \mu_{ac} G\left(\overline{\omega}\right)\right] sk = (k-1)\,\xi \tag{23}$$

[54] In fact, this is the ratio of the total finance to the internal finance. But, it mirrors the leverage ratio i.e. the ratio of external finance to total finance.

where the expected share of entrepreneurs' profits staying with the entrepreneur is $1-\Gamma(\overline{\omega})$, and the expected share of profits going to the bank is $\Gamma(\overline{\omega})-\mu_{ac}G(\overline{\omega})$.

$$\Gamma(\overline{\omega}) = \int_0^{\overline{\omega}} \omega f(\omega)\, d\omega + \overline{\omega}\int_{\overline{\omega}}^{\infty} f(\omega)\, d\omega \tag{24}$$

$$\mu_{ac}G(\overline{\omega}) = \mu_{ac}\int_0^{\overline{\omega}} \omega f(\omega)\, d\omega \tag{25}$$

B.0.5 First order conditions

Over $\overline{\omega}$

$$\lambda = \frac{\Gamma'(\overline{\omega})}{\Gamma'(\overline{\omega})-\mu_{ac}G'(\overline{\omega})} \tag{26}$$

Over k

$$s = \frac{\lambda\xi}{1-\Gamma(\overline{\omega})+\lambda\left[\Gamma(\overline{\omega})-\mu_{ac}G(\overline{\omega})\right]} \tag{27}$$

Combining equations 23 and 27 I obtain:

$$k = \frac{\lambda\xi}{\left[1-\Gamma(\overline{\omega})\right]s} \tag{28}$$

Notice that if $\mu_{ac}=0$ then $\lambda=1$ (Equation 26) and $s=1$ (Equation 27). In words - **if there were no auditing cost, there would be no external finance premium.** Notice that **if the cost of bank capital equals the cost of deposits** ($R^Z=R$), **or if the bank does not hold any capital** ($\frac{P^Z Z}{L}=0$), then $\xi=1$. In words - **bank balance sheet composition would not affect the external finance premium, and the bank capital channel would not exist**.

From 28 I obtain:

$$\frac{QK}{N} = z\left(\frac{R}{R^K}\xi\right) \tag{29}$$

Inverting the above I obtain equation 3 from Section 3.2.2

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

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 $\overline{\omega}$ is solved numerically by minimising the distance between the equation 28 and another link between k and s, which comes from the constraint on net worth accumulation and gives the following:[55]

$$k^{def} = \frac{1}{\gamma\left[1-\Gamma\left(\overline{\omega}\right)\right]\frac{s}{\beta}+\frac{(1-\alpha)(1-\Omega)}{\alpha}\left[\frac{s}{\beta}-(1-\delta)\right]} \tag{30}$$

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

C A log-linear version of the model

$$c_t = c_{t+1} - r_t \tag{31}$$

$$h_t = \gamma_{hs} w_t - \gamma_{hs} c_t \tag{32}$$

$$m_t - p_t = -\frac{1}{R_0^N - 1} r_t^n + c_t \tag{33}$$

$$q_{t+1} = \varphi i_{t+1} - \varphi k_t \tag{34}$$

$$r_t^k = (1-\nu)\left(y_t - k_{t-1} + mc_t\right) + \nu q_t - q_{t-1} \tag{35}$$

$$h_t = mc_t + y_t - w_t \tag{36}$$

$$\pi_t = \frac{\beta(1-\kappa)}{\phi^\pi}\pi_{t+1} + \frac{1-\theta}{\phi^\pi}\pi_{t-1} + \frac{\theta\kappa\left(1-\beta(1-\kappa)\right)}{\phi^\pi} mc_t \tag{37}$$

$$r_{t+1}^k = r_t + \psi\left(q_t + k_{t+1} - n_{t+1}\right) + \xi_t \tag{38}$$

$$efp_t = \frac{R_0^K}{R_0^K - R_0} r_{t+1}^k - \frac{R_0}{R_0^K - R_0} r_t \tag{39}$$

$$y_t = \frac{C_0}{Y_0}c_t + \frac{C_0^e}{Y_0}c_t^e + \frac{I_0}{Y_0}i_t + \frac{G_0}{Y_0}g_t \tag{40}$$

$$y_t = a_t + \alpha k_{t-1} + (1-\alpha)\Omega h_t \tag{41}$$

$$\begin{aligned} n_t \;=\; & \chi\left(\phi^{lev}+1\right) r_t^k - \chi\phi^{lev} r_{t-1} + \left[\chi\phi^{lev}\psi + \chi\right] n_{t-1} - \phi^{lev}\xi_t - \\ & -\chi\phi^{lev}\psi\left(q_{t-1} + k_{t-1}\right) + (1-\chi)\left(y_t + mc_t\right) \end{aligned} \tag{42}$$

[55] See Hall and Vila-Wetherilt (2002) for detailed explanation of the solution procedure.

$$c_t^e = \left(\phi^{lev}+1\right) r_t^k - \phi^{lev} r_t + \left(\phi^{lev}\psi+1\right) n_t - \phi^{lev}\xi_t - \phi^{lev}\psi\left(q_{t-1}+k_{t-1}\right) \tag{43}$$

$$k_t = \delta i_{t-1} + (1-\delta) k_{t-1} \tag{44}$$

$$b_t = \frac{\phi^{lev}+1}{\phi^{lev}}\left(q_t+k_t\right) + \frac{1}{\phi^{lev}} n_t \tag{45}$$

$$\xi_t = \gamma_1^{\xi}\left(r_{t+1}^{z} - r_t\right) + \gamma_2^{\xi}\left(p_t^{z} + z_t - b_t\right) \tag{46}$$

$$r_{t+1}^{z} = r_t + p_t^{z} - p_{t+1}^{z} + \gamma_1\left(1+\frac{1}{R_0}\right) z_{t+1} - \gamma_1 z_t - \frac{\gamma_1}{R_0} z_{t+2} + \frac{\gamma_{2,0}}{1-\gamma_{2,0}}\gamma_{2,t} \tag{47}$$

$$p_{t+1}^{z} = \gamma^{pz} p_t^{z} + \left(1-\gamma^{pz}\right) n_{t+1} \tag{48}$$

$$\gamma_{2,t} = \psi^{pbd} y_t \tag{49}$$

$$z_t = b_t - p_t^{z} \tag{50}$$

$$r_t = r_t^n - \pi_{t+1} \tag{51}$$

$$r_t^n = \rho^p r_{t-1}^n + (1-\rho^p)\gamma_1^p \pi_{t+1} + \varepsilon_t^p \tag{52}$$

$$a_t = \rho^a a_{t-1} + \varepsilon_t^a \tag{53}$$

$$g_t = \rho^g g_{t-1} + \varepsilon_t^g \tag{54}$$

With following parameters:

$$\gamma_{hs} = \frac{1-H_0}{H_0} \tag{55}$$

$$\nu = \frac{1-\delta}{\alpha\frac{1}{X_0}\frac{Y_0}{K_0} + 1 - \delta} \tag{56}$$

$$\chi = 1 - \frac{(1-\alpha)(1-\Omega)\frac{Y_0}{K_0}\frac{K_0}{N_0}}{X_0} \tag{57}$$

$$\phi^{\pi} = 1 - \kappa + (1-\theta)\left[1-(1-\kappa)(1-\beta)\right] \tag{58}$$

$$\phi^{lev} = \frac{K_0}{N_0} - 1 \tag{59}$$

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