Jukka Topi

Effects of moral hazard and monitoring on monetary policy transmission

Bank of Finland Studies
E:24 • 2003

Effects of moral hazard and monitoring on monetary policy transmission

SUOMEN PANKKI
BANK OF FINLAND
PO Box 160
FIN – 00101 HELSINKI
FINLAND

Phone: +358 9 1831
Fax: +358 9 174 872
Email: publications@bof.fi

Subscriptions to the E series of the Bank of Finland's research publications and changes in address details

Old address details

Company ....

....

Name ....

Address ....

....

New address details/subscriptions

Company ....

....

Name ....

Address ....

....

☐ New subscription ☐ Cancellation ☐ Number of copies

Jukka Topi

Effects of moral hazard and monitoring on monetary policy transmission

Bank of Finland Studies
E:24 • 2003

The views expressed in this study are those of the author and do not necessarily reflect the views of the Bank of Finland.

ISBN 952-462-031-6
ISSN 1238-1691
(print)

ISBN 952-462-032-4
ISSN 1456-5951
(online)

Vammalan Kirjapaino Oy
Vammala 2003

Abstract

This study discusses the effects of financial intermediation, banks' moral hazard and monitoring on monetary policy transmission in a simple model where borrowers are dependent on loans granted by banks with superior monitoring skills. As distinct from the prior literature on monetary policy transmission, this study does not regard banks' deposit funding as a reason for their special role in the monetary transmission. Instead, we focus on banks' role in monitoring their loan customers as part of financial intermediation and on the effects of monitoring on monetary policy.

We find that when the intensity of monitoring is endogenous banks acting as financial intermediaries with moral hazard problems respond less to monetary policy in lending than nonintermediary lenders that only lend their own capital without moral hazard problems. We also find that in the model the lending response of intermediary banks to monetary policy depends on the ratio of their own capital to the volume of lending. The finding is fairly insensitive to the market structure of the banking sector. In the case of a monopoly bank, an increase in the bank's capital-to-loans ratio always weakens the transmission of monetary policy to bank lending. In the case of competitive banks, an increase in the capital-to-loans ratio weakens the transmission of monetary policy to aggregate bank lending, up to a critical level.

Using a data set covering the Finnish banking sector in 1995–2000, we also offer some tentative empirical evidence that is broadly consistent with the model. Banks with higher capital ratios tend to respond less to changes in monetary policy. Our conclusion is that the outcome of the model might be helpful in explaining the heterogeneity of banks' responses to monetary policy, which frequently observed in the empirical literature.

Keywords: monetary policy transmission, monitoring, moral hazard, bank lending channel

Tiivistelmä

Tutkimuksessa tarkastellaan rahoituksen välityksen, pankkien moral hazard -ongelmien ja luottoasiakkaiden valvonnan vaikutuksia rahapolitiikan välittymiseen teoreettisessa mallissa. Lainanottajat ovat mallissa riippuvaisia lainoista, joita myöntävät pankit ovat muita lainanantajia kyvykkäämpiä valvomaan luottoasiakkaitaan. Poiketen aiemmasta rahapolitiikan välittymistä tarkastelevasta kirjallisuudesta pankkien erityistä asemaa ei tässä tutkimuksessa perustella niiden riippuvuudella talletusrahoituksesta. Sen sijaan tutkimuksessa korostetaan pankkien asemaa luottoasiakkaiden valvojina sekä valvonnan vaikutuksia rahapolitiikan välittymiseen.

Kun luotonantajat valitsevat mallissa luottoasiakkaidensa valvonnan intensiteetin, rahoituksen välittäjinä toimivien ja siten moral hazard -ongelmista kärsivien pankkien luotonannon havaitaan reagoivan rahapolitiikkaan vaimeammin kuin ainoastaan omaa pääomaa lainaavien luotonantajien luotonannon. Lisäksi havaitaan, että rahapolitiikan vaikutukset rahoitusta välittävien pankkien luotonantoon riippuvat pankkien oman pääoman ja luotonannon määrien välisestä suhteesta. Monopolipankin oman pääoman ja luotonannon välisen suhteen kasvu heikentää mallissa aina rahapolitiikan vaikutuksia luotonantoon. Kilpailullisten pankkien oman pääoman ja luotonannon suhteen kasvu heikentää rahapolitiikan vaikutuksia kokonaisluotonantoon, kun oman pääoman ja luotonannon suhde ei ylitä tiettyä kriittistä arvoa.

Suomen pankkisektorista vuosilta 1995–2000 saadun aineiston perusteella tutkimuksessa esitetään myös empiirisiä tuloksia, jotka tukevat tietyin varauksin teoreettisen mallin tuloksia. Pankit, joiden pääoma-asteet ovat korkeammat kuin muilla pankeilla, ovat taipuvaisia reagoimaan rahapolitiikan muutoksiin muita pankkeja vähemmän. Johtopäätös on, että teoreettisen mallin tulokset voivat olla hyödyllisiä selitettäessä empiriisisissä tutkimuksissa usein pankkien välillä havaittua vaihtelua rahapolitiikan vaikutuksista luotonantoon.

Asiasanat: rahapolitiikan välittyminen, valvonta, moral hazard, pankkiluottokanava

Foreword

The study could not have been completed without invaluable support from several people. The work was done for the most part during my stay in the Research Department of the Bank of Finland. I owe much to the department and my colleagues there, who provided a stimulating working environment. Above all, I would like to express my special gratitude to my supervisor Jouko Vilmunen, whose advice and encouragement have been indispensable throughout the project. I would also like to thank Juha Tarkka, Matti Virén, Esa Jokivuolle and David Mayes, whose general support and comments have been invaluable in the course of the project. Pertti Haaparanta and Pekka Ilmakunnas, from the Helsinki School of Economics, also deserve thanks for their support and advice. Special thanks go to my official examiners, Ari Hyytinen and Juha-Pekka Niinimäki, whose constructive and insightful comments improved considerably the final version of this study.

I also owe much to several other colleagues at the Bank of Finland. My superiors at the Financial Markets Department, Heikki Koskenkylä and Kimmo Virolainen, showed great patience during the last months of the project when I was making final revisions. The librarians at the Bank of Finland library were always fast and efficient in finding background material for the work. Glenn Harma was of invaluable help in improving my English. I thank Päivi Nietosvaara for editing the text and Heli Tikkunen for collecting data for the study.

Finally, my warmest thanks go my family and friends for their encouragement and support. Especially, I would like to thank my parents Anni and Jaakko for their unconditional support during this project.

Helsinki, December 2002
Jukka Topi

Contents

1 Introduction

In the literature on monetary policy transmission, the role of banks has gained a lot of attention in recent decades. Existing research has argued that monetary policy may have a particular transmission channel via the banking sector because some borrowers are bank-dependent and monetary policy shocks have special effects on the amount of deposits in banks' balance sheets. It is commonly believed that changes in deposits may then be reflected in banks' loan supply since deposits may be particularly beneficial sources of funds for banks. This bank lending channel of the monetary transmission mechanism (see eg Kashyap and Stein, 1994 for a survey of bank lending channel literature, and Stein 1998, or Bernanke and Blinder 1988, for a model of the bank lending channel) has gained support from empirical evidence on bank-level heterogeneity in responses to monetary policy (see eg Kashyap and Stein 2000, and Ehrmann et al 2001, and references therein, for recent empirical research on the bank lending channel).

However, recent developments in the financial markets and in the monetary policy regimes of several central banks have also raised doubts about the relevance of the bank lending channel as presented in the literature. First of all, it has long been argued that the availability of less reserve-intensive forms of finance have made banks less dependent on deposits and so have diminished their role in the monetary policy transmission (see eg Romer and Romer 1990 for an early criticism). On the other hand, and possibly more importantly, it could be argued that the impacts of monetary policy on deposits and other types of bank debts might be converging, which would contravene the basic argument for the bank lending channel. In fact, the central banks have increasingly tended to modify the operational procedures of monetary policy so that they no longer control the amount of their own liabilities on issue (ie reserves available to the banks) but instead set an interest rate at which they issue and remunerate those liabilities (for a discussion of the change in the monetary policy implementation, see eg White 2001). With such a change in the operational framework of monetary policy, the role of reserve requirements as a tool of monetary policy for influencing the banks' ability to issue deposits would likely disappear.

In an environment where the impacts of monetary policy are the same for deposits and other forms of finance, it seems unfounded that the special role of banks in monetary policy transmission could be explained by the influence of the central bank on the supply of bank loans through the determination of deposits available to the banks. Furthermore, the heterogeneity of bank loan responses to monetary policy could not then be explained purely by the differences in the banks' ability to accommodate shocks to deposit funding. In spite of such changes in monetary policy implementation, signs of heterogeneity across bank's reactions to monetary policy are still observed. Therefore, it seems reasonable and even necessary to examine more carefully other aspects of financial intermediation that could possibly help clarify the differences in monetary policy transmission as between direct and indirect finance, as well as between different financial intermediaries.

The purpose of this study is to examine whether the banking sector plays a special role in monetary policy transmission and what that role might be if there is no difference between monetary policy effects on deposits vs other debt items in banks' liabilities. Our starting point is that monetary policy effects may be different for indirect bank vs direct market finance because of moral hazard problems due to financial intermediation in the lending process. As monetary policy changes the impact of the incentive problems on lending, its overall influence on lending may be different than if incentive problems were not present or their consequences so severe as to prevent financial intermediation. Using a simple model of lending and monitoring, we are able to demonstrate that moral hazard problems in financial intermediation actually weaken intermediary banks' response to monetary policy as compared to lenders that rely solely on their own capital in funding their lending. Moreover, we find that banks' liability structures affect the strength of monetary policy transmission through their impact on banks' exposure to moral hazard. In fact, whenever the banks' capital-loans ratio is low enough, the model unambiguously concludes that an increase in the capital-loans ratio weakens the effects of monetary policy.

The approach of this study to banks' role in monetary transmission has its origins in the research on banks' capital constraints and the moral hazard problems involved in monitoring their borrowers (see especially Holmstrom and Tirole 1997). As a starting point, we assume that banks (or other financial intermediaries) are distinguished from securities market investors by their superior ability to monitor their borrowers' behaviour and mitigate moral hazard problems at firm level so as to enhance the expected repayment value of the loans. However, we assume that monitoring is privately costly to banks because monitoring costs cannot be verified ex post. Using a simple model, we then argue that the special monitoring skills of intermediary banks are crucial from the viewpoint of monetary policy transmission. Since it is privately costly to the bank, monitoring involves moral hazard problems whenever the bank is obliged to use external debt finance to fund its lending. Therefore, incentive problems set a lower limit on the use of banks' own capital in lending. If banks' access to capital is limited, the capital-loans ratio becomes binding to the banks, and the amount of bank capital affects not only the volume of lending but also monetary policy transmission.

The literature on capital constraints suggests that monetary policy affects the amount of bank capital, which then restricts the volume of lending because of binding capital requirements due to endogenous incentive problems (eg Holmstrom and Tirole 1997) or regulation (eg Van den Heuvel 2001). While we allow for possible effects of monetary policy on the stock of banks' own capital in the long run, we do not discuss this channel explicitly. Instead, we suggest that monetary policy is able to change banks' endogenous capital-loans ratio in the short run since banks' incentives to monitor their borrowers depend on monetary policy. Because the dependence of monitoring incentives on monetary policy varies with the proportion of capital to banks' total assets, the transmission of monetary policy to lending differs as between intermediary banks with different liability structures and as between intermediary and nonintermediary banks.

Our justification for banking (or financial intermediation) is banks' comparative advantage in monitoring (at least a group of) borrowers with severe moral hazard problems. Following the approach of

Holmstrom and Tirole (1997), we define monitoring[1] as all actions of the lender aimed at preventing opportunistic behaviour during the loan period, which thereby increase the probability of loan repayment. In fact, we assume that borrowers' incentive problems are so difficult that they are not able obtain finance from any source other than banks whose monitoring skills mitigate the incentive problems enough to enable lending funds to such borrowers. Now that monitoring also involves private costs to banks, the obvious question is how can the banks escape the moral hazard problem in monitoring corresponding to that of the borrowers. Unlike eg Diamond (1984, 1996) we do not motivate the delegation of monitoring by allowing banks to diversify their loan portfolios enough to eliminate the credit risk at the portfolio level[2]. Instead, we follow the approach of Holmstrom and Tirole (1997) where the banks must invest some of their own capital in order to eliminate the incentive problems. In an extreme case, nonintermediary banks only lend their own capital because of their poor monitoring skills.

We make no distinction between banks and other financial intermediaries. Instead, we contrast the behaviour of lenders in indirect vs direct finance from the viewpoint of monetary policy transmission. As to the sources of funds to be transmitted by intermediary banks, we assume that, besides banks' own capital, there is a fully competitive market for the bank funding and a single type of debt instrument issued by banks. We argue that intermediation of external funds involves additional incentive problems in the relation between bank and external source of intermediated funds, and these incentive problems influence the transmission of monetary policy. The incentive problems between the bank and its external sources of funds emerge since – as mentioned above – monitoring is privately costly to the bank, which reduces banks' incentives to monitor loans if it intermediates external funds to its borrowers. Repullo and

[1] Monitoring is often used in literature to refer to any activity of the lender aimed at preventing opportunistic behaviour of the borrower in a financial contract either by screening the projects before loan contracts have been signed, preventing opportunistic behaviour during the loan period, or punishing or auditing borrowers that fail their contractual obligations after the loan period (see eg Freixas and Rochet, 1997, page 29).

[2] Note that we also depart from the definition of monitoring by Diamond (1984, 1996) who consider it mainly punishing or auditing borrowers that fail their contractual obligations after the loan period.

Suarez (2000) compare the effects of monetary policy on bank lending and market lending in a model where the central bank conducts monetary policy by setting the risk-free refinancing rate in the financial markets[3]. Repullo and Suarez let the banks and market lenders differ from each other in monitoring intensity, but the intensity of monitoring is kept exogenous and monitoring involves no costs in their model. Thus, the lender's decisions on monitoring intensity are not affected by its decisions on lending or by monetary policy shocks.

In transmitting external debt finance (as loans) to borrowers, intermediary banks become exposed to a moral hazard problem as they decide how intensively to monitor borrowers after extending loans. The reason is that banks' liability with respect to external debts is limited. In case of default, the bank suffers only a loss of capital, whereas monitoring its borrowers involves unverifiable costs, irrespective of the bank's solvency. In addition, the bank cannot affect the cost of external debt at the time it decides on monitoring intensity since it has agreed beforehand on the external debt. Therefore, the bank has less incentive to monitor its borrowers when it uses external debt to finance its lending. The smaller the share of its own capital in the bank's liabilities, the lower the monitoring intensity, ceteris paribus. If banks do not have unlimited access to capital, the moral hazard problems of monitoring will limit the volume of lending to a multiple of the available bank capital.

In the context of the bank lending view, it has been pointed out that the responsiveness of the banking sector to monetary policy may depend on the structure of the banking market (eg Kashyap and Stein 1997, Cecchetti 1999, and Ehrmann et al 2001). In line with the bank lending view, one could argue that large banks show a minor response to monetary policy because they have better access to the securities market to replace deposit finance, which may be restricted by monetary policy in particular. Therefore, the monetary policy effects on bank lending should be weaker in the more concentrated banking markets. However, empirical findings on the different responses to monetary policy could also be linked to the effects of the competitive structure of the loan market on banks' monitoring incentives and on the relationship between monitoring incentives and monetary policy. Therefore, it would be interesting to

[3] That is, the central bank does not limit the amount of bank liabilities by restricting the banks' access to central bank reserves in their model.

examine whether different loan market structures imply qualitatively different results when moral hazard problems render intermediary banks special as regards monetary policy transmission. In this study we address this question in a simple way by comparing two extreme loan market structures. First, we model a monopoly bank in the loan market so that the bank's chosen volume of lending determines the yield on borrowers' projects that are financed. Second, we consider a case where perfect competition prevails in the loan market in the sense that the volume of lending chosen by an individual bank does not affect the aggregate number of projects financed. The inclusion of two different loan market structures also facilitates evaluation of the robustness of model results to differences in banks' behaviour.

Our model reveals that banks' moral hazard problems regarding external debt funding strengthens the link between volume of lending and monitoring intensity. More precisely, due to moral hazard at bank level, an increase in the volume of lending reduces the bank's incentive to monitor its borrowers more than otherwise, and vice versa. From the opposite viewpoint, however, an increase in monitoring intensity improves the probability of success of the bank and also increases the marginal expected benefit of lending relative to associated costs and thus the incentive to extend further credit as well. In a sense, monitoring and lending are substitutes for each other as banks' means of adjusting to monetary policy shocks. Consider eg a bank that is about to reduce its lending because of an adverse monetary policy shock that increases the marginal costs of lending. Such a reduction in lending leads to a greater monitoring intensity, and thereby improves the profitability of a marginal increase in lending. As the bank knows that the link between lending and monitoring is strengthened because of moral hazard problems, it need not reduce lending as much as a lender without moral hazard problems.

The moral hazard problem at bank level also creates a link from monetary policy to monitoring intensity. In fact, a monetary policy shock changes the difference between the values of remaining solvent and going bankrupt since the higher refinancing costs increase the repayment of external debt and thereby reduce the value of being solvent but do not affect the repayment of external debts if the bank is insolvent. Therefore, tighter monetary conditions per se reduce banks' monitoring intensity, and vice versa.

Indeed, monetary policy has two opposite effects on intermediary banks' monitoring intensity. It impacts monitoring directly but also through the effect on the volume of lending. In our model, the indirect effect appears to be dominant, and, for instance, a tightening of monetary policy increases the intensity of monitoring more than in the case without intermediary moral hazard. That is, intermediary banks react to monetary policy more through their monitoring intensity and less through their volume of lending, compared to nonintermediary lenders. So, the tradeoff between lending and monitoring results in a smaller response of lending to monetary policy shocks when the lender experiences moral hazard problems due to financial intermediation. This result appears to be insensitive to the structure of the loan market.

In the case of a monopoly bank, the links between monitoring, lending and monetary policy lead us to the conclusion that the more the bank relies on external funding (rather than its own capital), the more sensitively it responds to monetary policy shocks, given the limited liability of the bank as regards external finance. Thus, if the amount of the bank's own capital is limited, a higher level of moral hazard problem for the bank with respect to its funding (ie a lower share of external funding) leads to a decline in the power of monetary policy at a given level of borrowers' moral hazard problem. In the case of competitive banks, the aggregate response of the banking sector to monetary policy does not change monotonically with the share of bank capital in banks' liabilities. Indeed, with low values of the capital-loans ratio (probably typical of real world banks), banks' response to monetary policy falls as the share of their own capital grows. However, when the capital-loans ratio exceeds a threshold value, the model implies increasing sensitivity to monetary policy as the capital-loans ratio increases.

In order to compare the transmission of monetary policy via bank lending with that via market lending with no financial intermediation, market lenders could be viewed in terms of our model as nonintermediary banks whose only source of funding is their own capital. Market lenders would therefore lend their own capital only in the loan market and would not find it optimal to borrow additional funds for lending in the debt securities market. This approach would imply – contrary to the predictions of the traditional bank lending view of monetary policy transmission – that the response of market lending to monetary policy would be stronger than that of bank lending.

An extension of our framework to cover several lending periods might support the existing literature concerning the effects of capital constraints on monetary policy transmission. Monetary policy would cause a decline in the expected amount of bank capital in the future period if a monetary tightening reduced the expected profits of the bank and issuing additional equity in order to acquire additional capital would still be prevented by imperfections in the equity market. The subsequent fall in the banks' own capital would reduce the volume of bank lending, given that the amount of bank capital puts an upper limit on supply of bank loans. An explicit analysis in these lines is, however, left for future work.

Our model does not allow for the coexistence of different types of lenders and, consequently, we do not analyse possible borrower choices between different forms of credit, such as intermediated bank loans and direct finance. However, we may argue that our modelling assumptions are reasonable, possibly even relevant, since there appear to be many borrower segments for whom a choice between intermediated and direct lending is actually not feasible. These borrowers are in fact totally dependent on intermediated funds. Moreover, some financial intermediaries seem to specialise in these customer groups.

In the latter part of the study, we also present some tentative empirical evidence on the relevance of the implications of the theoretical model. To this purpose, we employ a data set covering the banks operating in Finland in the late 1990s. The evidence offers some support for the outcome of our theoretical model as to the relationship of liability structure and response of banks to monetary policy. In addition, empirical evidence gives support to the model's prediction that the amount of bank capital has a positive impact on the volume of lending. Collected partly from the aftermath period of the Finnish banking crisis of the early 1990s, the data set appears to be somewhat special in terms of our model because there seem to be exceptional trends in the capital structure of the sample banks as well some government measures affecting banks' incentives. However, the results remain broadly unchanged even if we control for this feature of the sample period by an alternative capital proxy where the common trend in the capital structure is eliminated.

The rest of the study is structured as follows. The literature on the role of banks in monetary policy transmission is surveyed in chapter 2. The theoretical model of lending and monitoring is introduced in chapter 3 in two versions, one for a monopoly bank and another for a competitive loan market. Chapter 4 offers empirical evidence on the differences between banks' responses to monetary policy. Chapter 5 concludes.

2 Role of banks in monetary transmission: Literature overview

There are several strands of literature related to our approach to analyse the transmission mechanism of the monetary policy. What is common to these approaches is that they aim to explain the differences in the impact of monetary policy on lending across different types of lenders or borrowers in the economy by some constraints due to financial market imperfections.

First of all, literature on the bank lending channel has assumed a major role in explaining the special role of bank lending in the monetary policy transmission. On the one hand, it relies on the assumption of indispensability of bank loans for some borrowers whose incentive problems are serious enough to prevent them from borrowing directly from the securities market. On the other hand, the bank lending channel presumes that the central bank has control over bank deposits through reserve requirements and determination of reserves available to the banks. Another prerequisite for operation of bank lending channel is that banks cannot completely replace deposits by other forms of finance in their liabilities.

Second, the more heterogeneous literature on the role of capital constraints on banks in monetary policy transmission examines how and for what reasons capital constraints may become binding for lending by banks or other financial intermediaries. The reasons for binding capital constraints may be regulatory or, more interestingly, due to the banks' incentive problems. In this area of the literature, monetary policy influences the supply of loans by affecting the available amount of bank capital. This approach to the role of banks in monetary transmission is quite parallel to the literature on the broad credit channel and to the closely related literature on financial accelerator mechanisms that consider the impact of capital constraints on borrowers due to moral hazard problems.

Even though the empirical implications of this study seem to be fairly similar to the ones of the bank lending channel, we actually question some of the basic assumptions maintaining the bank lending channel. While the bank lending channel does not remain without empirical support, some of the assumptions underlying the view do not conform with the current environment and operational framework of monetary policy in several countries. Therefore, we suggest an alternative to the bank lending channel to explain differences in responses to monetary policy by various lenders.

The present study is closer to the capital constraint literature since we also adopt the idea that the supply of intermediated loans is limited by the amount of capital available to the banks or other intermediaries. Thereby, we repeat the common result that an increase in the amount of bank capital raises the supply of loans. However, as regards the effect of monetary policy on the supply of loans, we differ from the relevant prior research. That is, while the existing literature presumes that the influence of monetary policy is due to its effect on the available amount of bank capital, we look at the impact of monetary policy on the constraint that links the supply of loans to the available amount of capital. In other words, we analyse how monetary policy affects the relative cost of marginal funding incurred by the bank when it is not able to fund its lending fully by the first-best liability but must instead rely on external finance, which carries additional agency costs due to the moral hazard problem.

2.1 Bank lending channel

During the past few decades, transmission channels of monetary policy through banks' balance sheets have been much debated. Recently, with the introduction of the common monetary policy in Europe, possible heterogeneity of responses in bank lending to monetary policy across banks in the euro area has received a lot of attention[4]. In addition to the traditional interest rate channel of monetary policy transmission[5], a bank lending channel has been put forward stressing that monetary shocks have a special effect on the

[4] See Ehrmann et al (2001) and the references therein.

[5] Interest rate channel is based on the assumption of an imperfect price adjustment mechanism that enables changes in real interest rates due to monetary policy shocks. Real interest rates then affect the demand for loans by reducing the profitability of investment projects. Imperfect price adjustment is assumed throughout the study.

availability of bank loans. See Kashyap and Stein (1994) or Peek and Rosengren (1995), for a survey of the bank lending channel, Bernanke and Blinder (1988) and Stein (1998) for more formal models justifying the bank lending channel, and eg Kashyap, Stein and Wilcox (1993) and Kashyap and Stein (1995, 2000) for empirical work.

The bank lending channel is usually based on two basic assumptions:

1. There are at least some borrowers in the economy that are dependent on bank finance due to the incentive problems that prevent them from borrowing from the securities market.

2. Monetary policy affects the amount of reservable deposits on the liability side of banks' balance sheets, and the effects on deposits are reflected at least to some extent in the amount of lending, as the banks are not able to accommodate the deposit shocks by other, non-reservable forms of finance.

The first hypothesis is often justified by considerations that motivate financial intermediation in general (see eg Diamond 1984). One major foundation of this literature is the view that banks or other financial intermediaries are able to provide more efficient monitoring services for certain types of borrowers than other types of lenders. That is, the incentive problems of some borrowers are so severe that they are not able to obtain loans from non-bank market lenders. The incentive problems may be linked to the low net worth of the borrowers in proportion to lenders' monitoring costs. This argument is discussed especially in the context of the balance sheet channel of monetary policy transmission (see below). For instance, Repullo and Suarez (2000) offer an explanation for the bank-dependence of some borrowers relying in their argument on banks' superior ability to monitor borrowers as compared to market lenders.

The second hypothesis of the bank lending channel approach is traditionally justified by the direct restrictions monetary policy sets on the amount of deposits the banks can issue in order to finance their loan portfolio. This view was put forward in Bernanke and Blinder (1988), where the central bank uses the amount of banks' required reserves as its policy instrument. For instance, in order to tighten monetary policy, the central bank contracts the available amount of bank reserves, which, in turn, reduces the amount of deposits issued by the banks.

In order to have a change in the amount of deposits influence the volume of bank lending, two further assumptions are needed. Firstly, the banks must not be able to replace deposits by some non-reservable form of liabilities in their balance sheet. This assumption was already strongly criticized by Romer and Romer (1990) who pointed out that banks may issue certificates of deposit or other bank liabilities in the securities market, which then foils the bank lending view of monetary transmission. However, the assumption has been defended by Stein (1998) who presents a model that incorporates banks with an adverse selection problem that limits their funding by non-deposit forms of liabilities.[6] It has also been pointed out (eg by de Bondt 2000) that a sufficient condition for the ability of the central bank to affect the quantity of bank lending through insured deposits is that the marginal costs of non-insured external finance be increasing.

Secondly, the bank lending channel of monetary policy also requires that the banks not be able to fully insulate the volume of lending from liability shocks by using some liquid assets in the balance sheet as a buffer (see eg Kashyap and Stein 1995). In empirical research, it has been hypothesised that while liquid assets in banks' balance sheets may weaken the bank lending channel, they do not totally rule out the functioning of that channel. For example, Kashyap and Stein (2000) take this view as their starting point and test the hypothesis that the share of liquid assets in a bank's balance sheet affects its response to monetary policy shocks.

On the whole, the bank lending channel, as outlined above, relies

[6] In the simplest version of his model there are two types of banks (G for good and B for bad) that differ in the value of their old assets while the type of an individual bank is not known by outside investors. The asymmetry of information about the type of banks creates an adverse selection problem for the banks with a potential loan portfolio exceeding in size their insured deposits. While insured deposits are used as a basic source of funding for new loans, the banks may also obtain non-insured external funds if insured deposits are not sufficient to cover funding needs. As the cost of using non-insured deposits depends on investors' perceptions about the bank's type, the banks of type G find it optimal to limit the use of non-insured external funds in order to signal their type to investors. When the central bank reduces the reserves of the banks and thereby decreases the amount of deposits, the banks (of type G) reduce their lending instead of replacing deposits fully with some non-insured external finance.

on the argument that in its conduct of monetary policy the central bank controls the reserves supplied to the banking sector, and thereby – through the binding reserve requirements set on insured deposits – determines the quantity of insured deposits. However, as discussed eg by White (2001), several central banks do not conduct monetary policy by affecting banks' deposit supply through the amount of reserves available to the banks. Instead, the central banks tend to offer reserves to the banking sector at the policy interest rate without affecting the supply of deposits through the interest rate.

In an attempt to reflect this change in the operational procedures of monetary policy, Repullo and Suarez (2000) try to produce micro foundations for the two basic hypotheses of the bank lending channel discussed above in a model that does not impose a link between monetary policy and insured deposits. First, Repullo and Suarez use a risk-free securities market interest rate to represent the stance of monetary policy while the traditional literature on bank lending channel assumes that the central bank changes its monetary policy stance by determining the amount of reserves available to the banking sector. Second, Repullo and Suarez assume that banks' liabilities consists of non-reservable, non-insured instruments that are traded in a perfectly competitive securities market. Therefore, the effects of monetary policy are transmitted in their model only through changes in the policy interest rate, and possible bank-specific effects come from relative changes in interest rates.

As such, the model of Repullo and Suarez (2000) justifies the first hypothesis of the bank lending channel regarding the bank-dependence of a group of borrowers. However, the model is somewhat inconsistent with the second hypothesis. It would be consistent with the second hypothesis if banks' lending rates reacted more strongly to a monetary policy shock than lending rates in the securities market, which is not viable in the model without further assumptions. To this purpose, Repullo and Suarez suggest that two regulatory variations be introduced into their model. First of all, deposit interest rate ceilings for the banks' liabilities appear to produce the hoped-for relative changes in lending rates due to a monetary shock. Capital adequacy requirements, on the other hand, appear to produce conclusions opposite to the bank lending channel approach as such. Repullo and Suarez note the possibility that the amount of banks' own capital might not be independent of monetary policy, in the short run, and thus binding capital requirements could offer an additional channel for monetary policy.

Empirical evidence on the bank lending channel

Aggregate studies with US data like Bernanke and Blinder (1992) have found evidence that a monetary contraction is followed by a decline in the aggregate volume of bank lending. However, while this piece of evidence is consistent with the bank lending channel, it does not exclude the possibility that the fall in the volume of lending is simply due to a fall in loan demand following the rise in interest rates. Attempts have been made to solve the problem at the aggregate level by Kashyap, Stein, and Wilcox (1993), who analyse the effects of monetary policy on both bank lending and commercial paper volume. They find that the volume of bank lending declines relative to commercial paper volume in response to a monetary contraction, which would suggest that the effects of monetary policy on bank lending are more pronounced than the effects on other forms of finance. However, the evidence provided by Kashyap, Stein, and Wilcox has been challenged by Friedman and Kuttner (1993) as well as Oliner and Rudebush (1996), who argue that the increase in the share of market finance after a monetary contraction may be due to a compositional shift of investment towards the large firms that, in generally difficult conditions, are doing better and are also able to use securities market as a source of finance[7].

Further empirical evidence has been produced with micro-level data. First, the firm-level evidence referred to above in the context of the balance sheet channel is also consistent with the bank lending channel as far as it suggests that monetary policy has stronger effects on the behaviour of small firms since these are assumed to be bank-dependent. However, the variation in the strength of the effect among firms may as well be due to the balance sheet channel of monetary policy that is also supposed to affect most the small firms. Therefore, testing of bank lending channel has been done with bank-specific comparisons that enable analysis of the relevance of the second hypothesis of the bank lending channel stated above. In other words, the empirical work is based on the view that banks differ in

[7] Kashyap, Stein and Wilcox (1996) respond to the critisism by producing evidence with sub-samples split by size of borrowing firm and get results that support their viewpoint.

their ability to replace deposits by non-reservable forms of liabilities, or in their ability to insulate their lending decisions from liability-side shocks by adjusting other types of assets.

Kashyap and Stein (1995) separate banks by asset size and test the differences in banks' ability to protect themselves from monetary policy shocks on deposits. They find that the smallest banks are most responsive to monetary policy, which conforms with the bank lending view if size is regarded as a proxy for information costs in the market for non-reservable funds. Kashyap and Stein (2000) extend the analysis and use liquidity as a bank-specific variable. Supporting the bank lending view, they find that banks holding more liquid assets in their balance sheets are less responsive to monetary policy shocks. As well, Kishan and Opiela (2000) offer evidence for the relevance of the bank lending channel using the capital-loans ratio as a bank-specific factor in order to explain variation between banks' responses to monetary policy. They find that the least-capitalized banks are most responsive to monetary policy shocks, which may support the existence of either the bank lending channel (if least-capitalized banks have difficulties in replacing lost deposits by market finance), or the balance sheet channel (if monetary policy shocks affect the balance sheets of banks' customers and thereby the value of bank capital). Kishan and Opiela also find that banks' capital positions and the creditworthiness of their customers are not clearly linked, and thus interpret the preceding result as favouring the bank lending channel.

Previously, the bank lending channel was tested mainly with US data, but in the last few years, monetary integration in Europe in particular has encouraged research comparing the impact of the banking sector on monetary transmission in the member countries of the Economic and Monetary Union (EMU). While this work has focused mainly on aggregate data (for a survey, see eg Dornbusch, Favero, and Giavazzi 1998), interesting cross-country comparisons have been done on the features of financial markets in European countries, specifically features that might be relevant to the existence of the bank lending channel. Most recently, within the framework of the Eurosystem, a large amount of empirical evidence on the bank lending channel of monetary policy transmission has been produced (see Ehrmann et al 2001 and references therein). This evidence points to at least some heterogeneity in banks' responses to monetary policy whereas the results are not totally conclusive as regards the operability of the bank lending channel. In this work, size liquidity and capitalisation are used as bank-specific characteristics explaining variation in lending response to monetary policy. Prior to this, Favero, Giavazzi and Flabbi (1999) also sought empirical evidence on the bank lending channel at the European level. Using data on the responses of banks in four large European countries to a (simultaneous) monetary tightening in 1992, they find no evidence of the bank-lending channel. On the basis of existing empirical work on the bank lending view, Kashyap and Stein (1997), on the other hand, anticipate possible variations in the transmission of common monetary policy in some countries of the euro area. Using the insights of the literature quoted in the preceding discussion, Kashyap and Stein measure the sensitivity of the banking sector in twelve European countries to monetary policy by the importance of small banks, health of banks, importance of small firms, and availability of non-bank finance. Their main finding is that the heterogeneity across banking sectors in the sample countries is considerable, which might result in clear differences in the transmission of the common monetary policy in the monetary union. The same conclusion is drawn by Cecchetti (1999), who finds that differences in the impact of monetary policy are linked to differences in financial structures of the countries that can be further traced to differences in national legal structures. Clements, Kontolemits and Levy (2001) also discuss differences in the monetary policy transmission mechanism across countries in the euro area. In their analysis using aggregate level data, they find that heterogeneity of responses to monetary policy in the euro area partly due to differences in the central bank reaction functions during the pre-EMU era. They also find that the interest-rate channel was the dominant factor explaining differences in the strength of monetary policy transmission. Using a slightly different approach, based on the bank lending channel via housing markets in Europe, Iacoviello and Minetti (2000) find cross-country heterogeneity that can be linked to structural features of the housing markets in each country.

2.2 Capital constraints in monetary transmission

2.2.1 Constraints on banks

Severe banking crises experienced in several countries in the early 1990s, as well as worldwide implementation of the Basle accord regulating the capital adequacy of the banks, have directed the attention to the links between banks' capital constraints and monetary policy transmission. On the one hand, tight monetary conditions have been seen as one reason for a reduction in the amount of banks' own capital, which is one of the explanations given for severe credit crunches in many economies (Holmstrom and Tirole 1997). On the other hand, capital adequacy requirements have been argued to lead to a situation where a monetary contraction may limit banks' loan growth opportunities in the short run through an adverse impact on bank capital, assuming an imperfect market for equity capital (Van den Heuvel 2001).

This strand of literature gives bank lending an interesting role in monetary transmission through the effects of banks' own capital. The effects of bank capital may be felt even in an economy where banks' ability to issue non-reservable debt instruments is unlimited. In such a case, the traditional bank lending channel is about to disappear, as suggested already by Romer and Romer (1990). In the literature on the effects of capital on monetary transmission the prevailing idea is that monetary policy has effects on the amount of capital available to the banking sector. Thereafter, the change in the amount of capital affects banks' lending choices because there is either an incentive- or regulatory-based ratio between the amount of capital and the volume of lending.

The seminal paper by Holmstrom and Tirole (1997) examines the effects of capital constraints on borrowers and financial intermediaries on the volume and costs of lending in a framework where the financial intermediaries (banks) are able to ameliorate the moral hazard problem of the borrowers by monitoring their behaviour. Contrary to a large portion of the literature on bank monitoring (see eg Diamond 1984, 1996), the banks' loan portfolios in Holmstrom and Tirole are not diversified, which creates a moral hazard problem for the banks as there are some private costs of monitoring. The moral hazard problem forces the banks to use some amount of their own capital to fund their lending in order to guarantee that they actually monitor their borrowers. Thus, due to the banks' incentives, the model produces an endogenous ratio between the amount of capital and the volume of bank lending. Although the amount of capital is exogenously determined in their model, Holmstrom and Tirole point out that the bank capital may be reduced as a consequence of tight monetary policy.

Part of the literature is focused on the effects of risk-based capital requirements of the banking sector and their interaction with monetary impulses. Several studies are based on the idea that maturity transformation is one of the functions of the banks. Thakor (1996) examines the link between monetary policy and aggregate bank lending in the presence of capital requirements. In his model, banks perform both screening of loan applicants before lending decisions and monitoring borrowers after lending decisions. Banks can invest in long-term loans that must be supported by capital according to credit risk-based capital requirements, but also in long-term government securities for which there are no capital requirements. Banks' investments are funded with short-term deposits and their own capital. There is unobservable heterogeneity in loan applicants, each of whom can simultaneously approach several banks. The outcome of the model is credit rationing where monetary policy affects the supply of loans through its effects on the term structure of interest rates. If an expansionary monetary policy shock increases the term premium (ie the difference between long-term and short-term interest rates), banks' investments in long-term securities (funded only with short-term deposits) become more profitable relative to investments in long-term loans (funded with short-term deposits and capital). Thus, somewhat surprisingly, the expansionary shock increases the probability of rationing for each loan applicant and decreases the supply of bank lending. If the expansionary monetary policy shock reduces the term premium, the result of the model is the opposite and traditional, leading to an increase in bank lending.

Van den Heuvel (2001) introduces a model in which the monetary policy impinges on the supply of bank loans through its effects on bank capital, due to a mechanism created by regulatory capital requirements. This mechanism is based on the imperfect market for bank equity capital and works even if banks face a perfect market for non-deposit liabilities. The implications of the model also rest on the presumption of maturity transformation as a function of banks that results in a negative effect of a rise of short-term interest rates on bank profits and a subsequent deterioration in capital adequacy. That is, banks are assumed to be either unwilling or unable to hedge their interest rate risk. In a dynamic context, this may have an effect on bank lending if imperfect equity markets do not allow immediate issuance of a sufficiently large amount of additional equity capital.

Also based on the existence of risk-based capital requirements, Chami and Cosimano (2001) identify a bank balance-sheet channel of monetary policy where monetary policy impacts banks' capacity to supply loans by affecting the option value of holding bank capital. That is, through a decrease in banks' capital, contractionary monetary policy leads to a decline in the supply of bank loans in the future. In their model, the market structure of the banking sector also affects transmission of monetary policy.

Bolton and Freixas (2000) have also examined the effects of monetary policy in a model where capital requirements are binding and asymmetric information on banks' net worth makes the cost of bank equity endogenous and limits banks' access to external equity capital. In their model, monetary policy works through its impact on the composition of nonfinancial firms' financing. Endogenous costs of bank equity also enable multiple equilibria for otherwise identical underlying parameters of the economy. What makes monetary policy important in the Bolton and Freixas framework is that a monetary contraction may induce a switch to a 'credit crunch' equilibrium in which bank lending is limited by a low stock of bank capital and bank lending spreads are wide.

2.2.2 Constraints on borrowers

A lot of research interest has been devoted to the role of capital or net worth of nonfinancial borrowers in the monetary policy transmission mechanism. The ideas put forward in this literature are, to some extent, applicable also to the discussion of incentive problems of banks and other financial intermediaries. Essentially, the balance sheet channel of monetary policy (also referred to as the broad credit channel or the net worth channel) starts with the argument that the changes in the monetary policy stance influence the net worth of potential borrowers (for a model, see Bernanke and Gertler 1989 and for a survey Bernanke, Gertler and Gilchrist 1996). The ability of borrowers to use debt-finance for their investments is constrained by the moral hazard problem in the debt-relationship, which increases the external finance premium required from the borrower (eg Bernanke and Gertler 1995). The net worth of the borrower then acts as collateral, which alleviates this moral hazard problem and reduces the external finance premium. Thus, the change in the net present value of the borrower's assets due to a monetary impulse may affect the borrower's ability to acquire credit more than the monetary impulse changes the demand for credit. The logic of the balance sheet channel approach is similar to that of the more general approach concerning credit cycles or the financial accelerator (see eg Kiyotaki and Moore 1997) where a change in the net value of borrowers' assets can be triggered not only by a specifically monetary policy related shock, but by any (aggregate) shock in the economy.

In an attempt to motivate the balance sheet channel of monetary policy transmission, Repullo and Suarez (2000) depart slightly from the traditional balance sheet literature. Their result is that a monetary policy shock triggers a change in the opportunity cost of capital which, in turn, changes the severity of the moral hazard problem of a firm with a given net worth. Thus a monetary impulse affects the critical level of the net worth of the borrower, which is required for the loan contract, and thereby changes the possible volume of lending. That is, in the Repullo and Suarez model, the monetary impulse need not to change the net worth of a borrower in order to produce the implications of the balance sheet channel, as the same effect is caused by the change in the level of net worth that the lender requires from any borrower due to the moral hazard problem.

However, in neither of its forms does the balance sheet channel introduce a special role for the banking sector in the monetary transmission process, although it may help to explain the bank-dependence of certain borrowers due to the banks' superior monitoring skills (Repullo and Suarez 2000). Therefore, unless one can find the appropriate links between banks and firms, the balance sheet channel seems to be unable to explain the observed differences between banks.

The balance sheet channel of monetary transmission has received a considerable amount of empirical support, a review of which is beyond the scope of this study. A comprehensive survey of the empirical results is offered eg by Bernanke, Gertler and Gilchrist (1996). As an example of empirical work with micro data, Gertler and Gilchrist (1994) examine the differences between reactions of small and large firms to monetary policy shocks and find that their effect on the behaviour of small firms was disproportionately strong. This might suggest that small firms that are particularly sensitive to moral hazard problems in their funding have suffered most from balance sheet deterioration. Recent empirical work on the balance-sheet channel of monetary policy transmission with European firm-level data can be found eg in Chatelain et al (2001) and references therein.

3 Model

We present a model that examines the lending process in the loan market and how monetary policy affects the lending process. The essential questions the model tries to answer are how the existence of moral hazard problems at bank level affects monetary policy transmission to bank lending, and how banks' liability structure affects transmission in the presence of the moral hazard problems.

We deal with moral hazard problems at two levels. Firstly, we assume that possible borrowers suffer from moral hazard problems because they are tempted to use the funds they borrow in an opportunistic manner that reduces the probability that they will be able to service their debts. Because we assume the group of nonfinancial borrowers to be homogeneous, their moral hazard problems lead to credit rationing in our equilibrium. The moral hazard problems of borrowers are not the core of our analysis but rather the explanation for the existence of banks.

Secondly – and more interestingly – we examine the effects of potential moral hazard problems at the level of banks that lend funds to firms in the loan market. The moral hazard problems may emerge because the banks also monitor their borrowers (ie give them incentives to act in a way that increases the probability of repaying loans) and monitoring is costly to banks. Since the influence of banks' moral hazard problems is the focus of the analysis, we discuss banks' behaviour in two alternative cases. In a benchmark case, banks do not act as intermediaries but lend only their own capital and thus do not have moral hazard problems in monitoring. In another case, banks lend their own capital but also act as intermediaries and fund part of their lending by issuing debt. In this case, moral hazard problems emerge between banks and the investors that buy the debt instruments issued by the banks.

The model has its origins in the previous literature on capital-constrained lending, based especially on Holmstrom and Tirole (1997). While this literature looks at the effects of a monetary policy on the stock of capital and thus to the volume of lending through the capital constraint, it ignores the possible incentive effects of banks' capital structure on monetary policy transmission. Our model is also related to Repullo and Suarez (2000) who present a model where the moral hazard problem between entrepreneurs and lenders creates a tradeoff between market and bank finance. Repullo and Suarez, in turn, ignore the possible moral hazard problem at bank level and take banks' monitoring activity as given, so that their analysis on the banks' role in monetary policy transmission remains incomplete. The present study aims to fill gaps in the previous literature by allowing for endogenous monitoring and monitoring costs and analysing the effects of moral hazard problems and monetary policy on monitoring.

The model is partial in nature since we only consider two groups of active agents, namely banks and firms[8]. Firms have investment projects for which they need external funding. Banks grant loans to firms in the loan market, and their liabilities comprise capital and possibly external debt. In addition to the loan market between banks and firms, there is a fully competitive debt securities market. Our assumption is that because of their limited liability as regards debts, the moral hazard problems of firms are severe enough to prevent them from borrowing directly from investors in the debt securities market. Banks, however, enjoy sufficient monitoring skills to mitigate the moral hazard problems of firms, which can thus borrow from banks. Furthermore, given their monitoring skills and capital endowments, banks can borrow funds from the debt securities market even though they transmit these funds to firms that do not have direct access to the debt securities market.

The ordering of model events is presented in table 3.1. The agents make their decisions during subperiods 1 and 2, the exogenous variables are determined in subperiod 0, and the outcome of the model is observed in the final subperiod 3. More specifically, banks receive an exogenous amount of equity capital (K or k) in subperiod 0 before they possibly enter the loan market.[9] The risk-free interest rate (R)

[8] Here, we follow the mainstream of literature on the role of banks in monetary transmission, which usually considers firms as borrowers. However, there is some empirical work on the monetary transmission mechanism in the housing market (see eg Maclennan, Muellbauer and Stephens 1999, and Iacoviello and Minetti 2000). Due to the definition of monitoring in our model, borrowers can more easily be interpreted as firms that carry out risky investment projects.

[9] As will be evident below, we consider two alternative market structures: in the monopoly market, the monopoly bank is endowed with amount K of equity capital, and in the competitive market, each potential bank is endowed with amount k of equity capital.

in the debt securities market is also determined by the central bank in subperiod 0. In subperiod 1, the firms first apply for loans in the loan market and sign loan agreements if their net value to the firms is positive. Irrespective of the structure of the loan market, the active banks choose both their lending interest rate (H) and volume[10] (L or l) to maximise their expected profits. In subperiod 1, the banks may then borrow from the debt securities market so as to fund their lending. In subperiod 2, the banks monitor the behaviour of their borrowers. Banks first choose the intensity of monitoring (θ) for their customer firms. The firms carry out their investment projects, deciding on their effort level and the subsequent success probability of their projects (p) subject to bank monitoring. Finally, in subperiod 3, the stochastic returns of the projects of the firms are realized. If the projects are successful, they repay their loans (incl. interest payments) to the banks. If the banks have borrowed funds, they then repay their debts in the debt securities market. We assume that there are no incentive problems in subperiod 3 as the success of the projects is assumed to be verifiable and the repayment of the loans and securities market debts enforceable.

Throughout the analysis, we only stick with interior solutions. Therefore, we assume away cases where the decision variables of banks or firms reach limit values. Thus we only consider solutions where l, L, H and θ are strictly positive and p is strictly between zero and unity.

[10] In the monopoly loan market, the bank chooses the aggregate volume of lending L; in the competitive market, each bank chooses its individual volume of lending l.

Table 3.1 Ordering of events in the model

SUBPERIOD	EVENT
0	Amount of bank capital and other exogenous variables and parameters determined
1	Each bank chooses whether to enter the loan market (competitive case), its volume of loans and the lending interest rate - Bank debt interest rate determined in the securities market
2	Banks choose their intensity of monitoring of borrowers - Firms choose their efforts and the subsequent success probability of projects
3	If projects successful, firms repay the loans If projects are successful, banks repay the debts

3.1 Firms

There is a large group of identical entrepreneurial firms in the economy. Each firm has an option to start one investment project that needs a capital injection of size one. The firms have no net worth and therefore they need a loan of size one in order to start a project. Firms attempt to fund their projects by borrowing from banks in the loan market. For simplicity, we assume that the size of a loan is fixed at unity, ie that the firm can only finance itself by a single loan from a single bank.

If the project of a firm succeeds, the firm gets a monetary payoff G. If the project fails, the monetary return is zero. We implicitly introduce the loan demand among firms by allowing G to vary with the total investment activity financed by the banks. To this end, we assume that the returns on each project are inversely related to the total number of projects financed, ie the aggregate volume of lending L. Thus G can be expressed as a function of the aggregate volume of lending in a general form, $G = G(L)$, with $\frac{dG}{dL} < 0$. The inverse relationship between the payoff and the volume of lending can be motivated eg by introducing increasing marginal costs of production in the nonfinancial sector or limited aggregate demand for commodities produced in the nonfinancial sector. By the inverse function theorem, it would also be possible to consider the relationship between L and G the other way round, expressing the demand for loans L, as an inverse function of the borrower's required return for the loan G. Let us assume that G is continuously differentiable and monotonically decreasing in L. Moreover, for simplicity, we assume isoelastic loan demand. To introduce this feature in the model, let us denote $m \equiv \frac{dG}{dL}\frac{L}{G}$ where m is a negative constant[11]. Because of the structure of the model, we also need to make the assumption $0 > m > -\frac{1}{4}$ to guarantee the existence of an equilibrium.

In many respects, we follow Repullo and Suarez (2000) in modelling the firm's objectives. The project of a firm succeeds with probability $p \in (0, 1)$[12]. We assume, for modelling purposes, that each active firm directly decides its own success probability (in subperiod 2) to maximise its utility. The firms are protected by the limited liability as regards their loans, and therefore the gross lending rate H, including borrowed capital, is repaid to the bank only if the project is successful. For simplicity, we also assume that the collateral value of a failed investment project is zero.

In addition to the verifiable monetary payoff of the project, a firm (or an entrepreneur) obtains non-verifiable private benefits if it starts the project, irrespective of its realisation. In subperiod 2, the firm decides how much effort it will devote to implementation of the project, and how much to allocate to other purposes to gain private benefits. The value of the private benefits is inversely related to the firm's efforts to make the project successful. On the other hand, we assume that banks are able to reduce the non-verifiable

[11] A consequence of the isoelasticity assumption is that $\frac{d^2G}{dL^2} > 0$ because $G(L) > 0$, $\frac{dG}{dL} < 0$ and $\frac{dm}{dL} = \frac{\frac{dG}{dL} + \frac{d^2G}{dL^2}L}{G(L)} - \frac{\left(\frac{dG}{dL}\right)^2 L}{(G(L))^2} = 0$.

[12] Note that we excluded corner solutions above by assumption.

private benefits of its borrowers, and thereby affect their decision on the allocation of resources between the project and possible private uses. Unlike Repullo and Suarez, we assume the private benefits of the firm to be independent of the yield of a successful project. Otherwise, the form of private benefits is quite similar to that in Repullo and Suarez, as we define private benefits of a firm to be $\frac{1-p^2}{2\theta}$, where θ is the bank's intensity of monitoring. With the random cash flows from the project, the expected profits of a firm are:

$$E\pi_f = p\left(G(L) - H\right) + \frac{1-p^2}{2\theta}. \tag{3.1}$$

Repullo and Suarez who deal with the moral hazard problems of the heterogenous firm sector in their analysis allow the net worth to vary across firms. Since our focus is on the moral hazard problem of the intermediary banks, we keep the structure of the firm sector as simple as possible and thus restrict firms' net worth to zero. Whereas Repullo and Suarez consider θ exogenous, we focus on the decision (see below) of the banks on the intensity of monitoring.

3.2 Banking sector

The focus of our model is on the impact of banking sector behaviour on the monetary policy transmission. Firstly, we ask whether the existence of moral hazard problems at bank level change the strength of monetary transmission to lending. Secondly, we ask how the liability structure of banks affects transmission, given the moral hazard problems.

At the first stage, we examine these issues in the case of a monopoly bank in the loan market (section 3.4). To complete the analysis, we also compute the results for the case of competitive banks in the loan market (section 3.5). In this way, we are able to verify whether the results are robust to changes in the structure of the banking sector or whether there are essential differences between the market structures, as suggested by a strand of empirical literature (see eg Ehrmann 2001, Cecchetti 1999, and Kashyap and Stein 1997).

Irrespective of the structure of the loan market, a key point of interest in the model is the influence of the liability structure of banks' balance sheets on their optimal effort to monitor borrowers' behaviour. Following Holmstrom and Tirole (1997), we make a distinction between banks' own capital (for which we also use terms 'bank capital' and 'capital' interchangeably) and external debt funding, both of which the banks may use to fund their loan portfolios. Banks' own capital is funding that is offered to banks by insiders (eg bank manager him/herself or, more broadly, bank equity holders) with whose interests the bank management is fully aligned. On the contrary, banks face limited liability as regards external debt funding since they do not have to repay these funds in case of insolvency and have no opportunity costs from the loss of these funds.

In order to analyse the effect of intermediation on monetary policy transmission, we compare two cases that differ as to the structure of the liability side of the banks' balance sheet. On the one hand, as a benchmark case we consider a banking sector with unlimited access to capital at the level of the aggregate banking sector. The use of only capital in the benchmark case means that there are no moral hazard problems between banks and the providers of their liabilities.

On the other hand, we examine a more realistic looking banking sector with a limited but positive supply of capital that is not excessive in comparison to the volume of lending in equilibrium. Restrictions on the amount of capital available to the banking sector introduce moral hazard problems at bank level. The limited supply of bank capital means that banks find it optimal to use external debt funding, in addition to their own capital, and so face moral hazard costs. The assumption of banks' imperfect access to capital is also made eg by Holmstrom and Tirole (1997) and Van den Heuvel (2001), the latter allowing the amount of bank capital to change due to retained earnings, in a dynamic framework. In our model, in addition to their own capital, banks end up borrowing from the debt securities market where the banks' default risks are fully reflected in debt pricing.

As regards the other side of a bank's balance sheet, we assume that loans to firms are the only assets. This also means that the amount of capital never exceeds the volume of loans in a single bank. Even in the case of a bank with an unlimited supply of capital, we assume the excessive part of the bank's own capital to remain off the balance sheet.

Banks are able to monitor their borrowers' behaviour in subperiod 2 so as to improve the probability of success of the projects and subsequently reduce the risk involved in their loans. Monitoring is understood to mean all actions taken by banks that reduce private benefits to the firms from choices that diminish the probability of their projects being successful. This would include making entrepreneurial firms more diligent, or preventing them from making more risky choices in their projects, which could offer greater private benefits.

Monitoring is assumed to be privately costly to banks so that they incur nonverifiable costs that are a function of monitoring intensity θ. To simplify the analysis, we ignore other possible types of costs of monitoring. If banks use external debt funding, the private costs of monitoring create a moral hazard problem to the banks and limit their volume of lending. In this respect, the model follows Holmstrom and Tirole (1997) who, however, keep the intensity of monitoring fixed while discussing their model in a formal manner. In our model banks decide on the monitoring intensity on the basis of both the beneficial effects of monitoring on borrowers' behaviour and the costs of monitoring. The costs of monitoring incurred by the banks are introduced in a quadratic functional form that makes the model more tractable. More precisely, the cost of monitoring a single unit of loan and the firm that has borrowed it is $\mu\theta^2$ where μ is the unit cost of monitoring. The cost term is quadratic in the intensity of monitoring θ, reflecting the intuition that more accurate monitoring involves increasing marginal cost.

To allow the use of external debt funding to have any effects on bank behaviour, we must assume some correlation among the projects financed by the banks. If the projects were not correlated at all and the banks' loan portfolios were large enough, there would be no uncertainty about the returns on the portfolios, and the banks' external debts would not require any compensation for risk (provided that the yield from lending would not fall short of the bank's liabilities). A positive correlation among projects can be due to geographic or other kinds of specialization by the banks, or some macroeconomic factors.[13] To simplify the model we assume that all the projects financed by a bank are perfectly correlated, as in Holmstrom and Tirole (1997).

The motivation for financial intermediation in our model comes from the differences between various types of lenders in their ability

[13] Winton (2000) eg discusses banks' choice between strategies of specialisation and diversification, arguing that diversification is not necessarily their optimal strategy choice.

to monitor borrowers. Investors in the securities market have poor monitoring skills. Therefore, they find it impossible to lend directly to firms that they find too difficult to monitor. Instead, the investors direct their funds in the debt securities market to either the risk-free investment option or to banks that are – thanks to better monitoring skills – able to act as financial intermediaries and grant loans to the firms. In fact, our conclusion is similar to the theory of delegated monitoring (see eg Diamond 1984, 1996) that motivates the existence of banks by the property that banks act as agents to whom monitoring has been delegated. However, our definition of monitoring differs eg from that of Diamond, who considers it punishing the borrower in the event it is not able to fulfill its contractual obligations. Moreover, here, unlike in Diamond, the incentives of the bank to monitor derive from the injection of bank capital into loans.

3.3 Firm effort decision

After the loan agreements are made, the bank determines its intensity of monitoring θ in subperiod 2 and is committed to this level for the whole subperiod. Firms take θ as given while choosing the success probability of projects, p, which appears to be common to every project as the firms as well as their projects are identical. We translate the choice of p to refer to a choice of resources diverted to the implementation of the project, or the choice of effort during the project.

As a firm maximises its expected profits (3.1) with respect to p in subperiod 2, taking θ and loan market variables L and H as given, its first-order condition yields

$$p = \theta \left(G(L) - H \right). \tag{3.2}$$

Condition (3.2) applies only as long as $0 \leq \theta(G(L) - H) \leq 1$. As we have ruled out corner solutions, for the present, we assume that $0 < \theta(G(L) - H) < 1$ holds in the equilibrium. Thus both θ and $(G(L) - H)$ must be strictly positive.

According to (3.2), the effort of the firm increases with the bank's monitoring intensity and the share of the project returns it retains in case the project succeeds. While considering the lending interest rate in subperiod 1, the bank has to take into account not only the direct effect of H on p but also how the lending rate changes the impact of monitoring on firm effort.

If we insert the effort choice of the firm (3.2) into the firm's expected profit (3.1), the expected profits becomes:

$$E\pi_f = \frac{1}{2\theta}\left[\theta^2\left(G(L) - H\right)^2 + 1\right]. \tag{3.3}$$

Interestingly, we see from (3.3) that whenever $G(L) \geq H$ the expected profit of a single active firm is positive, provided that the bank's monitoring intensity θ is non-negative. Therefore, a potential marginal borrower would be willing to take a loan and start a project since its opportunity cost of starting a project is zero and an infinitesimal rise in L would not turn the expected profit of the firm negative. So, whenever the return of a successful project is greater than the gross lending rate in an equilibrium, we may conclude that the supply of loans is below the demand for loans and binding in equilibrium.

With the result on the firms effort, we can analyse in more detail the obvious question touched above why the firms in question do not acquire their funding from the debt securities market. A possible answer to this question is that the ability of the lenders in the debt securities market to monitor the firms is so limited that there is no solution for the participation constraint of the securities market investors who require an expected return equal to the risk-free securities market rate, ie in current terms, $pH - R = 0$. If we combine this with (3.2), the condition becomes $\theta(G(L) - H)H - R = 0$. Let us assume for a moment that there is an exogenous monitoring intensity of the securities market investors that involves no monitoring costs and that is quite small, say θ_m. Then, the condition for market finance does not have a real solution if $\theta_m < \frac{4R}{(G(L))^2}$. The low intensity of monitoring in the securities market explains the demand for loans by banks with special monitoring skills.

3.4 Monopoly bank

First, we take a look at the case where there is a monopoly bank in the loan market. The bank maximises its expected profits taking into account the effect of its interest rate and loan supply decisions on both its own monitoring efforts and firms' behaviour in subperiod 2 and on the firms' project returns through the aggregate amount of investment. In fact, when the bank acts as a monopoly, it is able to fully determine the aggregate investment level by its volume of lending L. Moreover, as the monopoly bank that faces the inverse loan demand function $G(L)$ discussed above, it also determines indirectly the nominal yield of the firms projects. As the bank also chooses the monitoring intensity θ in subperiod 2, it has a very strong influence on firms' expected profits and the success probability of projects undertaken by the firms.

To answer the basic question about the impact of moral hazard problems on monetary policy transmission, we have to distinguish between the case where moral hazard problems affect bank behaviour and the benchmark case where they do not. To this end, we consider two types of monopoly bank. The first one is able to serve its optimal loan supply with its own capital and thus avoid moral hazard problems. The second one has a limited supply of capital and faces moral hazard problems as it borrows in the debt securities market.

In the analysis of a monopoly bank, we use two slightly differentiated versions of the model to cover both cases. It might however seem that we could consider a bank without moral hazard problems as simply a special case of a bank with potential moral hazard problems by letting it fund its lending totally by its own capital in the equilibrium. However, the moral hazard problems of the monopoly bank influence the model outcome whenever the bank does not freely choose the amount of its own capital. Even if the bank ends up lending exactly the amount of its own capital, ie the bank's moral hazard problems do not directly limit the volume of lending in equilibrium, the capital limitations do affect the monetary policy transmission process. This is because changes in monetary policy would potentially raise the volume of lending above the amount of bank capital, in which case external debt funding would be needed, implicating moral hazard problems for the bank.

In the benchmark case where the supply of capital is unlimited in relation to the bank's optimal volume of lending, the monopoly bank makes its decisions so as to maximise its expected profits, expressed in the following form:

$$E\pi_{bm} = pHL - RL - \mu\theta^2 L \tag{3.4}$$

Here, pHL is the expected gross return to lending, RL the expected funding cost of lending and $\mu\theta^2 L$ the nonverifiable cost of monitoring. In fact, RL is the opportunity cost of lending in the loan market, as the bank could invest the amount L also in the debt securities market at risk free gross interest rate R. Implicitly (3.4) also means that the benchmark bank chooses its own capital in the balance sheet to equal its volume of lending and the excessive amount of capital is left outside our analysis.

However, if the bank's available amount of capital is limited to a fixed amount K that remains below or at most equal to the optimal volume of lending L, the bank's expected profit is

$$E\pi_b = pHL - pB(L - K) - RK - \mu\theta^2 L \tag{3.5}$$

The expected funding cost of lending is $pB(L - K) + RK$. RK is the opportunity cost of lending the stock of bank capital K and $pB(L - K)$ is the expected funding cost of the rest of the lending $(L - K)$. Note that B is the required gross rate of return of bank bonds in the debt securities market, which has to be repaid if and only if the bank remains solvent (which happens with probability p). In the following, we examine the decisions of the bank to maximise its relevant expected profits.

Note that comparing (3.4) and (3.5) reveals that if the limited amount of bank capital, K, is in equilibrium equal to the volume of lending, L, the expected profits of the bank are equal in the two cases. So, with respect to the equilibrium volume of lending and other endogenous variables, we could treat the bank with unlimited capital as a special case of the bank with limited capital by setting $K = L$ in equilibrium. However, it will appear that this is not the case with the comparative statics that we are going to use to evaluate monetary policy effects on the volume of lending. As monetary policy transmission remains our main question, we have to proceed with separate model versions for the two types of banks. Alternatively, we might consider a constrained optimisation problem to combine the two cases.

In the form of the expected profits of the bank in (3.4) and (3.5), we make the simplifying assumption that the costs of monitoring are either nonmonetary in nature or otherwise excluded from the bank's balance sheet. The latter alternative could refer to a case where the bank had a fixed amount of funds designated for monitoring purposes so that the funds could not be used to extend loans. If not used for monitoring, the funds would increase the profits of the bank. Even though the calculations would become more complicated, the results of the model would not differ qualitatively if we allowed for monitoring costs in the bank's balance sheet.

We solve the bank's problem using backward induction, first looking at the bank's decision on the intensity of monitoring in subperiod 2, and then the decisions in the loan market in subperiod 1.

3.4.1 Monitoring decisions

Bank without capital restrictions

In subperiod 2, the bank that has unlimited access to capital (in relation to optimal lending) chooses θ to maximise (3.4). In this decision the bank takes into account the effect of monitoring on firm effort, shown in (3.2). Therefore, by inserting (3.2) into (3.4) the objective function of the bank becomes

$$E\pi_{bm} = \theta(G(L) - H)HL - RL - \mu\theta^2 L. \tag{3.6}$$

The bank takes R, H, L and subsequently G as given while choosing the intensity of monitoring. Optimization with respect to θ gives then the bank the first-order condition

$$\left[(G(L) - H)\, H - 2\mu\theta\right] L = 0. \tag{3.7}$$

We focus on the case where the equilibrium volume of lending L is positive. Now that there are no incentive problems involved with the liability side of the bank's balance sheet, we can express the intensity of monitoring explicitly in terms of the endogenous variables L and

H as well as other exogenous variables and parameters, denoted by O:

$$\theta\left(L, H; O\right) = \frac{\left(G(L) - H\right) H}{2\mu} \tag{3.8}$$

Because $\frac{dG}{dL} < 0$, the intensity of monitoring, θ, decreases due to an increase in the volume of lending even in the benchmark case without incentive problems in the bank's funding. As well, a rise in the cost of monitoring reduces the intensity of monitoring, which appears quite evident.

Bank with capital restrictions

In subperiod 2, a bank whose access to capital is limited to a fixed amount not exceeding the equilibrium volume of lending faces a moral hazard problem created by its need for the external finance it has to acquire from the securities market. The moral hazard problems arise because the nominal interest rate of the external finance is fixed in subperiod 2, which gives the bank an incentive to avoid privately costly monitoring efforts. That is, the cost of external finance is not contingent on the intensity of monitoring since the cost of monitoring is nonverifiable. Therefore, the bank has an incentive to reduce the intensity of monitoring after the price of its funding from the debt securities market has been fixed, since a lower intensity of monitoring also implies a lower probability of repaying the securities market debts. More precisely, after the interest rate for external finance has been agreed in subperiod 1, a drop in θ reduces the expected cost of external finance since it also reduces p in (3.5). Therefore, the monitoring intensity of the bank decreases when external finance is relied on, given the volume of lending. Moreover, monitoring effort becomes directly dependent on the risk-free debt securities market rate R that is assumed to measure the monetary policy stance.

Inserting firm condition (3.2) into (3.5), the objective of the bank now becomes

$$E\pi_b = \theta\left(G(L) - H\right) HL - \theta\left(G(L) - H\right) B(L-K) - RK - \mu\theta^2 L. \tag{3.9}$$

As implied above, the bank now takes as given the securities market rate on bank bonds B as well as other variables (apart from θ).

Optimisation with respect to θ now gives the bank the following first-order condition

$$(G(L) - H)\left[HL - B\left(L - K\right)\right] - 2\mu\theta L = 0 \tag{3.10}$$

To compare with the case without capital restrictions, the monitoring level of the capital-constrained bank is, ex post,

$$\theta = \frac{(G(L) - H)\left[H - B\left(1 - \frac{K}{L}\right)\right]}{2\mu} \tag{3.11}$$

So, at a given level of L and H and μ, intermediation of external funds lowers the monitoring intensity of the bank, since the term in the second brackets in the numerator of (3.11) is clearly smaller than the corresponding term H in (3.8). It must be noted that (3.11) does not give an explicit ex ante solution for θ since B is a function of the expected value of θ in subperiod 1, as we will see below.

3.4.2 Loan and securities market decisions

Bank without capital restrictions

In subperiod 1, the bank with an infinite supply of capital (in relation to optimal lending) maximises the expected profits in (3.6) by choosing the volume of lending L, and the lending rate H. The bank knows that the intensity of monitoring will be decided in subperiod 2 according to (3.8), and inserts therefore its expectation as to θ into (3.6) before deriving the first-order conditions. So, the bank faces the following problem:

$$\max_{H,L} E\pi_{bm} = \frac{(G(L) - H)^2 H^2 L}{4\mu} - RL. \tag{3.12}$$

First-order conditions with respect to H and L are, respectively,

$$\frac{HL\left(G(L) - H\right)\left(G(L) - 2H\right)}{2\mu} = 0. \tag{3.13}$$

$$\frac{(G(L) - H)\, H^2\left[(G(L) - H) + 2mG(L)\right]}{4\mu} - R = 0. \tag{3.14}$$

While (3.13) offers several solutions for H, the only one that avoids corner solutions and allows a solution for (3.14) with a non-zero R is[14]

$$H = \frac{G(L)}{2}. \tag{3.15}$$

Substituting solution (3.15) for H in (3.14) gives the following implicit equilibrium condition for L:

$$\frac{(G(L))^4 (1+4m)}{64\mu} - R = 0. \tag{3.16}$$

With the equilibrium choice of the lending interest rate, some non-active firms would be willing to borrow from the bank, and start their investment project, thereby marginally increasing L, but still leaving the firms' expected profits positive. This actually means that the demand for lending exceeds the supply of loans at the given lending rate. The underlying reason is actually the incentive problems of the firms that lead to a situation where the bank needs to keep the yield of a successful project to the borrowers high enough so as to keep their efforts at a sufficiently high level.

Inserting (3.15) and (3.16) into (3.8), we can express the equilibrium solution for θ in another form that can be compared with the case where the bank is capital constrained:

$$\theta = \frac{8R}{(G(L))^2 (1+4m)}. \tag{3.17}$$

Together, (3.15), (3.16), and (3.17) determine the equilibrium in the benchmark case where the bank does not suffer from incentive problems. From (3.16) we can see that the (inverse) elasticity of G with respect to L needs to be small enough in absolute terms so as to guarantee the existence of an equilibrium. Our assumption about the elasticity ($0 > m > -\frac{1}{4}$) is sufficient in this respect.

Our decision to rule out any corner solutions implies several requirements for model parameters and variables and their

[14]Note that if the solution for the lending rate were one of the other possible solutions for (3.13), $H = 0$ or $H = G(L)$, the first-order condition for the volume of lending (3.14) would not be fulfilled (unless the risk-free securities market rate is zero), and furthermore, given a positive volume of lending, the expected profit of the bank would be negative, as can be seen from (3.12).

relationships. For example, combining (3.2), (3.8) and (3.15) yields $p = \frac{(G(L))^3}{16\mu}$. To have $p \in (0, 1)$, we need $0 < \frac{(G(L))^3}{16\mu} < 1$. Together with (3.16) this also implies $G(L) > \frac{4R}{(1+4m)}$. This requirement means a fairly high return requirement for the firms' projects. One reason for this is that we consider here only the case where the projects are fully debt-financed. If the firms financed their projects partly with their own capital, the assumption would become less stringent. The assumption may also be related to the functional form of the bank's expected profit.

Next, let us turn to the effects of monetary policy by evaluating the impact of the risk-free securities market rate R, on lending. To eliminate the effect of volume of lending, we do the analysis by examining elasticity measures. By applying the implicit function theorem for equilibrium condition (3.16), we get the benchmark result for the monetary policy influence:

$$\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m}. \tag{3.18}$$

With our assumption about m ($-\frac{1}{4} < m < 0$), result (3.18) tells us that the response to monetary policy of a bank without incentive problems as to its liabilities is larger than one. The influence of monetary policy increases as the sensitivity of project returns to the bank's volume of loans falls. In other words, a monopoly bank that has a relatively strong influence on the return rate of firms' successful projects reacts less to a monetary policy shock than a bank whose influence is weaker. With (3.18) and (3.15), we can also see that even though the bank rations loans, changes in the risk-free securities market interest rate pass through to lending rates. In detail, now that the bank suffers no moral hazard problems, the elasticity of the lending rate with respect to the risk-free rate is fixed, ie $\frac{dH}{dR}\frac{R}{H} = \frac{1}{4}$, as $\frac{dH}{dL}\frac{L}{H} = m$ in equilibrium (from (3.15))[15].

Monetary policy also affects the bank's intensity of monitoring even in this benchmark case where the bank does not have moral hazard problems. This effect is only indirect, through the impact of monetary policy on the volume of lending, as we can see from (3.8) and (3.15) that in equilibrium $\theta_L \frac{L}{\theta} = 2m$. So, when the volume of lending grows, the intensity of monitoring falls, and vice versa. The explanation for this negative effect of lending on monitoring is that the bank knows that a larger amount of investment (loans) leads to lower returns to successful projects, which reduces the value of costly monitoring. On the contrary we see from (3.8) that there is no direct effect from R to θ, and the effect through the lending rate is zero, as $\theta_H = 0$ in equilibrium. Thereby, recalling (3.18) the elasticity of monitoring with respect to monetary policy interest rate is fixed, ie $\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1}{2}$. Further, (3.2) and (3.15) imply that in equilibrium, $p = \theta H$. Thus, combining the elasticities of the lending rate and monitoring intensity yields $\frac{dp}{dR}\frac{R}{p} = \frac{3}{4}$. This means that a tightening of monetary policy reduces the risk of failure in the projects undertaken. A monetary contraction cuts the volume of lending and thereby increases the value of successful projects, both to firms and to the bank, and makes them strive harder for success of the projects.[16]

Finally, the cost of monitoring affects the volume of lending even if the bank uses only its own capital. This is because the bank takes into account the decreasing expected returns to the number of projects started. In parallel with the result in (3.18), the elasticity of lending with respect to the private cost of monitoring is $\frac{dL}{d\mu}\frac{\mu}{L} = \frac{1}{4m}$. On the other hand, monitoring costs affect the intensity of monitoring.

[15] By combining this result with equilibrium condition (3.15) and with the equilibrium implication $G(L) > \frac{4R}{(1+4m)}$, we see an interesting detail concerning the effect of monetary policy on the bank lending premium: $\frac{d(H-R)}{dR} \gtrless \frac{1}{2(1+4m)} - 1$. If the yield of successful projects is sensitive enough to the loan volume, ie $m < -\frac{1}{8}$, a tightening of monetary policy unequivocally increases the bank lending premium. That is, when m is large enough in absolute value, a change in monetary policy rate is transmitted to lending rates at a rate above one. However, if m is not large enough in absolute value, the effect of monetary policy on the bank lending premium remains ambiguous.

[16] Note that in deriving these results the potential adverse effects of a monetary contraction on the probability of success of the projects, due to eg demand channels in the economy, are ignored.

Inserting (3.15) into (3.8) yields $\theta = \frac{(G(L))^2}{8\mu}$, which can be used to compute both the direct effect of μ on θ and the indirect effect through the volume of lending. Together these effects sum up to yield $\frac{d\theta}{d\mu}\frac{\mu}{\theta} = -\frac{1}{2}$. The higher cost of monitoring reduces the bank's incentive to monitor its borrowers. However, an increase in monitoring costs also decreases the volume of bank lending and thereby increases the returns to successful projects. The higher returns to successful projects raise the bank's incentive to monitor, partly offsetting the dominant negative direct effect of monitoring costs.

Bank with capital restrictions

Next, we turn to a bank with access only to a limited supply of capital. Therefore, if it finds it optimal to expand its loan stock beyond the amount of its own capital, the bank has to obtain the rest of the funds by borrowing from the debt securities market.

At the end of subperiod 1, after the loan supply has been fixed, the bank acquires amount $L - K$ in the debt securities market so as to balance its assets and liabilities. Investors in the fully competitive debt securities market have perfect foresight and rational expectations as to the choices of p and θ in subperiod 2, without uncertainty. The opportunity cost in the debt securities market is the risk-free rate R, and so the investors require a nominal rate from the bank higher than R to compensate for the risk of failure involved in bank debts. More precisely, investors require that the expected return on banks' bonds be equal to R, so that

$$B = \frac{R}{p} = \frac{R}{\theta\,(G(L) - H)}. \tag{3.19}$$

As the bank makes its interest rate and loan supply decisions in subperiod 1, it also understands the return requirement of securities market investors. Therefore, as the bank takes into account the first-order condition (3.10) for monitoring in subperiod 2 in making its loan market decisions in subperiod 1, it also keeps in mind the interest rate requirement set by the investors. So, from the perspective of subperiod 1, the condition becomes (by inserting (3.19) into (3.10))

$$(G(L) - H)\,H - \frac{R}{\theta}\left(1 - \frac{K}{L}\right) - 2\mu\theta = 0. \tag{3.20}$$

This condition now determines θ as an implicit function of endogenous variables H and L as well as the exogenous variables. If we denote the vector of exogenous variables and parameters by O, we can write $\theta = \theta(L, H; O)$. In order to calculate the optimum conditions for the bank's loan market decisions, we employ the implicit function theorem to compute the partial derivatives for θ with respect to H and L:

$$\theta_H = -\frac{(G(L) - 2H)}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu} \tag{3.21}$$

and

$$\theta_L = \frac{\frac{RK}{\theta L^2} - \frac{mG(L)H}{L}}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}. \tag{3.22}$$

In subperiod 1 the bank maximises its expected profits subject to the return requirement of securities market investors (3.19) because the risk premium on bank debt in the securities market has not yet been fixed yet. Thus we need to insert (3.19) into (3.9) before maximization. The bank also treats θ as a function of its decision variables H and L, and makes use of (3.21) and (3.22) as the associated partial derivatives. Hence the bank's problem in subperiod 1, with H and L as decision variables, is

$$\max_{H,L} \theta(H, L; O)\,(G(L) - H)\,HL - RL - \mu\,(\theta(H, L; O))^2\,L. \tag{3.23}$$

Using (3.20), (3.21), and (3.22), the first-order conditions can be presented in the following form for H and L, respectively[17]:

$$\theta L\,(G(L) - 2H)\left[1 - \frac{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right)}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}\right] = 0. \tag{3.24}$$

$$\frac{\mu\left[R\left(1 + \frac{K}{L}\right) - 2\mu\theta^2 - 2m\theta HG(L)\right]}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu} = 0. \tag{3.25}$$

As in the benchmark case, the only solution for (3.24), avoiding corner solutions and allowing for a feasible solution for (3.25), is the same as in (3.15) in the benchmark case above, which is replicated here for convenience:

$$H = \frac{G(L)}{2}. \tag{3.26}$$

[17] See appendix 1 for the derivation of (3.24) and (3.25) as well as the sufficient second-order conditions.

Given the expected profits of the firms, the optimal lending interest rate for the bank clearly leaves some firms that would be willing to borrow but are not granted loans by the bank. This means that due to the firms' moral hazard problem, the bank again rations loans to some extent. As a monopoly, the bank is able to determine the level of investment in the economy and hence the profit level of successful projects. An increase in the lending interest rate reduces the efforts of entrepreneurs. Therefore, even a monopoly finds it optimal to collect only half of the project returns from the entrepreneur so as to spur the firm to a higher effort level. If the firms' projects were partly self-financed, the optimal level of loan interest rate would be higher due to its smaller incentive effects.

Next, combining conditions (3.20), (3.24) and (3.25) yields an equilibrium condition for θ in terms of L and exogenous variables:

$$\theta = \frac{8R}{\left(G(L)\right)^2 (1+4m)}. \tag{3.27}$$

Note that (3.27) holds only in the equilibrium. Therefore, we do not use (3.27) to evaluate the partial effects of R or L on θ but derive those from condition (3.20), which determines the choice of monitoring intensity from the perspective of subperiod 1. In equilibrium the relationship between monitoring intensity and the volume of lending turns out to be identical to that of the benchmark case (3.17). However, the impacts of lending on the bank's incentive to monitor differ from each other, as we will see below. Therefore, there are differences in the two equilibria as well as in the effects of monetary policy on lending and monitoring.

Finally, by combing conditions (3.25), (3.26) and (3.27), and modifying the result, we get an implicit equilibrium condition for the volume of lending in terms of exogenous variables:

$$\left\{\frac{(1-4m)+\frac{K}{L}(1+4m)}{2}\right\}\frac{\left(G(L)\right)^4 (1+4m)}{64\mu} - R = 0. \tag{3.28}$$

The distinctive feature in equilibrium condition (3.28) in comparison with the benchmark equilibrium condition (3.16) is the first term in braces. It turns out that the term in braces does not exceed unity provided that the equilibrium volume of lending is at least equal to the amount of bank capital. This implies that the volume of lending of a capital-constrained bank is never higher than that of the benchmark bank, as the capital-constrained bank implicitly requires higher nominal returns from successful projects of borrowers.

3.4.3 Monetary policy transmission

The essential questions in our study are whether and how the moral hazard problems at bank level affect monetary policy transmission to the volume of lending, and how the response to monetary policy depends on bank liability structure, given the moral hazard problems. In answer to this question in terms of our model, let us apply the implicit function theorem to equilibrium condition (3.28) so as to calculate the elasticity of the monopoly bank's loan supply with respect to the monetary policy interest rate:

$$\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m - \frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}. \tag{3.29}$$

This result contains two major results of our model. First, comparing (3.29) with the benchmark result in (3.18) and noting that the term $\frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}$ in (3.29) is always positive leads us to the following proposition:

Proposition 1. *The moral hazard problems of a monopoly bank with a limited amount of capital always weaken the transmission of monetary policy to bank lending.*

Whenever the bank's amount of capital is positive, but does not exceed the volume of lending chosen by the bank in the equilibrium, the amount of capital is considered limited from the viewpoint of monetary policy transmission. In such a case, if there is a change in monetary policy (R changes), the bank behaviour is also affected by the change in the amount of external debt needed to fund lending. Note, however, that there is a regime shift in the exceptional case where the fixed amount of bank capital is equal to the volume of lending ($\frac{K}{L} = 1$). If monetary policy is eased at this point (R decreases), L increases and the amount of bank capital is limited. On the contrary, if monetary policy is tightened (R increases), the amount of bank capital becomes unlimited in the equilibrium as L falls below K. Such a regime shift also implies a discontinuity in monetary policy transmission at the point $\frac{K}{L} = 1$. By (3.29), $\frac{dL}{dR}\frac{R}{L} = \frac{1}{2m-\frac{1}{2}}$ when $\frac{K}{L} = 1$ and the amount of bank capital is limited while (3.18) shows that $\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m}$ when the amount of bank capital is unlimited.

Second, (3.29) shows that the sensitivity of intermediary bank lending to monetary policy depends on the bank's capital-loans ratio, leading us to the following proposition:

Proposition 2. *In the case of a monopoly bank with a limited amount of capital, an increase in the capital-loans ratio ($\frac{K}{L}$) always weakens the transmission of monetary policy to bank lending.*

In terms of equation (3.29), Proposition 2 says that as $\frac{K}{L}$ increases, the absolute value of $\frac{dL}{dR}\frac{R}{L}$ decreases, meaning that the response of bank lending to monetary policy decreases. This can be proven by treating $\frac{K}{L}$ as a parameter in $\frac{dL}{dR}\frac{R}{L}$ and then taking the respective partial derivative. As shown in appendix 2, this derivative is positive, implying Proposition 2.

Note that the capital-loans ratio $\frac{K}{L}$ in Proposition 2 is endogenous, since the volume of lending L is determined in the model. Thus, a change in $\frac{K}{L}$ is due to a shock in some exogenous variable. Note, first, that changes in monetary policy already affect its further impact on lending. For example, an increase in R, via its effect on L, increases $\frac{K}{L}$ and reduces thus the further effects of monetary policy. The most interesting question concerns, however, the effects of a change in the exogenous amount of bank capital K on the capital-loans ratio. Using equilibrium condition (3.28) yields

$$\frac{d\left(\frac{K}{L}\right)}{dK} = \left[\frac{-4m\left[(1-4m)+(1+4m)\frac{K}{L}\right]}{(1-4m)\left[(1+4m)\frac{K}{L}-4m\right]L}\right]. \tag{3.30}$$

Since the derivative in (3.30) is always positive, given our assumptions about m, an increase in the amount of bank capital always increases the bank's capital-loans ratio, ceteris paribus. Thus, on the basis of Proposition 2, an increase in bank capital, ceteris paribus, always weakens monetary policy transmission. In addition to R and K, a change in monitoring costs (μ) also affects the capital-loans ratio and monetary policy transmission. As will be discussed in appendix 3, an increase in monitoring costs reduces the volume of lending and thus increases the capital-loans ratio. Consequently, an increase in monitoring costs affects monetary policy transmission in the same way as an increase in bank capital.

Propositions 1 and 2 give interesting insights into the effects of bank moral hazard on monetary policy transmission, but it is also important to understand why restrictions imposed on the amount of bank capital and the subsequent moral hazard problems affect the transmission mechanism. It turns out that moral hazard problems change the way monetary policy affects the bank's monitoring behaviour. Monitoring behaviour is then reflected in the response of lending to monetary policy. In fact, the volume of lending and the intensity of monitoring are substitutes for each other as tools for banks to accommodate monetary policy shocks. From (3.27) and (3.17) we clearly see that if R changes, the monopoly bank – irrespective of the restrictions on capital – either has to adjust its volume of lending (so as to affect $G(L)$) or the intensity of monitoring. Thus, the link between the volume of lending and the intensity of monitoring, and the link between the intensity of monitoring and monetary policy actually influence the link between the volume of lending and monetary policy, ie monetary policy transmission.

To get a better picture of the role of monitoring in the effects of moral hazard problems on monetary policy transmission, we next review the effects of monetary policy and the volume of lending on the intensity of monitoring. Monetary policy has two opposing effects on the intensity of monitoring. First, monetary policy has a direct effect on monitoring intensity whenever the bank capital is limited. This direct effect can be derived from the first order condition (3.20):

$$\theta_R = \frac{\frac{1}{\theta}\left(1 - \frac{K}{L}\right)}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}. \tag{3.31}$$

The partial derivative in (3.31) is clearly non-positive as the denominator is negative in the equilibrium (by (3.25)) and the capital-loans ratio does not exceed unity. Whenever $\frac{K}{L} < 1$, θ_R is strictly negative. Thus, monetary policy tightening has an adverse direct effect on monitoring, while a fall in the monetary policy rate increases the intensity of monitoring. Now, as long as the bank's moral hazard problems keep the intensity of monitoring below the first-best level, an increase in monitoring also increases the expected return on marginal lending relative to the expected costs of marginal lending and hence the incentive for further lending. Formally, this can be seen eg in equilibrium condition (3.27). Therefore, the direct effect of monetary policy on monitoring strengthens the change in the relation between expected return on marginal lending and the expected costs of marginal lending. In equilibrium, the partial elasticity of monitoring with respect to R is

$$\theta_R \frac{R}{\theta} = \frac{\left(1 - \frac{K}{L}\right)}{2\left(\frac{4m}{1+4m} - \frac{K}{L}\right)} \tag{3.32}$$

The elasticity of monitoring with respect to monetary policy turns out to be decreasing in absolute value of the capital-loans ratio. In other words, the use of additional external funds reinforces the effects of monetary policy on the bank's monitoring incentive. This is because the effect of a change in R on the amount the bank has to pay back to investors if it remains solvent increases in the amount of bank's external debts. Therefore, the value of not going bankrupt, due eg to an increase in R, diminishes more if $\frac{K}{L}$ is small. This also means that the incentive to monitor borrowers in order to avoid bankruptcy decreases. If the bank is funded mainly with its own capital, monetary policy does not have the same impact on monitoring incentives, since the relative value of avoiding bankruptcy does not change that much. In fact, the observed variation in the direct impact of monetary policy on monitoring appears to be the crucial factor explaining heterogeneity in the response to monetary policy shocks across banks with different capital structures.

Second, monetary policy indirectly affects monitoring through its impact on lending[18]. A change in the volume of lending has the opposite effect on the bank's incentive to monitor in subperiod 2 (as seen in (3.22)). In part, this happens because a change in the volume of lending (and investment) is reflected in the returns on successful projects and thus in the efforts of borrowers. This effect, already present in the benchmark case, appears to be due to the possibility of substitution as regards borrower's incentives between bank monitoring and return on investment. When the amount of bank capital is fixed below the equilibrium volume of lending, a change in the volume of lending has an additional impact on the incentive to monitor since it changes the share of capital in the bank's liabilities, either mitigating or aggravating the bank's moral hazard

[18] Monetary policy does not affect monitoring incentives through the lending interest rate H in our model because the lending rate does not impact monitoring in equilibrium, as seen from (3.21) and (3.26).

problems with respect to external funding. Thus the effects of a monetary policy shock are weakened, since the lending response leads to the opposite effect on monitoring intensity, which then dampens the original monetary policy effect on the relation between marginal return and costs of lending. More specifically, when the bank reduces lending due to a tightening of monetary policy, the positive impact of loan reduction on monitoring reduces the size of the necessary adjustment to lending. The implied higher intensity of monitoring raises the expected return to lending relative to expected costs and hence the power of monetary policy is reduced. In equilibrium, the partial elasticity of monitoring with respect to lending turns out to be constant whenever the bank's own capital is constrained (by inserting (3.25) into (3.22)):

$$\theta_L \frac{L}{\theta} = -\frac{1}{2}. \tag{3.33}$$

Thus, in percentage terms, the bank's monitoring response to changes in its lending is not affected by the liability structure of the bank. With our assumption as to m, the elasticity of θ with respect to L is higher than that in the benchmark case (where the elasticity $\theta_L \frac{L}{\theta} = 2m$). In equilibrium, the indirect effect of monetary policy on monitoring intensity naturally also depends on the link between lending and monetary policy. Combining the link between monitoring and lending in (3.33) and the link between lending and monetary policy in (3.29) yields the indirect effect through lending (in percentage terms):

$$\theta_L \frac{dL}{dR} \frac{R}{\theta} = -\frac{1}{2} \frac{1}{4m - \frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}. \tag{3.34}$$

Combining the two opposite effects from (3.32) and (3.34)[19,20] gives us the total effect of monetary policy on the intensity of monitoring:

$$\frac{d\theta}{dR}\frac{R}{\theta} = \theta_R \frac{R}{\theta} + \theta_L \frac{dL}{dR}\frac{R}{\theta} = \left(1 - 2m \frac{dL}{dR}\frac{R}{L}\right) \tag{3.35}$$

Even though the effects are in opposite directions, the indirect one turns out to be so strong that the total effect of monetary policy

[19] See footnote 18.

[20] The same total effect can also be obtained from (3.27).

on monitoring intensity is always positive and even stronger than in the benchmark case, where the total effect of monetary policy on monitoring is $\frac{d\theta}{dR}\frac{R}{\theta}=\frac{1}{2}$. Thus, as the bank substitutes adjustment through monitoring intensity for adjustment through the volume of lending, the impact of monetary policy on lending by a bank with limited capital is smaller than that on lending by a bank with abundant capital.

It appears that both the direct and the indirect effects of monetary policy on the intensity of monitoring tend to weaken as the capital-loans ratio increases. However, the direct negative effect appears to decline more in absolute value in the capital-loans ratio $\frac{K}{L}$ than does the positive indirect effect. Therefore, the aggregate effect of monetary policy on monitoring intensity increases in the capital-loans ratio. As we have noticed that the bank considers monitoring and lending alternatives in accommodating monetary policy shocks, it is consistent that we see in (3.29) that the effect of monetary policy on lending decreases in the capital-loans ratio.

Finally, the model allows us to derive a result parallel to that in (3.29) concerning the transmission of monetary policy interest rate to the bank lending rate. From condition (3.26) and the definition of m, we conclude that the loan volume elasticity of the lending rate is constant in our model, ie $\frac{dH}{dL}\frac{L}{H}=m$. Combining this result with (3.29) reveals how the securities market rate passes through to the lending rates in elasticity terms:

$$\frac{dH}{dR}\frac{R}{H}=m\frac{dL}{dR}\frac{R}{L}=\frac{m}{4m-\frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}. \tag{3.36}$$

Comparing this result to the benchmark case (where $\frac{dH}{dR}\frac{R}{H}=\frac{1}{4}$), we see that changes in the monetary policy interest rate are transmitted to the bank lending rate less now that the bank acts as an intermediary.

3.4.4 Other results from comparative statics

Our model also allows for a rich analysis of the effects of the amount of bank capital and monitoring costs on the volume of lending, on the intensity of monitoring as well as on monetary policy transmission. From the monetary policy transmission point of view, the most interesting results are that an increase in the limited amount of bank capital or in monitoring costs leads to an increase in the capital-loans ratio ($\frac{K}{L}$) as pointed out above. It is also important to notice that the model actually implies that an increase (decline) in the amount of bank capital increases (decreases) the volume of lending. In this respect, the model seems consistent eg with Holmstrom and Tirole (1997) where monetary policy works through its impact on the amount of bank capital. A more comprehensive review of these comparative statics results is relegated to appendix 3.

3.5 Competitive loan market

Let us now turn to a competitive version of our model where the banks face a perfectly competitive loan market in subperiod 1. In the model, a perfectly competitive loan market refers to a situation where there is an unlimited number of potential bankers who are able to freely enter and exit the loan market. However, they may face an exogenous opportunity cost in entering the loan market (entry cost). The banks that are active in the loan market take the aggregate volume of lending L as given since, if a bank reduces its volume of lending, there will be new entrants that replace this loan supply. Therefore, the banks also take the return of successful projects $G(L)$ as given and independent of their own decisions on loan supply.

Nevertheless, the banks are free to make decisions on their own loan portfolios to maximise their expected profit. Thus each bank maximises its expected profit with respect to the lending interest rate H, and the volume of its own lending l (as distinct from the volume of aggregate lending L) in subperiod 1, and with respect to the intensity of monitoring θ in subperiod 2. In equilibrium, there are n banks active in the loan market, so that the aggregate lending is simply $L = nl$.

It is important to note that the banks do not take the lending interest rate H as given in the loan market. This is due to the fact that the demand for loans stays above the supply at the chosen level of lending rate because of the moral hazard problems at firm level. As we will see below, even without the moral hazard problems at bank level, a bank will be active only if $G(L) > H$. However, in the analysis of the firm effort in section 3.3 we concluded from (3.3) that $G(L) > H$ implies that there are marginal borrowers willing to borrow so as to increase the aggregate amount of lending L by at least an infinitesimal amount. Therefore, any bank could change the lending rate from H, at least marginally, without changing the demand for bank loans. Thus, credit rationing occurs.

In contrast to the monopoly case, the competitive loan market case enables us to introduce the benchmark case without bank moral hazard and the case where banks may suffer from moral hazard problems within a single version of the model. This is because if there are no entry costs to the competitive loan market, there will always be so many banks in the loan market that every bank lends only its own capital, irrespective of the monetary policy stance. Thus, in contrast to the monopoly case, monetary policy is not able to cause a regime shift from the bank moral hazard regime to the one without bank moral hazard problems.

The benchmark case refers to a situation where the entry cost to the loan market is zero, so that a sufficient number of banks enter the loan market to avoid use of external debt and ensuing moral hazard problems. The banks fund their lending by their own capital only in the benchmark case, and the volume of lending is not disturbed by the costs of bank moral hazard. Otherwise, the number of banks entering the loan market is limited by a positive entry cost, so that the active banks find it optimal to act as intermediaries, borrowing external funds from the debt securities market. In this competitive framework, the benchmark case closely resembles securities market lending where lenders also invest only their own capital.

As above, we solve the model using backward induction, starting from the monitoring decisions in subperiod 2.

3.5.1 Monitoring decisions

While the banks face competition in subperiod 1, we assume that there is no competition in subperiod 2 when the banks monitor those borrowers with whom they have loan contracts. The borrowers then respond to the bank's decision on monitoring intensity and on the lending rate set in subperiod 1 by choosing their efforts according to condition (3.2) just as in the case of a monopoly bank.

If there is a positive entry cost to the loan market, an active bank will find it optimal to acquire funds from the debt securities market in addition to the amount k of capital[21] allocated to each bank. In such a case, the distribution of banks' funding sources also affects their intensity of monitoring. As in the monopoly case, the securities market rate for bank debts is B, which includes a risk premium for the uncertainty involved in the banks' lending portfolio. Therefore, each individual bank chooses the monitoring intensity θ in subperiod 2 so as to maximise

$$E\pi_b^c = \theta\left(G(L) - H\right)Hl - \theta\left(G(L) - H\right)B(l-k) - Rk - \mu\theta^2 l. \quad (3.37)$$

This implies a first-order condition that resembles the corresponding condition in the monopoly case:

$$\left(G(L) - H\right)\left[Hl - B\left(l - k\right)\right] - 2\mu\theta l = 0. \quad (3.38)$$

If there is an entry cost and active banks fund their lending by external debt, (3.38) implies that an individual bank's volume of lending has an impact on its monitoring intensity. Note that the impact is different from the monopoly case, as the volume of lending by an individual bank does not affect the aggregate volume of lending L. In the benchmark case, where the entry cost is zero, the volume of lending of an individual bank equals the amount of its own capital (anticipating further results). In such a case, the intensity of monitoring does not depend on l (or k).

[21] The determination of k will be further discussed in the context of subperiod 1 below.

3.5.2 Loan and securities market decisions

In subperiod 1, there is an unlimited number of potential banks that can enter the loan market, each with a fixed amount of capital, k[22]. If a potential bank decides to enter the loan market, all its own capital will be used in lending to firms. Alternatively, if the bank decides to stay out of the loan market, its own capital will be invested in the debt securities market. Thus the aggregate amount of banks' own capital employed in the loan market K also depends on the number of banks active in the loan market n:

$$K = nk. \tag{3.39}$$

Let us first examine how the decisions in subperiod 2 are reflected in the behaviour of a single bank in subperiod 1. In making its loan market decisions each bank takes into account the influence of these decisions and the aggregate volume of lending on monitoring in subperiod 2. The debt securities market is perfectly competitive as before, and the investors with perfect foresight rationally anticipate the choices of borrowers (p) and banks (θ) in subperiod 2 and require a nominal rate B that is higher than the risk-free rate R, according to (3.19), so as to compensate the risk involved. Therefore, as the bank looks at the first-order condition for θ in subperiod 1, it inserts (3.19) into (3.38). Hence each bank uses the following condition in subperiod 1 to evaluate the partial effects of its decisions and exogenous shocks

[22] Alternatively, we could assume that the aggregate amount of bank capital, K, is fixed and distributed among the active banks in the economy. Thus the amount of capital available to an individual bank, as well as the number of banks, would be endogenously determined in the model. To keep the analysis tractable, this approach would require us to assume that own capital is evenly distributed among the active banks, which are therefore identical. This approach could be interpreted as a case with a pool of potential bankers who collaborate in various combinations to establish banks depending on the equilibrium outcome. The assumption would also imply that all the capital available to the potential bankers is actually employed in the loan market.

While the alternative assumption might be appropriate when we think of a group of well defined potential bankers that could form different types of banks, the prevailing assumption gives us a more plausible way to compare bank lending with the benchmark case, where banks lend only their own capital and do not intermediate the funds of other investors.

on its monitoring decision in subperiod 2 and how they are reflected in its profits:

$$(G(L) - H)\, H - \frac{R}{\theta}\left(1 - \frac{k}{l}\right) - 2\mu\theta = 0. \tag{3.40}$$

From the viewpoint of subperiod 1, equation (3.40) implicitly defines the intensity of monitoring as a function of the bank's decision variables for that subperiod, H and l, as well as the exogenous variables, denoted by O. Thus $\theta = \theta(H, l; O)$ and (3.40) allows us to derive the necessary partial derivatives of θ with respect to H and l. First, the effect of H on θ in the competitive environment is similar to the monopoly case:

$$\theta_H = \frac{-\left(G(L) - 2H\right)}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}. \tag{3.41}$$

Note that in equilibrium the lending interest rate does not have any marginal effect on the intensity of monitoring. The effect of l on θ is slightly different from the monopoly case, as each bank considers only how a change in the volume of its own lending affects its funding costs but understands that its volume of lending does not affect aggregate lending:

$$\theta_l = \frac{\frac{Rk}{\theta l^2}}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}. \tag{3.42}$$

In its optimization problem in subperiod 1, an individual bank chooses the lending rate H and the volume of lending l, taking into account the partial effect of H and l on the intensity of monitoring expressed in (3.41) and (3.42). Moreover, the interest rate on securities market debt is not yet fixed, and B from (3.19) is inserted into (3.37) before maximization:

$$\max_{H,l} \theta(H, l; O)\left(G(L) - H\right) Hl - Rl - \mu\left(\theta(H, l; O)\right)^2 l. \tag{3.43}$$

First, rearranging the first-order condition with respect to l yields[23]

$$\theta^2 = \frac{R\left(1 + \frac{k}{l}\right)}{2\mu}. \tag{3.44}$$

[23] See appendix 1 for second-order conditions and derivation of first-order conditions.

On the other hand, the first-order condition with respect to lending rate H is

$$-\frac{2\mu\theta l\left[G(L)-2H\right]}{\frac{R}{\theta^2}\left(1-\frac{k}{l}\right)-2\mu}=0, \qquad (3.45)$$

where the only solution consistent with our assumptions (μ, θ, l positive) and (3.44) is similar to the monopoly case:

$$H=\frac{G(L)}{2}. \qquad (3.46)$$

Recalling (3.3), equation (3.46) says that – because of moral hazard problems at firm level – a credit rationing solution emerges again, implying that loan demand in the equilibrium exceeds the aggregate volume of lending chosen by the banking sector. In this respect, the outcome is similar to that for a monopoly bank.

Next, we need to introduce a zero-profit condition for a bank's entry into the loan market. The condition sets the expected profits of each individual bank equal to the monetary equivalence of an exogenous entry cost U for entering the market. In the benchmark case, $U=0$; otherwise, the entry cost is positive. A potential bank will compare the expected profits (excl. any profits from investing the bank's own capital in a risk-free option) from entering the loan market as a bank to the benefits from not entering the loan market. As the number of banks in the loan market is large, we may ignore integer problems, and the entry condition is obtained by setting the expected profits in (3.37) equal to the exogenous entry cost and rearranging:

$$\theta(H,l;O)\left(G(L)-H\right)H-R-\mu\left(\theta(H,l;O)\right)^2-\frac{U}{l}=0. \qquad (3.47)$$

Since the returns to successful projects are decreasing in the amount of aggregate investments (and lending), (3.47) determines the upper limit to the volume of lending, given the intensity of monitoring and the optimal volume of lending of an individual bank determined by the first-order conditions of individual banks in subperiods 1 and 2.

Combining (3.47) with the condition for the banks in subperiod 2 considered from the perspective of subperiod 1, (3.40), and rearranging gives $\theta^2=\frac{Rk+U}{\mu l}$. Further, equating this to (3.44) leads to a condition for the volume of lending by an individual bank in terms of exogenous variables:

$$R(l-k)-2U=0. \qquad (3.48)$$

According to (3.48), the extent to which an individual bank intermediates external funds to the borrowers is increasing in the entry cost. Once the entry cost increases, the banks require higher income from entering the loan market. Since the banks are competitive and taking the optimal lending rate as effectively given, a higher volume of lending is required, even though the banks also respond to their volume of lending in choosing the intensity of monitoring.

If the entry cost is zero, an individual bank's volume of lending is limited to the amount of capital available to it, and we are in the benchmark situation. In such a case, there are enough banks to provide capital-based lending without bank moral hazard costs to the extent allowed by the firm-level moral hazard problems. Note that monetary policy does not affect the volume of lending by an individual bank under such circumstances. The conclusion from (3.48) is that for financial intermediation there must be a positive entry cost in order for the banks to be capable of monitoring borrowers.

To characterize the equilibrium for the loan market in the aggregate, we still need to establish another condition to determine the number of active banks in the loan market, given the volume of lending by an individual bank. This condition can be derived by inserting the first-order conditions (3.44) and (3.46) together with the equality $L = nl$ into condition (3.40) and rearranging:

$$\frac{\left(1 + \frac{k}{l}\right)}{2} \frac{\left(G(nl)\right)^4}{64\mu} - R = 0. \tag{3.49}$$

Conditions (3.48), and (3.49) now determine the equilibrium of the model with two endogenous variables, l and n, the product of which simply determines the aggregate volume of lending, L. With L available, (3.46) gives the equilibrium outcome for the lending rate H.

3.5.3 Monetary policy transmission

With the equilibrium conditions (3.48), and (3.49) at hand, we are able to proceed to examine the effects of monetary policy on bank lending in the competitive equilibrium with potential moral hazard problems at bank level. Deriving results for monetary policy transmission, we need to consider monetary policy effects on both the volume of lending of an individual bank, l, and the number of active banks, n. Taking total differentials of the equilibrium equations with respect to the monetary policy variable, R, yields

$$\begin{pmatrix} R & 0 \\ \left[4m\left(1+\frac{k}{l}\right)-\frac{k}{l}\right]\frac{R}{l\left(1+\frac{k}{l}\right)} & \frac{4mR}{n} \end{pmatrix} \begin{pmatrix} \frac{dl}{dR} \\ \frac{dn}{dR} \end{pmatrix} = \begin{pmatrix} -(l-k) \\ 1 \end{pmatrix} \tag{3.50}$$

The system of equations in (3.50) can be employed to calculate the elasticities of the endogenous variables with respect to R. First, the impact of monetary policy on the amount of lending of an individual bank is

$$\frac{dl}{dR}\frac{R}{l} = -\left(1-\frac{k}{l}\right). \tag{3.51}$$

Thus an increase (decrease) in the monetary policy interest rate always has a non-positive (non-negative) effect on the volume of lending of an individual bank, given that the banks intermediate a positive amount of external funds to the borrowers in the loan market. In the benchmark case, monetary policy does not change the volume of lending of an individual bank.

On the other hand, the effect of monetary policy on the number of active banks in the loan market is

$$\frac{dn}{dR}\frac{R}{n} = \left(1-\frac{k}{l}\right) + \frac{1}{4m}\frac{1+\left(\frac{k}{l}\right)^2}{1+\frac{k}{l}} \tag{3.52}$$

As before, a monetary policy contraction has a negative effect on the number of banks even though this cannot be clearly seen in (3.52).[24] As the opportunity cost of funding increases, the number of banks that find it profitable to stay in the loan market decreases.

Together, the responses of lending by individual banks active in the loan market and the number of banks that react to a monetary policy shock by entering or exiting the loan market determine the aggregate response of lending to monetary policy. Using the

[24] The elasticity in (3.52) can be rearranged to $\frac{dn}{dR}\frac{R}{n} = \frac{1+4m+\left(\frac{k}{l}\right)^2(1-4m)}{4m\left(1+\frac{k}{l}\right)}$, which is clearly negative, given that $0 > m > -\frac{1}{4}$.

elasticities derived above, and noting that aggregate lending is simply $L = nl$, we can express the elasticity of the volume of aggregate lending with respect to monetary policy as

$$\frac{dL}{dR}\frac{R}{L} = \left(n\frac{dl}{dR} + l\frac{dn}{dR}\right)\frac{R}{L} = \frac{1}{4m}\frac{1+\left(\frac{k}{l}\right)^2}{\left(1+\frac{k}{l}\right)}. \qquad (3.53)$$

The result in (3.53) contains the major outcome of the competitive version of the model with respect to monetary policy transmission and gives rise to the following proposition:

Proposition 3. *The moral hazard problems of competitive banks with a limited amount of capital always weaken the transmission of monetary policy to aggregate bank lending.*

Proposition 3 comes from (3.53), by comparing the elasticity measure in the benchmark case (where $\frac{k}{l} = 1$) with the elasticity measure in the moral hazard case (where $0 < \frac{k}{l} < 1$). It always gets a higher absolute value in the benchmark case. Proposition 3 clearly reinforces Proposition 1 concerning a monopoly bank. Thus the basic message as to the weaker response of the banking sector to monetary policy due to moral hazard considerations is robust to market structure.

Moreover, (3.53) also determines how the sensitivity of aggregate lending to monetary policy is linked to banks' capital-loan ratios, resulting in the following proposition:

Proposition 4. *In the case of competitive banks with a limited amount of capital, an increase in the capital-loans ratio ($\frac{k}{l}$) weakens the transmission of monetary policy to aggregate bank lending up to a critical capital-loans ratio, $\left(\frac{k}{l}\right)^*$, where the transmission is weakest. An increase in the capital-loans ratio above $\left(\frac{k}{l}\right)^*$ strengthens the transmission of monetary policy to aggregate bank lending.*

In contrast to the results for a monopoly bank, the strength of monetary policy does not increase here monotonically with the capital-loans ratio. The critical ratio can be obtained from (3.53) by letting $\lambda(u) = \frac{dL}{dR}\frac{R}{L}$ with $u = \frac{k}{l}$. Then maximising $\lambda(u)$ yields the corresponding argument u^* that is also $\left(\frac{k}{l}\right)^*$. By this exercise, the critical capital-loans ratio appears to be $\left(\frac{k}{l}\right)^* = -1 + \sqrt{2} \approx 0.41$.

It must be remembered, again, that the capital-loans ratio in Proposition 4 is endogenous and its changes are due to shocks in some exogenous variable. Note that a change in monetary policy affects the volume of lending and thus the capital-loans ratio, so that an increase in R increases $\frac{k}{l}$ and reduces further effects of monetary policy. As regards the effects of bank capital, using the equilibrium conditions (3.48) and (3.49) yields $\frac{d\left(\frac{k}{l}\right)}{dk} = \frac{1}{l}\left(1 - \frac{k}{l}\right)$ (see appendix 3 for further discussion). This means that an increase in bank capital always increases the capital-loans ratio. Thus, an increase in bank capital affects monetary policy transmission according to Proposition 4, depending on the level of the capital-loans ratio. As regards other exogenous variables possibly affecting the capital-loans ratio and monetary policy transmission, see appendix 3.

Note that Propositions 3 and 4 deal with the transmission of monetary policy to aggregate lending. As (3.51) states, the monetary policy effects at the level of individual banks are more straightforward and partly opposite to the effects at the aggregate level. From the empirical point of view it is interesting to notice that (3.51) predicts that an increase (decrease) in $\frac{k}{l}$ weakens (strengthens) monetary policy effects at bank level.

To better understand the results in Propositions 3 and 4 on the influence of moral hazard problems on the monetary policy transmission in competition, we analyse how they affect the impact of monetary policy on the intensity of monitoring. By analogy to the monopoly version of the model, the (aggregate) volume of lending and the intensity of monitoring are substitutes for each other, as the loan market must be adjusted to monetary policy. Combining (3.40) and (3.44) yields $\theta = \frac{8R}{(G(L))^2}$, which resembles (3.27) in the monopoly case, except for the lack of consideration of aggregate effects. This condition clearly says that if R increases, either θ has to increase, L has to decrease, or both. Therefore, to understand the link from R to L we have to take into account both the link from R to θ and the links from L to θ. Both the aggregate volume of lending and the volumes of lending of individual banks have effects on the intensity of monitoring, and the strength of both of these links also affects the monetary transmission process.

Without moral hazard problems, monetary policy would affect the intensity of monitoring only through its effect on the aggregate volume of lending. In fact, the equilibrium value of the elasticity of monitoring intensity with respect to monetary policy would remain constantly at half that in the benchmark case. If the bank has moral hazard problems, monetary policy still affects monitoring through aggregate lending, but it also works through other channels. Monetary policy has a direct incentive effect on monitoring, as well as an indirect channel via the volume of lending chosen by each individual bank. In the following, we will take a deeper look at these channels from monetary policy to monitoring.

First, moral hazard problems create a link between monitoring intensity and the volume of lending of an individual bank. Monitoring intensity varies with the volume of lending according to (3.42). For instance, as the bank responds to a monetary contraction by reducing the amount of loans in subperiod 1, it also knows that it will intensify monitoring efforts in subperiod 2. Using (3.44) in (3.42), we obtain

$$\theta_l \frac{l}{\theta} = -\frac{1}{2}. \tag{3.54}$$

The link between the intensity of monitoring and the volume of individual bank's lending is independent of the liability structure of the banks. Thus eg, if a bank reduces its own lending in subperiod 1, it will also increase its monitoring intensity in subperiod 2. This mitigates the original need for cutting back loans in equilibrium. The influence of the link expressed in (3.54) also depends on the way monetary policy is transmitted to the loan market, ie whether monetary policy acts more through the number of active banks in the loan market or through the volume of lending of an individual bank. Combining (3.54) with (3.51) we get the partial effect of monetary policy on the intensity of monitoring through the volume of lending of an individual bank in equilibrium:

$$\theta_l \frac{dl}{dR} \frac{R}{\theta} = \frac{1}{2} \left(1 - \frac{k}{l} \right). \tag{3.55}$$

The higher the banks' capital-loans ratio, the weaker the effect of monetary policy on monitoring via the volume of lending by individual banks and, accordingly, the less significant the link between θ and l.

Second, monetary policy also affects the intensity of monitoring chosen by an individual bank in subperiod 2 through its impact on the aggregate volume of lending in subperiod 1. Therefore, the link between θ and L is of interest to monetary policy transmission. From (3.40), this effect appears to be $\theta_L = \frac{-mH\frac{G(L)}{L}}{\frac{R}{\theta^2}\left(1-\frac{k}{l}\right)-2\mu}$. In equilibrium, the partial elasticity of monitoring with respect to L is thus (using equilibrium conditions (3.40), (3.44) and (3.46) to simplify)

$$\theta_L \frac{L}{\theta} = \frac{2m}{\frac{k}{l}}. \tag{3.56}$$

The strength of this link is inversely related to the capital-loans ratio, but its importance in the transmission process also depends on the effect of monetary policy on the aggregate volume of lending. Combining (3.56) and (3.53) gives the partial equilibrium effect of monetary policy on the intensity of monitoring through the volume of aggregate lending:

$$\theta_L \frac{dL}{dR} \frac{R}{\theta} = \frac{1}{2} \frac{1 + \left(\frac{k}{l}\right)^2}{\frac{k}{l} + \left(\frac{k}{l}\right)^2}. \tag{3.57}$$

While the effect of monetary policy on monitoring through aggregate lending decreases in the capital-loans ratio, its decline is slower than that of the effect through the volume of lending by individual banks. In fact, as $\frac{k}{l}$ approaches one, this link becomes the dominant one and determines the effect of monetary policy on monitoring. At $\frac{k}{l} = 1$, the partial elasticity of monitoring with respect to R through the volume of aggregate lending is $\frac{1}{2}$.

Finally, monetary policy has a direct effect on the intensity of monitoring. This effect can be derived from the condition for monitoring (3.40):

$$\theta_R = \frac{\frac{1}{\theta}\left(1 - \frac{k}{l}\right)}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}. \tag{3.58}$$

In the equilibrium, the elasticity of monitoring with respect to R, making use of equilibrium condition (3.44), is

$$\theta_R \frac{R}{\theta} = -\frac{\left(1 - \frac{k}{l}\right)}{2\frac{k}{l}}. \tag{3.59}$$

As in the monopoly case, the monetary policy interest rate has a direct adverse effect on the intensity of monitoring. This incentive effect is created because a rise in the risk-free securities market rate increases the costs incurred by a bank if the projects it has financed are successful, given that it has obtained some funding from the debt securities market. On the contrary, a rise in R does not raise the bank's costs attached to securities market funding in a failure of the projects (implying a default of the bank). So, a rise in R reduces the relative value of successful projects and thus the benefits from monitoring. The larger the share of external debts in the banks' liabilities, the stronger the direct adverse effect of monetary policy on monitoring.

It appears that, when the capital-loans ratio increases, the direct effect of R on θ weakens at a higher rate than its positive effect via aggregate lending. However, as the positive effect of R on θ through individual lending decisions also weakens as the capital-loans ratio increases, there appears to be a unique value of the capital-loans ratio that produces a maximum response to monetary policy through an adjustment in monitoring. Combining the different channels from (3.55), (3.59) and (3.57) gives the total effect of monetary policy on the intensity of monitoring in elasticity terms[25]:

$$\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1}{2}\left(1 + \frac{\frac{k}{l}\left(1 - \frac{k}{l}\right)}{1 + \frac{k}{l}}\right). \tag{3.60}$$

The response of banks to monetary policy through an adjustment in monitoring reaches its maximum when $\frac{k}{l} = \left(\frac{k}{l}\right)^*$, ie at the same ratio where the response of the banking system to monetary policy through an adjustment in the aggregate lending is at its minimum, as argued in Proposition 4. In symmetry with the effects on lending, (3.60) also reveals that the elasticity of θ with respect to R increases in the capital-loans ratio when $\frac{k}{l} < \left(\frac{k}{l}\right)^*$ and decreases in the capital-loans ratio when $\frac{k}{l} > \left(\frac{k}{l}\right)^*$.

Moreover, (3.60) reveals that the elasticity of monitoring with respect to monetary policy reaches its minimum in the benchmark case ($\frac{k}{l} = 1$). This means that a banking sector with moral hazard problems responds to monetary policy more through adjusting the intensity of monitoring and less through adjusting the volume of lending than a banking sector without moral hazard constraints.

From condition (3.46), we can conclude that the loan volume elasticity of the lending rate is constant in our model, ie $\frac{dH}{dL}\frac{L}{H} = m$.

[25] Note that, as in the monopoly case, $\theta_H = 0$ in the equilibrium, and therefore the effects of monetary policy on the monitoring intensity are not transmitted through the lending interest rate.

The relationship between the lending interest rate and the volume of aggregate lending is identical to the monopoly case, since the features of the borrower sector have not changed in spite of the change in the structure of banking sector. Combining the preceding result with (3.53) reminds us that the monetary policy pass-through to the lending rates also depends on the banks' liability structure, as $\frac{dH}{dR}\frac{R}{H} = \frac{1}{4}\frac{1+\left(\frac{k}{l}\right)^2}{\left(1+\frac{k}{l}\right)}$.

The competitive structure of the loan market introduced in this section also helps to characterise both bank and market lending, and draw comparisons about the monetary policy transmission between the two forms of lending. As an example of pure bank lending, we look at the case where the banks act as intermediaries and lend funds borrowed from the debt securities market to borrowers in the loan market ($\frac{k}{l} < 1$). Intermediation actually requires that $U > 0$, ie the active banks expect some profits (net of risk-free returns) from their loan market activities, or there are some (at least implicit) costs of entering the information-intensive loan market. On the other hand, market lending can be characterised by the benchmark case ($\frac{k}{l} = 1$) where the banks do not intermediate funds and expect no extra profits to compensate for entry costs ($U = 0$).

From equations (3.53) and (3.60), we can see that the market lenders (defined as those using only their own capital) respond to monetary policy through an adjustment in lending to a greater extent than intermediary banks. Correspondingly, intermediary banks respond to monetary policy more through an adjustment in the intensity of monitoring than as market lenders. In contrast to the literature on the bank lending channel of monetary transmission, our model suggests that bank lending responds less to monetary policy than direct market lending does, because banks are better able to respond to monetary policy shocks by changing their intensity of monitoring.

3.5.4 Other results from comparative statics

In addition to the results directly concerning monetary policy transmission, the competitive version of the model makes it possible to analyse the effects of monitoring costs, entry cost and bank capital.

While a more comprehensive examination of these comparative statics results can be found in appendix 3, let us point out some of the key issues.

The unit cost of monitoring does not change the capital-loans ratio of a single bank, but affects only the number of banks active in the loan market. Thus it has no effects on monetary policy transmission. In contrast, changes in the entry cost do have an impact on the volume of lending of an individual bank. An increase in the entry cost raises the volume of lending of an individual bank. Thus it forces banks to fund lending by external debt and a decline in the capital-loans ratio and subsequently changes also monetary policy transmission. In spite of this effect, an increase in entry cost reduces the number of active banks so much that its impact on aggregate volume of lending is negative.

Finally, a change in the amount of capital of individual banks has a positive effect on the volume of lending of an individual bank. A subsequent change in the capital-loans ratio is also seen in the transmission of monetary policy. The effect of a change in a single bank's own capital is negative on the number of active banks, but the overall effect on the aggregate volume of lending is positive, except for the benchmark case where changes in bank capital do not affect the aggregate volume of lending.

3.6 Comparison of loan market structures

In two previous sections we presented interesting results concerning monetary policy transmission in two loan market structures where banks may face moral hazard problems. The basic insights about the effects of moral hazard on monetary transmission point more or less in the same direction irrespective of market structure. In this section, we attempt to extend the comparisons between results for the two market structures when banks suffer from moral hazard problems in both cases. In addition to contrasting equilibrium outcomes of the model in the two market structures, we sketch some comparisons between bank lending reactions to monetary policy. However, one should interpret the comparisons with caution since other elements than bank competition may affect the model outcomes.

As the aggregate amount of banks' own capital is determined endogenously in the competitive loan market, we cannot compare the cases simply by setting all the exogenous variables equal across them. Instead, let us consider equilibria in the two market structures when the capital-loans ratios for the banks are equal, ie $\left(\frac{k}{l}\right)_{comp} = \left(\frac{K}{L}\right)_{mon}$ (where subindex *comp* refers to competition and subindex *mon* to monopoly), given that the other exogenous variables are equal. First, the aggregate volume of lending in equilibrium appears to be higher in competition. This can be seen by letting the capital-loans ratios be equal (ie $a \equiv \left(\frac{k}{l}\right)_{comp} \equiv \left(\frac{K}{L}\right)_{mon}$) and then combining (3.28) and (3.49). This yields the result that $\left(G\left(L_{mon}\right)\right)^4 > \left(G\left(L_{comp}\right)\right)^4$, which implies that $L_{comp} > L_{mon}$.

On the other hand, when the capital-loans ratios are equal, the intensity of monitoring appears to be higher in the monopoly loan market (ie $\theta_{comp} < \theta_{mon}$). This can be seen by keeping again the capital-loans ratios equal and combining conditions (3.20) and (3.40). Rearranging this, and using $L_{comp} > L_{mon}$ yields the requirement that $(\theta_{mon} - \theta_{comp})\left(R\left(1-a\right) - 2\mu\theta_{mon}\theta_{comp}\right) < 0$. As we also know that in both market structures $R\left(1-a\right) - 2\mu\theta^2 < 0$, the result is evident. So, given the capital-loans ratio, the monopoly bank monitors its borrowers at a higher intensity than the competitive banks under the corresponding conditions. This is apparently due to the decreasing returns to scale in investments that lead to a lower value of successful projects in the competitive loan market.

As regards monetary policy transmission, we cannot make unambiguous comparisons between market structures, given equal equilibrium capital-loans ratios. Depending on parameter values, the response of bank lending to monetary policy may be stronger either in competition or in monopoly. As a rough simplification though, we can say that with low values of m (approaching $-\frac{1}{4}$) monetary policy appears to be stronger in competition, and with high values of m (approaching zero) monetary policy appears to be stronger in monopoly.

Another comparison is possible if we let the equilibrium volume of lending be equal in the two market structures, ie $L_{comp} = L_{mon}$. First, the aggregate amount of required bank capital is lower in competition, ie $K_{comp} < K_{mon}$, which also means that $\left(\frac{k}{l}\right)_{comp} < \left(\frac{K}{L}\right)_{mon}$. This result is obtained by setting the aggregate lending volumes equal and combining (3.49) and (3.28), which gives the capital-loans ratio of the monopoly bank in terms of the capital-loans ratio of the corresponding competitive bank[26]

$$\left(\frac{K}{L}\right)_{mon} = \left[\left(\frac{k}{l}\right)_{comp} + 16m^2\right] / (1 + 4m)^2 . \tag{3.61}$$

This implies that moral hazard problems limit the use of external debt for funding bank lending less if the loan market is competitive.

In contrast, however, the lower capital-loans ratio in competition is negatively reflected in the intensity of monitoring, as we can show that $\theta_{comp} < \theta_{mon}$ if there is no difference in the aggregate volumes of lending. By combining (3.20) and (3.40) with $L_{comp} = L_{mon}$, and rearranging, we obtain $\theta_{mon} = \frac{A}{B}\theta_{comp}$, where $A \equiv R\left(1 - \left(\frac{K}{L}\right)_{mon}\right) - 2\mu\theta_{mon}\theta_{comp}$ and $B \equiv R\left(1 - \left(\frac{k}{l}\right)_{comp}\right) - 2\mu\theta_{mon}\theta_{comp}$. Now, we know that at least either $A < 0$ or $B < 0$ holds in equilibrium since we know that $R\left(1 - \left(\frac{K}{L}\right)_x\right) - 2\mu\theta_x^2 < 0$ holds in equilibrium for both $x = mon, comp$. Further, condition $\theta_{mon} = \frac{A}{B}\theta_{comp}$ requires that if one of A or B is negative, the other is negative as well, because we assume that both θ_{mon} and θ_{comp} are positive in equilibrium. As we also have $\left(\frac{k}{l}\right)_{comp} < \left(\frac{K}{L}\right)_{mon}$, we are able to conclude that $B > A$, or $|A| > |B|$, which implies the result $\theta_{comp} < \theta_{mon}$. That is, the adverse effects of moral hazards problems are more strongly experienced on the intensity of monitoring in the competitive loan market.

Finally, as regards monetary policy effects, a comparison between the two market structures with equal aggregate volumes of lending shows that, in the aggregate, competitive banks respond to monetary policy more strongly than the monopoly bank. To show this we need to prove that inequality $\frac{dL}{dR}\frac{R}{L}_{mon} > \frac{dL}{dR}\frac{R}{L}_{comp}$ holds where the former is determined by (3.29) and the latter by (3.53). Employing (3.61) and rearranging yields the desired outcome.

The comparisons between the loan market structures in the two special cases are highly tentative. However, they suggest that the competitive loan market structure leads to a lower need for capital

[26] This condition also implies that – to keep both $\left(\frac{K}{L}\right)_{mon}$ and $\left(\frac{k}{l}\right)_{comp}$ between 0 and 1 – we need to have $\left(\frac{k}{l}\right)_{comp} < 1 + 8m$ and $\left(\frac{K}{L}\right)_{mon} > \frac{16m^2}{1+8m+16m^2}$. Thus, to have feasible capital-loans ratios, we have to make a more limiting assumption about m than before, namely $-\frac{1}{8} < m < 0$.

in the banking sector. On the other hand, this is reflected in the intensity of monitoring, which is found to be higher in a monopoly market. As regards monetary policy transmission, the results are not decisive even though at the same aggregate volume of lending competitive banks seem to be more responsive to monetary policy.

3.7 Discussion of main results

The major aim of our model is to understand how monetary policy is transmitted to bank lending, and how the moral hazard problems at the bank level affect this transmission process. Consistent with traditional work on monetary policy transmission, the general prediction of the model is that tighter monetary policy – defined as a higher risk-free refinancing rate for banks – leads to lower volumes of bank lending. Our model provides a large set of results, but we focus on the most relevant ones from the viewpoint of monetary policy transmission. For more results, see summary tables A.1 and A.2 in appendix 4.

In contrast to the previous literature on monetary policy transmission, the banks' choice of intensity of monitoring their borrowers' actions is endogenous in the model. Due to endogenous and costly monitoring, banks who borrow external debt face moral hazard problems while lenders that rely solely on their own capital (a benchmark case) avoid such problems. Endogenous monitoring appears to affect the transmission of monetary policy to the volume of bank lending since it intertwines monitoring, lending and monetary policy through different links if banks fund their lending by external debt. (1) First, an increase (decrease) in the volume of lending[27] tends to decrease (increase) the intensity of monitoring more than in the benchmark case because of the moral hazard problems that are aggravated as the share of external funding in the bank balance sheet increases, given the amount of bank capital. (2) Second, contractionary (expansionary) monetary policy has a direct negative (positive) impact on monitoring intensity because, as such, it decreases (increases) the value of success in relation to default

[27] In the case of the competitive loan market, this holds true for both the volume of lending of an individual bank and the volume of aggregate lending.

from the banks' viewpoint. (3) Third, an increase (decrease) in the intensity of monitoring increases (decreases) the expected benefits of further lending in relation to the expected costs of further lending, as the intensity of monitoring is still below the optimal level due to banks' moral hazard problems.

Together, the combined influence of links (1) (indirect effect due to a monetary policy impact on lending) and (2) (direct effect) above is that eg a tightening of monetary policy always increases banks' monitoring intensity more than in the benchmark case. This means – because of link (3) above – that lending based on intermediation actually responds less to monetary policy than lending based on banks' own capital. As a matter of fact, banks respond to monetary policy in two different ways in our model. For example, after a contractionary monetary policy shock, they both reduce the volume of lending and increase the intensity of monitoring their borrowers. Because of the moral hazard problems, the intermediary banks respond more through adjusting the intensity of monitoring, and hence less through adjusting their volume of lending, compared to nonintermediary benchmark lenders (as put forward in Propositions 1 and 3).

Especially in the case of competitive loan market structure, it is straightforward to interpret the benchmark lenders in our model as market investors with sufficient monitoring skills. As reviewed in chapter 2, the traditional literature on the bank lending channel suggests that monetary policy is transmitted to investments more strongly through intermediary banks than through market investors. So, our model is in this respect in stark contrast to the bank lending channel of monetary policy.

On the other hand, our model also suggests that the strength of intermediary banks' lending response to monetary policy depends on their endogenous capital-loans ratio. In the monopoly loan market, an increase in the capital-loans ratio of the monopoly bank always weakens its response in lending to monetary policy (Proposition 2). Correspondingly, an increase in the capital-loans ratio strengthens the response of the bank's monitoring intensity to monetary policy. For example, the use of external funding makes a negative contribution to the bank's incentives to increase its monitoring intensity due to a monetary contraction (ie a rise in R) because the impact of the contraction on the relative value of solvency is lower if the bank relies relatively heavily on external funding. Consequently, as the bank with a relatively high share of external funding increases the intensity of monitoring after a rise in R relatively little, it reduces the volume of lending by a relatively large amount. This is because a small increase in monitoring intensity is reflected in the bank's funding costs only marginally, compared to the original rise in R.

In the competitive loan market, up to a certain critical capital-loans ratio, the effect of monetary policy on aggregate bank lending weakens (in percentage terms) as the capital-loans ratio increases, as in the case of a monopoly bank. Thereafter, the monetary policy effect begins to strengthen as the capital-loans ratio increases (Proposition 4). The non-monotonic variations in the competitive loan market are due to the complex links between the intensity of monitoring and the aggregate volume of lending. However, at the level of an individual bank, the monetary policy effect is linearly decreasing in the capital-loans ratio.

In the region of low capital-loans ratios, the model unambiguously predicts that a higher capital-loans ratio means a weaker impact of monetary policy. Interestingly, the literature on the bank lending channel points in the same direction in this respect, suggesting that well-capitalised banks do not respond as much to monetary policy, as they have better access to securities market finance. As reviewed in chapter 2, a growing empirical literature has also found support for this relationship between monetary policy effects and banks' liability structure. This empirical starting point establishes good grounds for our empirical analysis in chapter 4.

As regards the comparison between loan market structures with respect to monetary policy effects, we have not been able to find any fundamental differences. Although the examples presented in the previous section refer to quantitative differences and possibly to a higher response to monetary policy in a competitive market, it may be too early to suggest moral hazard considerations as an explanation for the differences observed between monetary policy effects in various market structures.

Finally, another outcome of greater relevance in our model is that the moral hazard problems of the banks regarding their decisions on monitoring intensity imply an endogenous capital-loans ratio

($\frac{K}{L}$ or $\frac{k}{l}$)[28]. This means that, ceteris paribus, the amount of capital determines the volume of lending for each bank. In this respect, our model follows the outcome of Holmstrom and Tirole (1997). The endogenous capital-loans ratio depends on the exogenous variables through their impact on the volume of lending. It should also be noted that an endogenous capital-loans ratio also implies the possibility of procyclical effects of the moral hazard problems. For instance, the amount of bank capital available is likely to decrease in worsening business conditions, which would further reduce the potential for lending.

[28] The existence of an endogenous capital-loans ratio implies that banks do not face any binding regulatory capital requirements. If these were in place, the outcome of the model would be different, also with respect to monetary policy effects.

4 Empirical evidence

In this part of the study, we take a tentative look at the outcome of the theoretical model in the light of empirical evidence, using a panel data set covering banks active in the Finnish loan market in 1995–2000. In the model we have established two main results of genuine interest concerning transmission of monetary policy, and our interest would be in testing these results. Unfortunately, one of the major results, put forward in Propositions 1 and 3 in chapter 3, stating that the existence of moral hazard problems weakens monetary policy effects, remains without clear empirical implications and quite difficult to formulate for empirical testing. The other main result concerning the relationship of banks' liability structure and their response to monetary policy is suitable for empirical test on the basis of bank-level data. Even though Propositions 2 and 4 are not completely consistent on monetary policy effects at the aggregate level, the effects on the lending of individual banks are unambigously decreasing in the capital-loans ratio. Therefore, we focus on the examination of the empirical relevance of this implication in the empirical part of the study. In addition to two major results mentioned above, the theoretical model generates several others that are more conventional in nature. We also incorporate some of the implications of these results along with some external controls in our empirical framework in order to support the main thrust of the analysis. Our data set does enable us to examine the response of banks to monetary policy and capital changes and to analyse how the responses to monetary policy vary with the banks' liability structure, controlling demand factors via aggregate measures.

The existing empirical research on the transmission of monetary policy through the bank lending channel could already offer us some tentative evidence on the relevance of the implications of our theoretical model. In a number of studies (see especially Kishan and Opiela 2000, Ehrmann et al 2001, and references therein, and, for the Finnish case, Topi and Vilmunen 2001), the capital-loans ratio or capital-assets ratio has been used as a proxy for the banks' access to securities market funding. In fact, those empirical results for the bank lending channel seem to be consistent with the implications of our model, as they indicate that less capitalised banks respond more strongly to monetary policy. Thus, in this respect, our model provides an alternative theoretical explanation for the bank heterogeneity observed in monetary policy transmission.

However, from the perspective of our model, the recent empirical research also leaves room for further work as it does not explicitly account for the linear effects of the banks' own capital shocks on bank lending. This point is especially relevant as we consider the relationship between this study and Topi and Vilmunen (2001) which employs the same data set to produce evidence of the role of banks in monetary transmission, approaching the issue from the viewpoint of the bank lending channel. As such, their results are consistent with the present model as regards the effect of banks' liability structure on monetary policy effectiveness. However, the capital measure enters their empirical specification only as a bank characteristic, without any clear interpretation of its role in determining the volume of lending. Specifically, the capital measure in Topi and Vilmunen is the level of each bank's capital-assets ratio, even though the specification is otherwise in first differences. Thus, even though the level of the capital-assets ratio obtains a positive coefficient estimate, it only suggests that a well capitalised bank enjoys a higher growth rate of lending than a poorly capitalised bank. However, this is not what the theoretical model says. Therefore, we find it necessary to refine the empirical specification in the manner discussed below to test the implication of our theoretical model by allowing for a distinct interpretation of the role of banks' own capital.

The theoretical model only gives the volume of lending as an implicit function of monetary policy and banks' own capital levels as well as other bank characteristics and loan demand factors. Therefore, a reduced form loan equation needs to be derived for the empirical work, on the basis of the results obtained from the comparative statics of the theoretical model. Our main interest lies in testing the implication of the model that banks' lending response to monetary policy varies with the their liability structure. To this end, we incorporate in the model, first, an interaction term between monetary policy and capital. However, to properly catch the second-order effects, we also need to take into account the respective linear effects.

In addition to monetary policy and bank capital, the reduced form equation has to incorporate the loan demand faced by the banks in the loan market. Ideally, we should control for bank-specific loan demand factors, but the lack of appropriate data at the level of individual banks forces us to rely on aggregate demand measures. In the reduced form equation, we also have to take into account that the influence of monetary policy is generally conceived to be of a dynamic nature. Our theoretical model does not offer guidance as to the dynamic structure of the empirical equation. Therefore, we rely on empirical experiments and standard tests of significance in choosing the exact dynamic specification.

In the following, we first set the backdrop for the empirical work by taking a brief look at some of the developments in the Finnish economy and financial markets. Then, we discuss the choice of the exact specifications of empirical equations to be estimated, and review the available data set and the required empirical method. Thereafter, we present the estimation results and finally discuss their relevance and implications.

4.1 Developments in the economy and financial markets in Finland: Background for the empirical work

Our data set for the empirical work covers the banks operating in Finland during the years 1995–2000. In comparison with the troubled years in the Finnish economy prior to it, this period was characterised by quite favourable and stable economic conditions. However, some questions and problems appearing in the empirical work may be due to the special nature of the data period in the aftermath of the deepest crisis in the economy and financial markets in decades.

Indeed, the period 1995–2000 was preceded by a boom-bust period from the late 1980s to mid-1990s. During the late 1980s both the economy and bank lending were booming, and reinforcing each other. Among other things, financial market deregulation and liberalisation of capital movements in the mid-1980s as well as rapid increases in financial and real asset prices, but also ineffective macroeconomic policies, have been cited as factors behind the overheated lending boom (see eg Koskenkylä 2000).

The turn of economic developments began in the very late 1980s when monetary policy was tightened at the mature stage of the expansion, and a little later when the Finnish economy was hit by large external shocks. As a result, interest rates rose and pressure on the Finnish markka increased, leading to a substantial devaluation of the markka in November 1991, and to a decision to allow it to float in September 1992. The markka depreciated so that by the spring of 1993 it had lost some 40% of its value prior to the devaluation in November 1991. In the same time, during the years 1991–1993, aggregate output losses amounted to approximately 13% while the aggregate unemployment rate skyrocketed from about 4% in 1991 to 20% in 1993. The turn of the developments was also reflected in asset values, as stock prices fell by two-thirds and housing prices halved.

In the financial markets, a severe banking crisis set in in the early 1990s. It has been suggested that the main reason behind the crisis was the unprecedented supply-shift induced lending boom[29], followed by a deterioration in macroeconomic conditions and a loss of international confidence reflected in the currency crisis. Developments in asset prices, particularly housing prices, also may have contributed to the banking crisis. Debt service problems mounted as an increasing share of banks' outstanding credit became non-performing while the number of bankruptcies multiplied. In the years 1992–1994, banks' loan losses amounted on average to 5.2% of total lending. The banking crisis as well as the collapse of the economy were also clearly reflected in bank lending, as the ratio of loans to nominal GDP dropped by over 30% from the end-1992 to end-1995. During the banking crisis, Finnish banks faced growing liquidity and solvency problems. A major commercial bank – which was also the central financial institution of the savings banks – in effect failed in 1991 and was taken over by the central bank and later sold to the government, and most of the remaining savings bank sector was taken over by the government in 1992. Other major banks in Finland also had to rely on some sort of direct public support.

[29] Recent theories of financial and banking crises have emphasised the role of lending booms in financial collapses (see eg Gourinchas et al 2001). The underlying idea in these theories is that since leverage increases and loans are extended to ever riskier projects, banking sector exposure and vulnerability increases as does the likelihood of a banking crisis.

In addition to capital support, the banking crisis prompted the authorities to take a number of measures so as to prevent a further credit crunch or other severe disturbance in the banking market. Such measures (discussed eg by Koskenkylä 2000, and Nyberg and Vihriälä 1994) lasted in part past the actual crisis period and may have had a considerable influence on the loan market in Finland by changing the banks' lending incentives. In particular, Parliament took a decision in favour of a state guarantee of banks' contractual commitments in early 1993. This resolution was in effect until December 1998, when it was rescinded. It might be expected that this kind of back-up for banks' funding would have made a positive contribution to bank lending.

After the severe economic recession and banking crisis in the early 1990s, the mid and late 1990s was characteristically a period of recovery for the economy on the whole and for the banking sector in particular. At the aggregate level, the economic growth was strong quite throughout the latter part of 1990s (see figure 4.1). At the same time, Finland's macroeconomic environment changed considerably as the country joined the EU in 1995 and the third stage of the Economic and Monetary Union in 1999. In the loan market, the growth was not as smooth in the late 1990s as lending growth remained quite slow until 1998, after which a drastic surge occurred, especially as regards business loans.

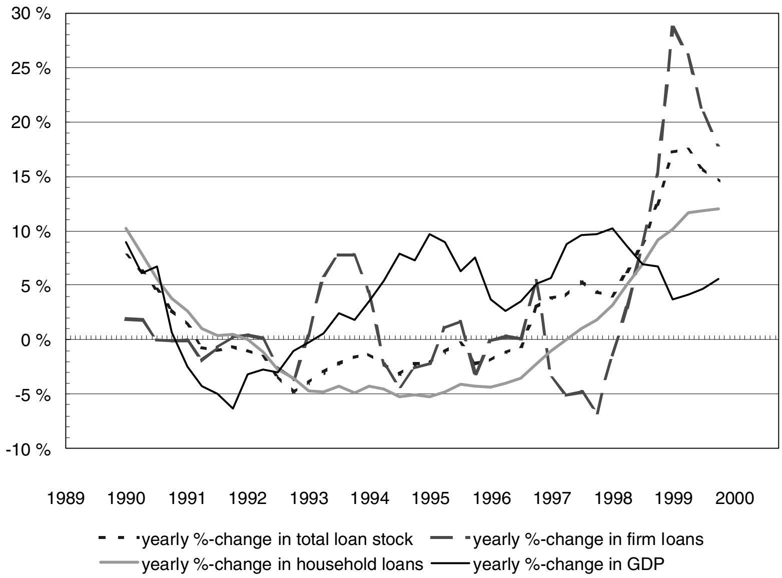

Figure 4.1 Yearly percentage changes in GDP and lending stocks in Finland, 1990–2000

One of the noteworthy developments concerning the Finnish banking sector in the latter part of the 1990s was the general upward trend in banks' own capital relative to the amount of total assets. In fact, we can see in figure 4.2 that both the mean and median of the capital-assets ratio almost doubled from the start of 1995 to the end of 2000. Though the increase in the capital-assets ratio continued over the entire period, the growth was particularly rapid in 1996–1997. The strong accumulation of bank capital may have been at least in part a response to imbalances in the capital-assets ratios of the Finnish banks due to a shrinking capital in the context of the banking crisis.

With respect to our theoretical model on bank lending, there are at least two interesting aspects of the developments of the Finnish banking markets that should be noted in the specification of the empirical equation. Special measures of the government to prevent disturbances in the financial markets continued until 1998, thereby having a possible effect on banks' behaviour that cannot be addressed in our simplified framework. On the other hand, the upward trend in the capital-assets ratio in the mid-1990s may reflect an adjustment to certain imbalances that may have been exacerbated by capital losses during the banking crisis in the early 1990s. It is therefore possible that this trend cannot be explained in terms of our static equilibrium model, and needs to be separately accounted for in the empirical work.

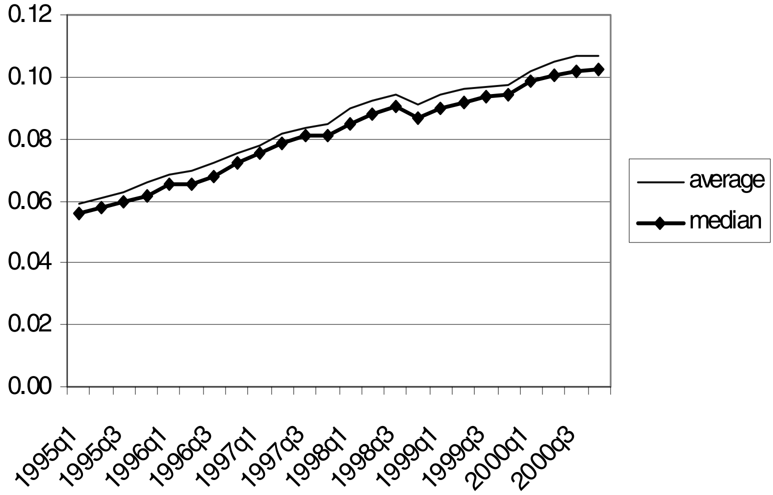

Figure 4.2 Capital per assets in the data sample, 1995–2000

4.2 Data description

The micro-level data set used in this study covers the Finnish banking sector during the years 1995–2000. The data set consists of quarterly observations and is collected from the banks' balance sheet reports to the Finnish Financial Supervision Authority. In principle, the data set covers all the banks active in the Finnish market. However, some of the banks are excluded from our data sample altogether due to reporting shortages. Our basic sample consists of 350 banks with up to 24 quarterly observations. However, because of data shortages, outlier exclusion and variable transformations, the number of observations to be used in the reported estimations is 5415. The aggregate data set employed in the estimations is collected from the database of the Bank of Finland. Consistent with the micro-level data set, it comprises quarterly observations and covers the years 1995–2000.

Table 4.1 (a) presents the yearly descriptive statistics for the estimation sample of the relevant bank-level variables. Observations are excluded from the sample as outliers in case of loans and capital if their first difference is below the 1st percentile or above the 99th percentile of the distributions of these variables for the whole sample. The estimation sample statistics indicate the extensive heterogeneity of the Finnish banking sector in their lending and capital. The capital-assets ratio is more uniform but shows some variation as well. The capital-assets ratios in the estimation sample show the same upward trend discussed above in the context of financial market developments. Table 4.1 (b) offers descriptive statistics for the macro level variables, which include the real GDP (Y), GDP deflator (D), monetary policy interest rate (tender) and 3-month money market rate (mmr).

Yearly descriptive statistics on bank-level data						
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Observations	328	327	327	325	325	316
Loans						
Mean	127 781	121 737	146 843	163 595	178 285	162 110
Median	21 203	22 132	22 195	23 504	25 735	27 658
Max	23 550 647	22 313 706	22 195 902	24 949 840	26 228 131	28 755 218
Min	651	608	584	537	431	1 425
Std. Dev.	1 304 854	1 237 353	1 304 290	1 476 771	1 545 289	1 622 849
Capital						
Mean	12 511	13 194	17 138	16 686	18 980	16 498
Median	2 233	2 657	3 091	3 334	3 622	4 117
Max	2 089 559	2 265 587	2 655 970	2 220 765	2 592 578	2 736 123
Min	102	101	104	106	105	263
Std. Dev.	118 060	127 325	152 949	133 666	154 685	154 068
Capital-assets ratio						
Mean	0.0668	0.0766	0.0855	0.0888	0.0937	0.1014
Median	0.0630	0.0742	0.0813	0.0856	0.0929	0.1021
Max	0.1382	0.1562	0.1724	0.1639	0.1705	0.1724
Min	0.0321	0.0316	0.0318	0.0326	0.0351	0.0374
Std. Dev.	0.0208	0.0264	0.0306	0.0302	0.0327	0.0330

Note:
Observations refer to the number of banks with loans included in the estimation sample.
End-of-the-year observations
Loans and capital in thousand euros.

Table 4.1 (a)

Descriptive statistics on aggregate variables				
	Y	D	tender	mmr
Mean	26910.58	103.25	0.0372	0.0392
Median	26938.16	103.20	0.0333	0.0357
Max	31869.93	110.21	0.0600	0.0605
Min	23118.10	97.96	0.0250	0.0263
Std. Dev.	2515.27	3.25	0.0102	0.0102
Note: Quarterly real GDP (Y) in million euros				

Table 4.1 (b)

Pairwise correlations between linear variables						
	Y	D	tender	mmr	loans	capital
D	0.89842					
tender	-0.42989	-0.26455				
mmr	-0.32143	-0.15911	0.98664			
loans	0.02033	0.01887	-0.01061	-0.00817		
capital	0.02494	0.02289	-0.01390	-0.01061	0.99138	
capital-assets ratio	0.36007	0.33900	-0.19758	-0.15372	-0.09218	-0.07725

Table 4.2

Table 4.2 shows the pairwise correlations among the linear variables used in the estimations. In addition, to better understand the loan market developments, we also include the capital variable in the correlation table. One would expect that the aggregate variables would show quite low correlation with bank-level variables, as the former involve only time variation. Instead, we notice an almost perfect correlation between capital and loans. Among macro variables, the real GDP and GDP deflator are highly positively correlated and show a relatively high negative correlation to interest rate variables. The two interest rate measures are also highly correlated.

4.3 Specification of empirical equation

Our theoretical model does not provide us with an explicit loan equation to test against the data. Therefore, we form a reduced form empirical equation for lending, making use of the results of the theoretical model. To begin with, a proxy for monetary policy and a measure for the bank's own capital are included in the reduced form equation. Thereafter, we are ready to add a second order approximation for the interaction between monetary policy and bank capital to test whether the effects of monetary policy weaken when the bank capital rises, as our model suggests. The reduced form equation also has to control for loan demand, only implicitly present in the theoretical framework.

As regards the influence of monetary policy – or the risk-free securities market interest rate in the theoretical model – on bank lending, the theoretical model anticipates a negative effect, ie that an increase in the interest rate would decrease the volume of lending, and vice versa. This is also the common presumption in the prior empirical literature. Therefore, we expect a negative coefficient estimate for the interest rate variable in the loan equation. As to banks' own capital, the theoretical model predicts a positive effect of an increase in capital on its volume of lending, and vice versa. Thus, we anticipate a positive coefficient estimate for the capital proxy in the loan equation.

As regards the cross term between monetary policy and bank's own capital, the theoretical model suggests that a higher level of capital, and hence a higher capital-loans ratio, mitigates the effects of monetary policy on a monopoly bank's behaviour, irrespective of the direction of the effect. As to the competitive loan market, the model also suggests that a higher level of bank capital mitigates the monetary policy effect on the volume of lending of individual banks. At the aggregate level, the effect of bank capital on monetary policy transmission would be reversed, according to the model, if the banks' capital-loans ratios exceeded a certain threshold level. In any case, as our empirical equation attempts to explain loan growth at the level of individual banks, we expect to find a positive parameter estimate for the second order term, which accounts for the change in the monetary policy effect on loan growth due to a change in bank capital.

The theoretical model would also allow us to include the effect of the cost of monitoring in the reduced form lending equation. However, due to lack of appropriate proxies in our database, the costs of monitoring are omitted from the empirical equation. Possible proxies for monitoring costs in future work could be eg branch density and personnel costs used by Hyytinen and Toivanen (2000).

Loan demand is represented in the theoretical model only by the implicit loan demand function $G(L)$ that expresses the returns of firm sector projects as a function of the aggregate number of projects undertaken. The model with the monopoly bank implies that an increase in G, with given L, would increase the volume of lending in equilibrium. For the competitive loan market, the model suggests that an increase in G, with given L, would lead to a rise in the aggregate volume of lending and number of active banks, but the volume of lending of an individual bank would not be affected by loan demand. In spite of this difference in the results, we allow for the effects of loan demand in the reduced form loan supply equation for individual banks, anticipating a positive effect of demand factors on lending.

Next, to find the final reduced form equation for estimation with the available data, we have to impose some assumptions on the functional structure of the loan equation as well as on the exact form of the variables to be employed. In general, the theoretical model does not suggest any specific functional form for the linear effects of monetary policy, banks' own capital, or loan demand factors. However, since we also let the effects of monetary policy depend on bank capital, it seems convenient to introduce the effect of the monetary policy interest rate on the volume of lending in elasticity terms, ie in logarithms. In this way, we are able to capture the effect of bank capital on the monetary policy transmission measured in elasticity terms, as required by the theoretical model. Therefore, as a starting point, we adopt a log-linear specification for the loan equation but do not require that all the variables enter in the log-linear form if the statistical significance suggests an alternative specification.

In order to avoid problems with apparent non-stationarity of the loan stock in the model, we employ a reduced form equation in first differences. That is, both the dependent variable and the first order contributions of the monetary policy and capital variables are differenced in the estimations, as a general rule.

The static nature of the theoretical model gives us little guidance as to the dynamic structure of the empirical equation. As it seems unlikely that the loan market instantly converges to an equilibrium, we have to impose some ad hoc dynamics to the structure of the reduced form equation. To allow for a dynamic structure for our empirical work, we employ an autoregressive distributed lag equation for which the exact dynamic form, ie four lags is chosen purely in accord with the statistical significance of the empirical results. That is, following much of the empirical work on monetary policy transmission (see eg Ehrmann et al 2001) we assume some persistence in the growth rate of lending.

While we have essentially all the elements to convey the story of the theoretical model, we still have to be more precise, especially as regards the proxies for capital and monetary policy, as well as the control variables for loan demand. In particular, bank's own capital in our theoretical model refers to the amount that is available to the bank for lending at each period. If we merely use (the logarithm of) the capital variable, we fail to measure how the banks' own capital level develops in relation to their loans and other assets. For instance, if a bank's own capital level falls in relation to its total assets, this actually means an effective negative capital shock, and a subsequent negative contribution to the volume of lending is possible according to the model, even if the amount of capital grows in absolute terms. As seen in table 4.2, the levels of bank capital and loans are extremely highly correlated in our sample. However, the high level of correlation does not necessarily reflect direct causality between capital and loan. Instead, we argue that it tells us about different background factors, eg general business conditions and economic growth, that change both variables. In our view, high correlation actually means that real changes in the effective amount of bank capital have been very rare. It must also be noted that while we model only bank loan growth, other bank assets may also affect the need for capital if they can cause moral hazard problems. Therefore, we prefer to normalise the amount of bank capital by the total amount of assets. Thus, our proxy for capital is the ratio of reported capital stock to total assets $\left(\frac{K}{A}\right)$, where K is the capital stock and A the total assets of the bank in question. Even though this variable may also reflect developments other than in the amount of capital, we think it is the most suitable one for the present purposes. In table 4.2 we notice that the capital-assets ratio has a small negative correlation with loans. However, this may simply reflect the complex nature of the relationships between the variables, which the contemporary pairwise correlations are not able to catch. On the basis of statistical reasoning, we include the capital proxy as a pure ratio, without taking logarithms, thereby departing slightly from the log-linear specification of the reduced form equation. On the other hand, we include the capital proxy as a lagged variable since we can – in terms of the theoretical model – consider the lending market a process where the decisions in each period depend on the amount of bank capital at the beginning of the period.

In order to clarify the interpretation of the estimation results concerning monetary policy transmission, we introduce two transformations for the capital proxy. The first one, $\left(\frac{K}{A}\right)^A$, is simply defined as a deviation of the capital-assets ratio of bank i in period t from the average over all banks and periods:

$$\left(\frac{K}{A}\right)^A_{it} = \frac{K_{it}}{A_{it}} - \frac{\sum_{t=1}^{T}\left(\frac{\sum_{j=1}^{N_t}\frac{K_{jt}}{A_{jt}}}{N_t}\right)}{T}. \tag{4.1}$$

The transformed proxy becomes zero for a bank whenever its capital-assets ratio equals the overall average. The advantage of the transformation is simply that we see the estimated response of such an average bank to monetary policy directly from the parameter estimate of the interest rate variable as such.

In our discussion on developments in the financial markets, we observed a notable upward trend in the mean as well as in the median of the capital-assets ratios of banks in Finland, especially in the years 1996–1997 (see figure 4.2). This observation raises the question whether the trend has been caused by some extraordinary events in the Finnish economy during the century. As implied in the discussion above, the Finnish banks experienced remarkable capital losses due to the banking crisis in the early 1990s, and the amounts of the bank capital were probably at an exceptionally low level still in the middle of the century. Accordingly, the accumulation of banks' own capital in the mid-1990s may have reflected a recovery from the crisis at the same time as the conditions in the banking sector gradually became normalised. It is possible that our model is not well suited for an analysis of the effects of banks' own capital on their loan behaviour in such abnormal circumstances.

To deal with the possible effect of this exceptional trend in the capital-assets ratio during the sample period, we introduce another transformation of the capital proxy, which removes the trend effect. This transformation, $\left(\frac{K}{A}\right)^B$, is defined as a deviation of the capital-assets ratio of bank i in period t from the cross-sectional average in period t:

$$\left(\frac{K}{A}\right)_{it}^{B} = \frac{K_{it}}{A_{it}} - \frac{\sum_{j=1}^{N_t} \frac{K_{jt}}{A_{jt}}}{N_t}. \tag{4.2}$$

The latter transformation of the capital proxy focuses on the cross-sectional variation in the capital-assets ratio and makes it possible to distinguish between its influence on the growth of lending and on the bank-specific response to monetary policy. The transformation $\left(\frac{K}{A}\right)_{it}^{B}$ also has the zero-average feature, as does $\left(\frac{K}{A}\right)^{A}$ (even in each period separately). In estimating the reduced form equation, we employ both transformations as proxies for bank capital.

Next, we need a proxy for monetary policy in the reduced form equation. Our theoretical model suggests the use of a risk-free refinancing interest rate for banks that is also fully determined by the central bank. This would refer to some generic risk-free securities market interest rate as well as to a monetary policy rate determined by the central bank. In fact, we do not have an obviously perfect candidate from real world data for approximating the interest rate suggested by the theoretical framework. Instead, we consider a couple of proxies, both of which have certain weaknesses. Irrespective of the choice for the interest rate measure to be used, we use a net interest rate measure that conveniently approximates the logarithm of the gross interest rate referred to in the theoretical model.

In the first place, we make estimations relying on the appropriate monetary policy rate (Bank of Finland tender rate for 1995–1998 and ECB rate for main refinancing operations for 1999–2000) that fulfils the condition of being determined by the central bank and reflecting to some extent the risk free refinancing rate of banks. One of the potential pitfalls with the monetary policy rate is that its maturity shortened in November 1997 from one month to two weeks, where it has since remained, even after the Bank of Finland tender rate was replaced by the ECB rate for main refinancing operations at the beginning of 1999. To test the robustness of the results, we also try the estimations using a representative 3-month money market rate (3-month HELIBOR for 1995–1998 and 3-month EURIBOR for 1999–2000). In principle, this interest rate measure contains some average risk premium of the banking sector and thus departs from the presumption of a risk-free interest rate. In this respect, the nature of the interest rate series changed in late 1998. Namely, as mentioned above, there was an implicit state guarantee for the Finnish banks' commitments in force until December 1998. Thus, prior to 1999, this supportive government measure may have – to some extent – reduced the risk premium otherwise attached to the money market rate.

As quarterly averages, the two interest rate variables and the shocks to them follow by and large the same path even though their developments differ at some points (see figures 4.3 and 4.4). The securities market rate follows the policy rate quite closely especially in the early years of the sample period. Probably due to changes in the risks the securities market rate reflects, there is a more discernible spread between the two interest rates in the latest years of the sample (figure 4.3). On the other hand, it is notable that in the latter part of the sample period, the changes in the money market rate – as measured in quarterly averages – seem to reflect overreaction to actual monetary policy changes, possibly due to changes in expectations as to further developments in the monetary policy rate. All in all, the processes lying behind the interest rate processes are somewhat different, which may show up as at least minor differences in the respective empirical results.

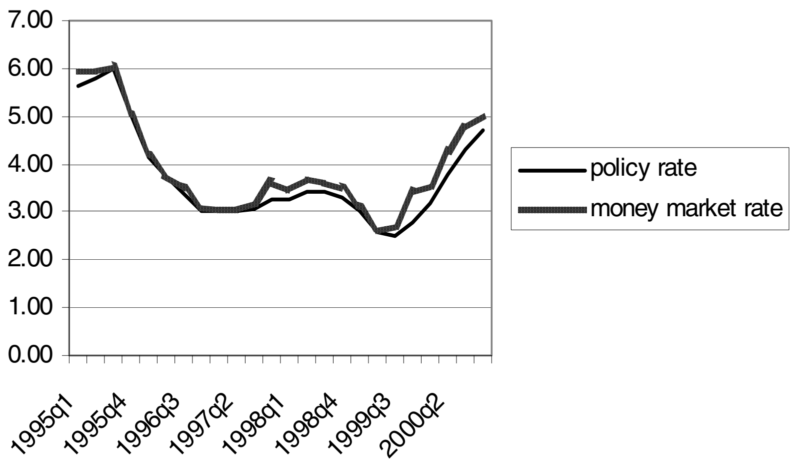

Figure 4.3 Comparison of monetary policy indicators, 1995–2000

We also need to determine the proxy for interaction between banks' own capital and monetary policy. Once again, we could allow for a relatively generous lag structure for this interaction in the model. However, we restrict our attention to possible interaction between the first lag of the capital proxy ($\left(\frac{K}{A}\right)_{it-1}$) and the different lags of the monetary policy proxy (r_{t-j}, $j = 1, ..., 4$). In this way, we are able to substantially limit the number of parameters to be estimated as we think the first lag of the capital proxy can capture the essence of the interaction.

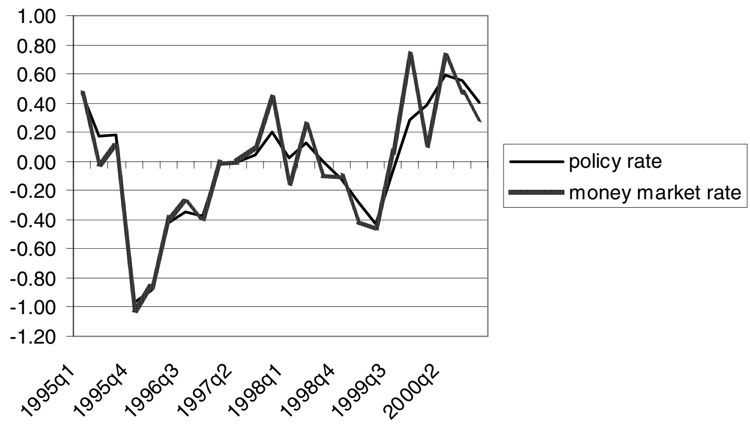

Figure 4.4 Comparison of monetary policy indicator differences, 1995–2000

As the equation is specified in first differences, the interaction terms should in principle be formed as differences of products of the first lag of the capital proxy and each lag of the monetary policy proxy, ie, $\Delta\left(\left(\frac{K}{A}\right)_{it-1} r_{t-j}\right)$ for $j = 1, ..., 4$. Now, this variable can be divided into two parts as $\Delta\left(\left(\frac{K}{A}\right)_{it-1} r_{t-j}\right) = \Delta\left(\frac{K}{A}\right)_{it-1} r_{t-j-1} + \left(\frac{K}{A}\right)_{it-1} \Delta r_{t-j}$. It is obvious that the first part of the variable ($\Delta\left(\frac{K}{A}\right)_{it-1} r_{t-j-1}$) could be highly correlated with the corresponding linear capital proxy ($\Delta\left(\frac{K}{A}\right)_{it-1}$), as the only distinctive factor is the monetary policy proxy without bank-specific variation. For instance, in our data set, using the central bank policy rate, correlation between variables $\Delta\left(\frac{K}{A}\right)_{it-1}$ and $\Delta\left(\frac{K}{A}\right)_{it-1} r_{t-2}$ is 0.963, ie the variables are almost perfectly correlated. The problems due to this feature in the interaction term could cause problems in the estimations, as the linear and interaction term cannot be clearly distinguished. Therefore we exclude the first part of the interaction term, and only include its second part in the empirical equation. The corresponding problem is not as severe concerning the second part of the variable since it ($\left(\frac{K}{A}\right)_{it-1}\Delta r_{t-j}$) differs from the corresponding linear monetary policy proxy (Δr_{t-j}) both in time and cross sectional dimensions. For instance, using again the central bank policy interest rate, correlation between variables Δr_{t-1} and $\left(\frac{K}{A}\right)_{it-1}\Delta r_{t-1}$ is –0.156. The second part of the interaction variable also seems relevant for our purposes as it captures the variation of the monetary policy effects across banks with different capital measures. Since our model implies that banks with a high capital level respond less strongly to monetary policy, we expect that the coefficient estimate of the variable will have a positive sign.

As regards changes in the loan demand factors, we have to rely on aggregate measures since the data set available does not provide us with appropriate time variant demand proxies for individual banks. First, because we should control inflation effects on loan demand, we include the GDP deflator, D, in the reduced form equation. We expect the nominal loan supply to increase in the GDP deflator, as this raises the nominal investment needs of potential borrowers. We could argue that it is the variation in the long-run growth of real credit that our model aims to explain. In that case, we should also observe the long-run elasticity of loan growth with respect to inflation (measured here by difference in GDP deflator) to be near unity. On the other hand, the real GDP, Y, is also used as a control variable to capture any loan demand variation due to changes in real economic activity at aggregate level. The loan volume growth is also expected to increase in real GDP growth since the investment activities of borrowers are likely to increase with general economic activity. Similarly to other explanatory variables, we introduce the GDP deflator, as well as real GDP, as lagged variables, as we do not expect their effect on the loan market to be immediate.

In addition to the variables suggested by theoretical considerations and loan demand factors, we allow for time invariant individual effects η_i in the banks' growth rates of lending. Allowing for the individual effects appears to be necessary for obtaining sensible results for the control variables. The underlying factors behind the individual effects might be interpreted as cost factors of the banks or loan demand effects not explicitly captured by our aggregate loan demand proxies.

Introducing the time invariant individual effects in the growth rates of bank lending naturally raises some doubts about the validity of the specification in our context because of the interpretation of these effects. If we allowed for time invariant individual effects to enter a stationary level regression, they could be interpreted as bank-specific long-run loan levels. However, as the time invariant individual effects appear in the first-differenced model, they have to be associated with differential deterministic trends in the volume of lending. In our context, where we control for the loan demand by real GDP growth and the GDP deflator in the loan growth equation, time invariant individual effects suggest that there are deterministic trends in bank loans relative to nominal GDP. Economic reasoning suggests that in the long run there can be no difference between the loan stock and the nominal GDP trends. Therefore, this feature of the specification calls for particular caution when the results are interpreted.

All in all, we end up with a reduced form empirical equation that takes the following form for bank i in period t:

$$\begin{aligned}\Delta \log L_{it} &= \eta_i + \sum_{j=1}^{4} \beta_j \Delta \log L_{it-j} + \sum_{j=1}^{4} \gamma_j \Delta r_{t-j} \\ &+ \sum_{j=1}^{4} \delta_j \Delta \left(\frac{K}{A}\right)^X_{it-j} + \sum_{j=1}^{4} \phi_j \left(\Delta r_{t-j} \left(\frac{K}{A}\right)^X_{it-1}\right) \\ &+ \sum_{j=1}^{4} \lambda_j \Delta \log D_{t-j} + \sum_{j=1}^{4} \mu_j \Delta \log Y_{t-j} + \nu_{it}\end{aligned} \tag{4.3}$$

where

Δ	is first difference ($\Delta x_t = x_t - x_{t-1}$),
L_{it}	outstanding stock of loans of bank i in period t,
η_i	individual bank effect,
r_t	monetary policy indicator in period t ($r_t = \log R_t$): either the monetary policy interest rate or securities market interest rate, as defined above,
$\left(\frac{K}{A}\right)^X_{it}$	capital proxy variable for bank i in period t: either $\left(\frac{K}{A}\right)^A_{it}$ or $\left(\frac{K}{A}\right)^B_{it}$, as defined above,
A_{it}	total amount of assets of bank i in period t,
D_t	GDP deflator index in period t,
Y_t	real GDP in period t,
ν_{ij}	error term,
β_j, γ_j, δ_j, ϕ_j, λ_j,μ_j	parameters to be estimated for lags $j = 1, 2, 3, 4$.

In addition, we include seasonal dummy variables and a dummy variable for periods prior to 1999, as discussed below.

To sum up the implications of the theoretical model and the analysis on the control variables above, the expected signs of the coefficients in equation (4.3) are listed in table 4.3:

Coefficient	Sign
β	+
γ	-
δ	+
ϕ	+
λ	+
μ	+

Table 4.3

Our primary expectation is that all the individual parameters in our estimations be signed according to table 4.3. However, as the theoretical model imposes no restrictions on the dynamic effects of the explanatory variables on lending, it is possible that, for some exogenous reasons, the effects portrayed by the model come with a (possibly varying) lag. Therefore, perhaps a more relevant, albeit more modest, expectation is that the sums of the parameter over the estimated lags for each variable be signed as anticipated in table 4.3.

4.4 Estimation method

As regards the estimation method, we have to pay attention to the nature of the model specification and data type. As we include the lagged values of the dependent variable as explanatory variables in a panel data model, the usual OLS estimator entails several problems. Therefore, estimation of the empirical equation (4.3) and its variants will be conducted using the generalised method of moments (GMM) estimator proposed by Arellano and Bond (1991)[30] for dynamic panel data models. This estimation method produces efficient and consistent estimates, provided that the instruments are properly chosen to take into account the serial correlation properties of the model. Following Arellano and Bond (1991), we instrument the lagged dependent variables with all the levels of the variable at lag two or more. Moreover we consider the capital proxy a predetermined variable and instrument it with all the levels of the variable at lag one or more. Otherwise, the explanatory variables are treated as exogenous. The problems with the OLS estimator, the characteristics of Arellano-Bond estimator and the associated methodology are reviewed in greater detail in appendix 5.

4.5 Estimation results

In this subsection, we discuss the estimation results in order to test the implications of the theoretical model. In the first place, we focus on the specifications broadly similar to that presented in equation (4.3), using the central bank's policy interest rate as a proxy for monetary policy. As to the proxy for bank capital, we try both transformations of the capital-assets ratio defined above in (4.1) and (4.2). We first use the specification including only the linear contributions of monetary policy and bank capital in (4.3), and then add the interaction term,

[30] See eg Arellano and Bover (1995) and Blundell and Bond (1998) for discussions of this types of estimators.

introducing the possible variation of the monetary policy influence in the capital-assets ratio.

The robustness of the basic results is then checked by replacing the policy interest rate by the securities market interest rate as monetary policy variable. Moreover, we also introduce an alternative specification of the equation where the dependent variable is normalised by its cross-sectional average whereas the aggregate variables (the linear part of the monetary policy proxy and loan demand control variables) are omitted. In fact, this specification corresponds to the one where aggregate variables are simply replaced by time dummies in the estimation. In this specification we do not need to take a position on the choice of aggregate loan demand variables; we focus instead on the cross-sectional variation of loan growth.

To anticipate the empirical outcome, the results concerning the implications of the theoretical model are more or less promising under the various specifications of the empirical model. First, coefficient estimates for the cross term testing the interaction between monetary policy and bank capital are generally of the expected sign, and summing up the estimates invariably show the expected signs. The individual coefficient estimates are not statistically significant. However, we find that when evaluated over time, the aggregate coefficient estimates show some significance. Otherwise, the coefficient estimates of the monetary policy and capital proxies are also as expected. Broadly speaking, the other variables also seem to behave as anticipated.

4.5.1 Basic specifications

We begin with the results reported in table 4.4 for the variants of the equation (4.3) with the central bank's policy interest rate as monetary policy variable. Estimation results are reported for both one-step and two-step GMM Arellano-Bond estimators.

As argued eg by Arellano and Bond (1991) and Blundell and Bond (1998), simulations suggest that the asymptotic standard errors for the two-step estimator may be biased and thus a poor guide for hypothesis testing, particularly when error terms are heteroscedastic. Therefore, we should put emphasis on inference based on standard errors for the one-step estimator. On the other hand, when we consider the validity of instruments, only the Sargan test based on the two-step estimator is heteroscedastic-consistent and should thus be followed.

Table 4.4 gives the results for four variants of the benchmark equation, which differ from each other according to whether the interaction term is included in or excluded from the specification and how the proxy for capital is defined. The central bank policy interest rate has been employed as the monetary policy proxy in all cases. Note that we also included constant and seasonal dummy variables in all the specifications in addition to those indicated in (4.3) but their coefficient estimates are not reported. The constant as well as some of the seasonal dummies showed significance.

We have incorporated our interaction term $\Delta r_{t-j}\left(\frac{K}{A}\right)^{*}_{it-1}$ in specifications (2) and (4) of table 4.4 so as to answer the question whether and how banks' own capital levels affect monetary policy transmission. If we make inferences only on the basis of the individual coefficients of the cross term, we are not able to draw very convincing conclusions about the effect of bank capital on monetary transmission. None of the lagged coefficient estimates becomes significant at traditional levels even though the second lag is marginally significant (p-value of the t-test varies between 0.12 and 0.13 in the one-step results), also being dominantly positive in size. At the aggregate level, however, the positive sum of the lagged coefficient estimates in the interaction term is found to be fairly significant, the level of significance depending on the capital proxy. The level of significance increases if we eliminate the common trend from the capital-assets ratio and use $\left(\frac{K}{A}\right)^{B}$ as the capital proxy, in which case we can reject the null hypothesis that the sum of the coefficients is zero at the 5% level. All in all, this outcome presents at least indicative support for the hypothesis generated by the theoretical model that banks with high capital levels respond less strongly to monetary policy. As regards the strength of interaction between bank capital and monetary policy, the aggregate coefficient estimates (ranging from 9.3 to 12.5 in table 4.4) are quite large compared to the coefficient estimates of the linear monetary policy proxy (ranging from –3.4 to –4.3 in table 4.4). As we see in table 4.1, the variation in the banks' capital-assets ratios in the estimation sample is quite large, the difference between maximum and minimum being over 10 percentage points throughout the sample period. Accordingly, due to this variation, the long-run semi-elasticity of loan growth with respect to monetary policy effects would be over one percentage point across the banks, according to the point estimates, which would generally mean more than 20% of the total monetary policy effect.

Although the estimated coefficients of the cross term are mainly of the expected sign, we are not able to fully rule out the possibility that the variation in the response to monetary policy does depend on demand side differences between the banks. As we are not able to control bank-specific loan demand factors, we cannot verify whether banks with high capital-assets ratios systematically direct their lending to bigger or safer borrowers, in which case the mitigated response to monetary policy could be due to differences in borrower quality. In the empirical literature of the bank lending channel, this problem has been frequently raised (see eg Kashyap and Stein 2000). On the other hand, as we are not able to separate business from household lending, we cannot rule out the possibility that for instance specialisation on eg mortgage lending is linked to higher capital-assets ratios. Thus, if mortgage loan demand responds less to monetary policy, the positive coefficients would again result from demand factors.

More generally, looking at the specifications (1)–(4) in table 4.4 most of the coefficient estimates appear reasonable, both in size and sign. Across the board, the standard errors for the one-step estimates appear to be smaller than the ones for the two-step estimates. This is interesting since simulation studies (see eg Blundell and Bond 1998 for further discussion) suggest that we should rely on the standard errors for the one-step estimator in inference since the standard errors for the two-step estimator may not be reliable due to possibly large biases in the asymptotic variance matrix of the two-step estimator. The results appear to be qualitatively robust to the choice of the proxy for capital, although this has implications for the size and significance of the coefficient estimates.

The persistence of the shocks to loan growth is quite low, the sum of the estimated coefficients of the lagged dependent variables varying between 0.15 and 0.18 in the one-step results. However, the sum of the autoregressive coefficient estimates seems to be significantly above zero (see test for H1 in table 4.4). The fourth autoregressive lag appears to be dominant and the only one entering with high significance. This outcome may refer to underlying seasonal variation in loan growth, even though this is in general controlled for in the estimations by the seasonal dummies not shown in (4.3).

Turning to the other explanatory variables of the specification, the contribution of the capital proxy $\left(\left(\frac{K}{A}\right)^A \text{ or } \left(\frac{K}{A}\right)^B\right)$ appears to be positive and significant at the aggregate level, irrespective of the choice of the proxy variable. Interestingly, both the size and the significance of the sum of the estimated coefficients are greater when the interaction term is included. The results concerning the response of (average) banks to monetary policy also appear to conform with our hypothesis. Across the lags, the policy interest rate enters with the expected negative sign, irrespective of the definition of the capital proxy. The sum of the lagged coefficient estimates of monetary policy shocks from the one-step estimates is consistently highly significant (at a level below 1%). Employing the one-step results, the long-run semi-elasticity of the loan growth with respect to policy rate changes[31] ranges from 4.5–4.6 in specifications (1) and (2) to 5.0–5.2 in specifications (3) and (4), reflecting the elimination of the common trend from the capital proxy variable $\left(\frac{K}{A}\right)^B$ used in specifications (3) and (4). Otherwise, the results concerning aggregate controls for loan demand also seem fairly satisfactory. Both real GDP and the GDP deflator yield at least marginally significantly positive coefficient estimates.

As discussed above, our sample can be divided into two subperiods as the first years in the sample period appear to represent an era of recovery from the banking crisis while the rest of the sample years can be characterised as more normal. In particular, the government measures aimed at supporting the banking sector that had started in the early 1990s continued until December 1998 when the state guarantee of banks' contractual commitments was rescinded. Overlapping the government support period, there was a period of exceptionally rapid growth in banks' capital-assets ratios, especially in 1996–1997. In order to isolate the potential effects of the government measures in the period of recovery, we included a dummy variable in the estimated specifications of the benchmark equation. The dummy

[31] Semi-elasticity is defined as the percentage change in the growth of lending due to a change of one percentage point in the net interest rate; the estimate is simply $-\frac{\sum_{j=1}^{4}\gamma_j}{1-\sum_{j=1}^{4}\beta_j}$.

takes a value of one as long as the state guarantee for the banks' commitments was in effect and zero thereafter, ie the dummy $D984$ is defined as $D984 = 1$ for $1995 : 1 \leqq t \leqq 1998 : 4$ and $D984 = 0$ for $1999 : 1 \leqq t \leqq 2000 : 4$. In the estimations, the dummy variable for government measures proves to be highly significant and of the expected sign, suggesting that the supportive measures for the banking sector had a positive impact on loan growth.

Incorporating the dummy as a linear variable is perhaps not quite sufficient. As the government supportive measures can be understood to provide investors with full support against bank moral hazard, we should expect the implications of the moral hazard problems to be more visible after the supportive measures were discontinued. This could be tested in this context by allowing for an interaction between the dummy variable and the relevant cross term between monetary policy and capital. However, this addition to the specification would benefit from a longer data period and is left for future work.

As to the test statistics for the specifications themselves, the first- and second-order autocorrelation tests (AR(1) and AR(2) reported in table 4.4) do not show evidence to reject the required assumption of serially uncorrelated error terms in levels. The AR(2) test does not reject the null hypothesis of the absence of second-order serial correlation in the differenced residuals (although the outcome is somewhat marginal in the case of the one-step estimator). On the other hand, the AR(1) test clearly rejects in every case the null of no first-order autocorrelation. The Sargan test results differ in their recommendations across one-step and two-step estimators. While the one-step Sargan test results clearly suggest the rejection of the null hypothesis of the validity of the instruments, the two-step Sargan test results refuse to reject it. Now, it should be noticed that only the Sargan test based on the two-step estimator is heteroscedasticity-consistent, so that we tend to conclude in favour of valid instruments.

4.5.2 Further robustness checks

To examine whether and to what extent our results depend on the specific choices we have made about the variables in the estimated equations, we also estimate some alternative specifications. First, we try an alternative proxy for monetary policy. Second, we explain cross-sectional variation in loan growth by bank capital and its interaction with monetary policy, excluding the aggregate level variables. In general, these robustness checks also provide support for our hypotheses.

Table A.3 in appendix 6 shows results for specifications similar to table 4.4, except that the central bank's policy rate is replaced by the three-month securities market rate as the monetary policy proxy. On the whole, the results are similar to those estimated with the central bank policy rate. This may not, after all, be surprising, given that the positive comovement between the interest rates is fairly strong. Interestingly, interaction between bank capital and monetary policy performs more plausibly when the securities market rate is used as the monetary policy proxy. Even though individual lags do not enter significantly, all the coefficients have positive estimates, as expected, and the significance levels for the sums of coefficient estimates are better. Although the monetary policy proxy is changed, bank capital behaves much in the same way as before. As to the specification tests, the results of the first-order autocorrelation and Sargan tests do not differ from those in the basic specifications. Even more definitely than before, we cannot find evidence of second order serial correlation in differenced residuals, as expected.

There are, however, some notable differences due to the change in the interest rate definition. In particular, some of the estimated coefficients of the aggregate variables lose their significance. For instance, only the estimated coefficient for the first lag of the monetary policy variable enters significantly across the specifications. At the aggregate level, however, monetary policy still enters significantly even though the evidence of policy effects is now statistically weaker. On the other hand, as regards real GDP, the sum of the coefficient estimates no longer differs significantly from zero. These changes in the estimation results in macro variables could be associated with increased correlation between differences in the interest rate and real GDP. Indeed, in our sample the correlation between the money market interest rate differences and the (log of) real GDP differences is about 0.150 while the correlation between the central bank's policy interest rate differences and the (log of) real GDP differences is only about 0.003.

One concern in the specifications where a monetary policy indicator and aggregate loan demand control variables are included is that the small number of time periods available in the data set may render the evidence concerning the effects of the aggregate variables themselves and the interaction of monetary policy and bank capital noisier or more uncertain and, in this sense, weaker. Therefore, we modified our specification once more, with the aim of explaining cross-sectional variation in loan growth with bank-specific variables while the aggregate explanatory variables are excluded[32]. For this purpose, the loan variable is now transformed into a deviation from the cross-sectional average in each period. The proxies for capital and the interaction term remain unaltered in the specification.

Table A.4 in appendix 6 presents the specifications without aggregate variables for the various proxies for capital and monetary policy in the interaction term. The estimation results for both bank capital and interaction between capital and monetary policy largely follow the specifications reported above, lending support to the implications of the theoretical model. The coefficient estimates do not differ too much from the specifications where the aggregate variables were included. While the individual lags of the interaction term do not enter significantly, the sum of the coefficient estimates is significant, at least at the 5% significance level. If the securities market rate is used as the proxy for monetary policy, the sum of the interaction coefficient becomes significant at the 1% level. At the aggregate level, bank capital enters at least at the 10% significance level while the fourth lag of bank capital always enters highly significantly below the 1% level (according to the one-step results). The results of the autocorrelation and heteroscedasticity-consistent Sargan tests are qualitatively similar to those in the previous specifications.

[32] These variables include the monetary policy proxy, loan demand proxies, seasonal dummies, and the dummy for government measures prior to 1999 ($D984$).

Table 4.4

Dependent variable: first difference of the amount of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the central bank's policy interest rate;
$(K/A)_i$: (1)–(2): deviation from average of $(K/A)_i$ over all periods
Sample 1995:1–2000:4

		(1)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0448341	0.073*	0.0323937	0.245
$\Delta logL_{it-2}$	(β_2)	0.00842124	0.698	0.00310933	0.900
$\Delta logL_{it-3}$	(β_3)	0.00660255	0.732	0.003351	0.876
$\Delta logL_{it-4}$	(β_4)	0.118953	0.000***	0.117118	0.000***
Sum of coeff.(1)	$\Sigma\beta_j$	0.17881089	0.0026***	0.15597203	0.0178**
Δr_{t-1}	(γ_1)	–2.07297	0.006***	–1.92358	0.035**
Δr_{t-2}	(γ_2)	–0.667279	0.462	–0.726077	0.481
Δr_{t-3}	(γ_3)	–0.594062	0.016**	–0.52336	0.068*
Δr_{t-4}	(γ_4)	–0.447573	0.184	–0.383846	0.303
Sum of coeff.(1)	$\Sigma\gamma_j$	–3.781884	0.0006***	–3.556863	0.0055***
$\Delta(K/A)_{it-1}$	(δ_1)	0.0832502	0.280	0.0606273	0.515
$\Delta(K/A)_{it-2}$	(δ_2)	0.125617	0.145	0.159667	0.117
$\Delta(K/A)_{it-3}$	(δ_3)	0.0312872	0.675	0.0651769	0.491
$\Delta(K/A)_{it-4}$	(δ_4)	0.182103	0.016**	0.220374	0.015**
Sum of coeff.(1)	$\Sigma\delta_j$	0.4222574	0.0614*	0.5058452	0.0648*
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)				
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)				
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)				
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)				
Sum of coeff.(1)	$\Sigma\phi_j$				
$\Delta logGDP_{t-1}$	(λ_1)	-0.163059	0.051*	–0.14713	0.111
$\Delta logGDP_{t-2}$	(λ_2)	0.25482	0.008***	0.253203	0.028**
$\Delta logGDP_{t-3}$	(λ_3)	0.403947	0.004***	0.393574	0.014**
$\Delta logGDP_{t-4}$	(λ_4)	0.0603148	0.714	0.0411322	0.824
Sum of coeff.(1)	$\Sigma\lambda_j$	0.5560228	0.1063	0.5407792	0.1720
$\Delta logDEF_{t-1}$	(μ_1)	–0.179557	0.104	–0.186576	0.139
$\Delta logDEF_{t-2}$	(μ_2)	0.534716	0.000***	0.48217	0.004***
$\Delta logDEF_{t-3}$	(μ_3)	0.422188	0.014**	0.393774	0.043**
$\Delta logDEF_{t-4}$	(μ_4)	–0.0170883	0.881	–0.0262754	0.834
Sum of coeff.(1)	$\Sigma\mu_j$	0.7602587	0.0238**	0.6630926	0.0915*
D984		0.00226132	0.000***	0.00240426	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		635.9	0.000***	323.3	1.000
AR(1)(2)		–13.85	0.000***	–10.75	0.000***
AR(2)(2)		–1.516	0.130	–0.5201	0.603
H1(3)		9.08877	0.0026***	5.61201	0.0178**
H2(3)		11.7729	0.0006***	7.70555	0.0055***
H3(3)		3.49806	0.0614*	3.40941	0.0648*
H4(3)					
H5(3)		2.60765	0.1063	1.86556	0.1720
H6(3)		0.586126	0.4439	0.576384	0.4477
H7(3)		5.10741	0.0238**	2.84824	0.0915*
H8(3)		0.0317561	0.8586	0.205786	0.6501

Notes:
(1): p-values are based on the Wald tests of the respective hypotheses, see note (3) below.
(2): AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
(3): H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table 4.4

Dependent variable: first difference of the amount of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the central bank's policy interest rate;
$(K/A)_i$: (1)–(2): deviation from average of $(K/A)_i$ over all periods
Sample 1995:1–2000:4

		(2)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0380696	0.129	0.0251252	0.384
$\Delta logL_{it-2}$	(β_2)	0.00226419	0.916	–0.0011146	0.964
$\Delta logL_{it-3}$	(β_3)	0.00395007	0.838	0.00329012	0.880
$\Delta logL_{it-4}$	(β_4)	0.115648	0.000***	0.114694	0.000***
Sum of coeff.[1]	$\Sigma\beta_j$	0.15993186	0.0066***	0.14199474	0.0335**
Δr_{t-1}	(γ_1)	–1.82777	0.016**	–1.65531	0.074*
Δr_{t-2}	(γ_2)	–0.929692	0.304	–0.886402	0.407
Δr_{t-3}	(γ_3)	–0.602076	0.012**	–0.496225	0.078*
Δr_{t-4}	(γ_4)	–0.424805	0.215	–0.321475	0.410
Sum of coeff.[1]	$\Sigma\gamma_j$	–3.784343	0.0006***	–3.359412	0.0092***
$\Delta(K/A)_{it-1}$	(δ_1)	0.125692	0.107	0.112384	0.240
$\Delta(K/A)_{it-2}$	(δ_2)	0.163144	0.064*	0.194462	0.068*
$\Delta(K/A)_{it-3}$	(δ_3)	0.0513985	0.496	0.0848928	0.387
$\Delta(K/A)_{it-4}$	(δ_4)	0.192361	0.010***	0.227467	0.013**
Sum of coeff.[1]	$\Sigma\delta_j$	0.5325955	0.0208**	0.6192058	0.0310**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)	2.06556	0.672	1.61161	0.816
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)	9.69717	0.116	8.25803	0.265
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)	–1.69946	0.707	–0.371768	0.948
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)	–0.387568	0.917	–0.165626	0.972
Sum of coeff.[1]	$\Sigma\phi_j$	9.675702	0.0696*	9.332246	0.1994
$\Delta logGDP_{t-1}$	(λ_1)	–0.140158	0.111	–0.121725	0.227
$\Delta logGDP_{t-2}$	(λ_2)	0.263979	0.006***	0.246741	0.033**
$\Delta logGDP_{t-3}$	(λ_3)	0.421832	0.003***	0.384922	0.019**
$\Delta logGDP_{t-4}$	(λ_4)	0.084862	0.607	0.0423465	0.825
Sum of coeff.[1]	$\Sigma\lambda_j$	0.630515	0.0636*	0.5522845	0.1678
$\Delta logDEF_{t-1}$	(μ_1)	–0.207099	0.060*	–0.201488	0.121
$\Delta logDEF_{t-2}$	(μ_2)	0.479714	0.001***	0.415836	0.014**
$\Delta logDEF_{t-3}$	(μ_3)	0.391425	0.027**	0.339048	0.096*
$\Delta logDEF_{t-4}$	(μ_4)	–0.0325409	0.782	–0.0502288	0.705
Sum of coeff.[1]	$\Sigma\mu_j$	0.6314991	0.0686*	0.5031672	0.2118
D984		0.00268927	0.000***	0.00280261	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		634.8	0.000***	322.5	1.000
AR(1)[2]		–13.79	0.000***	–10.6	0.000***
AR(2)[2]		–1.44	0.150	–0.5139	0.607
H1[3]		7.38813	0.0066***	4.52207	0.0335**
H2[3]		11.6731	0.0006***	6.78527	0.0092***
H3[3]		5.3463	0.0208**	4.65297	0.0310**
H4[3]		3.29305	0.0696*	1.64641	0.1994
H5[3]		3.44005	0.0636*	1.90232	0.1678
H6[3]		0.373755	0.5410	0.578275	0.4470
H7[3]		3.31511	0.0686*	1.55887	0.2118
H8[3]		0.346861	0.5559	0.747608	0.3872

Notes:
(1): p-values are based on the Wald tests of the respective hypotheses, see note (3) below.
(2): AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
(3): H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table 4.4

Dependent variable: first difference of the amount of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the central bank's policy interest rate;
$(K/A)_i$: (3)–(4): deviation from cross-sectional average of $(K/A)_i$:s at each period
Sample 1995:1–2000:4

		(3)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0399265	0.126	0.0296659	0.309
$\Delta logL_{it-2}$	(β_2)	0.00441477	0.843	0.00054819	0.983
$\Delta logL_{it-3}$	(β_3)	0.00476897	0.808	0.00293305	0.892
$\Delta logL_{it-4}$	(β_4)	0.118266	0.000***	0.120146	0.000***
Sum of coeff.(1)	$\Sigma\beta_j$	0.16737624	0.0066***	0.15329314	0.0253**
Δr_{t-1}	(γ_1)	–1.86588	0.024**	–1.50887	0.122
Δr_{t-2}	(γ_2)	–1.01475	0.284	–1.01892	0.347
Δr_{t-3}	(γ_3)	–0.637905	0.024**	–0.521464	0.109
Δr_{t-4}	(γ_4)	–0.796726	0.025**	–0.733539	0.072*
Sum of coeff.(1)	$\Sigma\gamma_j$	–4.315261	0.0003***	–3.782793	0.0077***
$\Delta(K/A)_{it-1}$	(δ_1)	0.104715	0.165	0.0832678	0.386
$\Delta(K/A)_{it-2}$	(δ_2)	0.116417	0.163	0.135524	0.188
$\Delta(K/A)_{it-3}$	(δ_3)	0.0237156	0.733	0.0432237	0.638
$\Delta(K/A)_{it-4}$	(δ_4)	0.197152	0.007***	0.213653	0.017**
Sum of coeff.(1)	$\Sigma\delta_j$	0.4419996	0.0339**	0.4756685	0.0766*
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)				
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)				
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)				
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)				
Sum of coeff.(1)	$\Sigma\phi_j$				
$\Delta logGDP_{t-1}$	(λ_1)	–0.220437	0.017**	–0.213433	0.043**
$\Delta logGDP_{t-2}$	(λ_2)	0.212642	0.037**	0.167459	0.184
$\Delta logGDP_{t-3}$	(λ_3)	0.458211	0.002***	0.418892	0.017**
$\Delta logGDP_{t-4}$	(λ_4)	0.158286	0.369	0.133535	0.505
Sum of coeff.(1)	$\Sigma\lambda_j$	0.608702	0.0932*	0.506453	0.2402
$\Delta logDEF_{t-1}$	(μ_1)	–0.216145	0.059*	–0.23044	0.085*
$\Delta logDEF_{t-2}$	(μ_2)	0.506744	0.001***	0.408515	0.028**
$\Delta logDEF_{t-3}$	(μ_3)	0.549768	0.003***	0.498337	0.021**
$\Delta logDEF_{t-4}$	(μ_4)	0.0682355	0.577	0.0586919	0.673
Sum of coeff.(1)	$\Sigma\mu_j$	0.9086025	0.0172**	0.7351039	0.1021
D984		0.00229106	0.000***	0.00246634	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		637.9	0.000***	326.8	1.000
AR(1)(2)		–13.86	0.000***	–10.68	0.000***
AR(2)(2)		–1.531	0.126	–0.4886	0.625
H1(3)		7.38619	0.0066***	5.00132	0.0253**
H2(3)		13.144	0.0003***	7.09721	0.0077***
H3(3)		4.49779	0.0339**	3.13551	0.0766*
H4(3)					
H5(3)		2.8188	0.0932*	1.3795	0.2402
H6(3)		0.382968	0.5360	0.62305	0.4299
H7(3)		5.67493	0.0172**	2.6724	0.1021
H8(3)		0.0383246	0.8448	0.0597996	0.8068

Notes:
(1): p-values are based on the Wald tests of the respective hypotheses, see note (3) below.
(2): AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
(3): H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table 4.4

Dependent variable: first difference of the amount of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the central bank's policy interest rate;
$(K/A)_i$: (3)–(4): deviation from cross-sectional average of $(K/A)_i$:s at each period
Sample 1995:1–2000:4

		(4)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0343904	0.185	0.0224476	0.455
$\Delta logL_{it-2}$	(β_2)	0.00018974	0.993	–0.0038849	0.880
$\Delta logL_{it-3}$	(β_3)	0.00177537	0.928	0.00113168	0.958
$\Delta logL_{it-4}$	(β_4)	0.115529	0.000***	0.1173	0.000***
Sum of coeff.[(1)]	$\Sigma\beta_j$	0.15188451	0.0125**	0.13699439	0.0472**
Δr_{t-1}	(γ_1)	–1.79634	0.029**	–1.38574	0.159
Δr_{t-2}	(γ_2)	–1.04631	0.269	–1.0463	0.340
Δr_{t-3}	(γ_3)	–0.622261	0.027**	–0.487121	0.129
Δr_{t-4}	(γ_4)	–0.791051	0.026**	–0.695335	0.089*
Sum of coeff.[(1)]	$\Sigma\gamma_j$	–4.255962	0.0003***	–3.614496	0.0101**
$\Delta(K/A)_{it-1}$	(δ_1)	0.146194	0.055*	0.138603	0.156
$\Delta(K/A)_{it-2}$	(δ_2)	0.151394	0.074*	0.171602	0.105
$\Delta(K/A)_{it-3}$	(δ_3)	0.0456729	0.516	0.0769642	0.423
$\Delta(K/A)_{it-4}$	(δ_4)	0.209309	0.004***	0.219329	0.016**
Sum of coeff.[(1)]	$\Sigma\delta_j$	0.5525699	0.0092***	0.6064982	0.0307**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)	0.697426	0.876	1.14725	0.862
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)	9.06071	0.128	8.22412	0.246
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)	–2.74943	0.543	–0.325467	0.953
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)	2.8264	0.422	3.44912	0.426
Sum of coeff.[(1)]	$\Sigma\phi_j$	9.835106	0.0377**	12.495023	0.0636*
$\Delta logGDP_{t-1}$	(λ_1)	–0.219865	0.017**	–0.204215	0.053*
$\Delta logGDP_{t-2}$	(λ_2)	0.20572	0.043**	0.159846	0.198
$\Delta logGDP_{t-3}$	(λ_3)	0.450905	0.002***	0.405483	0.020**
$\Delta logGDP_{t-4}$	(λ_4)	0.155519	0.377	0.124318	0.538
Sum of coeff.[(1)]	$\Sigma\lambda_j$	0.592279	0.1017	0.485432	0.2586
$\Delta logDEF_{t-1}$	(μ_1)	–0.221621	0.052*	–0.233001	0.088*
$\Delta logDEF_{t-2}$	(μ_2)	0.491502	0.001***	0.374897	0.044**
$\Delta logDEF_{t-3}$	(μ_3)	0.539847	0.004***	0.473743	0.028**
$\Delta logDEF_{t-4}$	(μ_4)	0.0652106	0.594	0.0505994	0.715
Sum of coeff.[(1)]	$\Sigma\mu_j$	0.8749386	0.0215**	0.6662384	0.1358
D984		0.00232233	0.000***	0.00251948	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		638	0.000***	323.5	1.000
AR(1)[(2)]		–13.82	0.000***	–10.55	0.000***
AR(2)[(2)]		–1.531	0.126	–0.4783	0.632
H1[(3)]		6.23687	0.0125**	3.93982	0.0472**
H2[(3)]		12.8407	0.0003***	6.6199	0.0101**
H3[(3)]		6.7901	0.0092***	4.67121	0.0307**
H4[(3)]		4.32059	0.0377**	3.44146	0.0636*
H5[(3)]		2.67832	0.1017	1.27649	0.2586
H6[(3)]		0.500263	0.4794	0.770561	0.3800
H7[(3)]		5.28592	0.0215**	2.22447	0.1358
H8[(3)]		0.00478794	0.9448	0.187724	0.6648

Notes:
(1): p-values are based on the Wald tests of the respective hypotheses, see note (3) below.
(2): AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
(3): H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

5 Conclusions

In this study, we have proposed a theoretical model where endogenous monitoring, and the associated moral hazard problems have been given a role in monetary policy transmission to bank lending. With this model we have demonstrated that there are some special features involved in monetary policy transmission through intermediary banks to investments when effects of monitoring are accounted for. The model also argues that the liability structure of banks affects the monetary policy transmission process. Thus our model suggests an alternative explanation for heterogeneity in banks' responses to monetary policy, which is commonly found in empirical studies that look for evidence for the more traditional bank lending channel. In contrast to the bank lending channel, however, our model suggests that monetary policy transmission is stronger through nonintermediary lending than through banks' intermediary lending.

The main insight provided by our model is that monetary policy is not only reflected in banks' lending decisions but also in their decisions concerning other activities such as monitoring the behaviour of their borrowers after loan agreements are concluded. Monetary policy, as well as banks' lending decisions affect banks' optimal intensity of monitoring, as these affect the expected benefits of monitoring. On the other hand, the intensity of monitoring also influences the expected yield of lending and thus affects the lending decisions. Since monitoring and lending decisions are interlinked, monetary policy transmission to bank lending is more complicated than in a situation where monitoring has no influence on lending decisions.

Monitoring is costly to banks that cannot commit themselves to a chosen monitoring intensity in advance because monitoring costs are not (at least totally) verifiable. Therefore, the banks' decisions on monitoring intensity also depend on the source of the funds they lend to their borrowers. If the banks lend only their own capital (for which they have full liability and for which they incur any losses if loans are not repaid), they fully appreciate the benefits of a higher intensity of monitoring, as it is assumed that a higher intensity of monitoring leads to a higher probability of loan repayments. By contrast, if the banks find it optimal to provide for their lending by borrowing external funds (for which they have limited liability), they do not appreciate the benefits of monitoring and choose a lower monitoring intensity. Accordingly, there is a need for a certain share of banks' funds to be equity capital so as to ensure sufficient incentives for them to monitor the borrowers. The liability structure of the banks affects not only their monitoring intensity but also the monetary policy impact on monitoring intensity. On the one hand, the liability structure affects how monetary policy changes the relative value of solvency for the banks and thus the banks' incentives to monitor. On the other hand, the liability structure also has an effect on how monetary policy affects monitoring through the banks' lending decisions.

Together, the role of monitoring and the effects of the banks' liability structure lead us to the following conclusions. First, if banks act as intermediaries and fund their lending by external funds, their lending responds less to monetary policy than if they are nonintermediaries and lend only their own capital. This suggests that intermediary banks actually dampen the effects of monetary policy on lending. Second, as regards intermediary banks, their liability structure has an effect on their lending response to monetary policy. Individual banks with high capital-loans ratios are less affected by monetary policy in their lending than individual banks with low capital-loans ratios. The impact of capital-loans ratios on the response of aggregate banking sector lending is similar in the monopoly loan market and in the competitive loan market if the comparison is made at sufficiently low levels of capital-loans ratios.

Introducing monitoring as a relevant function associated with bank and other lending thus gives a new perspective from which to look at monetary policy transmission and the role of intermediary banks. Traditionally, bank lending has been given a special role in the framework of the bank lending channel of monetary policy transmission. This view is based on the special role of demand deposits in banks' liabilities and as a channel for monetary policy effects. However, the role of deposits is gradually diminishing, both as banks' source of funding and in the implementation of monetary policy, which suggests that the theoretical foundations of the bank lending channel are weakening. In the meantime, empirical work on the bank lending channel is still ongoing and providing clear evidence of heterogeneity in banks' lending responses to monetary policy. Thus our framework enables a new explanation for the variation in banks' lending response to monetary policy. Our model can also be seen as complementary to more recent literature on the role of bank capital in monetary policy transmission. In this field, monetary policy affects lending via its impact on the stock of banks' own capital. Our model also accounts for the effect of the capital stock on the volume of lending but assumes no monetary policy impact on the size of the capital stock. Allowing for an impact of monetary policy on bank capital could be a possible venue for further work.

The empirical part of the study seems to lend at least some support to our theoretical model. The heterogeneity in banks' lending responses to monetary policy found in the estimations seems to accord with the predictions of the theoretical model. Moreover, the banks' own capital seems to have the expected impact on the volume of bank lending. In addition, as mentioned above, part of the empirical literature on the bank lending channel has found a similar type of heterogeneity in banks' response to monetary policy, supporting also the predictions of our model. Our empirical work might still be criticized for rudimentary empirical specifications and use of quite rough proxies for the variables. However, an even more challenging task for future empirical research would be to collect data on banks' monitoring and specify appropriate empirical models that account for both the lending and monitoring activities of banks.

References

[1] Arellano, M. – Bond, S.R. (1991) **Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations.** Review of Economic Studies, 58(2), 277–297.

[2] Arellano, M. – Bover, O. (1995) **Another Look at the Instrumental Variables Estimation of Error-Component Models.** Journal of Econometrics, 68(1), 29–51.

[3] Bernanke, B.S.– Blinder, A.S. (1988) **Credit, Money, and Aggregate Demand.** American Economic Review (Papers and Proceedings), 78 (2), 435–439.

[4] Bernanke, B.S. – Blinder A.S. (1992) **The Federal Funds Rate and the Channels of Monetary Transmission.** American Economic Review, 82(4), 901–921.

[5] Bernanke, B.S. – Gertler, M. (1989) **Agency Costs, Net Worth, and Business Fluctuations.** American Economic Review, 79(1), 14–31.

[6] Bernanke, B.S. – Gertler, M. (1995) **Inside the Black Box: the Credit Channel of Monetary Policy Transmission.** Journal of Economic Perspectives, 9(4), 27–48.

[7] Bernanke, B.S. – Gertler, M. – Gilchrist, S. (1996) **The Financial Accelerator and the Flight to Quality.** Review of Economics and Statistics, 78(1), 1–15.

[8] Blundell, R.W. – Bond, S.R. (1998) **Initial Conditions and Moment Restrictions in Dynamic Panel Data Models.** Journal of Econometrics, 87(1), 115–143.

[9] Bolton, P. – Freixas, X. (2001) **Corporate Finance and the Monetary Transmission Mechanism.** CEPR Working paper No. 2892.

[10] Bondt, G.J., de (2000) **Financial Structure and Monetary Transmission in Europe: A Cross-Country Study.** Edward Elgar, Cheltenham / Northampton.

[11] Cecchetti, S.G. (1999) **Legal Structure, Financial Structure, and the Monetary Policy Transmission Mechanism.** Federal Reserve Bank of New York Economic Policy Review, 5(2), 9–28.

[12] Chatelain, J.B. – Generale, A. – Hernando, I. – von Kalckreuth, U. – Vermeulen, P. (2001) **Firm Investment and Monetary Transmission in the Euro Area Countries.** European Central Bank Working Paper series 112.

[13] Chami, R. – Cosimano, T.F. (2001) **Monetary Policy with a Touch of Basel.** IMF Working Papers, 01/151.

[14] Clements, B. – Kontolemis, Z.G. – Levy, J. (2001) **Monetary Policy Under EMU: Differences in the Transmission Mechanism.** IMF Working Papers, 01/102.

[15] Diamond, D.W. (1984) **Financial Intermediation and Delegated Monitoring.** Review of Economic Studies, 51(3) , 393–414.

[16] Diamond, D.W. (1996) **Financial Intermediation and Delegated Monitoring: A Simple Example.** Federal Reserve Bank of Richmond Economic Quarterly, 82(3), 51–66.

[17] Doornik, J.A. – Hendry, D.F. (2001) **Econometric Modelling Using PcGive 10, Volume III.** Timberlake Consultants Ltd, London.

[18] Dornbusch, R. – Favero C.A. – Giavazzi F. (1998) **The Immediate Challenges for the European Central Bank.** Economic Policy, 26, 17–64.

[19] Ehrmann, M. – Gambacorta, L. – Martinez-Pagés, J. – Sevestre, P. – Worms, A. (2001) **The Role of Banks in Monetary Policy Transmission in the Euro Area.** European Central Bank Working Paper series 105.

[20] Favero, C.A. – Giavazzi, F. – Flabbi L. (1999) **The Transmission Mechanism of Monetary Policy in Europe: Evidence from Banks' Balance Sheets.** NBER Working Paper No. 7231.

[21] Freixas, X. – Rochet J.-C. (1997) **Microeconomics of Banking.** The MIT Press, Cambridge, Massachusetts.

[22] Friedman, B.M. – Kuttner, K.N. (1993) **Economic Activity and the Short-term Credit Markets: an Analysis of Prices and Quantities.** Brookings Papers on Economic Activity, (2), 193–283.

[23] Gertler, M. – Gilchrist, S. (1994) **Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms.** Quarterly Journal of Economics, 109(2), 309–340.

[24] Gourinchas, P.-O. – Valdes R. – Landerretche O. (2001) **Lending Booms: Latin America and the World.** NBER Working Paper, No. 8249.

[25] Guiso, L. – Kashyap, A.K. – Panetta, F. – Terlizzese D. (2000) **Will a Common European Monetary Policy Have Asymmetric Effects?** Banca D'Italia, Temi di discussione, 384.

[26] Holmstrom, B. – Tirole, J. (1997) **Financial intermediation, loanable funds, and the real sector.** Quarterly Journal of Economics, 112(3), 663–691.

[27] Hyytinen, A. – Toivanen, O. (2000) **Monitoring and Market Power in Loan Markets.** Bank of Finland Discussion Papers, 9/00.

[28] Iacoviello, M. – Minetti, R. (2000) **The Credit Channel of Monetary Policy and Housing Markets: International Empirical Evidence.** Bank of Finland Discussion Papers, 14/00.

[29] Kashyap, A.K. – Stein, J.C. (1994) **Monetary Policy and Bank Lending.** Ch. 7 in Mankiw (1994).

[30] Kashyap, A.K. – Stein, J.C. (1995) **The Impact of Monetary Policy on Bank Balance Sheets.** Carnegie-Rochester Conference Series on Public Policy, 42, 151–195.

[31] Kashyap, A.K. – Stein, J.C. (1997) **The Role of Banks in Monetary Policy: A Survey with Implications for the European Monetary Union.** Federal Reserve Bank of Chicago Economic Perspectives, September/October, 2–18.

[32] Kashyap, A.K. – Stein, J.C. (2000) **What Do A Million Observations on Banks Say About the Transmission of Monetary Policy?** American Economic Review, 90(3), 407–428.

[33] Kashyap, A.K. – Stein, J.C. – Wilcox, D.W. (1993) **Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance.** American Economic Review, 83(1), 78–98.

[34] Kashyap, A.K. – Stein, J.C. – Wilcox, D.W. (1996) **Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance: Reply.** American Economic Review, 86(1), 310–314.

[35] Kishan, R.P. – Opiela, T.P. (2000) **Bank Size, Bank Capital, and the Bank Lending Channel.** Journal of Money, Credit, and Banking, 32(1), 121–141.

[36] Kiyotaki, N. – Moore, J. (1997) **Credit cycles.** Journal of Political Economy, 105(2), 211–248.

[37] Koskenkylä, H. (2000) **Threats and Opportunities for Today's European Banks.** Bank of Finland Financial Markets Department Working Papers, 7/00.

[38] Maclennan, D. – Muellbauer, J. – Stephens M. (1999) **Asymmetries in Housing and Financial Market Institutions and EMU.** CEPR Discussion Paper, No. 2062.

[39] Mankiw, N.K. (ed) (1994) **Monetary Policy.** University of Chicago Press for NBER, NBER Studies in Business Cycles, Volume 29.

[40] Nyberg, P. – Vihriälä, V. (1994) **The Finnish Banking Crisis and Its Handling.** Bank of Finland Discussion Papers, 7/94.

[41] Oliner, S.D. – Rudebusch, G.D. (1996) **Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance: Comment.** American Economic Review, 86(1), 300–309.

[42] Peek, J. – Rosengren, E.S. (eds) (1995) **Is Bank Lending Important for the Transmission of Monetary Policy?** Federal Reserve Bank of Boston, Conference Series, No. 39.

[43] Repullo, R. – Suarez, J. (2000) **Entrepreneurial Moral Hazard and Bank Monitoring: a Model of the Credit Channel.** European Economic Review, 44(10), 1931–1950.

[44] Romer, C.D. – Romer, D.H. (1990) **New Evidence on the Monetary Transmission Mechanism.** Brookings Papers on Economic Activity, (1), 149–198.

[45] Stein, J.C. (1998) **An Adverse-selection Model of Bank Asset and Liability Management with Implications for the Transmission of Monetary Policy.** RAND Journal of Economics, 29(3), 466–486.

[46] Thakor, A.V. (1996) **Capital Requirements, Monetary Policy, and Aggregate Bank Lending: Theory and Empirical Evidence.** Journal of Finance, 51(1), 279–324.

[47] Topi, J. – Vilmunen, J. (2001) **Transmission of Monetary Policy Shocks in Finland; Evidence from Bank Level Data on Loans.** European Central Bank Working Paper series 100.

[48] Van den Heuvel, S.J. (2001) **The Bank Capital Channel of Monetary Policy.** The Wharton School, University of Pennsylvania, Mimeograph, March.

[49] White, B. (2001) **Central Banking: Back to the Future.** Reserve Bank of New Zealand, Discussion Paper Series 05.

[50] White, H. (1982) **Instrumental variables regression with independent observations.** Econometrica, 50(2), 483–499.

[51] Winton, A. (1999) **Don't Put All Your Eggs in One Basket?** Diversification and Specialization in Lending. Wharton Financial Institutions Center Working Papers 00-16.

A Appendices

A.1 Second-order conditions

A.1.1 Monopoly bank

Subperiod 2

In subperiod 2, the monopoly bank chooses the intensity of monitoring θ to maximise the expected profits in (3.9). Denote $g(\theta) = \theta (G(L) - H) HL - \theta (G(L) - H) B(L - K) - RK - \mu\theta^2 L$. Then the first-order condition is $g'(\theta) = (G(L) - H)[HL - B(L - K)] - 2\mu\theta L = 0$, as in (3.10). Thus the sufficient second-order condition $g''(\theta) = -2\mu L < 0$ holds, since both μ and L are positive.

Subperiod 1

In subperiod 1, the monopoly bank chooses the volume of lending L and the lending interest rate H to maximise the expected profits in (3.23) Denote $f(L, H) = \theta(H, L; O)(G(L) - H) HL - RL - \mu (\theta(H, L; O))^2 L$. To save space, denote $\theta(H, L; O) = \theta$ and $f(L, H) = f$ in the following.

Now the sufficient second-order conditions are $f_{LL} < 0$, f_{HH}, and $f_{LL} f_{HH} - f_{HL}^2 > 0$, once the first-order necessary conditions are satisfied. Due to the complicated nature of $f(L, H)$, we are unfortunately unable to express the second-order conditions purely in terms of exogenous variables. However, we use the first-order equilibrium conditions in the following to verify that the second-order conditions are satisfied.

To start with, the first-order partial derivative with respect to L is $f_L = \theta_L L [[G(L) - H] H - 2\mu\theta] + \theta H m G(L) + \theta \left[[G(L) - H] H - \frac{R}{\theta} - \mu\theta\right]$. Note that the bank takes condition (3.20) and its implications as binding in subperiod 1, and therefore these can be used to modify the equilibrium conditions. First, use (3.20) twice to modify the terms in square brackets to obtain $f_L = \frac{R}{\theta}\left(1 - \frac{K}{L}\right)\theta_L L + \theta H m G(L) + \mu\theta^2 - R\frac{K}{L}$. Next, impose θ_L from (3.22) and rearrange to yield $f_L = \mu\left[R\left(1 + \frac{K}{L}\right) - 2\mu\theta^2 - 2m\theta H G(L)\right] / \left[\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu\right]$, which also implies the form of the first-order condition given in (3.25).

Correspondingly, the first-order partial derivative with respect to H is $f_H = \theta_H L\left[\left[G\left(L\right) - H\right]H - 2\mu\theta\right] + \theta L\left[G\left(L\right) - 2H\right]$. Now using (3.20) to eliminate $\left[\left[G\left(L\right) - H\right]H - 2\mu\theta\right]$ and imposing θ_H from (3.21) yields $f_H = -2\mu\theta L\left[G\left(L\right) - 2H\right] / \left[\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu\right]$, which implies the form of the first-order condition given in (3.24) and (3.26).

Next, taking the second-order partial derivative of f with respect to L yields

$$f_{LL} = \frac{\begin{array}{c}\mu\left[-R\frac{K}{L^2} - 4\mu\theta\theta_L - 2m\theta_L HG\left(L\right) - \frac{2m^2\theta HG(L)}{L}\right] \\ +f_L\frac{R}{\theta^2}\left[\frac{2\theta_L}{\theta}\left(1 - \frac{K}{L}\right) - \frac{K}{L^2}\right]\end{array}}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}.$$

Combining (3.22) and (3.25) shows that in equilibrium we have $\theta_L = -\frac{1}{2}\frac{\theta}{L}$. By using this result, noting that in equilibrium the first-order condition states that $f_L = 0$, and rearranging, we can simplify the second-order partial derivative to $f_{LL} = \frac{\mu}{L}\left[-R\frac{K}{L} + 2\mu\theta^2 + m\theta HG\left(L\right)\left(1 - 2m\right)\right] / \left[\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu\right]$. Furthermore, (3.25) implies $m\theta HG\left(L\right) = \frac{R}{2}\left(1 + \frac{K}{L}\right) - \mu\theta^2$. This leads to the form

$$f_{LL} = \frac{\frac{\mu}{2L}\left[\left[R\left(1 - \frac{K}{L}\right) + 2\mu\theta^2\right]\left(1 + 2m\right) - 4mR\right]}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}.$$

Since we assume that $-\frac{1}{4} < m < 0$ and $0 < K \leq L$ and $\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu < 0$ by the first-order condition, we see that $f_{LL} < 0$ holds.

To examine the next of the second-order conditions, we take the second partial derivative of f with respect to H:

$$f_{HH} = \frac{-2\mu\theta_L L\left[G\left(L\right) - 2H\right] + 4\mu\theta L + f_H\frac{2R\theta_H^2}{\theta^3}\left(1 - \frac{K}{L}\right)}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}.$$

By (3.26), $G\left(L\right) = 2H$, which also means that $\theta_H = 0$ in equilibrium. This simplifies the partial derivative to

$$f_{HH} = \frac{4\mu\theta L}{\frac{R}{\theta^2}\left(1-\frac{K}{L}\right)-2\mu},$$

implying that the second-order condition $f_{HH} < 0$ holds.

Finally, for the third second-order condition, we need the cross partial derivative that is obtained eg as

$$f_{HL} = \frac{\partial f_H}{\partial L} = \frac{-2\mu\theta_L L\left[G(L)-2H\right]-2\mu\theta\left[G(L)-2H\right]-2\mu\theta m G(L)}{\frac{R}{\theta^2}\left(1-\frac{K}{L}\right)-2\mu}.$$

Using the equilibrium results $G(L) = 2H$ and $\theta_H = 0$ from above, this can be simplified to a convenient form:

$$f_{HL} = -\frac{2\mu\theta m G(L)}{\frac{R}{\theta^2}\left(1-\frac{K}{L}\right)-2\mu}.$$

Combining the second-order partial derivatives for the last second-order condition gives

$$\begin{aligned} f_{LL}f_{HH}-f_{HL}^2 &= \frac{4\mu^2\theta}{\left[\frac{R}{\theta^2}\left(1-\frac{K}{L}\right)-2\mu\right]^2}A \\ \text{where } A &= \frac{1}{2}\left[\left[R\left(1-\frac{K}{L}\right)+2\mu\theta^2\right](1+2m)-4mR\right] \\ &\quad -\theta m^2\left(G(L)\right)^2. \end{aligned}$$

The sign of $f_{LL}f_{HH} - f_{HL}^2$ depends on A since its other terms are clearly positive. By combining (3.25) and (3.26) we see that $\theta m\left(G(L)\right)^2 = R\left(1+\frac{K}{L}\right)-2\mu\theta^2$ in equilibrium. Inserting this result into A above and rearranging yields

$$A = \frac{R}{2}\left[1-\frac{K}{L}(1+4m)\right]+\mu\theta^2(1+4m)-2mR.$$

Given our assumptions, we see that $A > 0$. Subsequently, $f_{LL}f_{HH} - f_{HL}^2 > 0$ also holds, as well as the other second-order conditions for the monopoly bank's maximisation problem in subperiod 1.

A.1.2 Competitive loan market

Subperiod 2

In subperiod 2, each active bank chooses the intensity of monitoring to maximise the expected profits in (3.37). Denote $g(\theta) = \theta(G(L) - H) Hl - \theta(G(L) - H) B(l-k) - Rk - \mu\theta^2 l$. The first-order condition becomes $g'(\theta) = (G(L) - H)[Hl - B(l-k)] - 2\mu\theta l = 0$. The subsequent second-order condition $g''(\theta) = -2\mu l < 0$ clearly holds.

Subperiod 2

In subperiod 1, each active bank chooses its volume of lending l and the corresponding lending rate H to maximise the expected profits in (3.43). Denote $f(l, H) = \theta(H, l; O)[G(L) - H] Hl - Rl - \mu(\theta(H, l; O))^2 l$ To save space, we denote again $\theta(H, l; O) = \theta$ and also $f(l, H) = f$ in what follows.

The sufficient second-order conditions are $f_{ll} < 0$, f_{HH}, and $f_{ll} f_{HH} - f_{Hl}^2 > 0$ after the first-order necessary conditions have been satisfied. Due to the complicated nature of $f(l, H)$, we are unfortunately unable to express the second order conditions solely in terms of exogenous variables. However, we use the first-order equilibrium conditions in the following to verify that the second-order conditions are satisfied.

The first-order partial derivative with respect to l is $f_l = \theta_l l[[G(L) - H] H - 2\mu\theta] + \theta\left[[G(L) - H] H - \frac{R}{\theta} - \mu\theta\right]$. After inserting θ_l from (3.42) and using (3.40) to modify the two terms in square brackets, rearranging yields the form

$$f_l = \frac{R\left(1 + \frac{k}{l}\right) - 2\mu\theta^2}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}$$

which also implies (3.44) in the text. On the other hand, the first-order partial derivative with respect to H is $f_H = \theta_H l[[G(L) - H] H - 2\mu\theta] + \theta l[G(L) - 2H]$. Again, using (3.40) to modify the result in the first square brackets, inserting θ_H from (3.41), and rearranging yields

$$f_H = \frac{-2\mu l\left[G(L) - 2H\right]}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}.$$

This result implies (3.45) in the text.

Taking the second-order partial derivative of f with respect to l yields$f_{ll} = \left[-R\frac{k}{l^2} - 4\mu\theta\theta_l\right] / \left[\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu\right]$. Inserting $2\mu = \frac{R}{\theta^2}\left(1 - \frac{k}{l}\right)$, which is implied by the first-order condition in (3.42), reveals that in equilibrium $\theta_l = -\frac{1}{2}\frac{\theta}{l}$ holds. Inserting this result and $2\mu = \frac{R}{\theta^2}\left(1 - \frac{k}{l}\right)$ yields

$$f_{ll} = \frac{\frac{R}{l}}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}.$$

Since $\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu < 0$ by the first-order condition, $f_{ll} < 0$ obviously holds.

Next, taking the second-order partial derivative of f with respect to H yields $f_{HH} = \left[4\mu lH + f_H\frac{2R\theta_H}{\theta^3}\left(1 - \frac{k}{l}\right)\right] / \left[\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu\right]$. Because $f_H = 0$ in equilibrium, this simplifies to

$$f_{HH} = \frac{4\mu lH}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}$$

Again, $f_{HH} < 0$ clearly holds.

Finally, for the last second-order condition, the cross partial derivative becomes eg

$$f_{lH} = \frac{\partial f_l}{\partial H} = \frac{-4\mu\theta\theta_H + f_l\frac{2R\theta_H}{\theta^3}\left(1 - \frac{k}{l}\right)}{\frac{R}{\theta^2}\left(1 - \frac{k}{l}\right) - 2\mu}.$$

We know from (3.41) and (3.46) that $\theta_H = 0$ in equilibrium. On the other hand, $f_l = 0$ in equilibrium. Together these imply that $f_{lH} = 0$. This means that when both $f_{ll} < 0$ and $f_{HH} < 0$ hold, the last of the sufficient second-order conditions $f_{ll}f_{HH} - f_{Hl}^2 > 0$ also holds.

A.2 Proof of Proposition 2

Proposition 2 contends that the absolute value of the monetary policy transmission measure $\frac{dL}{dR}\frac{R}{L}$ decreases as the capital-loans ratio $\frac{K}{L}$ increases. Since $\frac{dL}{dR}\frac{R}{L} < 0$, Proposition 2 requires only that the derivative of $\frac{dL}{dR}\frac{R}{L}$ with respect to $\frac{K}{L}$ be positive if we consider $\frac{K}{L}$ as a parameter of $\frac{dL}{dR}\frac{R}{L}$.

Let us denote for the moment $w(\varepsilon) = \frac{dL}{dR}\frac{R}{L}$ with $\varepsilon = \frac{K}{L}$. By (3.29) and rearranging $w(\varepsilon) = \frac{1-4m+\varepsilon(1+4m)}{(1-4m)(4m-\varepsilon(1+4m))}$. Then $\frac{dw}{d\varepsilon} = \frac{(1+4m)(1-4m)}{[(1-4m)(4m-\varepsilon(1+4m))]^2}$. By assumption $0 > m > -\frac{1}{4}$, $\frac{dw}{d\varepsilon} > 0$ holds. **QED**

A.3 Comparative statics

A.3.1 Monopoly bank

Effects of monitoring costs

We can conclude from equilibrium condition (3.28) that, in elasticity terms, lending reacts to an increase of the unit cost of monitoring (μ) similarly to the way it reacts to a monetary policy shock (cf equation (3.29)). Thus an increase in the private cost of monitoring further limits the volume of lending

$$\frac{dL}{d\mu}\frac{\mu}{L} = \frac{1}{4m - \frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}. \tag{A.1}$$

Given the stock of bank capital K, the capital-loans ratio (K/L) increases with the unit cost of monitoring, since the more severe consequences of the bank's moral hazard problems curtail the volume of lending.

In contrast to the debt securities market rate, the unit cost of monitoring turns out to have a negative effect on the intensity of monitoring. As before, there are two opposing effects at work. On the one hand, the unit cost of monitoring has a direct negative incentive effect, which can be derived from condition (3.20):

$$\theta_{\mu} = \frac{2\theta}{\frac{R}{\theta^2}\left(1 - \frac{K}{L}\right) - 2\mu}. \tag{A.2}$$

In equilibrium, the partial elasticity of monitoring with respect to the cost is (using (3.28) and (A.1)), accordingly,

$$\theta_{\mu}\frac{\mu}{\theta} = \frac{(1-4m)}{2}\frac{dL}{d\mu}\frac{\mu}{L}. \tag{A.3}$$

On the other hand, a change in the unit cost of monitoring is also reflected in an opposite change of the volume lending, as can be seen from (A.1). This adjustment in turn works against the direct effect, since the volume of lending is negatively linked to the intensity of monitoring (see (3.22) or (3.33)). The combined impact of the direct and indirect effects in equilibrium is, using (3.33) and (A.3),[33]

$$\frac{d\theta}{d\mu}\frac{\mu}{\theta} = \theta_{\mu}\frac{\mu}{\theta} + \theta_{L}\frac{dL}{d\mu}\frac{\mu}{\theta} = -2m\frac{dL}{d\mu}\frac{\mu}{L}. \tag{A.4}$$

with $\frac{dL}{d\mu}\frac{\mu}{L}$ given by (A.1). Thus, although an increase in the unit cost of monitoring makes the bank reduce the volume of lending, which has a favourable effect on monitoring, this indirect positive effect is dominated by the direct adverse effect of the cost increase.

Turning to the influence of the cost of monitoring on monetary policy transmission, we notice from (3.29) that the effects of the unit cost of monitoring can be understood through its effects on the the volume of lending and thus on the capital-loans ratio:

$$\begin{aligned}\frac{d\left(\frac{dL}{dR}\frac{R}{L}\right)}{d\mu} &= \frac{\partial\left(\frac{dL}{dR}\frac{R}{L}\right)}{\partial L}\frac{dL}{d\mu} \\ &= \left[1 + \frac{dL}{d\mu}\frac{\mu}{L}(1-4m)\right]\frac{dL}{d\mu}\frac{1}{L}\left(\frac{dL}{dK}\frac{K}{L}\right).\end{aligned} \tag{A.5}$$

The sign of the derivative in (A.5) is positive since the unit cost of monitoring reduces lending, increases thereby the capital-loans ratio, and weakens the (negative) effects of monetary policy. By

[33] As with monetary policy, the unit cost of monitoring does not have an effect on the intensity of monitoring through the lending interest rate.

aggravating the moral hazard problem associated with monitoring, higher monitoring costs force the bank to use a smaller share of intermediated external funds.

Effects of bank capital

The volume of lending is increasing in the supply of bank capital because the additional capital alleviates the restriction caused by the incentive costs due to external finance:

$$\frac{dL}{dK}\frac{K}{L} = \frac{(1+4m)\frac{K}{L}}{(1-4m)\left[(1+4m)\frac{K}{L}-4m\right]}. \tag{A.6}$$

The larger the bank's reliance on capital as a source of funding, the larger the effects of a capital shock on lending. In fact, if the capital-loans ratio approaches zero, the elasticity of lending with respect to capital also approaches zero. The elasticity of lending with respect to capital increases in $\frac{K}{L}$, given $m < 0$. If the bank is becoming totally dependent on its own capital ($\frac{K}{L} \to 1$), the size of its lending response to capital shocks depends on the loan demand elasticity. We also see that elasticity of lending with respect to capital never exceeds unity, which is interesting since it implies that an increase in the supply of capital also increases the capital-loans ratio (K/L). This is due to the diminishing returns in the nonfinancial sector, which makes the loan expansion less profitable and pushes the optimal volume of lending so low that K/L increases. In fact, if there were no link between returns and investment volume, ie $m = 0$, we would have $\frac{dL}{dK}\frac{K}{L} = 1$, and the capital-loans ratio would remain unchanged after a capital shock.

A change in the amount of bank capital available also influences the bank's monitoring decisions in subperiod 2. As above, we must look at both the direct effect of the amount of capital and its indirect effect through the change in the volume of lending. Since an increase in the capital alleviates the incentive problems of the use of external finance, ceteris paribus, the direct effect of the capital on monitoring is positive:

$$\theta_K = \frac{-\frac{R}{\theta L}}{\frac{R}{\theta^2}\left(1-\frac{K}{L}\right)-2\mu}. \tag{A.7}$$

In equilibrium, the partial elasticity of monitoring with respect to K is

$$\theta_K \frac{K}{\theta} = \frac{-\frac{K}{L}}{2\left(\frac{4m}{1+4m} - \frac{K}{L}\right)}. \tag{A.8}$$

The elasticity of monitoring with respect to the amount of bank capital is increasing in the capital-loans ratio. Second, a change in the amount of capital has the opposite effect on monitoring through its influence on the volume of lending, as the correlation between K and L is positive and the volume of lending is inversely related to monitoring, as seen above. Together, the aggregate effect of bank capital on monitoring appears to be positive:

$$\frac{d\theta}{dK}\frac{K}{\theta} = \theta_K \frac{K}{\theta} + \theta_L \frac{dL}{dK}\frac{K}{\theta} = -2m\frac{dL}{dK}\frac{K}{L}. \tag{A.9}$$

The positive sign of the aggregate effect is due to the decreasing returns to scale of the potential projects, which weakens the adjustment of the volume of lending. As noted above, the share of external finance in the bank's liabilities contracts with an increase in the amount of capital and the incentive to monitor increases as the bank has more capital at stake. If the project returns were independent of the volume of lending ($m = 0$), the increase in bank capital would not have any effect on the intensity of monitoring.

As seen above, the elasticity between the volume of lending and lending interest rates is constant $\left(\frac{dH}{dL}\frac{L}{H} = m\right)$. The effect of a change in bank capital on lending rates then has a simple relation to its effects on the volume of lending:

$$\frac{dH}{dK}\frac{K}{H} = \frac{dH}{dL}\frac{dL}{dK}\frac{K}{H} = m\frac{dL}{dK}\frac{K}{L}. \tag{A.10}$$

Next, we look at the influence of bank capital on monetary policy transmission. One way to evaluate its influence is to derive the effect of K on the elasticity of the volume of lending with respect to (the monetary policy rate) R. Here again, we have to take into account both the direct effect and the indirect effect through the adjustment in the volume of lending:

$$\begin{aligned} \frac{d\left(\frac{dL}{dR}\frac{R}{L}\right)}{dK} &= \frac{\partial\left(\frac{dL}{dR}\frac{R}{L}\right)}{\partial K} + \frac{\partial\left(\frac{dL}{dR}\frac{R}{L}\right)}{\partial L}\frac{dL}{dK} = \\ & \left[1 + \frac{dL}{dR}\frac{R}{L}(1-4m)\right]\left(\frac{dL}{dK}\frac{K}{L} - 1\right)\frac{dL}{dK}\frac{1}{L}. \end{aligned} \tag{A.11}$$

First, the direct effect of an increase in K weakens monetary policy transmission, as it raises the share of internal funding of the bank and counteracts, in the case of a monetary contraction, the adversely affected monitoring incentives of the bank. Second, the increase in the volume of lending due to an increase in K reinforces monetary policy transmission, since the loan expansion requires more external funding, which in turn strengthens the adverse effects of contractionary monetary policy on the bank's monitoring incentives. While these effects partly offset each other, the direct effect is stronger because the returns on the borrowers' projects are decreasing in the number of projects, which lowers the share of external finance needed by the bank, as stated above. That, on aggregate, an increase in K weakens the policy effects, can also be seen in (A.11), where the first two terms in brackets on the right-hand-side are negative while the last term is positive. Therefore, the sign of the derivative is positive, which means that the negative effect of the capital market interest rate on lending (elasticity) is reduced if additional capital is supplied.

On the other hand, the effect of K on monetary policy transmission can be understood through the liability structure. An increase in capital increases the capital-loans ratio, which then mitigates the monetary policy effects.

A.3.2 Competitive loan market

Effects of monitoring cost and entry cost

Using the equilibrium conditions (3.48) and (3.49) that determine the two endogenous variables l and n, we are able to derive a system of equations parallel to (3.50) that gives the effects of the unit monitoring cost μ on the endogenous variables:

$$\begin{pmatrix} R & 0 \\ \left[4m\left(1+\frac{k}{l}\right)-\frac{k}{l}\right]\frac{R}{l\left(1+\frac{k}{l}\right)} & \frac{4mR}{n} \end{pmatrix}\begin{pmatrix} \frac{dl}{d\mu} \\ \frac{dn}{d\mu} \end{pmatrix} = \begin{pmatrix} 0 \\ \frac{R}{\mu} \end{pmatrix}. \tag{A.12}$$

The resulting partial effects of monitoring costs appear to be quite simple:

$$\frac{dl}{d\mu}\frac{\mu}{l} = 0. \tag{A.13}$$

$$\frac{dn}{d\mu}\frac{\mu}{n} = \frac{1}{4m}. \tag{A.14}$$

The elasticity measure in (A.13) first reveals that the unit cost of monitoring has no effect on the lending of an individual bank that is active in the loan market. Therefore, changes in the cost of monitoring do not affect the responses of banks to monetary policy since they do not change the capital-loans ratio of an individual bank. As equation (A.14) tells us, the response in the number of active banks to a change in the cost of monitoring is independent of the liability structure of the banks. Together (A.13) and (A.14) imply that the aggregate volume of lending indeed responds to shocks in the unit cost of monitoring but in a way independent of the capital-loans ratio of the banks:

$$\frac{dL}{d\mu}\frac{\mu}{L} = \frac{1}{4m}. \tag{A.15}$$

To obtain the effect of the unit cost of monitoring on the intensity of monitoring, we need to combine the direct effect of μ on θ and the indirect effect through aggregate lending (the indirect effect through the volume of lending of individual banks being zero, as implied by (A.13)). As before, we can see from (3.40) that the direct effect is $\theta_\mu = \frac{2\theta}{\frac{R}{\theta^2}\left(1-\frac{k}{l}\right)-2\mu}$. Using (3.44), the partial elasticity is in equilibrium $\theta_\mu \frac{\mu}{\theta} = -\frac{1}{2\frac{k}{l}} - \frac{1}{2}$. Combining this result with the indirect elasticity through L and using (3.56) and (A.15), yields the total effect in percentage terms[34]:

$$\frac{d\theta}{d\mu}\frac{\mu}{\theta} = -\frac{1}{2}. \tag{A.16}$$

Even though both the direct effect and the indirect effect (in percentage terms) depend on the capital-loans ratio, their sum is a negative constant. The effects dependent on $\frac{k}{l}$ offset each other while the negative direct effect is dominant.

On the other hand, the loan market equilibrium is affected by the monetary value of the entry cost U. Actually, this means that the expected profits of banks active in the loan market are equal to U without any new entrants to the market. U could be interpreted as a kind of barrier to competition as it enables profits in the loan market.

[34] As before, $\theta_H = 0$ in the equilibrium, and therefore the effects are not transmitted through the lending interest rate.

However, the barriers of entry possibly come from natural factors if U reflects eg the required investments in the required monitoring technology. The entry cost affects the structure of the loan market as well as the capital-loans ratios of individual banks. Thereby, it also has an impact on the response of the banking sector to monetary policy. To show this, let us establish the following system of equations using the equilibrium conditions (3.48) and (3.49):

$$\begin{pmatrix} R & 0 \\ \left[4m\left(1+\frac{k}{l}\right)-\frac{k}{l}\right]\frac{R}{l\left(1+\frac{k}{l}\right)} & \frac{4mR}{n} \end{pmatrix}\begin{pmatrix} \frac{dl}{dU} \\ \frac{dn}{dU} \end{pmatrix}=\begin{pmatrix} 2 \\ 0 \end{pmatrix}. \tag{A.17}$$

Accordingly, we can compute the following equilibrium partial elasticities of l and n, respectively:

$$\frac{dl}{dU}\frac{U}{l}=1-\frac{k}{l}. \tag{A.18}$$

$$\frac{dn}{dU}\frac{U}{n}=-\left(1-\frac{k}{l}\right)\left(1-\frac{\frac{k}{l}}{4m\left(1+\frac{k}{l}\right)}\right). \tag{A.19}$$

Thus, an increase in U, ceteris paribus, increases the size of the active banks in the loan market, measured by volume of lending. This also means that more profitable banks (with higher U) have lower capital-loans ratios, which is also reflected in the banks response to monetary policy. By (3.53), if $\frac{k}{l}<\left(\frac{k}{l}\right)^*$, an increase in U also implies a rise in the power of monetary policy, since it decreases banks' capital-loans ratios. If $\frac{k}{l}<\left(\frac{k}{l}\right)^*$, the effect of an increase in U is the opposite. The effect of U on l depends on the capital-loans ratio in a linear manner, so that the bank increases its volume of lending the more, the larger the share of external funds in its balance sheet.

On the other hand, an increase in U reduces the number of banks that enter the loan market. This is quite natural since U measures the utility of staying away from the loan market. Together, the effect of U on the aggregate volume of lending is derived by adding up the effects in (A.18) and (A.19):

$$\frac{dL}{dU}\frac{U}{L}=\frac{1}{4m}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{\left(1+\frac{k}{l}\right)}. \tag{A.20}$$

With our assumption on m, we see that the aggregate volume of lending decreases as U increases, since the effect of the entry cost on the number of active banks appears to dominate. This implies that loan markets with higher entry costs exhibit lower volume of lending, other things equal. As the capital-loans ratio $\frac{k}{l}$ grows, the negative effect of U on L strengthens (in percentage terms) as long as $\frac{k}{l} < \left(\frac{k}{l}\right)^*$ and weakens thereafter.

From (3.40) we see that the entry cost has no direct effect on the intensity of monitoring. The indirect effects through both l and L result in the following total effect, using (3.54), (3.56), (A.18) and (A.20),[35]:

$$\frac{d\theta}{dU}\frac{U}{\theta} = -\frac{1}{2}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{\left(1+\frac{k}{l}\right)}. \tag{A.21}$$

That is, an increase in the entry cost leads to a decrease in the intensity of monitoring, other things equal. Similarly to its effect on aggregate lending, the negative effect of U on θ strengthens (in percentage terms) as the capital-loans ratio $\frac{k}{l}$ increases as long as $\frac{k}{l} < \left(\frac{k}{l}\right)^*$ and weakens thereafter. Interestingly, note that an increase in U leads to a decrease in both the intensity of monitoring and the aggregate volume of lending. This is related to moral hazard problems in intermediation, which become more severe as U increases.

Finally we also see that the effect of entry cost on the lending rate is positive through its effect on the volume of aggregate lending, so that $\frac{dH}{dU}\frac{U}{H} = m\frac{dL}{dU}\frac{U}{L}$, which is positive, since both m and $\frac{dL}{dU}\frac{U}{L}$ are negative.

Effects of bank capital

Next, we turn to the effects of a change in the exogenous amount of capital of individual banks in the competitive loan market. In conformity with our assumption that each potential banker is representative, we maintain that a capital shock changes the amount of each potential banker simultaneously at the same rate. The system of equations needed for examining the effects of k is now

$$\begin{pmatrix} R & 0 \\ \left[4m\left(1+\frac{k}{l}\right)-\frac{k}{l}\right]\frac{R}{l\left(1+\frac{k}{l}\right)} & \frac{4mR}{n} \end{pmatrix}\begin{pmatrix} \frac{dl}{dk} \\ \frac{dn}{dk} \end{pmatrix} = \begin{pmatrix} R \\ -\frac{R}{l+k} \end{pmatrix}. \tag{A.22}$$

The associated elasticity measures are thus

[35] As before, $\theta_H = 0$ in the equilibrium, and therefore the effects are not transmitted through the lending interest rate.

$$\frac{dl}{dk}\frac{k}{l} = \frac{k}{l} \tag{A.23}$$

$$\frac{dn}{dk}\frac{k}{n} = -\frac{k}{l}\left(1 + \frac{1-\frac{k}{l}}{4m\left(1+\frac{k}{l}\right)}\right). \tag{A.24}$$

An increase (decrease) in the amount of capital available to individual banks unambiguously increases (decreases) the volume of lending of each active bank. In contrast, the direction of the change in the number of banks active in the loan market after a capital shock is unclear. A lower prevailing capital-loans ratio, however, makes it more probable that a positive (negative) capital shock has a positive (negative) effect on the number of active banks. Although the effects of k on n cannot be unambiguously signed, the effect of a capital shock on the aggregate volume of lending is clearly positive:

$$\frac{dL}{dk}\frac{k}{L} = -\frac{1}{4m}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{\left(1+\frac{k}{l}\right)}. \tag{A.25}$$

This result is qualitatively similar to the corresponding one in the case of a monopoly bank and consistent with the literature on the effects of capital constraints, eg the credit crunch result of Holmstrom and Tirole (1997). The positive effect of capital on lending reaches its maximum when $\frac{k}{l} = \left(\frac{k}{l}\right)^*$ and behaves in $\frac{k}{l}$ in a way similar to the effect of monetary policy on monitoring (see (3.60)).

The shock on capital of the banking sector also affects the capital-loans ratios of individual banks:

$$\frac{d\left(\frac{k}{l}\right)}{dk} = \frac{1}{l}\left(1-\frac{k}{l}\right). \tag{A.26}$$

In fact, from (A.23) we see that $\frac{dl}{dk} = 1$, ie the amount of bank specific loans is adjusted one-to-one to changes in k. Hence, since $k \leq l$, a given change in k ($k \to k + \Delta$) changes k more in percentage terms than l; thus $\frac{k}{l}$ increases. Therefore, a positive (negative) bank capital shock also weakens (strengthens) the monetary policy effects on bank lending, since the associated increase in $\frac{k}{l}$ makes the banks respond more (less) through adjustment in the intensity of monitoring and less (more) through adjustment in the volume of lending, provided that $\frac{k}{l}$ is below the critical level $\left(\frac{k}{l}\right)^*$.

Since, in equilibrium, the partial elasticity of the intensity of monitoring with respect to bank capital, $\theta_k \frac{k}{\theta}$, equals $\frac{1}{2}$[36], we can compute the effect of a change in k on the intensity of monitoring by combining this with equations (3.54), (3.56) and (A.25)[37]:

$$\frac{d\theta}{dk}\frac{k}{\theta} = \theta_k \frac{k}{\theta} + \theta_L \frac{dL}{dk}\frac{k}{\theta} + \theta_l \frac{dl}{dk}\frac{k}{\theta} = \frac{1}{2}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{\left(1+\frac{k}{l}\right)}. \tag{A.27}$$

A positive capital injection makes the banks intensify their monitoring. The elasticity of monitoring with respect to capital and the corresponding elasticity of aggregate lending are positively related, as $\frac{d\theta}{dk}\frac{k}{\theta} = -2m\frac{dL}{dk}\frac{k}{L}$. This result is comparable to the positive effect of a monetary contraction on the intensity of monitoring, whereas the effects of bank capital and monetary policy on the volume of lending are opposing. On the other hand, the effects of k on L and θ are opposite to those of U. In fact, an increase in k unambiguously mitigates the moral hazard problems, whereas an increase in U unambiguously exacerbates them.

Finally, the effect of capital shock on the lending rate H comes through its effect on aggregate lending. Recalling that $\frac{dH}{dL}\frac{L}{H} = m$ in equilibrium, we see that $\frac{dH}{dk}\frac{k}{H} = m\frac{dL}{dK}\frac{K}{L}$.

[36] The direct effect of own capital on monitoring is, using (3.40), $\theta_k = -\frac{\frac{R}{\theta l}}{\frac{R}{\theta^2}\left(1-\frac{k}{l}\right)-2\mu}$. The partial elasticity in equilibrium can be calculated by combining this with condition (3.44).

[37] As before, $\theta_H = 0$ in the equilibrium, and therefore the effects are not transmitted through the lending interest rate.

A.4 Summary tables

Table A.1 Loan market with a monopoly bank

Capital constraint	$\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m - \frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}$ $\frac{dH}{dR}\frac{R}{H} = \frac{m}{4m - \frac{\frac{K}{L}(1+4m)}{(1-4m)+\frac{K}{L}(1+4m)}}$ $\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1-\frac{K}{L}\frac{(1+4m)(1-2m)}{2m(1-4m)}}{2-\frac{K}{L}\frac{(1+4m)}{2m}}$	$\frac{dL}{dK}\frac{K}{L} = \frac{(1+4m)\frac{K}{L}}{(1-4m)\left[(1+4m)\frac{K}{L}-4m\right]}$ $\frac{dH}{dK}\frac{K}{H} = \frac{m(1+4m)\frac{K}{L}}{(1-4m)\left[(1+4m)\frac{K}{L}-4m\right]}$ $\frac{d\theta}{dK}\frac{K}{\theta} = -\frac{2m(1+4m)\frac{K}{L}}{(1-4m)\left[(1+4m)\frac{K}{L}-4m\right]}$
No capital constraint	$\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m}$ $\frac{dH}{dR}\frac{R}{H} = \frac{1}{4}$ $\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1}{2}$	$\frac{dL}{dK}\frac{K}{L} = 0$ $\frac{dH}{dK}\frac{K}{H} = 0$ $\frac{d\theta}{dK}\frac{K}{\theta} = 0$

Table A.2 Loan market with competitive banks

Capital constraint	$\frac{dl}{dR}\frac{R}{l} = -\left(1 - \frac{k}{l}\right)$ $\frac{dn}{dR}\frac{R}{n} = \left(1 - \frac{k}{l}\right) + \frac{1}{4m}\frac{1+\left(\frac{k}{l}\right)^2}{1+\frac{k}{l}}$ $\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m}\frac{1+\left(\frac{k}{l}\right)^2}{1+\frac{k}{l}}$ $\frac{dH}{dR}\frac{R}{H} = \frac{1}{4}\frac{1+\left(\frac{k}{l}\right)^2}{1+\frac{k}{l}}$ $\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1}{2}\left(1 + \frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{1+\frac{k}{l}}\right)$	$\frac{dl}{dk}\frac{k}{l} = \frac{k}{l}$ $\frac{dn}{dk}\frac{k}{n} = -\frac{k}{l}\left(1 + \frac{1}{4m}\frac{\left(1-\frac{k}{l}\right)}{1+\frac{k}{l}}\right)$ $\frac{dL}{dk}\frac{k}{L} = -\frac{1}{4m}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{1+\frac{k}{l}}$ $\frac{dH}{dk}\frac{k}{H} = -\frac{1}{4}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{1+\frac{k}{l}}$ $\frac{d\theta}{dk}\frac{k}{\theta} = \frac{1}{2}\frac{\frac{k}{l}\left(1-\frac{k}{l}\right)}{\left(1+\frac{k}{l}\right)}$
No capital constraint	$\frac{dL}{dR}\frac{R}{L} = \frac{1}{4m}$ $\frac{dH}{dR}\frac{R}{H} = \frac{1}{4}$ $\frac{d\theta}{dR}\frac{R}{\theta} = \frac{1}{2}$	$\frac{dL}{dk}\frac{k}{L} = 0$ $\frac{dH}{dk}\frac{k}{H} = 0$ $\frac{d\theta}{dk}\frac{k}{\theta} = 0$

A.5 Econometric framework

As the lagged values of the dependent variable are included, estimation of the empirical equation (4.3) and its variants will be conducted using the generalised method of moments (GMM) estimator proposed by Arellano and Bond (1991)[38]. This estimation method provides efficiency and consistency of the estimates, provided the instruments are properly chosen to take into account the serial correlation properties of the model.

The problems in the OLS estimation with dynamic panel data models become evident already in a very simple example, where we allow individual effects in the error term of the model and assume stationarity of data ($|\alpha| < 1$):

$$y_{it} = \alpha y_{it-1} + (\eta_i + \nu_{it}) \qquad \text{(A.28)}$$

where $i = 1, ..., N$ and $t = 1, ..., T$ with T fixed and the initial value of the dependent variable y_{i0} is assumed observed. Furthermore, the η_i are unobservable individual effects with $E(\eta_i) = 0$, and ν_{it} are assumed to be error terms independently distributed across individuals with $E(\nu_{it}) = 0$, for all t while different forms of heteroscedasticity across units and time are possible. We also make the assumption that the error terms are independent of the individual effects, ie $E(\eta_i \nu_{it}) = 0$. To obtain unbiased estimates with the OLS estimator, we should assume exogeneity of the lagged dependent variable conditional on the unobservable individual effects. This is, however, an unrealistic assumption, as we can see that $E(y_{it-1}\eta_i) > 0$ from $y_{it-1} = \alpha y_{it-2} + \eta_i + \nu_{it}$.

Now, if we can – instead of taking exogeneity of lagged dependent variables as given – impose restrictions on the serial correlation structure of the error term, we can employ different identification arrangements to estimate α. First, taking first differences[39] of (A.28), we are able to eliminate η_i from the transformed error terms:

$$\begin{aligned} \Delta y_{it} &= \alpha \Delta y_{it-1} + \Delta \nu_{it}, \text{ ie} \qquad \text{(A.29)} \\ (y_{it} - y_{it-1}) &= \alpha (y_{it-1} - y_{it-2}) + (\nu_{it} - \nu_{it-1}). \end{aligned}$$

[38] See also eg Arellano and Bover (1995) and Blundell and Bond (1998) for a discussion of this type of estimators.

[39] There are, or course, other transformations that eliminate individual effects from the transformed error term.

The OLS estimator would still be biased with first differences, since $E\left[\left(y_{it-1}-y_{it-2}\right)\left(\nu_{it}-\nu_{it-1}\right)\right] < 0$. Therefore, we have to employ GMM with appropriate instruments for the lagged dependent variables. To enable use of certain lagged levels of y as instruments, we make two assumptions. These pertain to the serial correlation of the original error term and the correlation between the original error term and the initial value of the dependent variable. On the one hand, we do not allow for arbitrary serial correlation of the original error term but instead assume $E\left(\nu_{it}\nu_{is}\right)=0$ whenever $s \neq t$. On the other hand, we also assume that the observed initial value of dependent variable is uncorrelated with the original error term, ie $E\left(y_{i0}\nu_{it}\right)=0$ for $t=1,...,T$. These assumptions enable us to use the following moment conditions in estimating α:

$$E\left(y_{is}\Delta\nu_{it}\right)=0, \quad t=2,...,T, \quad s=0,...,t-2 \tag{A.30}$$

In other words, all the levels of the endogenous variable at lag 2 or more can be used as instruments if the equation is in first differences.

The optimal choice of an instrument is different if the model is extended to include independent explanatory variables x_{it}:

$$y_{it}=\alpha y_{it-1}+\beta x_{it}+\eta_i+\nu_{it} \tag{A.31}$$

Let us assume that the explanatory variables are correlated with the individual effects so that transformation of the original equation is necessary. Then the optimal matrix of instruments depends on whether the explanatory variables are strictly exogenous with respect to the error term, ie whether $E\left(x_{it}\nu_{is}\right)=0$ for all t and s, or whether the explanatory variables are predetermined with respect to the error term, ie whether $E\left(x_{it}\nu_{is}\right)=0$ if $s \geq t$ and non-zero otherwise. In case of strictly exogenous variables, every x_{it} at every t is a valid instrument for all the equations, and there is no need to choose instruments other than the transformed variable in equation. In case of predetermined variables, the possible instruments are the levels of the predetermined variable at lag 1 or more if equation is in first differences, and the possible moment conditions are

$$E\left(x_{is}\Delta\nu_{it}\right)=0, \quad t=1,...,T, \quad s=0,...,t-1 \tag{A.32}$$

In any case, the GMM estimator for parameters in (A.31) would become (see eg Arellano and Bond 1991)

$$\begin{pmatrix} \widehat{\alpha} \\ \widehat{\beta} \end{pmatrix} = \left(\Delta X' Z A_N Z' \Delta X\right)^{-1} \Delta X' Z A_N Z' \Delta y \qquad \text{(A.33)}$$

where X is a stacked matrix of observations on y and x, Z is the appropriate choice of instruments combined from the instrument sets for each individual ($Z = [Z_1', ..., Z_N']$ for N individuals), which are chosen according to the guidelines set above, and $A_N = \left(N^{-1} \sum_{i=1}^{N} Z_i' H_i Z_i\right)^{-1}$. The optimal choice for the individual-specific $(T-2 \times T-2)$ weighting matrix H_i would be the square matrix composed of the cross products of the error terms. In the estimations, we report two sets of estimates related to the two different choices of H_i. In the *one-step estimation*, we do not use the error terms, and H_i is identical for every individual[40]:

$$H_i = \frac{1}{2} \begin{bmatrix} 2 & -1 & 0 & . & . & 0 \\ -1 & 2 & -1 & . & . & 0 \\ 0. & -1. & & & . & . \\ . & . & & & -1 & 0 \\ . & . & . & -1 & 2 & -1 \\ 0 & 0 & ... & 0 & -1 & 2 \end{bmatrix} \qquad \text{(A.34)}$$

It should be noted that the weighting matrix in (A.34) assumes homoscedasticity of error terms. In the *two-step estimation*, this weighting matrix can then be replaced by the square matrix of the error terms from the one-step estimation, ie $H_i = \Delta\widehat{\nu}_i \Delta\widehat{\nu}_i'$. The latter is more efficient if the error terms are heteroscedastic (see eg White 1982).

The assumption of no serial correlation in the error term is crucial for our estimator. Therefore, we report the results for tests of the absence of first- and second-order autocorrelation in differenced residuals. If the error terms in levels are not serially correlated, there should be no evidence of second-order serial correlation in the differenced residuals. However, this result could also follow if the error terms in levels follow a random-walk process. To exclude this option, we should observe significant negative first-order serial

[40] See Doornik and Hendry (2001), p. 67.

correlation in differenced residuals. The autocorrelation test statistics are based on standardised average residual autocovariances, which are asymptotically normally N(0,1) distributed under the null hypothesis of no autocorrelation.

We also test the validity of instruments by Sargan test of overidentifying restrictions. The test statistic is

$$S = \widehat{\nu}' Z A_N Z' \widehat{\nu} \tag{A.35}$$

where $\widehat{\nu}$ is the vector of residuals, Z is the instrument matrix, and A_N is the matrix defined above, the choice of the weighting matrix H_i depending on the step of estimation. If the weighting matrix is chosen optimally for the instruments of each individual, S is asymptotically distributed as a chi-square with as many degrees of freedom as there are overidentifying restrictions, under the null hypothesis of the validity of instruments. It should be noted that only the Sargan test statistic for the two-step estimation is heteroscedasticity-consistent.

A.6 Estimation results

Table A.3

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the 3 month securities market interest rate;
$(K/A)_i$: (1)–(2): deviation from average of $(K/A)_i$ over all periods
Sample 1995:1–2000:4

		(1)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.051184	0.036**	0.037622	0.169
$\Delta logL_{it-2}$	(β_2)	0.008006	0.708	0.001191	0.960
$\Delta logL_{it-3}$	(β_3)	0.015891	0.410	0.016905	0.424
$\Delta logL_{it-4}$	(β_4)	0.115384	0.000***	0.111893	0.000***
Δr_{t-1}	(γ_1)	–1.92143	0.000***	–1.97974	0.000***
Δr_{t-2}	(γ_2)	–0.67739	0.239	–0.721651	0.280
Δr_{t-3}	(γ_3)	–0.514436	0.138	–0.522658	0.194
Δr_{t-4}	(γ_4)	–0.269736	0.426	–0.250528	0.519
$\Delta(K/A)_{it-1}$	(δ_1)	0.097957	0.205	0.082223	0.393
$\Delta(K/A)_{it-2}$	(δ_2)	0.104761	0.215	0.134919	0.191
$\Delta(K/A)_{it-3}$	(δ_3)	0.008981	0.902	0.058563	0.534
$\Delta(K/A)_{it-4}$	(δ_4)	0.2009	0.007***	0.211539	0.024**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)				
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)				
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)				
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)				
$\Delta logGDP_{t-1}$	(λ_1)	–0.193329	0.063*	–0.18953	0.092*
$\Delta logGDP_{t-2}$	(λ_2)	0.302433	0.002***	0.30803	0.005***
$\Delta logGDP_{t-3}$	(λ_3)	0.312868	0.043**	0.316473	0.079*
$\Delta logGDP_{t-4}$	(λ_4)	–0.092101	0.598	–0.099767	0.622
$\Delta logDEF_{t-1}$	(μ_1)	–0.125041	0.055*	–0.120334	0.103
$\Delta logDEF_{t-2}$	(μ_2)	0.710942	0.000***	0.699462	0.000***
$\Delta logDEF_{t-3}$	(μ_3)	0.358654	0.099*	0.368959	0.145
$\Delta logDEF_{t-4}$	(μ_4)	–0.155103	0.263	–0.150119	0.354
D984		0.002153	0.000***	0.002177	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		634.5	0.000***	321.8	1.000
AR(1)		–13.86	0.000***	–10.71	0.000***
AR(2)		–0.9576	0.338	–0.2884	0.773
H1		10.8993	0.0010***	7.06194	0.0079***
H2		6.92317	0.0085***	5.4405	0.0197**
H3		3.45198	0.0632*	2.91636	0.0877*
H4					
H5		0.673413	0.4119	0.526834	0.4679
H6		1.40336	0.2362	1.12382	0.2891
H7		3.31759	0.0685*	2.51047	0.1131
H8		0.002112	0.9633	0.004531	0.9463

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table A.3

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the 3 month securities market interest rate;
$(K/A)_i$: (1)–(2): deviation from average of $(K/A)_i$ over all periods
Sample 1995:1–2000:4

		(2) one-step Coefficient	p-value	(2) two-step Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.045099	0.064*	0.032833	0.237
$\Delta logL_{it-2}$	(β_2)	0.00235	0.911	–0.002498	0.915
$\Delta logL_{it-3}$	(β_3)	0.012473	0.516	0.016236	0.446
$\Delta logL_{it-4}$	(β_4)	0.112998	0.000***	0.111268	0.000***
Δr_{t-1}	(γ_1)	–1.90694	0.000***	–1.96171	0.000***
Δr_{t-2}	(γ_2)	–0.695844	0.222	–0.7512	0.258
Δr_{t-3}	(γ_3)	–0.508691	0.142	–0.507012	0.206
Δr_{t-4}	(γ_4)	–0.240755	0.483	–0.202457	0.601
$\Delta(K/A)_{it-1}$	(δ_1)	0.128404	0.103	0.095761	0.337
$\Delta(K/A)_{it-2}$	(δ_2)	0.133991	0.121	0.141206	0.191
$\Delta(K/A)_{it-3}$	(δ_3)	0.028637	0.700	0.061515	0.531
$\Delta(K/A)_{it-4}$	(δ_4)	0.212474	0.004***	0.211983	0.025**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)	4.03713	0.114	5.19783	0.130
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)	3.77122	0.160	2.94642	0.366
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)	1.38702	0.579	2.08957	0.504
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)	1.12779	0.675	0.380543	0.912
$\Delta logGDP_{t-1}$	(λ_1)	–0.164634	0.132	–0.154821	0.194
$\Delta logGDP_{t-2}$	(λ_2)	0.313398	0.001***	0.324645	0.004***
$\Delta logGDP_{t-3}$	(λ_3)	0.306534	0.047**	0.312683	0.079*
$\Delta logGDP_{t-4}$	(λ_4)	–0.101826	0.559	–0.107552	0.595
$\Delta logDEF_{t-1}$	(μ_1)	–0.123117	0.068*	–0.11949	0.132
$\Delta logDEF_{t-2}$	(μ_2)	0.679676	0.000***	0.668691	0.000***
$\Delta logDEF_{t-3}$	(μ_3)	0.312675	0.154	0.323264	0.200
$\Delta logDEF_{t-4}$	(μ_4)	–0.175734	0.208	–0.173906	0.282
D984		0.002484	0.000***	0.002499	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		633.7	0.000***	317.7	1.000
AR(1)		–13.84	0.000***	–10.62	0.000***
AR(2)		–0.9292	0.353	–0.2856	0.775
H1		9.23326	0.0024***	6.29212	0.0121**
H2		6.82361	0.0090***	5.39388	0.0202**
H3		4.86662	0.0274**	2.86341	0.0906*
H4		5.4923	0.0191**	3.16028	0.0755*
H5		0.789363	0.3743	0.6592	0.4168
H6		1.39852	0.2370	1.00149	0.3170
H7		2.4811	0.1152	1.90851	0.1671
H8		0.090334	0.7638	0.078419	0.7795

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table A.3

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the 3 month securities market interest rate;
$(K/A)_i$: (3)–(4): deviation from cross-sectional average of $(K/A)_i$ at each period
Sample 1995:1–2000:4

		(3)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.048095	0.058*	0.03669	0.192
$\Delta logL_{it-2}$	(β_2)	0.006031	0.782	–0.000726	0.977
$\Delta logL_{it-3}$	(β_3)	0.014757	0.450	0.015564	0.468
$\Delta logL_{it-4}$	(β_4)	0.116046	0.000***	0.114986	0.000***
Δr_{t-1}	(γ_1)	–1.9516	0.000***	–2.00815	0.000***
Δr_{t-2}	(γ_2)	–0.635369	0.291	–0.595391	0.397
Δr_{t-3}	(γ_3)	–0.545047	0.134	–0.50543	0.232
Δr_{t-4}	(γ_4)	–0.382453	0.285	–0.332395	0.425
$\Delta(K/A)_{it-1}$	(δ_1)	0.09378	0.210	0.074566	0.444
$\Delta(K/A)_{it-2}$	(δ_2)	0.108315	0.181	0.123836	0.230
$\Delta(K/A)_{it-3}$	(δ_3)	0.003132	0.964	0.042863	0.644
$\Delta(K/A)_{it-4}$	(δ_4)	0.198454	0.007***	0.209585	0.021**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)				
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)				
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)				
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)				
$\Delta logGDP_{t-1}$	(λ_1)	–0.244721	0.034**	–0.248972	0.053*
$\Delta logGDP_{t-2}$	(λ_2)	0.297497	0.003***	0.286863	0.013**
$\Delta logGDP_{t-3}$	(λ_3)	0.325601	0.044**	0.30398	0.107
$\Delta logGDP_{t-4}$	(λ_4)	–0.074898	0.686	–0.103138	0.631
$\Delta logDEF_{t-1}$	(μ_1)	–0.130861	0.050**	–0.109043	0.153
$\Delta logDEF_{t-2}$	(μ_2)	0.713617	0.000***	0.697226	0.000***
$\Delta logDEF_{t-3}$	(μ_3)	0.429886	0.064*	0.406675	0.134
$\Delta logDEF_{t-4}$	(μ_4)	–0.147199	0.324	–0.149304	0.392
D984		0.00203	0.000***	0.002058	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		641.8	0.000***	324.7	1.000
AR(1)		–13.87	0.000***	–10.68	0.000***
AR(2)		–0.9896	0.322	–0.2724	0.785
H1		9.67282	0.0019***	6.47297	0.0110**
H2		6.7969	0.0091***	4.789	0.0286**
H3		3.90212	0.0482**	2.68757	0.1011
H4					
H5		0.519703	0.4710	0.240344	0.6240
H6		1.49402	0.2216	1.47562	0.2245
H7		3.39944	0.0652*	2.4267	0.1193
H8		0.011423	0.9149	0.000482	0.9825

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table A.3

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$)
Δr_{it-1}: (1)–(4): 1st difference of the 3 month securities market interest rate;
$(K/A)_i$: (3)–(4): deviation from cross-sectional average of $(K/A)_i$ at each period
Sample 1995:1–2000:4

		(4)			
		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.042086	0.095*	0.030395	0.291
$\Delta logL_{it-2}$	(β_2)	0.000988	0.964	–0.003694	0.879
$\Delta logL_{it-3}$	(β_3)	0.011379	0.559	0.015987	0.459
$\Delta logL_{it-4}$	(β_4)	0.113284	0.000***	0.113277	0.000***
Δr_{t-1}	(γ_1)	–1.92799	0.000***	–1.97678	0.000***
Δr_{t-2}	(γ_2)	–0.605797	0.316	–0.611107	0.387
Δr_{t-3}	(γ_3)	–0.520174	0.153	–0.489135	0.245
Δr_{t-4}	(γ_4)	–0.358461	0.316	–0.313646	0.446
$\Delta(K/A)_{it-1}$	(δ_1)	0.132228	0.081*	0.110486	0.265
$\Delta(K/A)_{it-2}$	(δ_2)	0.140657	0.088*	0.149955	0.152
$\Delta(K/A)_{it-3}$	(δ_3)	0.025751	0.712	0.064012	0.503
$\Delta(K/A)_{it-4}$	(δ_4)	0.213429	0.004***	0.214613	0.021**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)	3.26059	0.182	4.18014	0.233
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)	3.7649	0.149	3.01789	0.371
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)	1.30975	0.586	2.64609	0.388
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)	1.74673	0.491	1.48124	0.648
$\Delta logGDP_{t-1}$	(λ_1)	–0.238221	0.039**	–0.241206	0.061*
$\Delta logGDP_{t-2}$	(λ_2)	0.290025	0.004***	0.286223	0.013**
$\Delta logGDP_{t-3}$	(λ_3)	0.310952	0.055*	0.297926	0.113
$\Delta logGDP_{t-4}$	(λ_4)	–0.085069	0.647	–0.105489	0.623
$\Delta logDEF_{t-1}$	(μ_1)	–0.131973	0.047**	–0.113656	0.138
$\Delta logDEF_{t-2}$	(μ_2)	0.69764	0.000***	0.684006	0.000***
$\Delta logDEF_{t-3}$	(μ_3)	0.40771	0.080*	0.398166	0.141
$\Delta logDEF_{t-4}$	(μ_4)	–0.157111	0.292	–0.155053	0.372
D984		0.002066	0.000***	0.002065	0.000***
Observations		5415		5415	
		test value	p-value	test value	p-value
Sargan test		642.7	0.000***	321.4	1.000
AR(1)		–13.84	0.000***	–10.56	0.000***
AR(2)		–0.9859	0.324	–0.2885	0.773
H1		8.13027	0.0044***	5.69372	0.170**
H2		6.39978	0.0114**	4.70172	0.0301**
H3		6.01201	0.0142**	3.60965	0.0574*
H4		6.57964	0.0103**	3.62423	0.0569*
H5		0.432127	0.5109	0.234606	0.6281
H6		1.74245	0.1868	1.52453	0.2169
H7		3.0158	0.0825*	2.27286	0.1317
H8		0.001149	0.973	0.00314	0.9553

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H8 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\gamma_j=0$, H3: $\Sigma\delta_j=0$, H4: $\Sigma\phi_j=0$, H5: $\Sigma\lambda_j=0$, H6: $\Sigma\lambda_j/(1-\Sigma\beta_j)=1$, H7: $\Sigma\mu_j=0$, H8: $\Sigma\mu_j/(1-\Sigma\beta_j)=1$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

Table A.4

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$) defined as its deviation from cross-sectional average
Δr: (2), (5): 1st difference of the central bank's policy interest rate; (3), (6): 1st difference of the 3 month securities market interest rate
(K/A): (1)–(3): deviation from average of $(K/A)_i$ over all periods;
Sample 1995:1–2000:4

		(1)				(2)				(3)			
		one-step		two-step		one-step		two-step		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0544	0.019**	0.0518	0.044**	0.0504	0.028**	0.0477	0.071*	0.0503	0.028**	0.0515	0.052*
$\Delta logL_{it-2}$	(β_2)	0.0114	0.597	0.0103	0.661	0.0082	0.7	0.0079	0.734	0.0075	0.724	0.0091	0.692
$\Delta logL_{it-3}$	(β_3)	0.0194	0.303	0.0234	0.244	0.0173	0.358	0.0212	0.29	0.0172	0.359	0.0229	0.254
$\Delta logL_{it-4}$	(β_4)	0.1177	0.000***	0.1194	0.000***	0.1161	0.000***	0.1191	0.000***	0.1161	0.000***	0.1199	0.000***
$\Delta(K/A)_{it-1}$	(δ_1)	0.0979	0.142	0.092	0.233	0.1075	0.102	0.0945	0.233	0.1024	0.118	0.0841	0.278
$\Delta(K/A)_{it-2}$	(δ_2)	0.0884	0.211	0.1171	0.154	0.0935	0.184	0.1042	0.233	0.0871	0.217	0.0842	0.323
$\Delta(K/A)_{it-3}$	(δ_3)	–0.015	0.808	0.0034	0.963	–0.018	0.766	–0.007	0.922	–0.025	0.684	–0.015	0.842
$\Delta(K/A)_{it-4}$	(δ_4)	0.1999	0.002***	0.1997	0.012***	0.1956	0.002***	0.1915	0.018**	0.1969	0.002***	0.1895	0.020**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)					0.7684	0.87	–0.28	0.968	3.5081	0.156	3.7587	0.267
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)					8.2754	0.149	8.2485	0.288	3.1802	0.194	2.1932	0.466
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)					–1.995	0.608	0.3478	0.949	1.2703	0.545	3.2437	0.199
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)					1.6091	0.622	–0.97	0.837	1.3816	0.547	0.0974	0.974
Observations		5415		5415		5415		5415		5415		5415	
		test value	p-value	test value	p-value	test value	p-value	test value	p-value	test value	p-value	test value	p-value
Sargan test		638.3	0.000***	338.4	1.000	634.6	0.000***	336.3	1.000	635.1	0.000***	332.1	1.000
AR(1)		–14.01	0.000***	–10.84	0.000***	–13.97	0.000***	–10.77	0.000***	–13.99	0.000***	–10.8	0.000***
AR(2)		–0.9919	0.321	–0.2694	0.788	–0.9827	0.326	–0.296	0.767	–0.9629	0.336	–0.2715	0.786
H1		13.3179	0.000***	11.8828	0.001***	12.3013	0.001***	10.7508	0.001***	12.2376	0.001***	11.6834	0.001***
H2		4.49512	0.034**	3.75807	0.053*	4.81302	0.028**	2.78354	0.095*	4.37401	0.037**	2.28691	0.131
H3						4.55467	0.033**	1.63144	0.202	7.5391	0.006***	4.15562	0.042**

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H3 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\delta_j=0$, H3: $\Sigma\phi_j=0$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

cont.

Table A.4

Dependent variable: first difference of the volume of lending in logarithms ($\Delta logL_{it-1}$) defined as its deviation from cross-sectional average
Δr: (2), (5): 1st difference of the central bank's policy interest rate; (3), (6): 1st difference of the 3 month securities market interest rate
(K/A): (4)–(6): deviation from cross-sectional average of $(K/A)_i$: at each period
Sample 1995:1–2000:4

		(4)				(5)				(6)			
		one-step		two-step		one-step		two-step		one-step		two-step	
		Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
$\Delta logL_{it-1}$	(β_1)	0.0535	0.022**	0.0495	0.052*	0.0477	0.041**	0.0443	0.092*	0.0474	0.042**	0.0459	0.081*
$\Delta logL_{it-2}$	(β_2)	0.0107	0.621	0.0098	0.68	0.006	0.779	0.007	0.765	0.0052	0.808	0.0068	0.77
$\Delta logL_{it-3}$	(β_3)	0.0195	0.301	0.0213	0.293	0.0162	0.392	0.0203	0.322	0.0159	0.399	0.0211	0.306
$\Delta logL_{it-4}$	(β_4)	0.1174	0.000***	0.1184	0.000***	0.1148	0.000***	0.1157	0.000***	0.1149	0.000***	0.1164	0.000***
$\Delta(K/A)_{it-1}$	(δ_1)	0.0744	0.328	0.0964	0.288	0.1217	0.111	0.1287	0.164	0.1178	0.123	0.126	0.162
$\Delta(K/A)_{it-2}$	(δ_2)	0.0773	0.33	0.1093	0.253	0.1175	0.147	0.1389	0.164	0.1146	0.156	0.1321	0.175
$\Delta(K/A)_{it-3}$	(δ_3)	–0.009	0.9	0.0161	0.84	0.0168	0.808	0.0346	0.678	0.0163	0.813	0.0261	0.746
$\Delta(K/A)_{it-4}$	(δ_4)	0.1946	0.007***	0.1878	0.044**	0.2087	0.004***	0.1871	0.048**	0.2113	0.004***	0.1862	0.048**
$\Delta r_{t-1}{}^*(K/A)_{it-1}$	(ϕ_1)					1.027	0.82	2.8523	0.645	3.3298	0.178	4.9609	0.112
$\Delta r_{t-2}{}^*(K/A)_{it-1}$	(ϕ_2)					9.5163	0.107	7.3604	0.292	4.0135	0.123	2.7443	0.363
$\Delta r_{t-3}{}^*(K/A)_{it-1}$	(ϕ_3)					–2.447	0.586	–0.902	0.873	1.5383	0.512	2.9391	0.303
$\Delta r_{t-4}{}^*(K/A)_{it-1}$	(ϕ_4)					2.5256	0.476	2.444	0.579	1.9507	0.441	1.763	0.568
Observations		5415		5415		5415		5415		5415		5415	
		test value	p-value	test value	p-value	test value	p-value	test value	p-value	test value	p-value	test value	p-value
Sargan test		641.6	0.000***	338.7	1.000	639.9	0.000***	337	1.000	641	0.000***	333.3	1.000
AR(1)		–13.99	0.000***	–10.83	0.000***	–13.94	0.000***	–10.75	0.000***	–13.95	0.000***	–10.78	0.000***
AR(2)		–0.9614	0.336	–0.3304	0.741	–0.9545	0.340	–0.3394	0.734	–0.9276	0.354	–0.3172	0.751
H1		12.9111	0.000***	10.921	0.001***	10.9429	0.001***	9.56344	0.002***	10.8331	0.001***	9.88203	0.002***
H2		2.84202	0.092*	2.69519	0.101	5.13535	0.023**	3.48279	0.062*	5.07104	0.024**	3.46119	0.063**
H3						5.85034	0.016**	4.13096	0.042**	8.42784	0.004***	6.40077	0.011**

Notes:
AR(1), AR(2) refer to the first- and second-order autocorrelation tests.
H1–H3 are Wald tests for the following null hypotheses: H1: $\Sigma\beta_j=0$, H2: $\Sigma\delta_j=0$, H3: $\Sigma\phi_j=0$, where the greeks refer to appropriate parameters, see the second column of this table.
*, ** and *** denotes significance at 10, 5 and 1 percent level, respectively.

Publications of the Bank of Finland

Series E (ISSN 1238-1691, print) (ISSN 1456-5951, online)

(Series E replaces the Bank of Finland's research publications series B, C and D.)

E:1 Jukka Vesala **Testing for Competition in Banking: Behavioral Evidence from Finland**. 1995. 206 p. ISBN 951-686-447-3.

E:2 Juha Tarkka **Approaches to Deposit Pricing: A Study in the Determination of Deposit Interest and Bank Service Charges.** 1995. 166 p. ISBN 951-686-457-0.

E:3 Timo Tyrväinen **Wage Determination, Taxes, and Employment: Evidence from Finland.** 1995. 212 p. ISBN 951-686-459-7.

E:4 Sinimaaria Ranki **Realignment Expectations in the ERM: Causes and Measurement.** 1996. 164 p. ISBN 951-686-507-0.

E:5 Juhana Hukkinen **Kilpailukyky, ulkomaankaupan rakenne ja taloudellinen kasvu** (Competitiveness, structure of foreign trade and economic growth). 1996. 134 p. ISBN 951-686-512-7.

E:6 Eelis Hein **Deposit Insurance: Pricing and Incentives.** 1996. 120 p. ISBN 951-686-517-8.

E:7 Vesa Vihriälä **Banks and the Finnish Credit Cycle 1986–1995.** 1997. 200 p. ISBN 951-686-537-2.

E:8 Anne Brunila **Fiscal Policy and Private Consumption-Saving Decisions: European Evidence.** 1997. 147 p. ISBN 951-686-558-5. (Published also as A-131, Helsinki School of Economics and Business Administration, ISBN 951-791-225-0, ISSN 1237-556X)

E:9 Sinimaaria Ranki **Exchange Rates in European Monetary Integration**. 1998. 221 p. ISBN 951-686-564-X.

E:10 Kimmo Virolainen **Tax Incentives and Corporate Borrowing: Evidence from Finnish Company Panel Data**. 1998. 151 p. ISBN 951-686-573-9. (Published also as A-137, Helsinki School of Economics and Business Administration, ISBN 951-791-290-0, ISSN 1237-556X)

E:11 Monica Ahlstedt **Analysis of Financial Risks in a GARCH Framework**. 1998. 181 p. ISBN 951-686-575-5.

E:12 Olli Castrén **Fiscal-Monetary Policy Coordination and Central Bank Independence**. 1998. 153 p. ISBN 951-686-580-1.

E:13 Antti Ripatti **Demand for Money in Inflation-Targeting Monetary Policy**. 1998. 136 p. ISBN 951-686-581-X.

E:14 Risto Koponen – Kimmo Soramäki **Intraday Liquidity Needs in a Modern Interbank Payment System. A Simulation Approach**. 1998. 135 p. ISBN 951-686-601-8.

E:15 Liisa Halme **Pankkisääntely ja valvonta. Oikeuspoliittinen tutkimus säästöpankkien riskinotosta** (Banking regulation and supervision: A legal policy study of risk taking by savings banks). 1999. XLIV + 560 p. ISBN 951-686-606-9, print; ISBN 951-686-607-7, online.

E:16 Juha Kasanen **Ilmoitusvelvollisten osakeomistus ja -kaupat Helsingin Pörssissä** (Corporate insiders shareholdings and trading on the HEX Helsinki Exchanges). 1999. 146 p. ISBN 951-686-630-1, print; ISBN 951-686-631-X, online.

E:17 Mikko Spolander **Measuring Exchange Market Pressure and Central Bank Intervention.** 1999. 118 p. ISBN 951-686-645-X, print; ISBN 951-686-646-8, online.

E:18 Karlo Kauko **The Microeconomics of Innovation: Oligopoly Theoretic Analyses with Applications to Banking and Patenting**. 2000. 193 p. ISBN 951-686-651-4, print; ISBN 951-686-652-2, online. (Published also as A-166, Helsinki School of Economics and Business Administration, ISBN 951-791-442-3, ISSN 1237-556X)

E:19 Juha Kilponen **The Political Economy of Monetary Policy and Wage Bargaining. Theory and Econometric Evidence**. 2000. 180 p. ISBN 951-686-665-4, print; ISBN 951-686-666-2, online.

E:20 Jukka Vesala **Technological Transformation and Retail Banking Competition: Implications and Measurement**. 2000. 211 p. ISBN 951-686-695-6, print; ISBN 951-686-696-4, online. (Published also as A-184, Helsinki School of Economics and Business Administration, ISBN 951-791-518-7, ISSN 1237-556X)

E:21 Jian-Guang Shen **Models of Currency Crises with Banking Sector and Imperfectly Competitive Labor Markets**. 2001. 159 p. ISBN 951-686-711-1, print; ISBN 951-686-712-X, online.

E:22 Kari Takala **Studies in Time Series Analysis of Consumption, Asset Prices and Forecasting**. 2001. 300 p. ISBN 951-686-759-6, print; ISBN 951-686-760-X, online.

E:23 Mika Kortelainen **Edge: a model of the euro area with applications to monetary policy**. 2002. 166 p. ISBN 952-462-001-4, print; ISBN 952-462-002-2, online. (Published also as A-204, Helsinki School of Economics and Business Administration, ISBN 951-791-715-5, ISSN 1237-556X)

E:24 Jukka Topi **Effects of moral hazard and monitoring on monetary policy transmission**. 2003. 148 p. ISBN 952-462-031-6, print; ISBN 952-462-032-4, online.

Effects of moral hazard and monitoring on monetary policy transmission

Bank of Finland Studies E:24 • 2003

ISBN 952-462-031-6
ISSN 1238-1691

Vammalan Kirjapaino Oy
Vammala 2003