Identifying a Credit Channel of Monetary Policy Transmission and Empirical Evidence for Germany

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Abstract

In this paper, the empirical relevance of the credit channel for the explanation of monetary policy transmission in Germany during the period of monetary targeting from 1975 to 1998 is analyzed. While existing studies of the credit channel rely mostly on the analysis of monetary policy effects on balance sheet items, both quantities and financing costs are considered here in order to identify supply and demand effects on the credit market. Using vector autoregressive models, impulse response analysis and forecast error variance decompositions, strong empirical evidence for the effectiveness and relevance of a credit channel in Germany can be reported.

Keywords: bank lending channel, broad credit channel, credit channel, impulse response analysis, monetary policy transmission, vector autoregressive model.

JEL classification: C32, E44, E52.

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1 Introduction

While it seems to be consensus in macroeconomics that monetary policy has real effects and that money is not simply a veil, it is still an open question how monetary policy is transmitted to real variables. The stylized facts of the monetary transmission mechanism that are are widely accepted can be described as follows: the effects of a contractionary monetary policy impulse are (Favero, 2001, p. 97) "(1) the aggregate price level initially responds very little; (2) interest rates initially rise; (3) aggregate output initially falls, then follows a j-shaped response with a zero long-run effect of the monetary impulse." The purpose of this paper is to contribute to the empirical investigation of the "black box" (Bernanke and Gertler, 1995) through which monetary policy effects are transmitted to real variables like prices and output. Information about this black box is strictly necessary for the development and evaluation of structural theoretical models of the transmission mechanism. Theoretical models usually form the basis for the assessment of monetary policy effects on welfare and should therefore reflect the relevant structural relationships of the respective economy. Concentrating on Germany and the period of monetary targeting by the Bundesbank from 1975 to 1998 it is shown that the money view relying on the assumption that it is sufficient to distinguish between money and non-monetary financial assets is not able to explain the transmission of monetary policy exclusively. Moreover, empirical evidence for the relevance of a credit channel stressing the importance of credit markets for the explanation of the transmission mechanism is presented.

The approach followed in this paper is to analyze the effects of monetary policy shocks in vector autoregressive (VAR) models. This approach is motivated and explained in Christiano et al. (1999). Monetary policy shocks are defined as that part of variability in the monetary policy instrument that cannot be explained by a monetary policy reaction function. The main reason for the concentration on monetary policy shocks is that systematic monetary policy responds on economic developments and does therefore reflect the effects of all shocks hitting the system. By analyzing the responses to monetary policy shocks in VAR models, monetary policy effects can be isolated.[1]

Before the empirical analysis is presented in section 3, the theoretical foundations of the credit channel are reviewed in section 2. The credit channel is one possible explanation of the transmission mechanism among numerous other theories about the transmission of monetary policy. An overview can be found in the 1995 fall issue of the Journal of Economic Perspectives, where Mishkin (1995) distinguishes between interest rate channel (money channel), exchange rate channel, other asset price effects, and credit channel. The main element of the credit channel theories is that credit markets are considered explicitly, such that the number of financial assets increases from two (for example money and bonds in the IS-LM model that describes the money channel) to at least three (for example money, bonds, and loans in the Bernanke and Blinder (1988) model, see section 2.2). Due to market imperfections like informational problems and transaction costs, agency costs play an important role on credit markets and influence the decision whether expenditures are financed internally, for example by retained earnings of firms, or externally by raising credit. The credit market is characterized by the existence of financial intermediaries, especially banks, which contribute to the efficient allocation of resources. Therefore, credit can be raised di-

[1] Citing the finding of Clarida et al. (1998) that shocks are only responsible for 1.9% of the variance of the monetary policy instrument in Germany (1.6% in the U.S. and 3.0% in Japan), McCallum (1999) offers a critical discussion of this approach.

rectly, for example by emitting shares or bonds, or indirectly by borrowing from banks. According to the credit view, monetary policy does systematically affect the conditions on the credit markets and therefore the ability of firms and households to finance expenditures. Two versions of the credit view are considered in this paper: the bank lending channel, which stresses the importance of banks, and the broad credit channel, which is more general and relies on the existence of agency costs. If such a credit channel has been operative in Germany in the period from 1975 to 1998 and how relevant it is for the explanation of the transmission mechanism is analyzed empirically in section 3. Much emphasis is put on the identification of a potential credit channel by considering not only quantities but also financing costs in terms of interest rates. Conclusions that follow from the empirical evidence are drawn in section 4.

2 Theoretical Foundations of the Credit Channel

Very good studies surveying the theoretical foundations of monetary policy transmission through the credit channel do already exist. Gertler (1988) reviews the interdependence of financial structure and aggregate economic activity, Bernanke and Gertler (1995) analyze the sequence of effects within the credit channel, Baltensperger (1996) focuses on the microeconomic and macroeconomic role of financial intermediation, Freixas and Rochet (1997) give a broad and detailed overview of the microeconomics of banking, Walsh (1998, chapter 7) stresses macroeconomic consequences of credit market imperfections, and Hartmann-Wendels et al. (2000) address the credit channel from a business administration perspective. The following subsections are only intended to review the most important aspects that are relevant for the empirical analysis in section 3.

2.1 Credit Market Imperfections

An important function of credit markets is to support the efficient allocation of savings and investment. Two forms of credit can be observed: direct credit and indirect credit via financial intermediaries. Reasons for the existence of financial intermediaries are credit market imperfections like incomplete and asymmetric information as well as transaction costs. The informational problems on credit markets can be divided into adverse selection, moral hazard, monitoring costs (or costly state verification), and agency costs, see Walsh (1998, chapter 7). Adverse selection describes a situation in which different types of agents exist but the type of the respective contract partner is not known before conclusion of a business contract. A bank, for example, does not know in advance whether a potential lender is a good or a bad credit risk. A situation in which one contract partner cannot observe the actions of the other contract partner is denoted by moral hazard. This is the case if the creditor cannot observe how the debtor spends the borrowed money. Adverse selection and moral hazard build the basis of the Stiglitz and Weiss (1981) credit rationing model. Monitoring costs occur, if the actions of the contract partner are observable in principle but this is costly. This is for example relevant if the repayment amount does depend on the wealth of the debtor in case of default. Monitoring costs are the driving force in models of Williamson (1986, 1987a,b). Agency costs are a more general category of costs than the other ones. Agency costs result from all kinds of principle-agent relationships. In case of credit, the creditor is the principle who delegates the spending decision to a debtor. Due to agency costs, external financing is more expansive for a firm than internal financing using retained earnings. The cost differential is called external finance premium (EFP) and is an important component of the financial accelerator models of Bernanke and Gertler (1989) and Bernanke et al. (1996, 1999).

Given these credit market imperfections, the existence of financial intermediaries can be explained with the availability of a technology reducing the negative impact of these imperfections together with economies of scale or scope, see Bondt (2000, p. 3). Following Bhattacharya and Thakor (1993), financial intermediaries fulfill two functions: firstly, they match borrowers and lenders without changing the characteristics of the credit contract (brokerage) and secondly, they transform risk and/or maturity (qualitative asset transformation). Therefore, financial intermediaries play an important role for the efficient allocation of resources. In Germany, the average share from 1975 to 1998 of financial intermediaries in gross value added is about 5%. Lending from banks has an average share of 24.5% in total financing and of 67.5% in external financing.

In the following, more details about two distinct versions of the credit channel – the bank lending channel and the broad credit channel – are provided. They have in common that the simplifying assumption of only two financial assets, namely money and non-money (mostly named bonds), is relaxed.

2.2 The Bank Lending Channel

A standard model describing the bank lending channel is the model of Bernanke and Blinder (1988). It is an extension of the well known IS-LM model. While the traditional IS-LM model consists of three markets (bonds, money, goods), the model of Bernanke and Blinder comprises the bank lending market as an additional market, that is, credit equals bank lending (loans). Being an extension of the IS-LM model, the Bernanke and Blinder (1988) model describes only the demand side of an economy with given price level. However, this model can be augmented with an aggregate supply equation like the usual IS-LM model. The balance sheet equation of banks in this model is

$$B^b + L^S + E = (1-\tau)D, \tag{2.1}$$

where B^b are bonds held by banks, L^S denotes supply of loans, E denotes excess reserves, τ is the required reserve rate, and D are deposits of non-banks. An equilibrium on the credit market can be characterized as follows:

$$\underbrace{\lambda(\overset{+}{R^\ell}, \overset{-}{R})(1-\tau)D}_{L^S} \quad = \quad \underbrace{L(\overset{-}{R^\ell}, \overset{+}{R}, \overset{+}{Y})}_{L^D}. \tag{2.2}$$

The supply of loans depends negatively on the interest rate on bonds R, positively on the interest rate on loans R^ℓ, and on the amount of deposits not needed to fulfill the reserve requirement. $\lambda(R^\ell, R)$ is a function comparable to the money multiplier. The demand for loans L^D depends negatively on the interest rate on loans and positively on the interest rate on bonds, and positively on the scaling variable income, Y.

The LM relation, which describes output-interest rate combinations for which money supply and money demand are equal at a given price level, as well as the IS equation, which describes output-interest rate combinations for which the planned and actual expenditures on output are equal, are as usual. Combining equilibrium on the money market and on the credit market with the IS equation yields the so-called CC relation (commodities and credit):

$$Y = Y(\overset{-}{R^{\ell}}, \overset{-}{R}). \tag{2.3}$$

Furthermore, it can be shown that the interest rate on loans depends positively on the interest rate on bonds and income, but negatively on money supply M^S, which is considered as exogenous policy variable in this model:

$$R^L = R^L(\overset{+}{R}, \overset{+}{Y}, \overset{-}{M^S}). \tag{2.4}$$

The bank lending channel can now be summarized as follows: Restrictive monetary policy has an impact on both the LM and the CC relation: the interest rate on loans increases and income decreases.

The effectiveness of the bank lending channel depends on three conditions: (1) Loan supply has to react on monetary policy actions. (2) Non-banks have no perfect substitutes for bank loans. (3) Expenditures of firms and households depend on loan supply. These conditions are analyzed empirically in section 3.2.2.

The Bernanke and Blinder (1988) model has been extended in several respects. Kashyap et al. (1993) consider explicitly the financing decision of firms and Bårdsen and Klovland (2000) augment the model with a supply side equation as well as a foreign sector.

2.3 The Broad Credit Channel

While the bank lending channel focuses on the importance of bank lending, the broad credit channel stresses all kinds of external finance. The broad credit channel is modeled by Bernanke et al. (1999), for example. They specify a dynamic stochastic general equilibrium model with nominal rigidities, monopolistic competition, and a credit market with heterogenous agents. Firms have the possibility to borrow from banks or to finance their investments by internal financing. Due to monitoring costs, the external finance premium depends on net wealth of the borrower: the larger net wealth, the smaller is the difference between external and internal financing costs. As a consequence, the external finance premium follows movements in net wealth which is reduced by restrictive monetary policy: if interest rates increase due to restrictive monetary policy, interest payments increase and present values of collateral decrease. The variation in the external finance premium enlarges the effects of monetary policy and is therefore also called financial accelerator. Money is also considered in the model of Bernanke et al. (1999) such that the money channel and the credit channel can be compared to each other.

A broad credit channel is operative if (1) monetary policy has a systematic impact on the external finance premium and if (2) the external finance premium does systematically affect aggregate output. The empirical relevance of these conditions is studied in section 3.

It should be noticed that the existence of a broad credit channel has also microeconomic implications. Under the assumption that the external finance premium of different borrowers is not affected to the same extent, monetary policy does not only change the aggregate level of economic activity but also the income distribution. It is for example reasonable to assume that the monetary policy effect on the financing costs of households and small firms is stronger than on the financing costs of big firms. These microeconomic aspects are not considered here.

3 Empirical Analysis of the Credit Channel

3.1 Existing Evidence

3.1.1 General Aspects and International Evidence

The major contributions to the empirical analysis of the credit channel are concerned with U.S. data. Bernanke (1983) analyzes the role of credit markets during the Great Depression, Kashyap and Stein (1994, 1995, 2000) study the bank lending channel in the USA, King (1986) investigates credit rationing, Kashyap et al. (1993), Bernanke et al. (1996), Friedman and Kuttner (1992, 1993, 1998) and Oliner and Rudebusch (1996) explore the broad credit channel. Overviews are given by Gertler and Gilchrist (1993) and Hubbard (2001). The empirical results are far from being unambiguous but the majority of the cited studies finds evidence that the credit channel plays an important role in the transmission of monetary policy. The main problem that is discussed in the empirical literature on the credit channel is the identification of supply and demand side effects on credit markets. While building on a decrease in credit supply, a decrease in the quantity of credit after a restrictive monetary policy action is neither necessary nor sufficient for the existence of a credit channel. It is not necessary because the decline in credit supply can solely result in an increase in the interest rate on credit without affecting its quantity. This would be the case if the demand for credit was perfectly unelastic. A decline in the quantity of credit is not sufficient because it can also be totally demand determined, this would be compatible with the traditional money view. Different approaches to distinguish between supply and demand effects on the credit markets have been proposed. Kashyap et al. (1993) assume that a change in the demand for credit affects all kinds of external finance, that is, indirect borrowing from banks (loans) and direct borrowing on capital markets (commercial paper) in the same way while supply side effects should only reduce the supply of loans. Therefore, they interpret a decrease in the loan-paper ratio as a decrease in loan supply. Bernanke et al. (1996) make use of the distributional aspects mentioned above in order to identify supply side effects. According to this view, different reactions of lending to heterogenous borrowers indicates supply effects assuming that the reaction of credit demand is identical across borrowers. Friedman and Kuttner (1993) stress that not only changes in quantities but also changes in prices should be analyzed in order to identify supply and demand side effects. This suggestion is followed here in a way that is described in section 3.2.2.

3.1.2 Institutional Framework and Evidence for Germany

It can be seen in figure 1 that external financing has approximately a share of 37% in total financing of German firms from 1975 to 1998. Notice that the share of external finance tends to increase in recessions (early 80s and early 90s). As a consequence, interest payments of firms are increasing, too, see figure 3. This has a negative impact on cash flow. Figure 2 shows a disaggregation of external finance into its components short-term bank loans, long-term bank loans and other liabilities (like shares and bonds). As mentioned before, lending from banks has an average share of 24.5% in total financing and of 67.5% in external financing.

The role of external finance and the existence of a credit channel in Germany is analyzed in studies by Guender and Moersch (1997), Worms (1998), Ehrmann and Worms (2001), Kalckreuth (2001),

Figure 1: Internal and External Financing of German Firms (1975-1998)

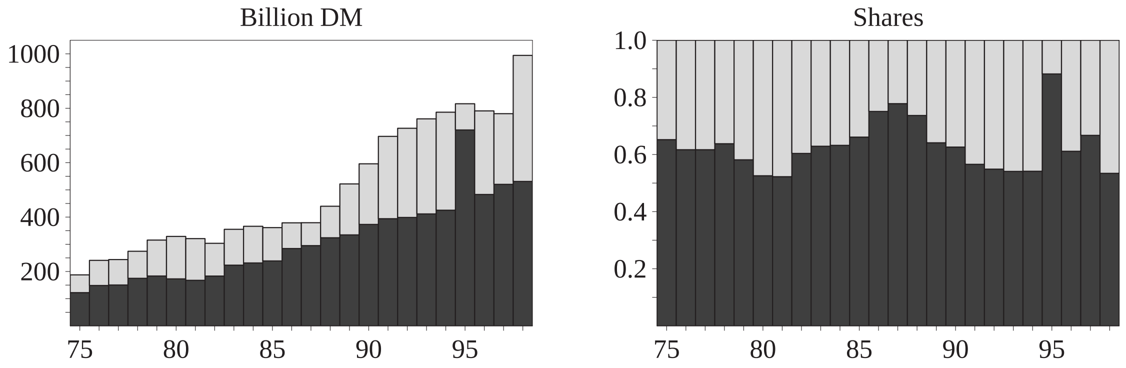


Figure 2: Components of External Financing (1975-1998)

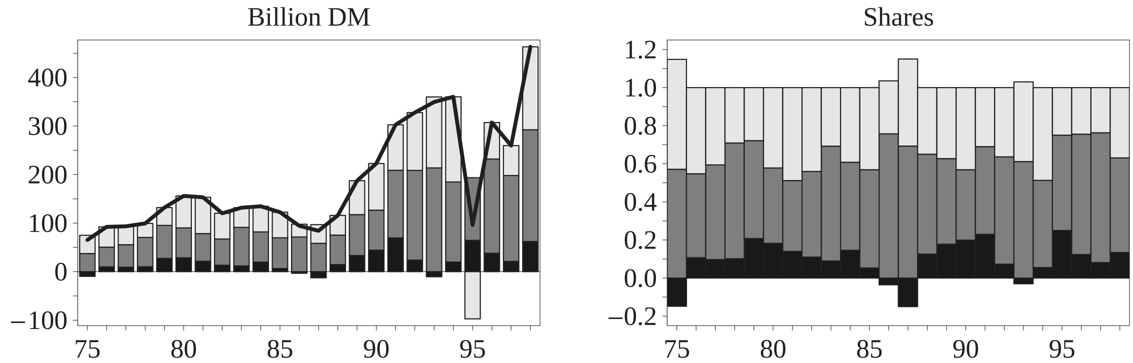
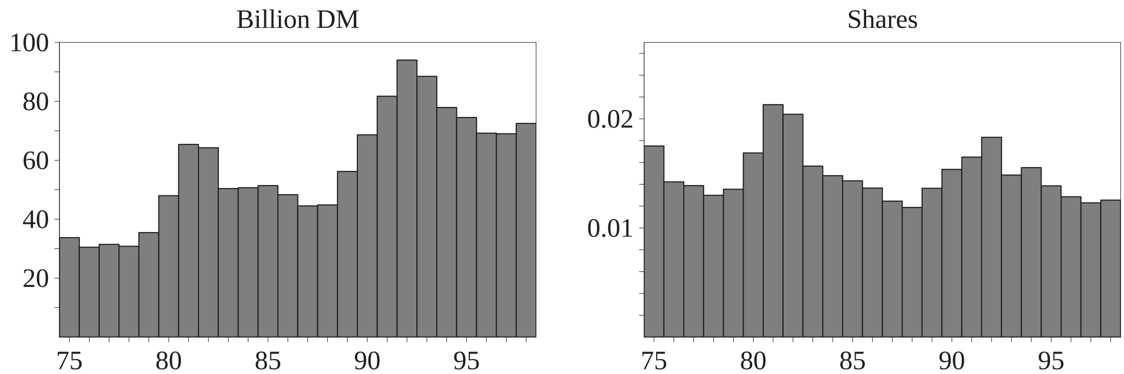


Figure 3: Interest Payments of West German Firms (1975-1998)



Notes:
Fig. 1: Internal financing is dark gray, external financing bright gray.
Fig. 2: The solid line describes the development of external financing; short-term bank loans are dark gray, long-term bank loans medium gray, and other liabilities bright gray.
Data for figures 1 and 2 stem from the Bundesbank’s Financial Accounts for Germany published once a year in the monthly bulletin. The data for figure 3 is also taken from the monthly bulletin of the Bundesbank.

Hülsewig et al. (2001) and Küppers (2001), for example. International comparisons are conducted by Kashyap and Stein (1997) and Bondt (2000). Guender and Moersch (1997) apply three vector autoregressive (VAR) models using monthly data from 1969 to 1994 to analyze the existence of a bank lending channel in Germany. Their main finding is that short-term bank lending does increase after a restrictive monetary policy shock. This response is rationalized by the so-called *Hausbankbeziehung* between German banks and firms. However, an increase in the share of short-term lending in response to increasing interest-rates is not surprising and can already be observed in figure 2 (interest rates have been relatively high in the early 80s and 90s like the share of short-term lending). If borrowers expect that interest rates will decrease again it is only rational to borrow at short maturities. Furthermore, it is total credit that is relevant for the credit channel not only short-term lending. Additionally, the results of Guender and Moersch (1997) suffer from the choice of the sample period and from a not convincing identification of supply and demand side effects on the market for bank loans. Similar results are reported by Worms (1998) who states that the bank lending channel is only of secondary importance. Ehrmann and Worms (2001) do also support this view. They analyze the response of bank loans with respect to the size of the bank. Only for small banks that are not organized in credit cooperatives or the savings banks sector a negative response of loans to restrictive monetary policy shocks is found. This group of banks, however, has only a share of 2.9% in total bank lending (Ehrmann and Worms, 2001, table 2, p. 7). Big banks and banks that are organized in credit cooperatives or the savings bank sector respond to a restrictive monetary policy shock not by decreasing loans but by decreasing net foreign assets. All these results are based on the analysis of banks' balance sheet items without considering interest rates on loans. An alternative approach is followed by Kalckreuth (2001) who specifies an autoregressive distributed lag model for investment spending. His results also indicate that the credit channel is only of minor importance compared to the interest rate channel. Evidence that is supportive for a credit channel is reported by Hülsewig et al. (2001), Küppers (2001) and Worms (2001). Hülsewig et al. (2001) estimate a cointegrated VAR and identify the demand for and supply of loans as cointegrating vectors, Küppers (2001) uses heterogenous groups for identification, and Worms (2001) conditions his panel data study on the ratio of short-term interbank deposits to total assets.

Bondt (2000, chapter 5) compares financial structure and monetary policy transmission in six countries of the European Union. He estimates vector error correction models for quarterly data from 1980 to 1996 using gross domestic product as demand proxy and total private wealth as supply proxy. The impulse responses reveal that loans and wealth react immediately after a monetary policy shock while GDP reacts with a lag of approximately one year. Therefore, the reaction of loans is interpreted as supply effect supporting the credit view.

Kashyap and Stein (1997) describe the financial structure in the countries participating in the European Monetary Union. An important result is that the financial structure in these countries is still quite different. Therefore, it can be assumed that the relevance of the credit channel varies across countries which has to be considered by the European Central Bank when conducting a single monetary policy for the Euro area.

3.2 New Evidence for the Effectiveness of a Credit Channel in Germany

Before the identification of a bank lending channel and a broad credit channel in Germany is addressed, a benchmark model of the interest rate or money channel is discussed.

3.2.1 A Benchmark Model of the Money Channel

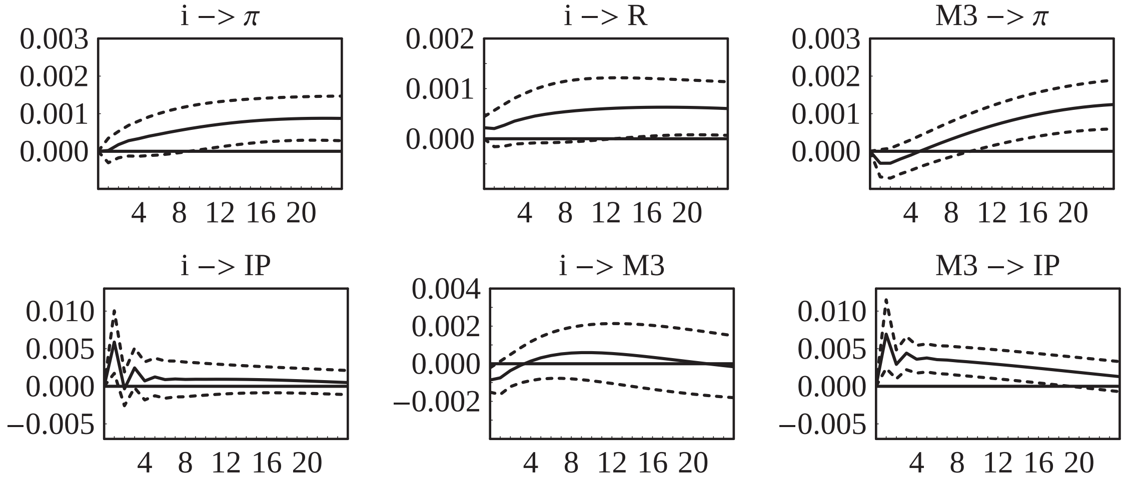
The traditional view of the monetary policy transmission mechanism is the interest rate or money view. This view can be described with an IS-LM model augmented with a supply side. This class of models is characterized by the assumption that money and bonds are the only relevant financial assets. The stylized transmission process according to this view is as follows. Monetary policy actions change the nominal short-term interest rate by changing the nominal money supply. This change is transmitted to the real long-term interest rate that is relevant for investment decisions of firms as well as for certain consumption decisions (durable goods, for example). A restrictive monetary policy shock that increases the nominal short-term interest rate increases the real long-term rate. Subsequently, investment and consumption spending decrease and total output decreases, too.

The conditions for the money channel to be effective are, see Hubbard (2001):

1. There are no perfect substitutes for base money such that the central bank can influence the development of the nominal money stock by increasing or decreasing the amount of base money. This condition has been satisfied in Germany from 1975 to 1998 due to the reserve requirement.
2. The central bank is able to control not only the nominal short-term interest rate but also the real short-term interest rate. This condition can be considered as satisfied because prices do not react instantaneously on monetary policy.
3. Changes in the real short-term interest rate are transmitted to the real long-term interest rate. A long-run equilibrium relationship between the short-term and the long-term interest rate in Germany is not observable. The spread is non-stationary like the short-term and the long-term interest rates themselves, see Hassler and Nautz (1995) and Wolters (1995). Nautz and Wolters (1999), however, are able to show that an instationary spread does not necessarily contradict the expectations theory of the term structure and that innovations in the short-term rate do systematically affect the long-term rate. The non-stationarity of the spread could possibly be the consequence of a non-stationary liquidity premium.
4. Output is elastic with respect to the real long-term interest rate. Kalckreuth (2001) shows that investment spending in Germany decreases by approximately 4% after an increase in the nominal interest rate of 1%. The impact of the real rate, however, is not clear. Furthermore, the interest rate sensitivity of total output can also not be considered as known. This is still an open question.

Empirical models of the interest rate channel in Germany are provided by Brüggemann (2001) for monthly data and by Lütkepohl and Wolters (2001) for quarterly data. In both studies, a vector error correction model is specified and the transmission process is analyzed by inspecting the impulse responses to an innovation in the short-term interest rate. Without specifying any cointegration relationships this analysis is repeated in the following. A VAR in levels is estimated for the variables short-term interest rate (i_t), long-term interest rate (R_t), inflation rate (π_t), logarithmic

Figure 4: Money Channel Model: Impulse Responses to a Restrictive Monetary Policy Shock



Notes: The figure shows impulse responses that are calculated from a six dimensional VAR in levels with two lags assuming a recursive identification scheme. Endogenous variables are in the ordering used to identify the monetary policy shock: $(im, \pi, IP, i, R, M)_t$. The data are adjusted for the structural break due to the German unification, see the notes to table 1 in Appendix B. A constant, seasonal dummies, and a time trend are included.

industrial production[2] (IP_t), and logarithmic real money stock (M_t^r). Additionally, the logarithmic import price index (im_t) is included into the system like in Lütkepohl and Wolters (2001). It is assumed that import prices are a component in the central bank's reaction function. The vector of endogenous variables is therefore:

$$x_t = (im_t, \pi_t, IP_t, i_t, R_t, M_t^r)'. \tag{3.5}$$

It can be shown that the considered variables are instationary and cointegrated, see Appendix B. A VAR model in levels like it is applied in the following gives consistent estimates of the impulse response functions in this case though more efficient estimates can be obtained from a VECM estimation, see Breitung (2000). A lag number of two is chosen like suggested by the Hannan-Quinn criterion, diagnostic tests are reported in table 2 in Appendix B. A recursive identification scheme is applied to identify monetary policy shocks. The ordering of the variables is $(im, \pi, IP, i, R, M)_t$. This ordering is based on the following structural assumption: first, the central bank observes the status of the real world; second, the central bank sets the nominal short-term interest rate that has no contemporaneous effect on the real world but an impact in subsequent periods; third, financial variables adjust to changes in the short-term rate contemporaneously. The responses on a monetary policy shock measured by the innovation in the short-term interest rate equation are depicted in figure 4 . Quite consistent with the evaluation of the conditions for effectiveness of the money channel, the impulse responses do not give a completely satisfying picture of the transmission mechanism. The responses of inflation and industrial production to innovations in the short-term interest rate have even signs that are not compatible with general assumptions about monetary policy transmission. This is possibly an effect of the applied recursive identification scheme, see

[2] Lütkepohl and Wolters (2001) use real GDP, Brüggemann (2001) interpolated real GDP. The results reported here are based on industrial production. The share of industrial production in total gross value added has decreased from 38% in 1975 to 30% in 1998. Albeit weaker, the principle results of this paper can also be achieved by using the interpolated GDP series. Industrial production, however, has a more pronounced cyclical behavior than GDP.

Holtemöller (2002). However, the monetary policy shock has a negative impact on the money stock, and innovations in the money stock lead to increasing inflation with a lag of approximately one year. This is compatible with the view that inflation is a monetary phenomenon in the long run. A hump-shaped response of industrial production on shocks in the money stock can also be observed. Overall, there is some evidence for the money channel of monetary policy transmission. In the next section, the VAR is extended in order to allow also for a bank lending channel and to evaluate the relative relevance of money channel and bank lending channel.

3.2.2 A Model of the Bank Lending Channel

In section 2.2, the Bernanke and Blinder (1988) model has been presented as a simple model capturing the bank lending channel. This model builds the theoretical foundation for the empirical bank lending channel model that is specified in this section. Notice that there is one modification of the original model: it is assumed like in the previous section that the short-term interest rate is the operating target of the central bank not the money stock like in the Bernanke and Blinder (1988) model, but this does not exclude that the central bank influences money supply via interest rate changes. It has to be stressed that it is not sufficient to add only the loan stock as an additional variable to the VAR. As explained before, in section 3.1.1, a negative response of loans on a restrictive monetary policy shock is neither necessary nor sufficient for the existence of a bank lending channel. Therefore, I follow the approach of Hülsewig et al. (2001) in order to identify supply and demand effects on the loans market. It is assumed that the supply of loans depends on equity capital of banks. This assumption is reasonable because banks are obliged to underlay loans with a certain amount of equity capital. Additionally, it is assumed that only the demand for loans depends on production but not the supply of loans. The market is cleared by changes in the interest rate on loans. Therefore, if changes in the quantity of loans and in the interest rate on loans can be observed after a monetary policy shock has occurred, it is possible to identify supply and demand shocks.[3] If a decrease in the loan stock is accompanied by an increase in the interest rate on loans in the aftermath of a restrictive monetary policy shock, this can be interpreted as a shock to the supply of loans. A shock to the demand for loans would bring about a decreasing interest rate on loans. The variables included in the VAR analysis are now:

$$x_t = (im_t, \pi_t, IP_t, i_t, R_t, Eq^r_t, R^L_t, M^r_t, L^r_t)', \tag{3.6}$$

where Eq^r_t is real equity capital of banks, R^L_t is the interest rate on loans, and L^r_t is the real loan stock. The lag length is again set to two as suggested by the Hannan-Quinn Criterion, and the relevant impulse responses are shown in figure 5. It can be seen that a restrictive monetary policy shock is followed by a small decline in the quantity of loans and a strongly significant increase in the interest rate on loans. This can be interpreted as shock on loan supply. It can also be seen that shocks to the interest rate on loans lead to a transitory decrease in production and to an increasing inflation rate in the long run. Having established that monetary policy has a considerable effect on loan supply, which finds mainly reflection in the interest rate on loans, there remains an important question: how do commercial banks compensate the loss in deposits in reaction to a restrictive monetary policy shock without lowering loans outstanding? Deposits decrease because of a liquidity effect; the response of the money stock, which consists mainly of

[3] The idea underlying this identification is well known from economic theory but seldom applied when addressing the bank lending channel. Friedman and Kuttner (1993) have put much emphasis on this point.

Figure 5: Bank Lending Channel Model: Impulse Responses

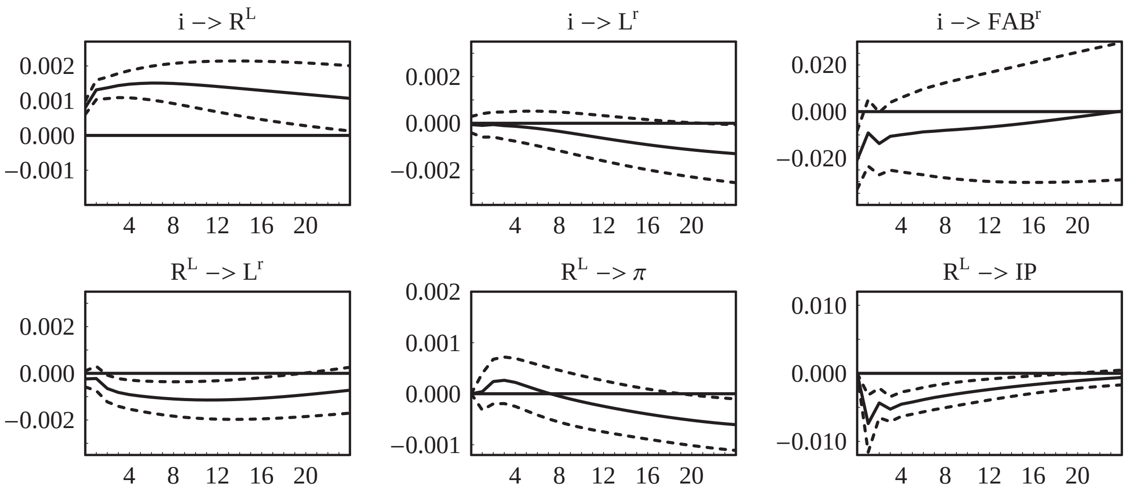
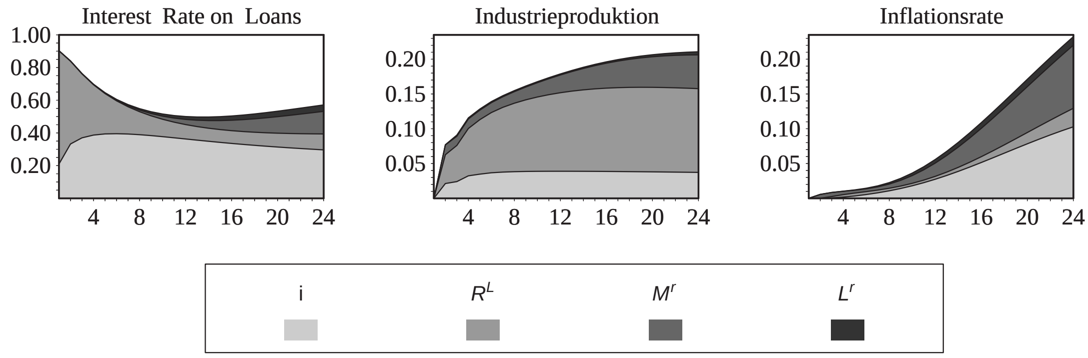


Figure 6: Bank Lending Channel Model: Forecast Error Variance Decompositions



Notes: The figures show impulse responses and forecast error variance decompositions that are calculated from a nine-dimensional VAR in levels with two lags assuming a recursive identification scheme. Endogenous variables are in the ordering used to identify the monetary policy shock: $(im, \pi, IP, i, R, Eq^r, R^L, M^r, L^r)_t$. FAB^r denotes the foreign asset position of banks. The data are adjusted for the structural break due to the German unification, see the notes to table 1 in Appendix B. A constant, seasonal dummies, and a time trend are included.

deposits, is not depicted here but is approximately like in the money channel model of the previous section. Replacing the loan stock subsequently by other balance sheet items of banks in the VAR model reveals that the net foreign asset position of banks exhibits a reaction on monetary policy shocks that compensates the loss of deposits. This is compatible with the findings of Ehrmann and Worms (2001). This analysis shows that conditions (1) – reaction of loan supply on monetary policy – and (3) – reaction of production on loan supply – for the effectiveness of a bank lending channel in Germany are fulfilled in the considered sample period. Condition (2) – the absence of short-run substitution possibilities for bank loans – cannot be tested explicitly in a time series analysis because appropriate data are not available. The institutional setting in Germany, however, seems to support the assumption that condition (2) is also fulfilled.[4]

The relevance of the respective shocks for the development of industrial production and inflation rate can be assessed by inspecting the forecast error variance decompositions (FEVD), see figure 6. The short-term interest rate has a considerable impact on the interest rate on loans, and inno-

[4] See Kashyap and Stein (1997) for a discussion of institutional settings on financial markets in European countries.

Figure 7: Broad Credit Channel Model: Impulse Responses

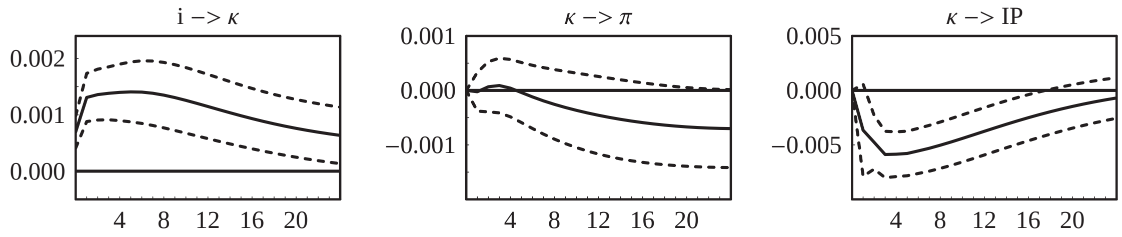
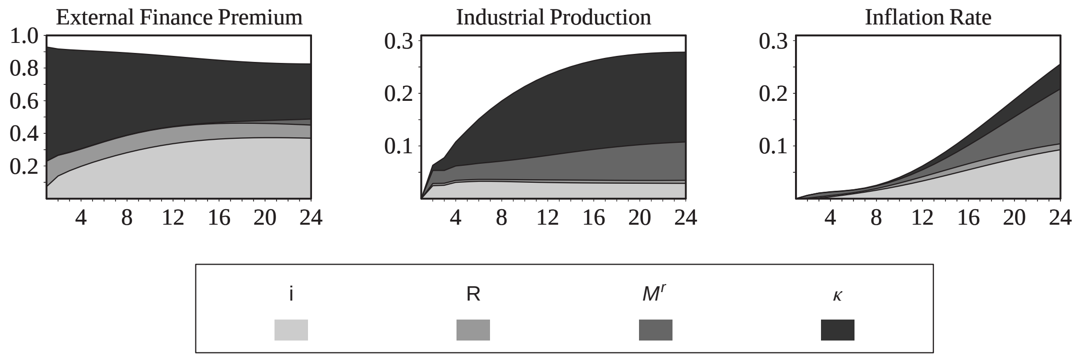


Figure 8: Broad Credit Channel Model: Forecast Error Variance Decompositions



Notes: Figures 7 and 8 show impulse responses and forecast error variance decompositions that are calculated from a seven-dimensional VAR in levels with two lags assuming a recursive identification scheme. Endogenous variables are in the ordering used to identify the monetary policy shock: $(im, \pi, IP, i, R, M^r, L^r, \kappa)_t$. The data are adjusted for the structural break due to the German unification, see the notes to table 1 in Appendix B. A constant, seasonal dummies, and a time trend are included.

vations in the interest rate on loans are responsible for a larger part of the forecast error variance of industrial production than short-term interest rate innovations or innovations in money. The inflation rate, however, is affected mostly by short-term interest rate innovations and innovations in money. While the transmission of monetary policy to the inflation rate may be well described by the money channel, the bank lending channel is capable to describe the transmission of monetary policy to industrial production.

3.2.3 A Model of the Broad Credit Channel

The benchmark model of the money channel cannot only be extended to capture a bank lending channel but also to capture a broad credit channel, which does not rely on the special role of banks in the transmission process. The main argument of the broad credit channel is that restrictive monetary policy increases the external finance premium, lowers the firms' and households' ability to borrow and does therefore reduce aggregate output. This effect can be analyzed in a VAR with the endogenous variables

$$x_t = (im_t, \pi_t, IP_t, i_t, R_t, M_t^r, \kappa_t)', \tag{3.7}$$

where κ_t is the external finance premium. Now the problem occurs how to measure the external finance premium. Friedman and Kuttner (1992) have suggested to use the spread between the interest rate on loans and the yield on government bonds. This spread is in general positive because of a risk premium and a liquidity premium. These two terms are not constant and are presumably affected by monetary policy. The external finance premium is therefore measured in the following as:

$$\kappa_t = R_t^L - R_t^{\text{Gov}}, \tag{3.8}$$

where R_t^{Gov} is the yield on government bonds. The mean of this spread from 1975 to 1998 is 1.8 percentage points and the standard deviation is 1.5. In figure 7 it can be seen that positive innovations in the short-term interest rate increase the external finance premium, and shocks to the external finance premium have a weak negative impact on the inflation rate as well as a hump-shaped and significant negative impact on industrial production. The forecast error variance decompositions can be found in figure 8. Innovations in the external finance premium have a major share in the total forecast error variance of industrial production while like in the bank lending channel model the short-term interest rate and the money stock innovations have larger shares in the forecast error variance of the inflation rate.

4 Conclusions

The empirical analysis of the monetary policy transmission mechanism stands in the center of attention of this paper. As reviewed in section 2, the credit channel with its two forms bank lending channel and broad credit channel offers a theoretically well founded explanation of the monetary policy transmission mechanism. The empirical evidence reported in section 3 shows that the money channel cannot be considered as an exclusive explanation of the transmission mechanism. While inflation can be assumed to be a monetary phenomenon in the long run, the impact of monetary policy on output can be explained to a considerable extent by the credit view. Restrictive monetary policy tends to increase refinancing costs, which can be seen in the bank lending channel model (interest rate on loans) and in the broad credit channel model (external finance premium). In both models, a hump-shaped response of output to innovations in the variable reflecting the financing costs can be observed. These results are encouraging for the research on structural theoretical models of the transmission mechanism that are necessary to evaluate the welfare effects of monetary policy. However, there remains still a number of open questions and further problems. While in this paper only the short-run dynamics are addressed, it would be interesting to identify the long-run relationships (cointegration vectors) between the considered variables and to reduce the number of estimated coefficients, for example by estimating subset VARs or by detecting exogenous variables. Additionally, alternative identification schemes for the structural shocks have to be considered in order to improve the theoretical foundation of the VAR analysis and to check the robustness.

Appendix A. Data Description

Import Price Index (im): Logarithmic import price index, Deutsche Bundesbank (UUZI01).

Industrial Production (IP): Logarithmic industrial production, 1991=100, West Germany, 1975:1-1990:12, Detusche Bundesbank (UU02NA) and logarithmic industrial production, 1991=100, Germany, 1991:1-1998:12, Federal Statistical Office Germany (4206002, rebased).

Inflation Rate (π): Twelfth differences of the logarithmic consumer price index, Deutsche Bundesbank (UU01FA, UUFA01).

Interest Rate on Loans (R^L): Average interest rate on current account credit (DM 1 million and more but less than DM 5 million), Deutsche Bundesbank (SU0004).

Long-term Interest Rate (R): Yields on bonds outstanding, industrial bonds, Deutsche Bundesbank (WU0022).

Real Equity Capital (Eq^r): Logarithmic equity capital of banks, Deutsche Bundesbank (OU0322), deflated with the consumer price index (see inflation rate).

Real Loans (L^r): Logarithmic loan stock (bank lending to residential non-banks), Deutsche Bundesbank (OU0085), deflated with the consumer price index (see inflation rate).

Real Money Stock (M^r): Logarithmic money stock M3, Deutsche Bundesbank (TU0800) deflated with the consumer price index (see inflation rate).

Real Net Foreign Assets of Banks (FAB^r): Lending of banks to foreign banks (OUA013) plus lending of banks to foreign non-banks (OUA020) minus deposits of foreign banks (OUA028) minus deposits of foreign non-banks (OUA034), Deutsche Bundesbank, logarithmic, deflated with the consumer price index (see inflation).

Short-term Interest Rate (i): Money market rate reported by Frankfurt banks, day-to-day money, Deutsche Bundesbank (SU0101).

Yield on Government Bonds (R^{Gov}): Yields on bonds outstanding, public bonds, Deutsche Bundesbank (WU0004)

Appendix B. Preliminary Data Analysis and Diagnostic Tests

Table 1: Unit Root Tests and Adjustment for German Unification, Sample Period: 1975:1-1998:12

Variable	Lags	Statistic	Det. Terms	Test	Mean Shift	Break Point
im	1,9	-2.35	c,s	ADF	–	–
Δim	–	-8.64^{***}	c,s	ADF	–	–
IP	1,2,7,9,11	-2.61	c,s,t	ADF	–	–
ΔIP	1,7,8,11	-24.94^{***}	c,s	ADF	–	–
π	1,4,9,10,12	-1.55	c,t	ADF	$-0.0243^{a)}$	1991:1$^{a)}$
$\Delta\pi$	10,11,12	-13.02^{***}	c	ADF	–	–
R^L	1,4	-2.23	c	ADF	–	–
ΔR^L	1,2,3	-5.00^{***}	–	ADF	–	–
R	1,2	-1.23	c	ADF	–	–
ΔR	1	-10.52^{***}	–	ADF	–	–
Eq^r	1,2	-2.00	c,s,t	LLS	0.1332	1990:6
ΔEq^r	1	-11.26^{***}	c,s	ADF	–	–
L^r	1,2,3,4	-0.97	c,s,t	LLS	0.0722	1990:6
ΔL^r	1,2,3	-4.02^{***}	c,s	ADF	–	–
M^r	1,2,3,4	-1.63	c,s,t	LLS	0.1388	1990:6
ΔM^r	1,2	-7.38^{***}	c,s	ADF	–	–
FAB^r	1..13	-1.31	c,s,t	LLS	-0.0571	1990:6
ΔFAB^r	11	-23.02^{***}	c,s	ADF	–	–
i	1,6	-2.21	c	ADF	–	–
Δi	1,2,6	-8.58^{***}	–	ADF	–	–
R^{Gov}	1	-1.46	c	ADF	–	–
ΔR^{Gov}	–	-11.11^{***}	–	ADF	–	–

Notes: The table shows unit root tests for the variables used in the VAR models of this paper. ADF is the Augmented Dickey-Fuller Test and LLS is the test (τ^{*+}_{int}) proposed by Lanne et al. (2002). The LLS test is used for time series that exhibit a structural break due to the German unification. The mean shift parameter estimated during the LLS algorithm is used to adjust the data for the mean shift due to German unification. Three asterisks denote significance at the 1% level.

The diagnostic tests in table 2 are the following: JB denotes the Jarque-Bera test for normality, LM(k) the Lagrange multiplier test for serial correlation of the residuals (k lagged residuals included), ARCH(k) the Lagrange multiplier test for autoregressive conditional heteroskedasticity, and RESET(1) the Regression Specification Error Test considering the second powers of the fitted values from the original regression. Mean and standard deviation (S.D.) of the dependent variable are also given. $\overline{R}^2$ is the adjusted sample multiple correlation coefficient and S.E. is the standard error of the regression.

Table 2: Diagnostic Tests: VAR Models (3.5), (3.6) and (3.7), Sample Period: 1975:1-1998:12

Eq.	Mean	S.D.	$\overline{R}^2$	S.E.	JB	LM(1)	LM(12)	ARCH(1)	ARCH (2)	RESET(1)
Money Channel Model (3.5): $x_t = (im_t, \pi_t, IP_t, i_t, R_t, M_t^r)'$, 2 Lags										
im	4.60	0.13	1.00	0.01	7.24	0.05	1.28	0.41	1.88	0.31
					[0.03]	[0.82]	[0.23]	[0.52]	[0.04]	[0.58]
π	0.03	0.02	0.97	0.00	55.25	0.08	6.34	0.10	8.29	0.89
					[0.00]	[0.78]	[0.00]	[0.76]	[0.00]	[0.32]
ip	4.46	0.13	0.92	0.04	0.07	64.47	10.51	0.07	0.78	0.54
					[0.96]	[0.00]	[0.00]	[0.79]	[0.67]	[0.46]
i	0.06	0.02	0.98	0.00	880.00	0.08	0.90	54.85	1.46	0.15
					[0.00]	[0.77]	[0.55]	[0.00]	[0.04]	[0.70]
R	0.08	0.01	0.98	0.00	60.13	1.10	0.83	1.22	3.41	0.35
					[0.00]	[0.29]	[0.62]	[0.27]	[0.00]	[0.56]
M^r	7.14	0.23	1.00	0.01	52.64	0.16	2.19	0.41	0.75	2.60
					[0.00]	[0.69]	[0.01]	[0.52]	[0.70]	[0.11]
Bank Lending Channel Model (3.6): $x_t = (im_t, \pi_t, IP_t, i_t, R_t, Eq_t^r, R_t^L, M_t^r, L_t^r)'$, 2 Lags										
im	4.60	0.13	1.00	0.01	6.88	0.10	1.23	5.52	2.33	0.01
					[0.03]	[0.75]	[0.26]	[0.02]	[0.01]	[0.92]
π	0.03	0.02	0.97	0.00	40.40	0.47	5.67	0.10	6.89	1.34
					[0.00]	[0.49]	[0.00]	[0.75]	[0.00]	[0.25]
ip	4.46	0.13	0.94	0.03	8.07	40.98	7.32	0.00	0.41	0.54
					[0.02]	[0.00]	[0.00]	[0.97]	[0.96]	[0.46]
i	0.06	0.02	0.98	0.00	827.71	0.02	0.97	54.15	1.55	0.02
					[0.00]	[0.90]	[0.48]	[0.00]	[0.11]	[0.88]
R	0.08	0.01	0.98	0.00	70.70	0.30	1.16	0.00	4.22	0.00
					[0.00]	[0.58]	[0.32]	[0.96]	[0.00]	[0.93]
Eq^r	5.08	0.39	1.00	0.00	49.16	0.35	1.72	9.75	1.45	0.29
					[0.00]	[0.55]	[0.06]	[0.00]	[0.14]	[0.59]
R^L	0.09	0.02	0.99	0.00	2328.45	0.05	0.45	1.40	1.45	0.18
					[0.00]	[0.82]	[0.94]	[0.24]	[0.14]	[0.67]
M^r	7.14	0.23	1.00	0.01	63.79	0.02	2.10	0.19	0.40	0.55
					[0.00]	[0.89]	[0.02]	[0.66]	[0.67]	[0.46]
L^r	7.80	0.20	1.00	0.00	10.96	0.01	0.47	0.43	0.88	8.06
					[0.00]	[0.92]	[0.93]	[0.51]	[0.57]	[0.00]
Broad Credit Channel Model (3.7): $x_t = (im_t, \pi_t, IP_t, i_t, R_t, M_t^r, \kappa_t)'$, 2 Lags										
im	4.60	0.13	1.00	0.01	6.24	0.08	1.40	0.40	2.10	0.22
					[0.04]	[0.78]	[0.16]	[0.53]	[0.02]	[0.64]
π	0.03	0.02	0.97	0.00	54.40	0.06	6.27	0.11	8.32	1.14
					[0.00]	[0.80]	[0.00]	[0.74]	[0.00]	[0.29]
ip	4.46	0.13	0.92	0.04	5.60	63.49	8.92	0.03	0.86	0.40
					[0.05]	[0.00]	[0.00]	[0.85]	[0.59]	[0.53]
i	0.06	0.02	0.98	0.00	878.89	0.02	0.89	56.53	1.51	0.85
					[0.00]	[0.88]	[0.55]	[0.00]	[0.12]	[0.36]
R	0.08	0.01	0.98	0.00	70.68	0.01	1.30	0.07	6.08	2.51
					[0.00]	[0.91]	[0.22]	[0.80]	[0.00]	[0.11]
M^r	7.14	0.23	1.00	0.01	49.00	0.28	2.17	0.48	0.76	3.44
					[0.00]	[0.59]	[0.01]	[0.49]	[0.69]	[0.06]
κ	0.02	0.01	0.97	0.00	254.56	0.23	2.13	0.91	5.36	1.65
					[0.00]	[0.63]	[0.02]	[0.34]	[0.00]	[0.20]

Table 3: Cointegration Tests, Sample Period: 1975:1-1998:12

H_0	MC Model (3.5) c,s	MC Model (3.5) c,s,t^r	BLC Model (3.6) c,s	BLC Model (3.6) c,s,t^r	BCC Model (3.7) c,s	BCC Model (3.7) c,s,t^r
$r = 0$	161.98***	193.05***	386.02***	436.22***	245.36***	278.39***
$r = 1$	86.76***	116.46***	264.43***	304.67***	151.47***	180.76***
$r = 2$	47.70***	69.29**	178.89***	216.27***	90.12***	115.75***
$r = 3$	24.20	41.25	123.73***	154.83***	53.53**	72.83***
$r = 4$	8.09	20.02	71.51**	100.10***	30.61**	42.33
$r = 5$	0.10	7.57	41.66	61.37	9.11	20.45
$r = 6$			22.81	36.84	0.00	8.72
$r = 7$			6.08	18.25		
$r = 8$			0.97	4.46		

Notes: The table shows the Johansen trace statistic used to test the hypothesis of at most r cointegration relations. Two different specifications of the deterministic terms (constant and centered seasonal dummies: c,s; constant, centered seasonal dummies and a trend that is restricted to the cointegration space: c,s,t^r) are considered for each of the three models discussed in the text. *** (**) symbolizes rejection of the null hypothesis at a significance level of 1% (5%).

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