Bank Lending and Monetary Policy Transmission in Germany

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vorgelegt von:
Diplom–Volkswirt
Oliver Matthias Hülsewig
aus Bad Neustadt an der Saale

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Erstgutachter: Prof. Dr. Peter Bofinger

Für meine Eltern und Grosseltern

Vorwort

Die vorliegende Arbeit entstand während meiner Tätigkeit als wissenschaftlicher Mitarbeiter am Lehrstuhl für Geld und internationale Wirtschaftsbeziehungen an der Bayerischen Julius Maximilians Universität Würzburg. Sie wurde am Fachbereich Wirtschaftswissenschaften der Universität Würzburg im November 2003 als Dissertation angenommen.

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Trotz aller Unterstützung wäre diese Dissertation nicht ohne die Hilfe meiner Familie entstanden. Dies gilt für meine Eltern und Großeltern, die mich immer gefördert und ermutigt haben. Hierfür danke ich ihnen von Herzen. Zuletzt möchte ich mich bei Steffi und Tanja bedanken, die mich bei der Entstehung dieser Arbeit begleitet und manche meiner Launen ertragen haben.

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1 Introduction and Overview

1.1 Aim

Since 1 January 1999, the European Central Bank has assumed responsibility for monetary policy in the euro area. The conduct of monetary policy by the Eurosystem requires understanding the monetary transmission process that characterizes the impact of monetary policy on output and inflation. The discussion on monetary policy transmission – see Mishkin (1995), Bernanke and Gertler (1995) and Taylor (1995) – has highlighted the basic transmission channels through which monetary policy is effective.

The *credit channel* emphasizes the importance of banks in the transmission of monetary policy, which stems from the notion that financial markets are incomplete. Since banks are unique in extending credit – basically, because of their expertise in mitigating financial frictions – the manner they adjust their credit conditions to changes in monetary policy has a bearing on expenditure decisions. By contrast, the *interest rate channel* describes the effects of monetary policy on the attraction of investment and saving that prevail when financial markets are complete. Changes in monetary policy trigger changes in the cost of capital and yield on savings, which exert an influence on spending decisions. Although, the credit channel and the interest rate channel depart in stressing the relevance of financial considerations they are deemed complementary, which means that these transmission channels can coexist simultaneously.[1] This study addresses the credit channel of monetary policy transmission.

Analyzing the credit channel in Germany requires a thorough knowledge of the way monetary policy is implemented. Policy implementation by the Eurosystem is based on an operational framework, which is designed to signal monetary policy intentions by steering short–term money market rates. Banks play a pivotal role in the transmission of monetary policy, since their behavior in passing on policy–induced changes in short–term money market rates has implications for the propagation of monetary policy measures.

Yet, the framework surrounding the credit channel – as illustrated by an extended IS–LM model due to Bernanke and Blinder (1988) – has insufficiently

[1] In addition, monetary policy can also operate through the *asset price channel*, the *expectations channel* and the *exchange rate channel*. See Mishkin (1995) and Bofinger (2001) – among others – for a survey and discussion.

taken into account that monetary policy is conducted by means of an interest rate targeting. Instead, monetary policy is assumed to operate according to a form of monetary base control, which is a major impediment when analyzing the impact of monetary policy actions. Agreement prevails that the underpinning of the credit channel – specifically, the modified IS–LM model – is to some extent misleading.[2] This study aims at dealing with this issue.

1.2 Outlook

The study is organized as follows. In *Chapter 2*, we address the credit channel of monetary policy by discussing the theoretical underpinning – i.e. the extended IS–LM model developed by Bernanke and Blinder (1988) – and the empirical evidence that has been established on the basis of aggregate and disaggregated data. The focus includes an assessment whether the assumption of a policy rule that is conducted via a monetary base targeting is accurate for evaluating the effects of monetary policy measures. Essentially, empirical evidence for Germany suggests that treating the monetary base as an exogenous policy instrument is invalid.

Chapter 3 outlines the operational framework of the ECB, which constitutes the means through which monetary policy is implemented. Monetary policy operations by the Eurosystem – following the prior practice of the German Bundesbank – are aimed at controlling the overnight rate so as to influence money market rates at longer maturities.[3] According to the expectations hypothesis of the term structure, the link between money market rates at different maturities is established by market expectations about future monetary policy measures. We investigate this prediction – which is an important ingredient for an interest rate targeting procedure – empirically by using cointegration analysis and error correction models.

Chapter 4 explores the credit channel in Germany on the basis of a structural analysis of aggregate bank loan data. We begin our analysis by presenting a stylized model of the banking firm, which incorporates a policy rule that is conducted through an interest rate targeting. Using the model as a guide, we apply a vector error correction model (VECM), which allows to identify long–run cointegration relationships that can be interpreted as loan supply and loan demand equations. Our findings suggest that bank behavior plays

[2] See Dale and Haldane (1993b, 1993c), Goodfriend (1995), Bofinger, Reischle and Schächter (1999) and Bofinger (2001) for a critical discussion.

[3] See e.g. European Central Bank (2001a) and Deutsche Bundesbank (1995).

a meaningful part in the transmission of monetary disturbances.

Extending the VECM analysis, *Chapter 5* assesses the existence of the credit channel in Germany by means of innovation analysis, which displays some stylized facts about the monetary transmission mechanism by assessing the impact of a monetary policy shock. The main implication of our results is that the credit channel appears to be effective, as we find that loan supply effects in addition to loan demand effects contribute to the propagation of monetary policy actions.

Finally, *Chapter 6* provides concluding remarks.

2 The Credit Channel of Monetary Policy: A Survey and Discussion

2.1 Introduction

In recent years the interest in the monetary transmission process has revived.[4] The current debate – see Bernanke and Blinder (1988), Bernanke and Gertler (1995), Friedman and Kuttner (1993), Gertler and Gilchrist (1993) and Kashyap and Stein (1994) – focuses on the credit channel, which assigns banks an important role in the propagation of monetary disturbances to the real economy. It is based on the assumption that financial markets are characterized by imperfections arising from information asymmetries between borrowers and lenders. Banks specialize in extending credit to borrowers that cannot obtain other types of credit because of information–related financial frictions. If banks adjust their loan supply following a change in the stance of monetary policy, this has a bearing on real activity, since at least some borrowers have to rearrange their expenditure decisions.[5]

The credit channel departs from the interest rate channel – as described e.g. by the standard IS–LM framework – which rests on the assumption that financial markets operate frictionless. In perfect financial markets – that is, a world in which the Modigliani and Miller (1958) proposition holds – all forms of financing are perfect substitutes and yield the same interest rate (Dale and Haldane, 1993a, p. 479). According to the interest rate channel, the absence of financial frictions renders financial considerations meaningless, so that monetary policy works exclusively through its impact on the integrated rate of interest with consequences for real activity. Despite the difference, the credit channel and the interest rate channel are not mutually exclusive but complementary, with the implication that monetary policy can be effective through these transmission channels simultaneously (Cecchetti, 1995, p. 86).[6]

[4]See Mishkin (1995, 2001), Meltzer (1995), Taylor (1995), Cecchetti (1995) or Hubbard (1995, 2000) for a survey and discussion about the different approaches of the monetary transmission mechanism.

[5]It is important to note that the credit channel should not be confused with credit rationing. In credit rationing models – as elaborated e.g. by Jaffee and Russell (1976) and Stiglitz and Weiss (1981) – banks limit the availability of credit regardless of price, which means that borrowers who are willing to pay the market interest rate are constrained from obtaining credit. In the credit channel this is not necessarily the case; the credit market may clear by price (Gertler and Gilchrist, 1993, p. 46).

[6]As noted by Bernanke and Gertler (1995), the credit channel should not be seen

This chapter discusses the credit channel of monetary policy transmission.

As Hubbard (1995) and Kashyap and Stein (1994) point out, the underpinning of the credit channel – that builds on a modified IS–LM model due to Bernanke and Blinder (1988) – postulates that monetary policy is conducted by the central bank according to a form of monetary base control. In this setup, there are two necessary conditions that must be satisfied for the credit channel to operate (Oliner and Rudebusch, 1995, p. 3): (1) banks cannot insulate their loan supply from a policy–induced change in reserves by rearranging their portfolio of other assets and liabilities; and, (2) some borrowers are bank–dependent, which means that they cannot insulate their spending from a drop in the availability of bank loans. These two conditions embody the notion that for both banks and borrowers different forms of credit – bank loans and bonds – are less than perfect substitutes. If this holds, an open market sale by the central bank directly constrains bank lending by causing a fall in reserves, which in turn constrains the spending of borrowers that cannot replace loan losses with other types of finance. In terms of the IS–LM model, this implies that the effects of monetary policy are amplified through an additional credit multiplier that operates alongside the conventional monetary multiplier (Dale and Haldane, 1993b, p. 6).[7] The crucial issue is the extent to which monetary policy exercises control over the level of base money.

A number of studies have sought to establish whether the credit channel is working in addition to the interest rate channel. Empirical work can be broadly divided into research based on aggregate and disaggregated data. At the aggregate level, many studies have investigated the timing patterns of financial and real aggregates following a monetary contraction; at the

"[...] as a distinct, free–standing alternative to the traditional monetary transmission mechanism, but rather as a set of factors that amplify and propagate conventional interest rate effects." (Bernanke and Gertler, 1995, p. 28).

[7]Notice that this version of the credit channel is frequently denoted as the 'narrow' credit channel as opposed to the 'broad' credit channel that elaborates the impact of information–related financial frictions in the propagation of monetary policy measures. In the broad credit channel – that has been suggested by Gertler and Hubbard (1988), Gertler and Gilchrist (1993), Bernanke and Gertler (1989, 1995), Calomiris and Hubbard (1990), Bernanke, Gertler and Gilchrist (1996, 1999) or Oliner and Rudebusch (1996a) – the financial position of borrowers – which can be derived from their balance sheets – plays a crucial role for the possibility of obtaining external finance. This is reflected in the size of an external finance premium, which is defined as the cost differential between external and internal funds. Contractionary monetary policy weakens the financial position of borrowers, either by decreasing the collateral value of their assets or by increasing their debt service, which pushes up the external finance premium and curbs investment and consumer spending.

disaggregated level, much work has examined heterogeneity across agents in an attempt to reveal the distributional consequences of monetary policy actions that follow from information–related financial frictions. While studies based on disaggregated data data have provided convincing results, studies based on aggregate data have been less conclusive.

The remainder of this chapter is organized as follows. Section 2.2 outlines the extended IS–LM model, as suggested by Bernanke and Blinder (1988), with special attention concerning the way monetary policy is integrated. Section 2.3 surveys the empirical evidence of the credit channel that has been established on the basis of aggregate and disaggregated data. The focus is on the United States, which have been the main field of research in this area. Section 2.4 provides a brief summary and concluding remarks.

2.2 The extended IS-LM Framework

2.2.1 Preliminaries

Within an extended IS–LM model, Bernanke and Blinder (1988) illustrate the credit channel operating alongside the interest rate channel by accommodating the notion that financial markets are incomplete.[8] The standard IS–LM model comprises two financial assets – money and bonds – and a single interest rate. Money is assumed to receive a zero rate of return, so the interest rate is the return on bonds that is taken to be a summary statistics for all credit financing conditions (Kashyap and Stein, 1995, p. 154). The modified IS–LM model distinguishes three financial assets – money, bonds and bank loans – which differ from each other in meaningful ways and are accounted for separately. With three financial assets, the model determines the interest rates on bonds and loans, which are consistent – for a given price level – with an equilibrium in the money market, the market for bank loans, and the equality of output and aggregate demand (Walsh, 1998, p. 303). Since the model concentrates on how monetary policy affects aggregate demand, it ignores aggregate supply and simply treats the price level as given.[9] Monetary policy is supposed to gain leverage by controlling the monetary

[8]The importance of financial considerations in the transmission of monetary policy has – in one form or another – been earlier addressed by Gurley and Shaw (1955, 1960), Roosa (1951), Tobin and Brainard (1963), Brainard (1964) and Brunner and Meltzer (1963). See Gertler (1988), Mattesini (1993), Kakes (2000) or Trautwein (2000) for a survey.

[9]See Blinder (1987), Greewald and Stiglitz (1990, 1993) or Fiorentini and Tamborini (2001) for approaches that focus on the interaction between the loan market and aggregate supply.

base. Similar approaches have been developed by Hall and Thomson (1992), Kashyap, Stein and Wilcox (1993), Dale and Haldane (1993b), Miron, Romer and Weil (1994), Walsh (1998) and Hallsten (1999).

2.2.2 Structure of the Model

The extended IS-LM model incorporates a stylized banking sector, which attributes to the notion that bank loans and bonds are less than perfect substitutes.[10] Banks are assumed to hold loans (L), bonds (B^b) and reserves (R) as assets, and transaction deposits (D) as liabilities. Reserves consist of excess reserves (E) and required reserves (aD), where (a) is the required reserve ratio on deposits. The adding–up bank balance sheet constraint is given by:

$$L + B^b + E = (1 - a)D. \tag{2.1}$$

Loans and bonds receive positive rates of return, (ρ) and (i), while the rates of return on reserves and transaction deposits are supposed to be zero. The banks' aggregate loan supply is described by:

$$L^s = H(\rho, i)D(1 - a), \tag{2.2}$$

where (H) expresses the proportion of financial resources invested in loans, which depends on the rates of return on the available assets: $H_\rho > 0$ and $H_i < 0$.[11] Accordingly, aggregate loan supply is positively related to the interest rate on loans (ρ) and negatively related to the interest rates on bonds (i). Similar expressions can be derived for the share of bond holdings (B^b) and the share of excess reserves (E).[12]

The nonbank private sectors' holdings of nominally denominated assets is given by: $W = B^p + D - L$, and comprises net holdings of bonds (B^p), deposits (D) and bank loans (L). The stock of nominally denominated assets is assumed to be fixed in the short term. Aggregate loan demand by the

[10] It is noteworthy that imperfect substitutability between bank loans and bonds is meant here as reflecting the intermediary case between perfect substitutability and no substitutability between these different forms of debt financing.

[11] Let subscripts denote partial derivatives.

[12] The assumption that banks regard loans and bonds as imperfect substitutes in their balance sheets is based on a number of factors (Dale and Haldane, 1993b, p. 12; Bernanke, 1993, p. 56): First, since loans and bonds differ in their risk characteristics, it may be optimal for banks to hold both assets in order to diversify risk. Second, while banks hold loans primarily for their expected return, bonds are held for liquidity, to be used as collateral, and to satisfy various legal requirements.

nonbank private sector is:

$$L^d = L^d(\rho, i, y), \tag{2.3}$$

where (y) denotes the output level. The demand for loans is negatively related to the interest rate on loans: $L^d_\rho < 0$, and positively related to the interest rate on bonds and the level of income: $L^d_i > 0$ and $L^d_y > 0$. The dependency on output can be thought of capturing the transactions demand for loans that might arise from working capital or liquidity considerations (Bernanke and Blinder, 1988, p. 435). If credit rationing is ignored, the loan market equilibrium is given by:

$$L^d(\rho, i, y) = H(\rho, i)D(1 - a). \tag{2.4}$$

The money market is described by a conventional LM curve. Assuming that banks hold excess reserves equal to $(\epsilon(i)D(1 - a))$[13], then total reserves are given by $R = (\epsilon(i)D(1 - a) + aD)$. The supply of deposits is: $D^s = m(i)R$, where the money multiplier is defined as: $m(i) = (\epsilon(i)(1 - a) + a)^{-1}$, with $m' > 0$. The nonbank private sectors' demand for deposits follows a standard liquidity preference schedule: $D^d = D^d(i, y)$, and depends negatively on the interest rate on bonds and positively on the income level and total wealth. Since the latter is supposed to be constant it is neglected. Ignoring further the existence of cash, the LM curve is described by:

$$D^d(i, y) = m(i)R. \tag{2.5}$$

The bond market is suppressed by *Walras's Law*. Implicitly, however, the nonbank private sectors' demand for bonds follows from the holdings of nominally denominated assets, since bond demand and money demand less loan demand must equal total financial wealth (Bernanke and Blinder, 1988, p. 436).

The goods market is summarized by a conventional IS curve:

$$y = y^d(i, \rho), \tag{2.6}$$

except for the difference that aggregate demand (y^d) is negatively related to both the interest rate on bonds (i) and the interest rate on loans (ρ). An alternative representation of the IS curve can be derived by using equation (2.5) to replace $D(1 - a)$ on the right side of equation (2.4) by $m(i)R(1 - a)$.

[13] For ease of exposition, excess reserves are supposed to be only dependent on the interest rate on bonds.

The loan interest rate (ρ) can then be solved as a function of (i), (y) and (R):

$$\rho = \Phi(i, y, R). \tag{2.7}$$

Totally differentiating both sides of the modified equation (2.4) gives the following expressions for the right side:

$$\begin{aligned} dL &= H_\rho mR(1-a)d\rho + Hm(1-a)dR \\ &\quad +(H_i mR(1-a) + Hm'R(1-a))di. \end{aligned}$$

and for the left side:

$$dL = L_i^d di + L_\rho^d d\rho + L_y^d dy,$$

which shows that: $d\rho/di = \Phi_i > 0$, $d\rho/dy = \Phi_y > 0$ and $d\rho/dR = \Phi_R < 0$. Accordingly, the loan interest rate (ρ) depends positively on the interest rate on bonds (i) and the level of income (y) and negatively on the volume of reserves (R).[14] Substituting the function of the loan interest rate (2.7) into the equilibrium locus of the goods market (2.6) gives a second relationship between the output level and the bond interest rate:

$$y = y^d\left(i, \Phi(i, y, R)\right). \tag{2.8}$$

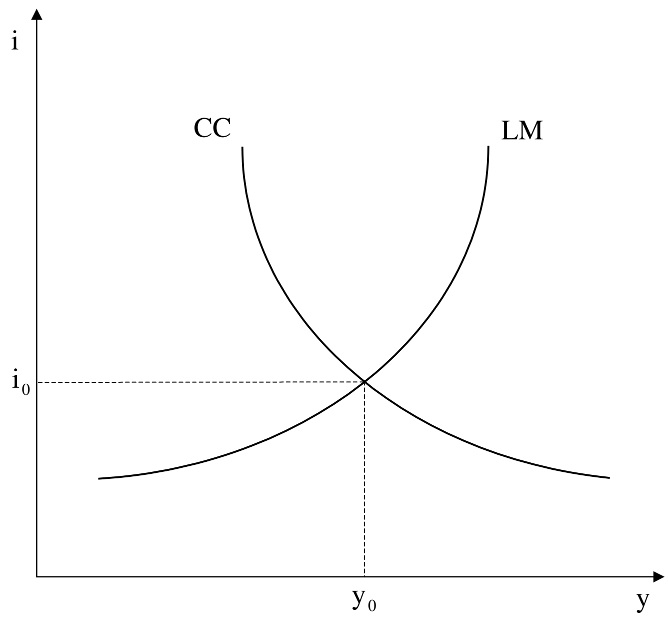
This relationship is denoted as the CC curve, which is a transformation of the conventional IS curve. It describes the geometrical locus of simultaneous equilibria in the markets for commodities and credit. The CC curve is downwards slopped:

$$\left.\frac{dy}{di}\right|_{CC} = \frac{y_i^d + y_\rho^d \Phi_i}{1 - y_\rho^d \Phi_y} < 0,$$

and reacts like the IS curve to all shocks affecting the market for goods; but, unlike the IS curve, it is also shifted by monetary policy shocks, in particular by variations in the level of reserves. The CC and LM curves are outlined in Figure 2.1, where the intersection of these curves determines the equilibrium level of output (y_0) and the equilibrium interest rate on bonds (i_0). It is noteworthy that the CC curve reduces to the conventional IS curve when bank loans and bonds are perfect substitutes, since there are either banks or borrowers that will arbitrage between the loan market and the bond market to equalize the loan and the bond interest rate.

[14]Notice that the loan interest rate is an increasing function of the bond interest rate only if the interest rate elasticity of the money multiplier is not too large (Bernanke and Blinder, 1988, p. 436). Notice further that Φ_i, Φ_y and Φ_R become zero, if either $H_\rho \to \infty$ or $L_\rho^d \to -\infty$. See the Appendix for a discussion.

Figure 2.1: Equilibrium in the extended IS–LM model



2.2.3 Implications for Monetary Policy Transmission

Within the extended IS–LM model, monetary policy can operate through the credit channel and the interest rate channel by inducing changes in the level of base money.[15] The effects of monetary policy are seen by totally differentiating the system of the two equations (2.5) and (2.8), which gives the partial derivative of income with respect to reserves:

$$\left.\frac{dy}{dR}\right|_{CCLM} = \frac{(D_i^d - m'R)y_\rho^d \Phi_R + m\left(y_i^d + y_\rho^d \Phi_i\right)}{(D_i^d - m'R)\left(1 - y_\rho^d \Phi_y\right) + D_y^d\left(y_i^d + y_\rho^d \Phi_i\right)}. \tag{2.9}$$

As in the standard IS–LM model, an expansionary monetary policy – corresponding with an increase in the amount of reserves – will raise the income level: $dy/dR|_{CCLM} > 0$. It is worth mentioning that the solution collapses to the conventional result of the IS–LM model:

$$\left.\frac{dy}{dR}\right|_{ISLM} = \frac{my_i^d}{(D_i^d - m'R) + D_y^d y_i^d},$$

[15] Since cash is ignored, the monetary base coincides with the amount of reserves.

if bank loans and bonds are perfect substitutes, either for banks: $H_\rho = +\infty$, or for borrowers: $L^d_\rho = -\infty$, which implies that financial market imperfections play no substantial role in the transmission of monetary policy (Kashyap and Stein, 1994, p. 236).

Suppose the central bank imposes a monetary tightening by conducting an open market sale. This leads the banking sector to decrease their stock of loans and their deposit level in order to meet – owing to legal reserve requirements on deposits – the policy–induced drop in the amount of reserves.[16] The fall in loans and deposits causes an increase in the loan and the bond interest rate. This curtails investment and consumer spending by the nonbank private sector, which in turn stimulates a decline in the output level. As shown in Figure 2.2, a contractionary monetary policy shifts both the LM curve and the CC curve inward from LM_0 to LM_1 and CC_0 to CC_1, which causes a drop in the level of output from y_0 to y_1. While the shift in the LM curve reflects the fall in the volume of deposits, the shift in the CC curve results from the fall in the stock of loans emanating from a monetary tightening. The implication is that the effects of monetary policy on aggregate output are reinforced through an additional credit multiplier (i.e. the credit channel) that operates alongside the conventional monetary multiplier (i.e. the interest rate channel).

At least partially, the contractionary impact of monetary policy is offset by second round effects, since the drop in the output level limits the raise in the interest rate on bonds by decreasing deposit demand (Dale and Haldane, 1993b, p. 14). Conceivably, a policy–induced fall in reserves might even decrease the bond interest rate. This ambiguity is shown by:

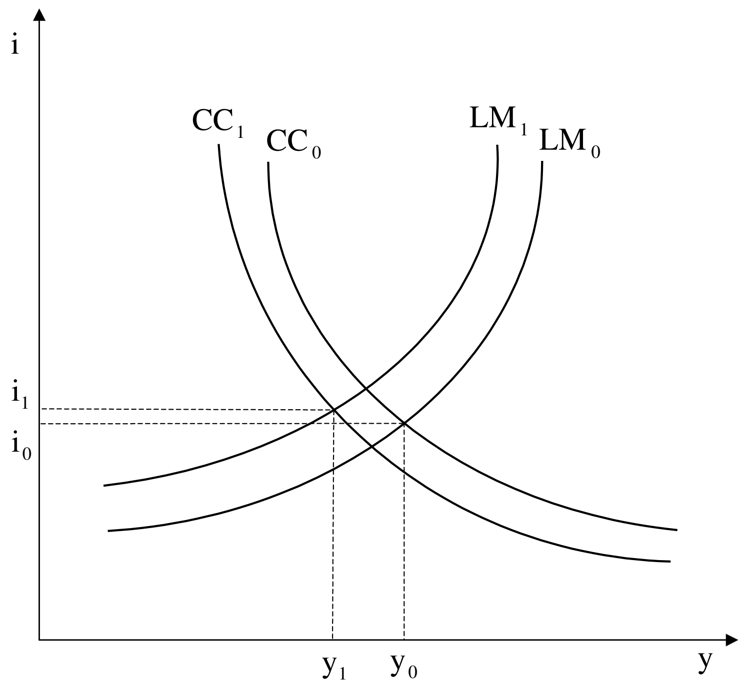
$$\left.\frac{di}{dR}\right|_{CCLM} = \frac{m\left(1 - y^d_\rho \Phi_y\right) - D^d_y y^d_\rho \Phi_R}{\left(D^d_i - m'R\right)\left(1 - y^d_\rho \Phi_y\right) + D^d_y\left(y^d_i + y^d_\rho \Phi_i\right)}, \tag{2.10}$$

which implies that the sign of $di/dR|_{CCLM} \gtrless 0$ cannot be determined *a priori*. Assuming that the income elasticities of the demand functions for loans L^d_y and deposits D^d_y are not too different, the bond interest rate is raising after a monetary tightening, but not necessarily to a remarkable extent.[17] This

[16] As Gertler and Gilchrist (1993) pointed out: *"An important step in the argument is the contention that legal reserve requirements on deposits provide the [central bank, O.H.] with considerable direct leverage over the quantity of funds that banks may obtain"* (Gertler and Gilchrist, 1993, p. 45). Of course, the banking sector may also decrease bond holdings in order to meet the decline in deposits and reserves. But, since bank loans and bonds are assumed to be less than perfect substitutes, this implies that loans bear a substantial portion of the balance sheet adjustment.

[17] Graphically, the ambiguity arises because a contractionary monetary policy shifts both

Figure 2.2: Contractionary Monetary Policy



means that monetary policy measures can have an impact on investment and consumer spending even if they do not move the bond rate by much (Kashyap and Stein, 1997a, p. 2).

Kashyap and Stein (1994) resume the necessary conditions that must hold for the credit channel to operate in addition to the interest rate channel: (1) banks regard loans and bonds as imperfect substitutes on the asset side of their balance sheets: $H_\rho < +\infty$, which implies that they cannot completely insulate their lending activities from policy–induced shocks to reserves by paring bond holdings; (2) at least some borrowers consider loans and bonds as imperfect substitutes on the liability side of their balance sheets: $L^d_\rho > -\infty$, which means that they cannot readily offset a decline in the availability of bank loans by borrowing through bond issues; and, (3) aggregate demand must be sensitive to both a change in the interest rate on bonds: $y^d_i < 0$, and a change in the interest rate on loans: $y^d_\rho < 0$ (Miron et al., 1994, p. 269).[18]

the LM and the CC curves inward. As can be seen in Figure 2.2, if the shift in the LM curve is relatively small and/or the shift in the CC curve is relatively large, it is possible that the interest rate on bonds falls after a policy–induced decline in reserves (Bernanke and Blinder, 1988, p. 437; Dale and Haldane, 1993b, p. 20).

[18] In addition, prices should not adjust instantly, which prevents monetary policy shocks

If either of these necessary conditions fail to hold, the loan market becomes irrelevant in the transmission of monetary policy. A monetary contraction enacted through a drop in reserves works then exclusively through the money market by increasing the interest rate on bonds, which means that if bank loans fall, this arises solely from a decline in loan demand stimulated by a decrease in the output level (Romer and Romer, 1990, p. 159). The opposite extreme emerges if money and bonds are perfect substitutes: $D_i^d = -\infty$, which suggests that the money market becomes meaningless in the transmission of monetary policy (Bernanke and Blinder, 1988, p. 436). This implies that monetary policy shocks work exclusively through the loan market with consequences for investment and consumer spending.[19]

While the assumption that borrowers condition part of their spending on the availability of credit is beyond dispute, the idea that monetary policy affects the flow of credit by inducing changes in the amount of reserves gives rise to severe criticism.

2.2.4 Critical Assessment

Analyzing the behavior of banks in the transmission of monetary policy requires a sound understanding of the way monetary policy is implemented. According to Dale and Haldane (1993c) and Bofinger (2001), the credit channel – as illustrated in the extended IS–LM model – suffers from the flaw that it simplifies the interaction between the central bank and the banking sector by assuming a policy rule that is conducted according to a form of monetary base control. Monetary policy affects the flow of credit by inducing a change in the level of deposits, which – because of legal reserve requirements on deposits – arises from a change in the amount of reserves. The monetary base is treated as the exogenous policy instrument: *"A monetary policy action begins with a change in the level of bank reserves"* (Cecchetti, 2001, p. 174).

As central banks – almost everywhere – implement their policies by admin-

from being neutral. If prices adjust frictionlessly, a change in nominal reserves will be met with an adjustment of prices in the same scale, and both bank and nonbank balance sheets will remain unchanged in real terms. However, this condition is not only related to the credit channel, but also to the conventional interest rate channel. See Blinder (1991, 1994) or Ball and Mankiw (1994) for a discussion on the rationale of sticky prices.

[19] Romer and Romer (1990) and Thornton (1994) argue that the credit channel may fail to operate if banks can insulate their lending activities from monetary policy measures by using managed liabilities – such as time deposits or certificates of deposits – against which no reserve requirements are imposed. See Kashyap and Stein (1994) and Hubbard (1995) for a discussion on this objection.

istering official interest rates, this perception is sharply in contrast with the way monetary policy is actually conducted. Changes in the stance of monetary policy are reflected by changes in official rates, which have an impact on short–term money market rates. Central banks satisfy the liquidity needs of the banking sector at these official rates, which implies that the monetary base is endogenously determined; it responds passively to shocks to base money demand.

Applying Granger causality tests for Germany supports this notion by showing that the growth rates of the monetary aggregates M1 and M3 are not affected by the growth rate of the monetary base B.[20] The results, which are reported in Table 2.1, are based on the regression equations:

$$\begin{aligned} \Delta M_t &= a_0 + \sum_{j=1}^{k} a_j \Delta M_{t-j} + \sum_{j=1}^{k} b_j \Delta B_{t-j} + season + u_t \\ \Delta B_t &= c_0 + \sum_{j=1}^{k} c_j \Delta B_{t-j} + \sum_{j=1}^{k} d_j \Delta M_{t-j} + season + v_t, \end{aligned}$$

where k is the number of lags and u_t and v_t are error terms. The growth rate of the monetary base is Granger–causal for the growth rate of the money stock, if the test statistic $\widehat{F}$ is sufficiently large or if the corresponding p–value is sufficiently small.[21] The results indicate that the lagged growth rates of the monetary base are not significant for the growth rates of the monetary aggregates, whereas the lagged growth rates of the monetary aggregates have a significant impact on the growth rate of the monetary base. This finding raises serious doubts about a policy rule that is conducted according to a

[20] The analysis is based on monthly data taken from the German Bundesbank and the German Council of Economic Experts (Sachverständigenrat). It covers the period from 1980 to 1998, but is split into the samples 1980.01–1989.12 and 1991.01–1998.12 due to the possible distortion effects of the German unification. The monetary base is adjusted from the impact of changes of required reserves and its source components (multiplicatively adjusted monetary base). The provision of the adjusted base by the Sachverständigenrat is gratefully acknowledged.

[21] In general, the Granger Causality Test utilizes the F-statistic to explore whether lagged values of x contribute significantly to the explanation of y_t, once lagged values of y have been incorporated. If they do not, then x is said not to 'Granger cause' y, and if they do, x 'Granger causes' y. Similarly, examining whether y 'Granger causes' x, the contribution of lagged values of y to the explanation of x is examined (having already accommodated the contribution of lagged x to its own explanation). Note that the statement "x Granger causes y" does not imply that y is the effect or the result of x. Granger causality measures precedence and information content but does not by itself indicate causality in the more common use of the term (Darnell, 1997, p. 41).

Table 2.1: Granger Causality Tests for Germany

Sample	$\widehat{F}(\Delta B)$	$p(\Delta B)$	$\widehat{F}(\Delta M1)$	$p(\Delta M1)$
80.01–89.12	0.48	0.86	3.51	0.002
91.01–98.12	0.41	0.91	2.39	0.029
	$\widehat{F}(\Delta B)$	$p(\Delta B)$	$\widehat{F}(\Delta M3)$	$p(\Delta M3)$
80.01–89.12	0.68	0.55	3.01	0.006
91.01–98.12	0.61	0.76	2.16	0.048

Notes: $\widehat{F}(\Delta B)$ and $\widehat{F}(\Delta Mx)$ are the F-statistics of the growth rates of the monetary base B and the monetary aggregates Mx, $x = 1, 3$. The results – here reported for a lag length of eight – are robust to different lag specifications.

form of monetary base control.[22]

On balance, the underpinning of the credit channel – as outlined in the extended IS–LM model – is misleading. The main flaw is the contention that monetary policy gains direct leverage over the flow of credit by inducing changes in the level of reserves, which stems from the presumption of a policy rule that is conducted in the form of a monetary base targeting. As Goodhart (1987) notes: *"In reality, the more exogenous, or policy determined, variable is the change in (short–term) interest rates, while both the monetary base and monetary aggregates are endogenous variables. This reality is, unfortunately, sharply in contrast with the theoretical basis of many economists' models [...]. The fact that it is commonplace to find economists treating the monetary base and/or the money stock as exogenously determined in their models does not mitigate the error; the fact is that this approach is simply incorrect."* (Goodhart, 1987, p. 501). On this account, much empirical work on the credit channel has quantified monetary policy by choosing a short–term money market rate as the policy indicator.

[22]Empirical analyses for Germany by Nautz (2000), Brand (2001) and Holtemöller (2003) draw similar conclusions. Within a vector error correction model, Nautz (2000) shows that the monetary aggregates M1 and M3 are not controlled by variations in the monetary base. His results suggest that, for both M1 and M3, it is the volume of base money that adjusts to the movements in the monetary aggregates and not vice versa. Brand (2001) reports a similar finding by estimating a state space model for interest rates, the money stock and bank reserves. He concludes that interest rates and money are exogenous to bank reserves while the opposite seems invalid. Holtemöller (2003) finds a stable relationship between the money stock and the monetary base, but the adjustment is done by the monetary base rather than the money stock if deviations from equilibrium occur.

2.3 Empirical Findings in the Literature

A number of studies have sought to establish whether the credit channel is working besides the interest rate channel by using aggregate and disaggregated data. At the aggregate level, research has focused on the link between financial aggregates and real aggregates following a monetary contraction; at the disaggregated level, research has explored heterogeneity across agents in an attempt to reveal the distributional consequences of monetary policy that arise from financial frictions. The following survey outlines the empirical evidence established for the United States, which have been the main field of research in this area. See also Bernanke (1993), Bernanke and Gertler (1995), Bernanke et al. (1996, 1999), Cecchetti (1995), Gertler and Gilchrist (1993), Hubbard (1995, 2000), Kashyap and Stein (1994, 1997b), Ramey (1993) and Walsh (1998) for an overview and discussion.

2.3.1 Aggregate Data

Several studies have explored the timing patterns of financial and real aggregates following a monetary tightening. Using vectorautoregression (VAR) analysis, Bernanke and Blinder (1992) find that bank loans and real output decline by degrees roughly contemporaneously after a monetary policy shock.[23] This finding is consistent with the credit channel, as banks appear to decrease their loan activities in response to a monetary tightening, and when bank lending drops this curtails real activity. Romer and Romer (1990) report a similar result, but relate it to the interest rate channel, because of the sluggish decline in bank loans that coincides with the decline in real output.[24] King (1986) and Ramey (1993) observe that bank loans perform badly in predicting real activity, which prompts the conclusion that bank lending has an inferior impact on spending; whereas, Morgan (1998) shows that the sluggish adjustment of bank loans can be explained by loan commitments, which suggests that the loan level may not drop immediately when monetary policy tightens.

As Cecchetti (1995) and Hubbard (1995) point out, the different interpre-

[23]Bernanke and Blinder (1992) use the *federal funds rate* as a measure for the stance of monetary policy.

[24]The analysis by Romer and Romer (1990) rests on the *narrative approach*, which centers on the identification of a limited number of 'moments' of change in monetary policy, based on a qualitative analysis of historical information, in particular statements by the monetary authorities with regard to periods of monetary stringency. See e.g. Tsatsaronis (1995) or Kakes (2000) for a discussion.

tation of the observable decline in bank loans after a monetary contraction reflects a serious identification problem. While the credit channel emphasizes a shift in loan supply, the interest rate channel postulates a shift in loan demand, which stems from a drop in real activity due to higher interest rates. Distinguishing between these predictions is a difficult task: *"It is not possible using reduced–form estimates based on aggregate data alone, to identify whether bank balance sheet contractions are caused by shifts in loan supply or loan demand"* (Cecchetti, 1995, p. 92).[25] Agreement has been reached that finding evidence on the credit channel requires: *[...] to make a set of identification assumptions to argue that the supply, rather than the demand for credit, has moved in response to a monetary policy shock"* (Eichenbaum, 1994, p. 257).

In an attempt to solve the identification problem, Kashyap et al. (1993) explore the behavior of the mix between bank loans and commercial paper following a monetary policy shock. The idea is that if a fall in bank loans is induced by loan supply, then commercial papers issuance as an alternative source of credit finance should raise after a tightening in monetary policy; whereas, if a slowdown in bank loans is induced by loan demand, then commercial paper issuance should fall to the same degree after monetary policy tightens. Therefore, the adjustment of the mix between bank loans and commercial paper in response to contractionary monetary policy ought reflect whether supply or demand factors are at work.

Kashyap et al. (1993) find that when monetary policy contracts commercial paper issuance surges while bank loans decline gradually, which – in their interpretation – indicates a change in loan supply rather than a change in loan demand. Adding some detail, they explore whether the policy–induced adjustment of the mix contains considerable predictive power for real activity, and find evidence that monetary policy and financial factors are important for inventory movements.

However, a refinement by Gertler and Gilchrist (1993) and Oliner and Rudebusch (1995) suggests that movements in the mix between bank loans and commercial paper are not driven by bank versus nonbank lending but by small firms versus large firms borrowing. Oliner and Rudebusch (1995) find that for both small and large firms bank debt behaves little differently from

[25] Along similar lines, Bernanke and Gertler (1995) note that *"[...] examining the dynamic responses of various credit aggregates to shifts in monetary policy (or comparing these responses to those of monetary aggregates) is largely uninformative about the existence or importance of the credit channel. Credit aggregates, like monetary aggregates, are determined jointly by supply and demand."* (Bernanke and Gertler, 1995, p. 44).

nonbank debt after a monetary policy shock, which implies that – at the disaggregated level – there is no conclusive evidence that a monetary contraction limits the supply of bank debt relative to alternative sources of debt finance.[26] Gertler and Gilchrist (1993) report a similar result, as they cannot find striking evidence that firms substitute from bank debt to nonbank debt after a change in the stance of monetary policy.

Yet, research based on aggregate data has provided empirical evidence that is consistent with the credit channel; but, the sorts of objections imply that clear predictions are difficult to establish. Owing to identification problems, observable facts can often be related to different explanations, which are hard to distinguish unless *a priori* restrictions are imposed that allow to separate the loan supply effects from the loan demand effects that may emerge following a monetary contraction.

2.3.2 Disaggregated Data

In light of the ambiguities, various studies have examined heterogeneity across agents in an attempt to revealed the distributional consequences of monetary policy by using disaggregated data. These studies have shown that agents of different size – firms and banks – are differently affected by monetary policy actions because of financial frictions.[27]

Following Fazzari, Hubbard and Petersen (1988), much work has employed cross–sectional firm level data in an attempt to gauge the importance of financial constraints on investment.[28] Kashyap, Lamont and Stein (1994)

[26]The conclusions drawn by Oliner and Rudebusch (1995) have been questioned. See Kashyap, Stein and Wilcox (1996) and Oliner and Rudebusch (1996b) for a discussion.

[27]In particular, this research strategy is based on the idea that large firms imply less pronounced information problems than small firms, since they can be easier evaluated and monitored. Therefore, a monetary contraction should have a stronger impact on small firms than on large firms as regards the terms of lending and the availability of finance. The same may also apply to banks, with large banks facing more favorable refinancing conditions than small banks, which may have implications for their lending activities. See e.g. Kashyap and Stein (1995) and Hubbard (1995) for a discussion.

[28]According to Cecchetti (1995) and Houston and James (2001), these approaches rest on the assumption that financial market imperfections create a preference for internal over external financing. The magnitude of these imperfections is measured by the extend to which a firm's investment is correlated with its cash flow. In particular, firms that find it relatively more costly to borrow in the capital market are thought to demonstrate a greater sensitivity of investment to cash flow. This view – that has been originally elaborated by Myers and Majluf (1984) and Myers (1984) – is frequently denoted as the *pecking–order hypothesis*. See e.g. Myers (2001), especially pp. 91–94 for an overview and discussion.

look at the differences in inventory investment between publicly traded firms with bond ratings and publicly traded firms without bond ratings. Since nonrated firms are typically much smaller than rated firms, they are more likely to be bank–dependent. They find that during different recessions – prior to which monetary policy was restricted – the inventory movements of the nonrated firms are more sensitive to their own cash holdings than are the inventory movements of the rated firms. By contrast, during periods when monetary policy is loose, there is little relation between cash holdings and inventory movements for either rated and nonrated firms. Kashyap et al. (1994) interpret the differences in the cash sensitivity of inventory investment as consistent with the notion that bank lending is varying with monetary policy. Gertler and Hubbard (1988) show that the fixed investment of (small) firms that do not pay dividends is more sensitive to cash–flow and liquidity during policy–induced recessions than the fixed investment of (large) firms that pay dividends, which may be attributable to the presence of financial constraints. Subsequent work by Carpenter, Fazzari and Petersen (1994) reports a similar result.

Gertler and Gilchrist (1994) explore the cyclical behavior of small firms and large firms concerning sales, inventories and short–term debt. While small firms obtain virtually all their short–term financing through intermediated credit, large firms satisfy their short–term financing needs through several sources of funding. The authors find that, following a monetary contraction, large firms let their inventory–sales ratio initially rise as sales decline, while small firms shed inventories immediately to the extent that their inventory–sales ratio falls significantly despite an extensive drop in sales. The pattern of short–term debt implies that large firms appear able to borrow to carry inventories as sales fall, thereby mitigating pressures to reduce production, whereas small firms appear to encounter financial constraints, which prevents them from abiding their inventories as sales decline. As small firms contract substantially relative to large firms after a monetary tightening, this suggests that financial factors are effective. In a complementary study, Oliner and Rudebusch (1996a) find that capital investment by small and large firms follows a similar pattern, with small firms cutting back investment relatively more quickly than large firms when cash flows decline. Bernanke et al. (1996) observe that the sales, inventories and short–term debt of small firms fall considerably stronger than the sales, inventories and short–term debt of large firms at the beginning of a recession. Their results suggest that the lending to small firms contracts substantially relative to the lending to large firms after a monetary tightening and these cross–sectional differences appear large enough to be potentially significant for economic activity.

Choosing a different angle, Kashyap and Stein (1995, 2000), Peek and Rosengreen (1995) and Kishan and Opiela (2000) investigate the behaviour of banks in response to monetary policy actions by employing cross–sectional bank level data. Kashyap and Stein (1995) focus on the lending decisions of banks of different asset size. They show that bank loan growth in the small asset category is more responsive to monetary policy measures than in the large asset category, which suggests that a monetary contraction has distributional consequences on lending activities. Although, this finding is consistent with the credit channel, the approach may not be stringent enough to distinguish between loan supply effects and loan demand effects, as small banks lend in a larger proportion to small businesses whose demand tends to be procyclical. In a refinement, Kashyap and Stein (2000) separate banks by asset size and liquidity and find that the impact of monetary policy on lending is stronger for banks with less liquid balance sheets – i.e. banks with lower ratios of securities to assets – which is largely attributable to the smaller banks. Peek and Rosengreen (1995) examine banks in the U.S. state of New England during the 1990–1991 downturn. They find that poorly capitalized banks shrink by more than equivalent banks with higher net worth. The implication is that capital market imperfections also apply to banks, as some of them cannot raise additional funds in the open market to offset a balance sheet contraction after a tightening in monetary policy. Kishan and Opiela (2000) extend this approach by using the bank capital leverage ratio as an additional differentiating characteristic along with asset size. Their findings indicate that bank portfolio structure is an important factor in assessing the magnitude and distributional effects of monetary policy on bank loan growth and real economic activity. Lending by small and poorly capitalized banks is most responsive to monetary policy and these banks appear unable to tab new sources of funds to continue financing their loans during a period of monetary stringency.

Matching borrowers and lenders, Hubbard, Kuttner and Palia (2002) focus on the measuring effects of bank and borrower characteristics on the terms of lending. They find that large banks, as measured by the degree of capitalization, seem to require lower cost of borrowing than small banks. Since small banks tend to specialize in small business loans, whereas large banks tend to lend more heavily to large businesses, the cost difference is primarily borne by firms for which information costs and incentive problems are *a priori* important. Bank loan contractions mainly affect firms with high information costs, since these face high costs of switching between different sources of finance, which inevitably has an impact on their investment spending. Houston and James (2001) show that adverse changes in the banking sector as a result of changes in monetary policy can adversely affect the investment activity of informationally intensive firms that rely heavily on bank debt.

Overall, empirical research based on disaggregated data has provided convincing evidence that can be reconciled with the notion that financial frictions shape the effects of monetary policy actions.

2.4 Concluding Remarks

2.4.1 Summary

This chapter has addressed the credit channel of monetary policy by discussing the theoretical underpinning and the empirical evidence that has been established on the basis of aggregate and disaggregated data.

The credit channel builds on the notion – as illustrated by the extended IS–LM model due to Bernanke and Blinder (1988) – that monetary policy is conducted by the central bank according to a form of monetary base control. In this setup, there are two necessary conditions that must be satisfied for the credit channel to be effective: (1) banks cannot insulate their loan supply from monetary policy measures; and, (2) some borrowers are dependent on bank loans for finance. Monetary policy constrains the flow of bank credit by inducing a fall in reserves, which in turn constrains the spending of borrowers that cannot replace loan losses with other types of credit. Obviously, the perception that the monetary base is an exogenous policy instrument is misleading. Since policy implementation by central banks is based on the control of short–term money market rates, this suggests that the level of base money is endogenously determined. Hence, the underpinning of the credit channel suffers from an incorrect premise concerning the way monetary policy is conducted, which is a major impediment when analyzing the effects of monetary policy measures.

Empirical research on the credit channel has searched for evidence by employing aggregate and disaggregated data. While studies based on aggregate data have reported ambiguous results that derive from serious identification problems, studies based on disaggregated data have shown that heterogeneity across agents characterizes the distributional consequences of monetary policy actions that arise from financial market imperfections.

2.4.2 Outlook

Analyzing the credit channel in Germany requires understanding the way monetary policy is conducted. The Eurosystem implements monetary policy – similar to the prior example of the German Bundesbank – on the basis of an operational framework, which is designed to signal monetary policy intentions by steering short–term money market rates. Banks play a crucial role in the transmission of monetary policy, since the manner they adjust their credit conditions to policy–induced changes in short–term money market rates has important implications for the propagation of monetary policy measures.

Based on this notion, this work addresses the credit channel in Germany by means of a structural analysis of aggregate bank loan data. The empirical analysis is carried out within a vector error correction model (VECM) – suggested by Johansen (1988, 1995) – that allows to derive long–run loan supply and loan demand relationships by imposing restrictions on cointegration vectors. In contrast to a reduced–form approach based on aggregate data, this addresses the identification problem by imposing more structure on the relationships between the aggregate variables. The short–run dynamics of the VECM is investigated on the basis of innovation analysis, which sets out some stylized facts about the transmission mechanism of monetary policy by assessing the impact of a monetary policy shock. As we are not concerned about a disaggregated analysis of micro–bank data – that tackles the identification problem by exploiting heterogeneity across agents – our structural approach and the micro–based approach may be seen complementary.

We begin our analysis by discussing the operational framework of the ECB so as to gain a deeper insight into the way monetary policy is implemented. Since monetary policy operations by the Eurosystem are aimed at affecting the evolution of short–term money market rates, these are to be regarded as the first step in the transmission mechanism of monetary policy.

Appendix: The extended IS–LM Model

2.A Perfect Substitution

The standard IS–LM framework presumes that bonds and loans are perfect substitutes. The equilibrium conditions in the ordinary IS–LM model are:

$$\begin{array}{lrcl} \text{Money market:} & D^d(i,y) - m(i)R & = & 0 \\ \text{Goods market:} & y - y^d(i) & = & 0. \end{array}$$

Totally differentiating the system of two equations yields:

$$D_i^d di + D_y^d dy - m'Rdi - mdR = 0$$

$$dy - y_i^d di = 0.$$

In matrix form:

$$\begin{bmatrix} D_i^d - m'R & D_y^d \\ -y_i^d & 1 \end{bmatrix} \begin{bmatrix} di \\ dy \end{bmatrix} = \begin{bmatrix} mdR \\ 0 \end{bmatrix}$$

with: $|A| = (D_i^d - m'R) + D_y^d y_i < 0$.

In the conventional IS–LM model a shift in monetary policy gives the following solutions by applying *Cramer's rule*:

$$\left.\frac{dy}{dR}\right|_{ISLM} = \frac{\begin{vmatrix} D_i^d - m'R & m \\ -y_i^d & 0 \end{vmatrix}}{|A|} = \frac{my_i^d}{(D_i^d - m'R) + D_y^d y_i^d} > 0$$

and:

$$\left.\frac{di}{dR}\right|_{ISLM} = \frac{\begin{vmatrix} m & D_y^d \\ 0 & 1 \end{vmatrix}}{|A|} = \frac{m}{(D_i^d - m'R) + D_y^d y_i} < 0.$$

2.B Imperfect Substitution

In the extended IS–LM model the equilibrium conditions are:

$$\begin{array}{rrcl} \text{Loan market:} & L^d(\rho, i, y) & = & H(\rho, i)D(1-a) \\ \text{Money market:} & D^d(i, y) & = & m(i)R \\ \text{Goods market:} & y^d(i, \rho) & = & y. \end{array}$$

Using the equilibrium condition of the money market, to replace $D(1-a)$ on the right side of the equilibrium condition of the loan market by $(1-a)m(i)R$ and solving for the loan interest rate as a function of (i), (y) and (R) gives:

$$\rho = \Phi(i, y, R).$$

Totally differentiating the new loan market equilibrium condition gives:

$$\begin{array}{rcl} L_i^d di + L_\rho^d d\rho + L_y^d dy & = & H_\rho mR(1-a)d\rho + Hm(1-a)dR \\ & & +(H_i mR(1-a) + Hm'R(1-a))di, \end{array}$$

implying that: $d\rho/di = \Phi_i > 0$, $d\rho/dy = \Phi_y > 0$ and $d\rho/dR = \Phi_R < 0$, since:

$$\Phi_i = \frac{L_i^d - (H_i mR(1-a) + Hm'R(1-a))}{H_\rho mR(1-a) - L_\rho^d},$$

$$\Phi_y = \frac{L_y^d}{H_\rho mR(1-a) - L_\rho^d} \quad \text{and} \quad \Phi_R = \frac{-Hm(1-a)}{H_\rho mR(1-a) - L_\rho^d}.$$

Note that if either $H_\rho = +\infty$ or $L_\rho^d = -\infty$, then Φ_i, Φ_y and Φ_R will converge to zero. Notice further that $\Phi_i > 0$ only holds if the interest elasticity of money multiplier is not too large.

Substituting the function of the loan interest rate into the goods market equilibrium condition gives a system of two equations:

$$\begin{array}{rcl} D^d(i, y) - m(i)R & = & 0 \\ y - y^d(i, \Phi(i, y, R)) & = & 0. \end{array}$$

Totally differentiating the system yields:

$$D_i^d di + D_y^d dy - m'Rdi - mdR = 0$$

$$dy - y_i^d di - y_\rho^d \Phi_i di - y_\rho^d \Phi_y dy - y_\rho^d \Phi_R dR = 0.$$

In matrix form:

$$\begin{bmatrix} D_i^d - m'R & D_y^d \\ -(y_i^d + y_\rho^d \Phi_i) & 1 - y_\rho^d \Phi_y \end{bmatrix} \begin{bmatrix} di \\ dy \end{bmatrix} = \begin{bmatrix} mdR \\ y_\rho^d \Phi_R dR \end{bmatrix}$$

with $|B| = (D_i^d - m'R)\left(1 - y_\rho^d \Phi_y\right) + D_y^d \left(y_i^d + y_\rho^d \Phi_i\right) < 0$.
The solutions are by *Cramer's rule*:

$$\begin{aligned} \left.\frac{dy}{dR}\right|_{CCLM} &= \frac{\begin{vmatrix} D_i^d - m'R & m \\ -(y_i^d + y_\rho^d \Phi_i) & y_\rho^d \Phi_R \end{vmatrix}}{|B|} \\ &= \frac{(D_i^d - m'R) y_\rho^d \Phi_R + m(y_i^d + y_\rho^d \Phi_i)}{(D_i^d - m'R)\left(1 - y_\rho^d \Phi_y\right) + D_y^d \left(y_i^d + y_\rho^d \Phi_i\right)} > 0 \end{aligned}$$

and:

$$\begin{aligned} \left.\frac{di}{dR}\right|_{CCLM} &= \frac{\begin{vmatrix} m & D_y^d \\ y_\rho^d \Phi_R & 1 - y_\rho^d \Phi_y \end{vmatrix}}{|B|} \\ &= \frac{m(1 - y_\rho^d \Phi_y) - D_y^d y_\rho^d \Phi_R}{(D_i^d - m'R)\left(1 - y_\rho^d \Phi_y\right) + D_y^d \left(y_i^d + y_\rho^d \Phi_i\right)} \lesseqgtr 0. \end{aligned}$$

Notice that if either borrowers or lenders regard bonds and bank loans as perfect substitutes, Φ_i, Φ_y and Φ_R will become zero and the solutions in the modified IS–LM analysis reduce to the ordinary IS–LM results.

3 The Operational Framework of the European Central Bank

3.1 Introduction

The operational framework of the European Central Bank (ECB) is the means through which monetary policy is implemented. The main elements include open market operations, standing facilities – a marginal lending facility and a deposit facility – and minimum reserve requirements. Policy implementation by the ECB is based on the control of the overnight rate so as to influence money market rates at longer maturities.[29] According to the expectations hypothesis of the term structure, the relationship between money market rates at different maturities is determined by market expectations about future monetary policy actions.

This chapter discusses the operational framework of the Eurosystem, which comprises the set of instruments used for effectively steering short–term money market interest rates. While the overnight rate plays an important role in the conduct of monetary policy by constituting the basic maturity in the yield curve, money market rates at longer maturities are deemed relevant for the transmission of monetary policy.[30] The evolution of money market rates in the euro area should reflect – as emphasized by the expectations hypothesis of the term structure – expectations about future monetary policy decisions.

The remainder of this chapter is organized as follows. Section 3.2 outlines the operational framework of the Eurosystem and the associated steering of the overnight rate. Section 3.3 addresses the expectations hypothesis of the term structure by exploring the link between the overnight rate and euro area

[29] As pointed out by Manna, Pill and Quiros (2001) and Gaspar, Perez–Quiros and Sicilia (2001), although the ECB does not have an official operating target for the overnight rate, monetary policy operations – similar to the former practice of the German Bundesbank (see e.g. Deutsche Bundesbank, 1995) – are aimed at directly influencing the evolution of the overnight rate. See also Hartmann, Manna and Manzanares (2001) and Perez–Quiros and Mendizabal (2001) for a discussion.

[30] In the monetary framework of central banks, the overnight rate normally represents the key variable, which is influenced directly by means of interest rate policy measures (see e.g. Borio, 1997). The market for overnight liquidity plays a pivotal role in the interbank money market, because it mainly serves to regulate the individual reserve position of particular banks.

money market rates at longer maturities. The analysis is based on empirical testing using a cointegration framework and error correction models. Section 3.4 provides concluding remarks.

3.2 The Eurosystem's Operational Framework

The operational framework of the Eurosystem constitutes the means through which monetary policy is implemented. The main instruments include open market operations, standing facilities and a minimum reserve system. Table 3.1 provides an overview of the monetary policy operations that are used for effectively controlling short–term money market rates. See ECB (1998, 2001a), Borio (2000) and Issing, Gaspar, Angeloni and Tristani (2001) for a discussion about the different monetary policy instruments and monetary policy procedures.[31]

3.2.1 Open Market Operations

Main Refinancing Operations
The main refinancing operations of the Eurosystem are the most important open market operations, playing a pivotal role in pursuing the aims of managing liquidity and steering interest rates in the money market. They are reverse transactions – applicable either as repurchase agreements or as collateralized loans – and are conducted on the basis of standard tenders, with a weekly frequency and a maturity of two weeks. The main refinancing operations are the prime refinancing source of the banking system and their dealing rate is the key official rate that signals the stance of monetary policy. Nearly all monetary policy operations of the Eurosystem are carried out by the use of these operations, or are at least prepared and accompanied by them.[32]

The Eurosystem executes the main refinancing operations in the form of either fixed rate or variable rate tenders. In a fixed rate tender, the ECB Governing Council specifies the tender rate in advance and the banks bid the amount of liquidity they wish to receive at the fixed tender rate. In

[31] See also Bofinger (2001) and Blenck, Hasko, Hilton and Masaki (2001) – among others – for a comparison of the monetary policy operating procedures across the EMU, the United States and Japan. Borio (1997) provides a general survey concerning the monetary policy framework of central banks in industrialized countries.

[32] Notice that between 1999 and 2002, the main refinancing operations averaged out around 72% of the total refinancing volume provided through open market operations.

Table 3.1: Eurosystem Monetary Policy Operations

Monetary policy operations	Types of transactions: Liquidity providing	Types of transactions: Liquidity absorbing	Maturity	Frequency
Open market operations				
Main refinancing operations	Reserve transactions	–	Two weeks	Weekly
Longer–term refinancing operations	Reserve transactions	–	Three months	Monthly
Fine–tuning operations	Reserve transactions Foreign exchange swaps	Foreign exchange swaps Collection of fixed–term deposits Reserve transactions	Non–stand.	Non–reg.
	Outright purchases	Outright sales		
Structural operations	Reserve transactions	Issuance of debt certificates	Stand./ non–stand.	Reg./ non–reg.
	Outright purchases	Outright sales	–	Non–reg.
Standing facilities				
Marginal lending facility	Reserve transaction	–	Overnight	Access at discr. of counterp.
Deposit facility	–	Deposits	Overnight	Access at discr. of counterp.

Source: ECB (2001a, p. 62, Table 4.1).

a variable rate tender, the ECB Governing Council announces a minimum bid rate in advance and the banks bid the amount of liquidity they wish to receive at different interest rates, taking into account the fixed minimum bid rate. Normally, the allotment of liquidity is allocated pro rata if the bids exceed the amount of liquidity to be allotted.

The Eurosystem effectively retains the option of using either fixed rate or variable rate tender auctions.[33] Since variable rate tenders with a minimum bid rate become similar to fixed rate tenders, both tender auctions are suited for steering short–term money market rates and signaling the stance of monetary policy (ECB, 2001b, p. 56).[34]

Longer–Term Refinancing Operations
The longer–term refinancing operations of the Eurosystem are aimed at providing the banking sector with base refinancing. They take the form of reverse transactions and are conducted as standard tenders, with a three month maturity and a monthly frequency. The longer–term refinancing operations represent solely a limited part of the global refinancing volume and are not conducted with the intention of steering the liquidity situation, of sending signals to the market or of guiding money market rates. In these operations, the Eurosystem acts as a pure rate taker and executes them in the form of genuine variable rate tenders with pre–announced allotment volumes.

Other Open Market Operations
Other open market operations include fine–tuning operations and structural operations, which are executed only in exceptional circumstances. The fine–tuning operations are aimed at managing liquidity and steering interest rates in the money market, in particular to smooth the effects on interest rates of unexpected liquidity fluctuations. They are not standardized with regard to their frequency and maturity. The structural operations are aimed at adjusting the structural liquidity position of the Eurosystem vis–*á*–vis the banking system, i.e. the amount of liquidity in the market over the longer term. Their frequency can be regular or non–regular and their maturity is

[33]Until 21 June 2000, the Eurosystem conducted the main refinancing operations as fixed rate tenders, while from 27 June 2000, the main refinancing operations were executed as variable rate tenders with a minimum bid rate using a multiple rate procedure. The reason for the change was severe overbidding in the fixed rate tender main refinancing operations, which resulted from market expectations about increasing future policy rates. The switch to variable rate tenders stopped the severe overbidding. See ECB (2000, 2001b), Breitung and Nautz (2001) and Nautz and Oechssler (2003) – among others – for a discussion.

[34]Notice that this form of the variable rate tender is frequently denoted as a fixed rate tender in disguise (Bofinger, 2001, p. 355).

not standardized.

3.2.2 Standing Facilities

The open market operations of the Eurosystem are escorted by two standing facilities – the marginal lending facility and the deposit facility – which pursue the functions of providing and absorbing overnight liquidity, signaling the general stance of monetary policy and setting an interest corridor for the overnight rate. The standing facilities are available to the banks on their own initiative and their access is in principle without constraint.[35]

The marginal lending facility can be used to obtain overnight liquidity against eligible assets, while the deposit facility can be used to deposit overnight surplus funds. The interest rates on the standing facilities provide a ceiling and a floor for the overnight rate and may be used to signal the medium–term orientation of monetary policy. The corridor spanned by the official rates bounds the volatility of the overnight rate as a result of money market arbitrage (Issing et al., 2001, p. 119).

3.2.3 Minimum Reserve System

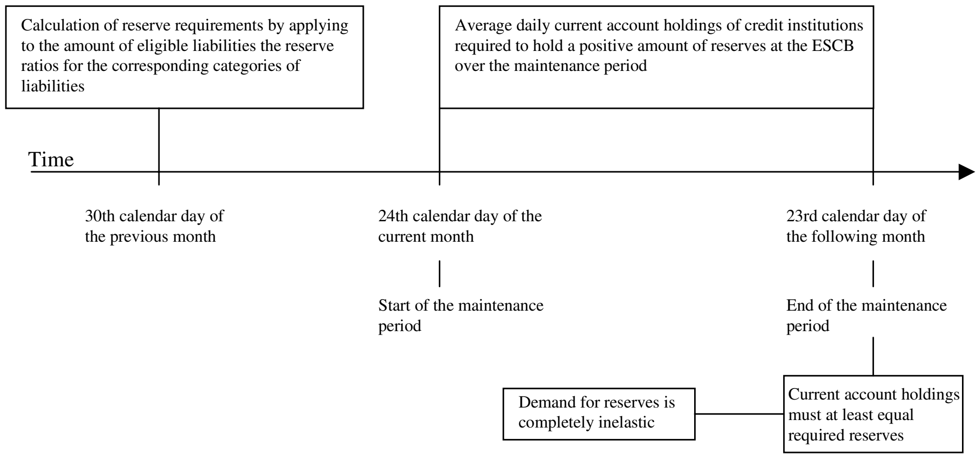
The minimum reserve system of the ECB is aimed at contributing to the stabilization of short–term money market rates.[36] Reserve requirements are imposed on banks in the proportion of the reserve base and the reserve ratios. The reserve base comprises the liabilities of banks with a maturity of up to two years to which a reserve ratio of 2% is applied; whereas a reserve ratio of 0% is applied to the liabilities with a maturity of more than two years. Liabilities vis–*á*–vis the central bank and other banks are excluded (ECB, 2001a, pp. 69–71).[37]

[35]Normally, the recourse to the standing facilities is unlimited, although the ECB can impose restrictions or adapt the conditions connected to their use in particular circumstances. See ECB (1998) for details.

[36]A second function assigned to the minimum reserve system is the creation of a structural liquidity shortage within the banking sector, which facilitates the conduct of monetary policy. The need for credit institutions to hold reserves on central bank accounts contributes to increasing the demand for central bank refinancing, which in turn eases the steering of money market rates through regular liquidity–providing operations (ECB, 2001a, p. 72).

[37]The final reserve requirement is derived by deducting a lump–sum allowance of Euro 100.000 from the amount calculated by the reserve base and the reserve ratios.

Figure 3.1: Minimum Reserves Maintenance Period



Minimum reserve requirements operate through an averaging provision. This gives banks an incentive to spread liquidity shocks over time, which smoothes short–term money market rates. The obligations under the minimum reserve system are complied by banks if their average daily reserve holdings, as computed over a reserve maintenance period running from the 24^{th} calendar day of each month to the 23^{rd} calendar day of the following month, is at least equal to their reserve requirement, which is determined by the liabilities taken from their balance sheets on the last calendar day of the previous month. Figure 3.1 summarizes the sequence of the maintenance period.

In the course of the reserve maintenance period, banks can tolerate daily changes in their central bank balances in the expectation that such fluctuations will balance out on average over the period. Minimum reserve holdings are remunerated at an averaging interest rate that is determined by the main refinancing operations executed over the reserve maintenance period (Issing et al., 2001, p. 119).[38]

[38] Normally, the remuneration rate of required reserves is close to the overnight interest rate, which should mitigate the burden which a minimum reserve system imposes on the private sector, as well as the effects it might have on the competitiveness of banks located in the euro area (ECB, 1999, p. 32).

3.2.4 Overnight Interest Rate Control

In the monetary setup of the ECB, the main refinancing operations play a crucial role in controlling the overnight interest rate. The liquidity allotment is aimed at allowing banks to fulfill their reserve requirements smoothly as an average over the reserve maintenance period, which ensures the overnight rate close to the key policy rate. If liquidity shocks emerge, banks can use the standing facilities, which bounds the volatility of the overnight rate inside the official interest corridor set by the standing facility rates.[39] Steering the overnight rate establishes the link to money market rates at longer maturities, which are relevant for the transmission of monetary policy (see e.g. Bofinger, 2001; Manna et al., 2001).

Figure 3.2 depicts the ECB key official rates and the EONIA, i.e. the Euro Over Night Index Average.[40] Between January 1999 and May 2003, the EONIA rate has kept relatively close to the key policy rate – i.e. the rate of the fixed rate tenders and the minimum bid rate of the variable rate tenders – that has been mainly set in the middle of the official interest corridor spanned by the standing facilities rates. At any time the volatility of the EONIA rate was effectively bounded by the standing facilities.

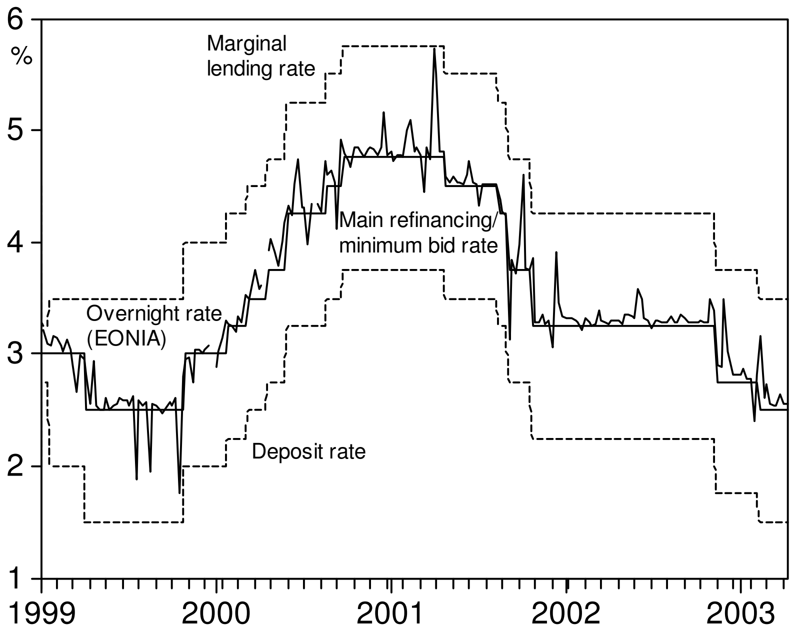
The minimum reserve system contributes to the stabilization of the overnight rate, as the averaging provision admits banks to spread liquidity surpluses and deficits over the reserve maintenance period. If banks regard reserves balances held on different days of the same maintenance period as equivalent for meeting reserve requirements, they will arbitrage away any expected difference between the current and the future overnight interest rate.[41] This implies that in the course of the reserve maintenance period expectations concerning changes in the key policy rate have an impact on the current overnight rate. Solely on the last day of the maintenance period the ability to smooth out liquidity surpluses and deficits over time is disrupted as reserve requirements become binding. If liquidity imbalances persist, banks

[39] As Bindseil (2000a, 2000b) and Bindseil and Seitz (2001) point out, liquidity shocks mainly arise from autonomous factors, i.e. the autonomous sources of reserves that are outside the control of the central bank such as banknotes in circulation and government deposits. See also Borio (2000), Cabrero, Camba-Mendez, Hirsch and Nieto (2002), Nyborg, Bindseil and Strebulaev (2002) and Ejerskov, Moss and Stracca (2003) – among others – for a discussion.

[40] The EONIA rate refers to the weighted average of the rates on all overnight (unsecured) lending transactions reported by banks with the highest volume of business in the euro area money market.

[41] See Bindseil and Seitz (2001), Perez–Quiros and Mendizabal (2001), Gaspar et al. (2001), and Würtz (2003) for a discussion and empirical evidence.

Figure 3.2: ECB Official Rates and the EONIA
(January 1999 – Mai 2003)



Source: ECB, monthly bulletins diverese issues. Percentages per annum, weekly data.

will have to take recourse to the standing facilities at the end of the reserve maintenance period, which will push the overnight rate towards the relevant standing facility rate. This explains the spikes in the EONIA rate – see Figure 3.2 – that occasionally emerge at the end of the maintenance period (ECB, 2001a, p. 71).

3.3 The Term Structure of Euro Area Money Market Rates

Policy implementation by the ECB is based on the control of the overnight rate so as to influence money market rates at longer maturities. The expectations hypothesis of the term structure accounts for the link between interest rates at different maturities by postulating that long–term rates are mainly determined through expectations about future short–term rates. According to the expectations hypothesis, long–term rates ought contain information about future monetary policy measures by forecasting the development of future short–term rates.

In accordance with Campbell and Shiller (1987), the following analysis addresses the expectation hypothesis of the term structure by means of cointegration tests using euro area money market rates. Empirical evidence – see e.g. Wolters (1995), Cuthbertson, Hayes and Nitzsche (1998), Nautz (2000) and Hassler and Wolters (2001) for Germany, Balduzzi, Bertola and Foresi (1997) for the U.S., or Cuthbertson (1996) for the U.K. – shows that the expectation hypothesis can at least partly explain the evolution of money market rates. This suggests that the expectations hypothesis of the term structure appears capable for describing the initial part of the transmission mechanism of monetary policy.

3.3.1 The Rational Expectations Hypothesis of the Term Structure

The rational expectations hypothesis of the term structure (REHTS) describes the relationship between interest rates with different times to maturity.[42] In linearized form the REHTS can be written as (see e.g. Shiller (1979, 1990); Campbell and Shiller (1991)):

$$R_t^{(n)} = \frac{1}{n}\sum_{i=0}^{n-1} E_t[r_{t+i}] + \phi^{(n)}, \tag{3.1}$$

where $R_t^{(n)}$ are interest rates with a maturity of n periods ($n = 2, 3, ..., T$), r_t is the short–term interest rate, $\phi^{(n)}$ is a time–invariant but maturity dependent liquidity premium, and E_t is the expectations operator conditional on information available at time t, which implies that expectations are formed rationally. The REHTS postulates that a long–term interest rate equals an average of expected future short–term interest rates plus a liquidity premium term. The liquidity premium $\phi^{(n)}$ is usually described as reflecting public attitudes toward risk and is assumed to be constant (Shiller, 1979, p. 1191).

Let the yield spread be defined as $S_t^{(n)} = R_t^{(n)} - r_t$, this allows to restate equation (3.1) according to (Campbell and Shiller, 1991, pp. 446–447):

$$S_t^{(n)} = \sum_{i=1}^{n-1}(1 - i/n)E_t[\Delta r_{t+i}] + \phi^{(n)}, \tag{3.2}$$

[42] The rational expectations hypothesis of the term structure can be stated in several different ways. In the following, the expectations hypothesis is described in its simplest form, where – for example – coupon effects are neglected. See Shiller (1990) or Carstensen (2000) for a detailed discussion on the expectations theory of the term structure.

by using $r_{t+i} = r_t + \Delta r_{t+1} + ... + \Delta r_{t+i}$, for $i = 1, 2, ..., n-1$, where Δ denotes the difference operator. Equation (3.2) describes the relation between the term spread and a weighted average of the expected future changes in short–term rates. The intuition behind (3.2) can be seen by rearranging terms:

$$\sum_{i=1}^{n-1}(1 - i/n)E_t[\Delta r_{t+i}] = S_t^{(n)} - \phi^{(n)}, \tag{3.3}$$

which shows that a positive interest spread is accompanied by an expected increase in short rates. Given that equation (3.3) is true, this implies that the interest spread has predictive power for the short–term interest rate.

The REHTS assumes linear relations in levels between interest rates with different times to maturity. If interest rates are difference stationary, which means Δr_{t+i} and $E_t[\Delta r_{t+i}]$ are stationary, then $S_t^{(n)}$ should be stationary.[43] Since the term spread constitutes a linear combination of interest rates, a stationary spread implies bivariate cointegration with cointegrating vector $[1, -1]'$, which establishes a necessary condition for the expectations hypothesis to hold (see e.g. Campbell and Shiller, 1987). In the following, we investigate the cointegration relationships between the overnight interest rate and interest rates at longer maturities in the euro area money market.[44]

3.3.2 Data Base

We use interest rate data on a weekly basis, collected from the statistics of the ECB, including the EONIA rate and EURIBOR rates with a one–month, three–month, six–month and twelve–month maturity. The sample period begins in January 1999 and runs until May 2003. Figure 3.3 displays the money market rates in levels and first differences.[45]

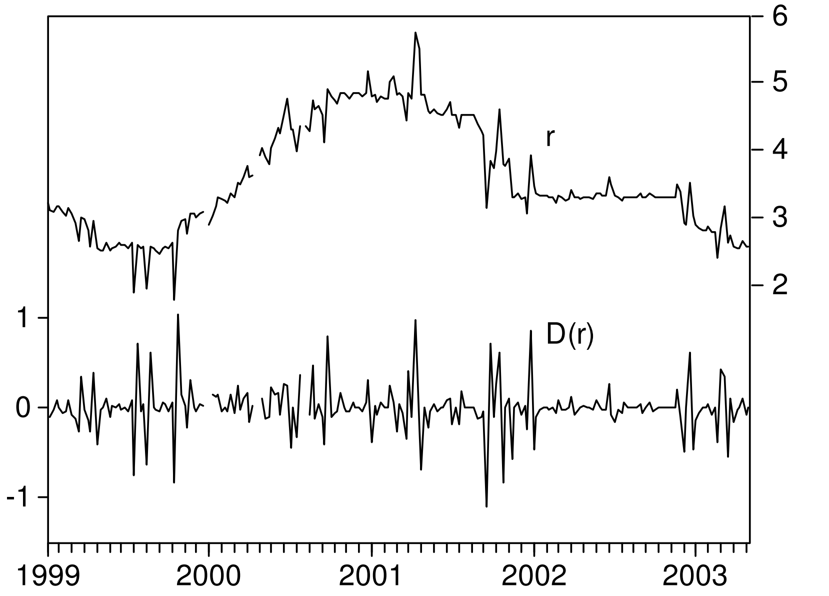
The EONIA rate is denoted by r, and the EURIBOR rates are denoted by $r1$, $r3$, $r6$ and $r12$ with regard to the respective maturities. We begin our analysis by exploring the interest rate data time series properties.

[43] Notice that the assumption of rational expectations implies: $E_t[\Delta r_{t+i}] - \Delta r_{t+i} = \varepsilon_{t+i}$, where ε_{t+i} has zero mean and is uncorrelated with time t information.

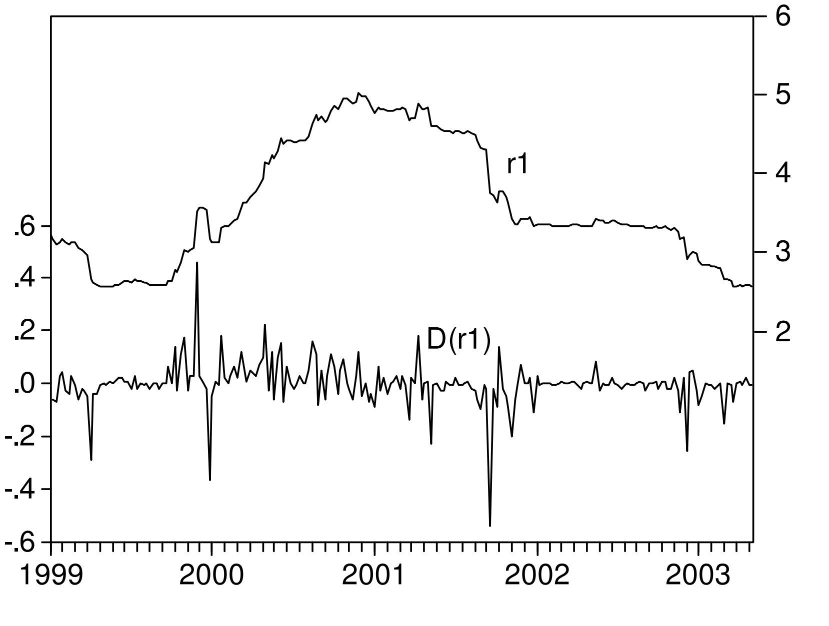
[44] Preliminary, it should be mentioned that our empirical analysis comes with a short sample period because of limited data availability. Therefore, given the similar monetary policy operations of the ECB and the German Bundesbank, our findings may be interpreted along with the results obtained for German money market interest rates.

[45] Note that the gaps in EONIA come from missing observation points.

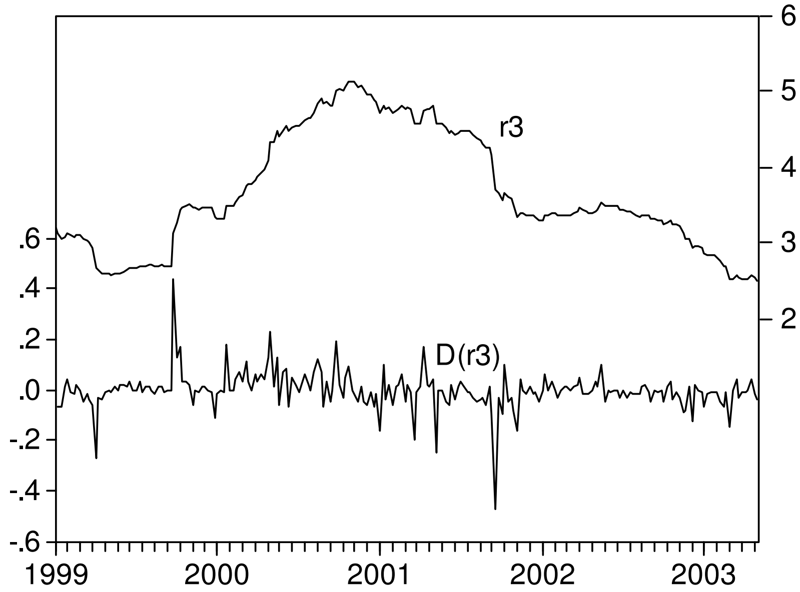
Figure 3.3: Euro Area Money Market Rates
(Levels and First Differences)



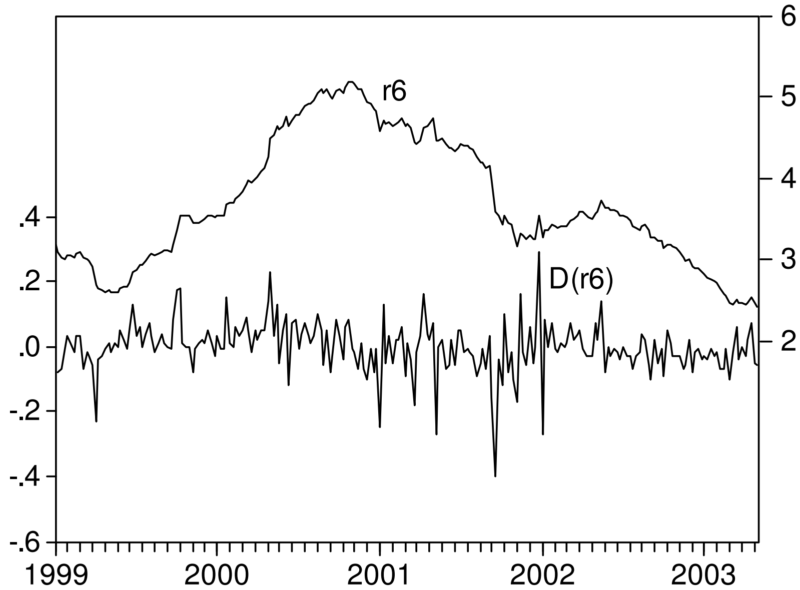
(Overnight interest rate)



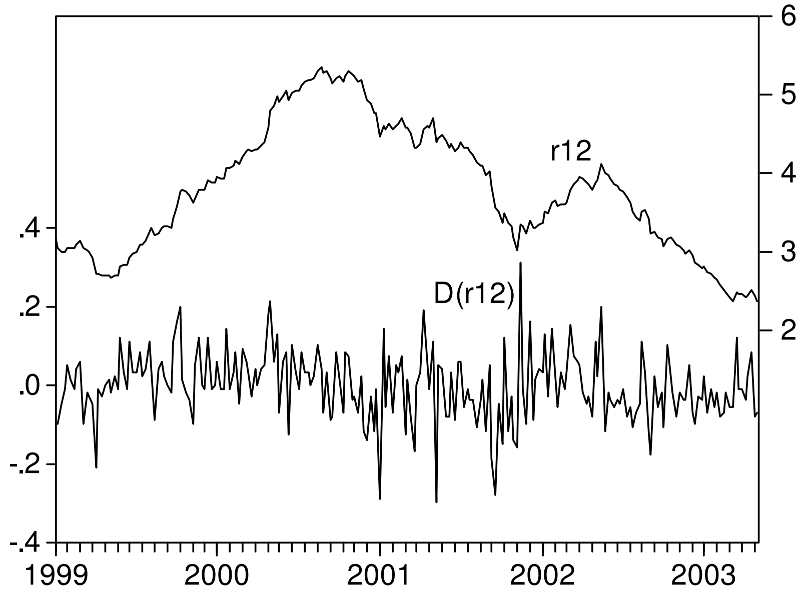
(One–month EURIBOR rate)



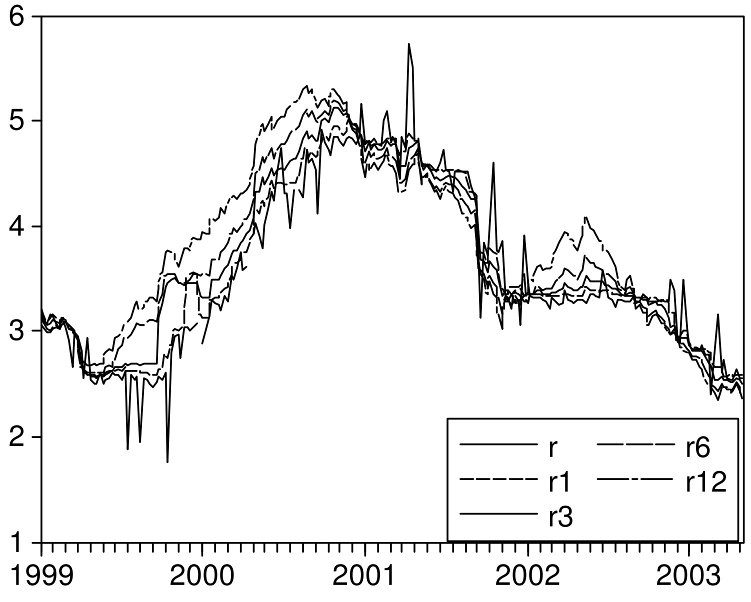
(Three–month EURIBOR rate)



(Six–month EURIBOR rate)



(Twelve–month EURIBOR rate)



(All rates in levels)

3.3.3 Unit Root Tests

A series y_t is said to be integrated of order d – denoted I(d) – if it takes d differencing operations to make the series stationary.[46] If y_t is nonstationary and I(1) its first difference is stationary and I(0). Testing for the order of integration of a series is referred to as testing for unit roots.

Dickey and Fuller (1979, 1981) propose a method of testing for the presence of a unit root.[47] The Augmented Dickey–Fuller (ADF) test is based on the regression equation:[48]

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta y_{t-i} + u_t, \tag{3.4}$$

where $\Delta y_t = y_t - y_{t-1}$ and k is the number of lags, which should be chosen sufficiently large enough to render the error term empirically white noise. The ADF test consists of testing the null hypothesis $H_0 : \rho = 0$ against the alternative hypothesis $H_1 : \rho < 0$. If $\rho = 0$, the process generating y_t is integrated and nonstationary, and if $\rho < 0$, the y_t sequence is I(0) and stationary. The test statistic is the standard t-statistic $t(\hat{\rho})$, which under the null hypothesis follows a nonstandard distribution.[49] Appropriate critical values for the ADF statistic are provided by Dickey and Fuller (1979, 1981) and MacKinnon (1991) and have been derived in simulation experiments.

We examine the time series properties of the interest rates by using ADF tests for the levels and first differences.[50] Table 3.2 reports the results of these unit root tests. Besides the test statistic of the ADF tests, $t(\hat{\rho})$, the table shows the number of lags included in the ADF regression in the columns heading with k. The lag order has been determined by choosing the smallest lag length such that the residuals of the ADF regression yield empirically white

[46]While a stationary variable tends to return to its mean value and has a finite variance that is time invariant, a nonstationary variable has different means at different points in time and its variance increases with the sample size (Harris, 1995, p. 15).

[47]See Hassler (1994), Enders (1995), Harris (1995), Charemza and Deadmen (1997) and Darnell (1997) – among others – for a survey and discussion of unit root tests.

[48]Dickey and Fuller (1979) consider different regression equations that can be used to test for unit roots. The differences concern the presence of deterministic elements.

[49]If the process generating y_t is $I(1)$, equation (3.4) represents a regression of a $I(0)$ variable on a $I(1)$ variable. In this case the resulting t-statistic does not have a limiting normal distribution. Its distribution is negatively skewed and appropriate critical values are not amenable to analytic constructions (Darnell, 1997, pp. 411–412; Charemza and Deadman, 1997, p. 99).

[50]All computations reported in this section were done by EVIEWS 4.0.

Table 3.2: Unit Root Tests

	Levels		First differences	
Variable	$t(\hat{\rho})$	k	$t(\hat{\rho})$	k
r	-1.22	2	-15.05	1
$r1$	-0.65	2	-8.86	1
$r3$	-0.64	2	-7.94	1
$r6$	-0.58	3	-6.65	2
$r12$	-0.62	3	-6.61	2

Notes: ADF tests have been run by including a constant for the levels and no constant for the first differences. The MacKinnon (1991) critical values for the ADF statistic at the 10% level are -2.58 (with constant) and -1.62 (no constant).

noise as measured by means of the Ljung–Box test statistic. The results indicate that the levels of the interest rates are nonstationary, while the first differences are stationary, which suggests that all money market rates can be treated as integrated of order one, i.e. I(1). Exploring level relations between interest rates therefore requires cointegration analysis.

3.3.4 Cointegration and Error Correction Models

According to Engle and Granger (1987), the series y_t and x_t are said to be cointegrated of order (d, b), denoted by $y_t, x_t \sim \mathrm{CI}(d, b)$, if (i) the series are integrated of order d, and (ii) there exists a linear combination of y_t and x_t – say $\alpha_1 y_t + \alpha_2 x_t$ – that is integrated of order $(d - b)$, where $b > 0$. The vector $[\alpha_1, \alpha_2]'$ is called the cointegrating vector.

Suppose the series y_t and x_t are CI(1, 1), the regression equation:

$$y_t = \beta x_t + u_t, \tag{3.5}$$

with stationary residuals u_t, then implies that the linear combination of y_t and x_t given by $y_t - \beta x_t$ with cointegrating vector $[1, -\beta]'$ is stationary.[51] Given y_t and x_t are drifting together in time, $y_t = \beta x_t$ can be interpreted as the long–run equilibrium and u_t can be referred to as the equilibrium error, which has zero mean and constant variance. Testing for cointegration amounts to testing for a unit root in the residuals. If y_t and x_t are integrated and not cointegrated, then the residual series u_t will be integrated; if y_t and

[51] Here $\alpha_1 = 1$ and $\alpha_2 = -\beta$.

x_t are integrated and cointegrated, then u_t will be stationary (Engle and Granger, 1987, p. 275; Stock, 1999, pp. 144–145).

Following the Granger representation theorem[52], if y_t and x_t are cointegrated of order (1,1) there exists an error correction representation of the form:

$$\Delta y_t = \alpha_1 + \gamma_1(y_{t-1} - \beta x_{t-1}) + \text{lagged}(\Delta y_t, \Delta x_t) + \varepsilon_{1t}, \quad (3.6)$$

$$\Delta x_t = \alpha_2 + \gamma_2(y_{t-1} - \beta x_{t-1}) + \text{lagged}(\Delta y_t, \Delta x_t) + \varepsilon_{2t}, \quad (3.7)$$

where γ_1 or γ_2 are different from zero and where the error terms $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]'$ are $iid(0, \Sigma)$. The error correction models (3.6) and (3.7) relate the current variations in y_t and x_t to the error correction term $y_{t-1} - \beta x_{t-1}$, which describes the previous deviation from the long–run equilibrium, and to the lagged variations in y_t and x_t. The parameters γ_1 and γ_2 denote the speed of adjustment parameters. If $y_{t-1} > \beta x_{t-1}$, then $\gamma_1 < 0$ and $\gamma_2 > 0$ imply that Δy_t falls and Δx_t rises, which means y_t and x_t adjust towards equilibrium. Notice, when $\gamma_1 < 0$ and $\gamma_2 = 0$, the adjustment falls on y_t, and when $\gamma_1 = 0$ and $\gamma_2 > 0$, the adjustment falls on x_t. While the size of the adjustment parameters indicates the convergence rate towards long–run equilibrium, the lagged variations in y_t and x_t are referred to as reflecting the short–run impact (see e.g. Enders, 1995, pp. 365–373).

3.3.5 Empirical Results

Cointegration Analysis

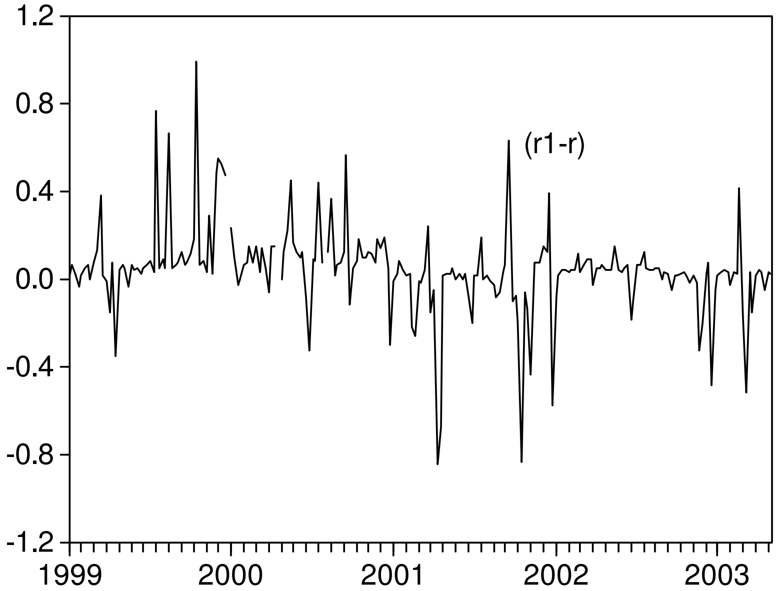
A precondition for the REHTS to hold is the existence of linear relations in levels between interest rates with different times to maturity. Following Campbell and Shiller (1987), Wolters (1995) and Nautz (2000), the interest rate spreads:

$$S_t^{(n)} = rn_t - r_t, \quad (3.8)$$

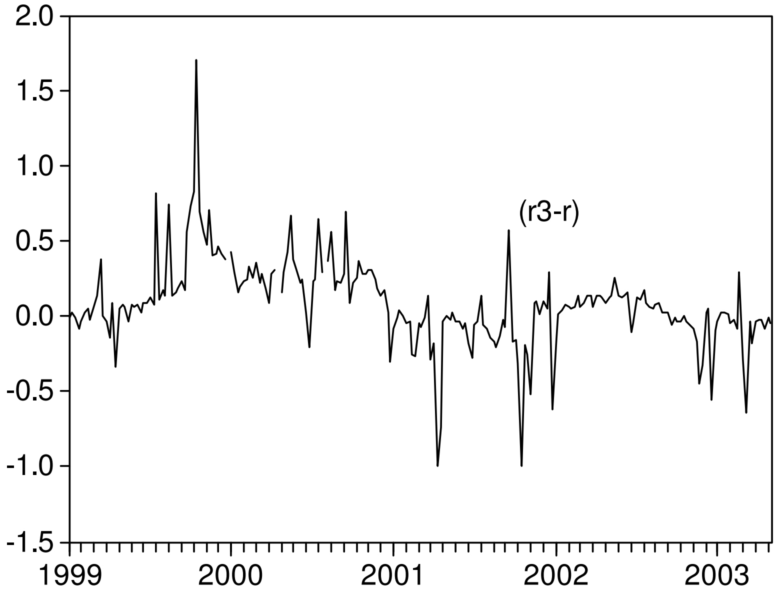
between the money market rates along the maturity spectrum ($n = 1, 3$, 6 and 12) and the overnight rate should then be stationary, which implies bivariate cointegration with cointegrating vector $[1, -1]'$. Figure 3.4 displays the interest rate differentials for the different maturities.

[52]See Engle and Granger (1987, pp. 255–258).

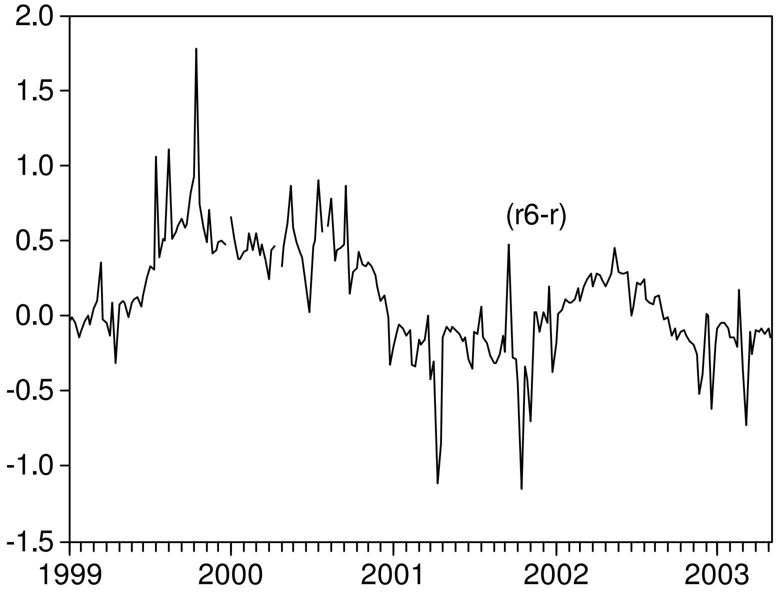
Figure 3.4: Interest Rate Differentials



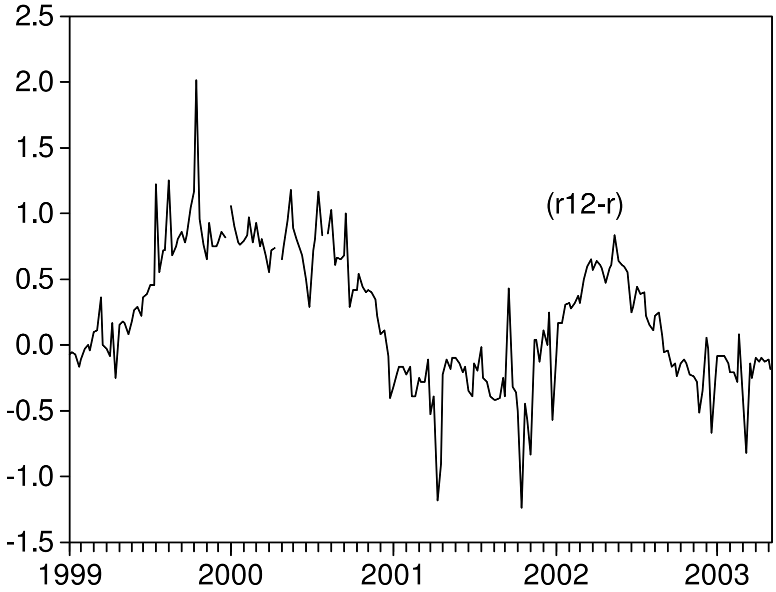
(Spread to the one–month rate)



(Spread to the three–month rate)



(Spread to the six–month rate)



(Spread to the twelve–month rate)

Applying cointegration analysis, the results of the ADF tests for the interest spreads are presented in Table 3.3, which reports the ADF statistics, the number of lags k and the Ljung–Box test statistic against serial correlation up to the $24th$ order, denoted by $Q(24)$. Each ADF regression includes a constant term. The lag length has been chosen to obtain white noise residuals. The MacKinnon (1991) critical values for the ADF statistics are -3.47 at the 1% and -2.88 at the 5% significance level.

Table 3.3: Cointegration Tests

Spreads	ADF	k	Q(24)
$S_t^{(1)}$	-7.78	1	24.24 [0.45]
$S_t^{(3)}$	-5.13	1	23.36 [0.44]
$S_t^{(6)}$	-3.73	1	24.15 [0.45]
$S_t^{(12)}$	-2.89	1	27.17 [0.30]

Notes: ADF tests have been run by including a constant term in each regression. The MacKinnon (1991) critical values for the ADF statistic at the 1% and 5% level are -3.47 and -2.88. Q(24) denotes the Ljung–Box Q–statistic against serial autocorrelation of the 24th order; p–values are reported in brackets.

In accordance with the REHTS, the cointegration tests support the existence of stationary linear combinations between euro area money market rates at different maturities. While for the one–month spread, the three–month spread and the six–month spread the results indicate stationarity at the 1% level, for the twelve–month spread stationarity holds at the 5% level. Apparently, market expectations about the short–term development of the overnight rate in the euro area money market appear to be reflected in the slope of the short end of the term structure. This finding is in line with the results obtained by Wolters (1995), Wolters and Hassler (1998), Nautz and Wolters (1999), Nautz (2000), Cuthbertson et al. (1998), Hassler and Wolters (2001) and Boero and Torricelli (2002) for German money market rates with adjacent maturities. Similar evidence has been reported by Balduzzi et al. (1997) for the US, Cuthbertson (1996) for the UK, Cuthbertson and Bredin (2000) for Ireland or by Gerlach and Smets (1997) in a multi–country comparison.

Error Correction Equations for the Overnight Interest Rate
Following Campbell and Shiller (1987, 1988), any forecast equation for the overnight rate can be specified as an error correction model with the lagged

interest spreads as the error correction term:

$$\Delta r_t = \alpha_0 + \gamma(rn - r)_{t-1} + \sum_{j=1}^{p} \alpha_j \Delta r_{t-j} + \sum_{j=1}^{q} a_j \Delta rn_{t-j} + \varepsilon_t, \tag{3.9}$$

where $n = 1, 3, 6$ and 12. Each error correction equation has initially been tested with a lag length of $p = q = 12$. Using a *general to specific* approach, the insignificant lags have then gradually been excluded in order to achieve a parsimonious specification. Weak significant variables have been left in the regression equations only if these have improved the autocorrelation structure of the residuals.

The forecast equations for the overnight rate including the various interest spreads were estimated as:[53]

Lagged spread to the one–month rate:

$$\begin{aligned} \Delta r_t \;=\; & -\underset{(-2.56)}{0.04} + \underset{(11.02)}{0.79}(r1 - r)_{t-1} - \underset{(-2.02)}{0.12}\Delta r_{t-6} - \underset{(-1.99)}{0.12}\Delta r_{t-7} \\ & - \underset{(-2.40)}{0.48}\Delta r1_{t-4} + \widehat{\varepsilon}_t \end{aligned} \tag{3.10}$$

$R^2 = 0.38$ $\quad DW = 2.14$ $\quad Q(24) = 26.38$ [0.33] $\quad ARCH(12) = 0.31$ [0.98]

Lagged spread to the three–month rate:

$$\begin{aligned} \Delta r_t \;=\; & -\underset{(-3.64)}{0.06} + \underset{(8.31)}{0.57}(r3 - r)_{t-1} - \underset{(-2.88)}{0.18}\Delta r_{t-1} - \underset{(-2.03)}{0.12}\Delta r_{t-6} \\ & - \underset{(-2.03)}{0.12}\Delta r_{t-7} - \underset{(-2.93)}{0.62}\Delta r3_{t-2} - \underset{(-3.78)}{0.84}\Delta r3_{t-3} \\ & - \underset{(-1.96)}{0.46}\Delta r3_{t-4} + \widehat{\varepsilon}_t \end{aligned} \tag{3.11}$$

$R^2 = 0.38$ $\quad DW = 2.09$ $\quad Q(24) = 22.49$ [0.55] $\quad ARCH(12) = 0.44$ [0.95]

[53] t–ratios in parentheses underneath the estimated coefficients.

Lagged spread to the six–month rate:

$$\begin{aligned}\Delta r_t \;=\;& -\underset{(-2.97)}{0.05} + \underset{(6.03)}{0.32}(r6-r)_{t-1} - \underset{(-5.08)}{0.35}\Delta r_{t-1} - \underset{(-2.55)}{0.19}\Delta r_{t-2}\\ & - \underset{(-1.78)}{0.12}\Delta r_{t-3} - \underset{(-2.78)}{0.63}\Delta r6_{t-2} - \underset{(-1.41)}{0.32}\Delta r6_{t-3}\\ & - \underset{(-2.45)}{0.54}\Delta r6_{t-4} + \widehat{\varepsilon}_t \qquad (3.12)\end{aligned}$$

$R^2 = 0.34 \quad DW = 2.04 \quad Q(24) = 27.39\ [0.29] \quad ARCH(12) = 0.41\ [0.96]$

Lagged spread to the twelve–month rate:

$$\begin{aligned}\Delta r_t \;=\;& -\underset{(-2.91)}{0.05} + \underset{(5.31)}{0.19}(r12-r)_{t-1} - \underset{(-6.56)}{0.45}\Delta r_{t-1} - \underset{(-3.89)}{0.30}\Delta r_{t-2}\\ & - \underset{(-3.18)}{0.25}\Delta r_{t-3} - \underset{(-2.34)}{0.19}\Delta r_{t-4} - \underset{(-2.15)}{0.17}\Delta r_{t-5} - \underset{(-1.98)}{0.14}\Delta r_{t-6}\\ & - \underset{(-2.77)}{0.55}\Delta r12_{t-2} + \widehat{\varepsilon}_t \qquad (3.13)\end{aligned}$$

$R^2 = 0.34 \quad DW = 2.03 \quad Q(24) = 19.74\ [0.71] \quad ARCH(12) = 0.52\ [0.89]$

The numbers in brackets behind the values of the test statistics are the corresponding p–values. DW denotes the Durbin–Watson statistic, $Q(24)$ is the Ljung–Box Q–statistic against serial autocorrelation of the 24th order, and $ARCH(12)$ is an LM test for autoregressive conditional heteroscedasticity of the 12th order.[54] For each equation the test statistics indicate that the residuals dismiss signs of autocorrelation or conditional heteroscedasticity.

In line with the REHTS, the results show that observed deviations from the long–run equilibrium, i.e. lagged interest rate spreads, explain future changes of the overnight rate. In each error correction equation, the adjustment parameter $\widehat{\gamma}$ is significant and has a plausible sign, implying that – for example – if the interest spread is negative, the overnight rate is expected to fall.[55] Apparently, variations in the stance of monetary policy seem to be partly anticipated by the market.

[54] As regards the residuals in each error correction equation, there are no signs of autocorrelation up to the 24th order and tests for ARCH effects of lower orders indicate that none of the test statistics are significant at conventional levels.

[55] Notice that in each forecast equation for the overnight rate the term $-\alpha_0/\gamma > 0$ can be interpreted as the average liquidity premia of the different money market rates against the overnight rate (Nautz, 2000, p. 120).

Single Equation Specification (β unrestricted)
According to Banerjee, Dolado and Mestre (1998), an alternative way of testing for cointegration is to estimate the following dynamic equation with non–linear least squares:

$$\Delta r_t = \beta_0 + \delta(rn_{t-1} - \beta r_{t-1}) + \sum_{j=1}^{p} \beta_j \Delta r_{t-j} + \sum_{j=1}^{q} b_j \Delta rn_{t-j} + \varepsilon_t, \quad (3.14)$$

where the cointegration parameter β is unrestricted. Using the critical values from Banerjee et al. (1998, p. 276, Table 1), the null hypothesis of non–cointegration can be rejected if δ is significantly different from zero. The critical values are -3.92 at the 1% level and -3.27 at the 5% level. Table 3.4 documents the results of the single–equation approach.

Table 3.4: Forecast Equations for the Overnight Rate: Single–equation estimation

Lagged spread to	$\hat{\delta}$	$\hat{\beta}$	Wald–test $H_0 : \beta = 1$	Confidence interval for β
$r1$	0.83 (10.73)	0.972 [0.022]	0.21	[0.93 ; 1.02]
$r3$	0.65 (8.66)	0.954 [0.028]	0.11	[0.90 ; 1.01]
$r6$	0.34 (5.97)	0.948 [0.058]	0.38	[0.83 ; 1.06]
$r12$	0.22 (5.45)	0.848 [0.094]	0.11	[0.66 ; 1.03]

Notes: t–values are reported in parentheses; standard errors in brackets. The Wald–test reports the corresponding p–value. Confidence intervals were calculated according to: $\hat{\beta} \pm 1.96se(\hat{\beta})$.

The cointegrating implications of the REHTS are supported – in line with our previous findings – by the significant adjustment of the overnight rate to the error correction terms. The estimates $\hat{\beta}$ of the cointegrating parameters indicate values smaller than one, nevertheless formal statistical tests show that the null hypothesis $\beta = 1$ cannot be rejected. The confidence intervals of the estimated βs seem to confirm this finding.

3.4 Concluding Remarks

This chapter has discussed the operational framework of the ECB, which constitutes the means through which monetary policy is implemented. Policy implementation by the Eurosystem aims at signaling monetary policy intentions by steering the overnight rate, which exerts an influence on money market rates at longer maturities. According to the expectations hypothesis of the term structure, the relationship between money market rates at different maturities – which is an essential component for an interest rate targeting procedure – is established by market expectations about future monetary policy measures. In the euro area, the expectations hypothesis appears capable of explaining the evolution of interest rates in the money market. Empirical evidence suggests that money market rates at longer maturities contain some information about future monetary policy decisions by predicting the future overnight rate.

Our discussion of the monetary framework of the ECB has aimed at highlighting the way monetary policy operations work through an interest rate targeting. The next chapter focuses on the behavior of banks in the transmission of monetary policy, when monetary policy is implemented by steering short–term money market rates.

4 Monetary Policy and Bank Loan Supply: A VECM Analysis for Germany

4.1 Introduction

The credit channel emphasizes the importance of banks in the transmission of monetary policy, which stems from the notion that financial markets are characterized by information asymmetries between borrowers and lenders.[56] Banks are special in extending credit to borrowers that cannot access other types of credit, because of their expertise in overcoming information–related financial frictions.[57] If banks decrease their loan supply following a monetary contraction – either by raising lending rates or by tightening conditions – this has a negative impact on real activity, since at least some borrowers have to revise their expenditure decisions.

As Hubbard (1995) and Bernanke and Gertler (1995) point out, the credit channel is considered as working in addition to the interest rate channel, according to which monetary policy affects the level of investment and consumer spending by inducing changes in the cost of capital and yield on savings. Although, these transmission channels diverge in assessing the relevance of financial considerations, they are not mutually exclusive but complementary, with the implication that monetary policy can be effective through the credit channel and the interest rate channel simultaneously.

This chapter aims at shedding light on the credit channel in Germany by means of a structural analysis of aggregate bank loan data. We begin our analysis by presenting a stylized model of the banking firm, which characterizes the loan supply decisions of banks when monetary policy is implemented

[56]Information asymmetries in financial markets – as illustrated by Leland and Pyle (1977), Diamond (1984) and Boyd and Prescott (1986) – may lead to adverse selection and moral hazard problems that can create severe distortions. Adverse selection and moral hazard require lenders to screen and monitor borrowers, which gives rise to agency costs that tend to be high, when information problems are keen (see e.g. Gorton and Winton, 2002). Akerlof (1970) elaborates the basic idea that asymmetric information may cause market failure.

[57]This idea centers on the notion that some borrowers – in particular small and medium–sized firms – cannot issue corporate bonds at reconcilable terms, because of information problems or high costs associated with launching debt securities (see e.g. Deutsche Bundesbank, 2000 and 2001). Banks as financial intermediaries specialize in gathering and distilling information, which enables them to make loans to these borrowers at more favorable terms (Bernanke, 1993, p. 56).

through an interest rate targeting. Using the model as a guide, we apply a vector error correction framework (VECM) – suggested by Johansen (1988, 1995) – that allows to derive long–run supply and demand relationships in the market for bank loans by imposing restrictions on cointegrating vectors.[58] The main implication of our results is that the credit channel in Germany seems to be effective, as we find that loan supply effects in addition to loan demand effects contribute to the propagation of monetary policy actions.

The remainder of this chapter is organized as follows. Section 4.2 offers a simple model of bank behavior that establishes the basis for our empirical testing. Applying the Johansen procedure, Section 4.3 sets out a VECM analysis of the German loan market, which accounts for endogeneity and nonstationarity of time series. After a brief discussion of the methodology we introduce the data base and present our results. Section 4.4 provides concluding remarks.

4.2 A Stylized Model of the Banking Firm

We base our analysis of the credit channel on a stylized model of the banking firm, which specifies the loan supply decision of banks in the light of expectations about the future course of monetary policy that is conducted through an interest rate targeting. With banks caring about the expected future trend of monetary policy, the way they pass on monetary disturbances has an impact on the propagation of monetary policy measures.[59] The model refers to Cosimano (1988) and Bofinger (2001).[60] Similar approaches have been developed by Elyasiani, Kopecky and van Hoose (1995), Bofinger and Schächter (1995), Bofinger et al. (1999) and Mitusch and Nautz (2001).[61]

[58]The analysis is based on Hülsewig, Winker and Worms (2004). See Kakes (2000) for a VECM study on the characteristics of the credit market in the Netherlands.

[59]It should be noted that the model presented here is only partial equilibrium in nature. Stein (1995) provides a more rigorous analytical framework, which includes several extensions in order to specify the entire monetary transmission mechanism. However, a drawback of his approach is the assumption that monetary policy initiates through a monetary base targeting.

[60]The model extends the approaches of Cosimano (1988) and Bofinger (2001) in two ways: In contrast to Bofinger (2001), the framework is dynamic; in contrast to Cosimano (1988), the loan volume is treated as a nonstationary variable in order to account for the time series properties of bank loan aggregates.

[61]See Santomero (1984), Cuthbertson (1985), Bhattacharya and Thakor (1993), Swank (1996) and Freixas and Rochet (1997) for a survey on the theory of the banking firm. Recent work by Van den Heuvel (2000) and Chami and Cosimano (2001) extends the analysis of bank behavior by incorporating the presence of capital adequacy regulations,

4.2.1 Structure of the Model

Suppose there is a banking sector with many identical banks that act as price takers. Banks grant loans to nonbanks (L_t^n), which they finance with deposits (D_t^n) and central bank credits (B_t^n) after subtracting required reserves (R_t^n).[62] Each bank takes the loan rate (r_t^L) and the deposit rate (r_t^D) as given. The central bank is assumed to administer the policy rate (r_t^M) that determines the interest rate on the interbank money market.

For a single bank, profit at time $t + j$ is given by:

$$\pi_{t+j} = r_{t+j}^L L_{t+j} - r_{t+j}^D D_{t+j} - r_{t+j}^M (B_{t+j} - R_{t+j}) - C_{t+j}, \tag{4.1}$$

where:

$$\begin{aligned}
\pi_{t+j} &= \text{profit at time } t+j, \\
L_{t+j} &= \text{loans at time } t+j \text{ at rate } r_{t+j}^L, \\
D_{t+j} &= \text{deposits at time } t+j \text{ at rate } r_{t+j}^D, \\
B_{t+j} &= \text{net position on the interbank money market} \\
&\quad\ \text{at time } t+j \text{ at rate } r_{t+j}^M, \\
R_{t+j} &= \text{minimum reserves at time } t+j \text{ at rate } r_{t+j}^M, \\
C_{t+j} &= \text{costs of evaluating and adjusting the stock} \\
&\quad\ \text{of loans at time } t+j.
\end{aligned}$$

Note that equation (4.1) is defined for $j = 0, 1, 2, ...$

Bank profit matches the difference between the revenues and costs in the credit business. Besides interest costs, the bank faces costs associated with administering the loan portfolio, C_{t+j}, which may be represented by the following quadratic cost function (see e.g. Cosimano, 1988):

$$C_{t+j} = (a/2)(L_{t+j} - L_{t+j-1})^2, \tag{4.2}$$

where (a) is a positive constant. The costs of administering the stock of loans can be thought of reflecting the allocation of resources necessary to evaluate the creditworthiness of customers and to monitor loans during the duration. If the bank realizes a change in the size of its loan portfolio, this requires to

which gives rise to a 'bank capital channel' by which monetary policy affects bank lending through its impact on bank equity capital.

[62] Let variables that carry the index (n) refer to the banking system, whereas variables without the index, except for interest rates, refer to a single bank. Subscript (t) denotes time.

reshuffle the amount of resources devoted to these activities.[63] Assume the banking sector comprises (n) banks with identical cost functions.

A single bank seeks to maximize the expected present value of its profit flow:

$$V_t = E_t \sum_{j=0}^{\infty} \beta^j \pi_{t+j}, \tag{4.3}$$

where (E_t) is the expectation operator conditioned on the set of information (I_t) disposable at time t, and (β) is a discount factor $(0 < \beta < 1)$. Let the information set (I_t) include the past values of all variables and the present values of all interest rates, i.e. $E_s(x_t) \equiv E(x_t|I_s)$.

The maximization is subject to the balance sheet constraint:

$$L_{t+j} + R_{t+j} = D_{t+j} + B_{t+j}, \tag{4.4}$$

where minimum reserves are given by: $R_{t+j} = dD_{t+j}$, with (d) describing the minimum reserve ratio $(0 < d < 1)$.[64] Minimum reserves are remunerated at the policy–controlled money market rate (r^M_{t+j}). Following traditional reserve management models, we assume that a single bank takes its level of deposits (D_{t+j}) as given (see e.g. Orr and Mellon, 1961; Klein, 1971; Baltensperger, 1980). Depending on stochastic flows, the bank adjusts its net position on the interbank money market (B_{t+j}) according to the balance sheet constraint.[65] Therefore, we expect the deposit rate (r^D_{t+j}) to adjust to the interbank money market rate (r^M_{t+j}) due to arbitrage conditions (Freixas and Rochet, 1997, p. 57). At the aggregate level, we assume that the volume of deposits (D^n_{t+j}) of the banking sector is determined by the aggregate stock of loans (L^n_{t+j}) and attached to the amount of central bank refinancing (B^n_{t+j}) via the usual money multiplier (Bofinger, 2001, pp. 55–63; Mitusch and Nautz, 2001, p. 2093).[66]

[63]We assume that the costs of adjusting the loan portfolio are symmetric and thus do not depend on whether the change in the loan volume is positive or negative.

[64]Suppose each bank has an unlimited access to the interbank money market and to central bank refinancing, which makes a liquidity management in terms of excess reserves superfluous.

[65]Notice that for a single bank the net position on the interbank market (B_{t+j}) may either be positive or negative depending on whether the bank borrows or lends on net at the prevailing interbank market interest rate. At the aggregate level, the volume of central bank refinancing (B^n_{t+j}) is positive (as regards the liability side of the aggregate bank balance sheet), since the interbank positions of all banks sum up to zero.

[66]See also Bofinger and Schächter (1995) and Bofinger et al. (1999) for a rationalization of this assumption.

4.2.2 Deriving Optimal Loan Supply

A single bank maximizes the expected present value of its profit flow by choosing the optimal path of loans subject to the balance sheet constraint and conditional on the set of available information.

Bank i's optimal loan supply is given by:[67]

$$L_{t+j} = L_{t+j-1} + a^{-1} \sum_{i=0}^{\infty} \beta^i E_{t+j}(r^L_{t+j+i} - r^M_{t+j+i}).^{68} \tag{4.5}$$

which is raising with an expected increase in the loan rate and falling with an expected increase in the policy rate.[69] If the cost of adjustment parameter for loans, (a), increases, this requires a higher expected credit margin in order to maintain a specific level of lending.

Notice that optimal loan supply is derived from the first order–condition:

$$r^L_{t+j} - a(L_{t+j} - L_{t+j-1}) + a\beta E_{t+j}(L_{t+j+1} - L_{t+j}) - r^M_{t+j} = 0, \tag{4.6}$$

which shows that the optimal loan level is characterized by the equation of the spread between the loan rate and the policy rate and the marginal costs of evaluating and adjusting the loan portfolio. The first–order condition is valid for $j = 0, 1, 2, ...$; when $j = 0$ the variables refer to the presently observed and expected values.

4.2.3 Loan Market Repercussions

Our stylized model implies the assumption of a single and homogeneous loan market. Aggregate loan supply of the banking sector satisfies (here, evaluated for $j = 0$):

$$L^n_t = L^n_{t-1} + na^{-1} \sum_{i=0}^{\infty} \beta^i E_t(r^L_{t+i} - r^M_{t+i}), \tag{4.7}$$

which is the sum of the supplies of the (n) identical banks that refer to the currently observed and expected values.

[67] The procedure for the derivation of optimal loan supply is taken from Sargent (1979). See the Appendix for details.

[68] For $j = 0, 1, 2, ...$

[69] Similar expressions have been derived by Cosimano (1988), Elyasiani et al. (1995) and Mitusch and Nautz (2001).

Aggregate loan demand is assumed to be given by:

$$L_t^n = L_{t-1}^n + b_1 y_t - b_2 r_t^L + u_t, \tag{4.8}$$

where (y_t) is the output level, (b_1) is a positive parameter and (u_t) is a serially uncorrelated random variable, which is white noise with zero mean and variance (σ_u^2). The parameter (b_2), with $0 < b_2 < \infty$, denotes the interest elasticity of aggregate loan demand. A higher (b_2) means that the demand for loans is less sensitive to changes in the loan rate, i.e. in the borderline case: $b_2 \to 0$, aggregate loan demand is completely inelastic with respect to the interest rate on loans.

The loan market equilibrium is characterized by the equilibrium loan level and the equilibrium loan rate. The equilibrium loan volume that maximizes the banks' present value is (for $j = 0$):[70]

$$L_t^n = L_{t-1}^n + n(a\beta)^{-1}\lambda^{-1} \sum_{i=0}^{\infty} \left(\frac{1}{\lambda}\right)^i E_t \left(B_1 y_{t+i} - r_{t+i}^M\right), \tag{4.9}$$

where $B_1 = b_1/b_2$ and $\lambda = (na^{-1}B_2+1)\beta^{-1}$, with $B_2 = 1/b_2$. The equilibrium loan volume increases with an expected future increase in the output level and decreases with an expected future increase in the policy–administered rate. Substituting the equilibrium loan level (4.9) into the loan demand equation (4.8) determines the equilibrium loan rate.

Since banks need time to adjust their loan portfolio, their forecast of the future trend of the output level and the policy–administered rate are crucial factors. Suppose the banks base their forecasts on:

$$\begin{aligned} r_{t+1}^M &= \delta r_t^M + \eta_{t+1}, \quad |\delta| < 1/\beta \\ y_{t+1} &= \gamma y_t + \varepsilon_{t+1} \quad\quad |\gamma| < 1/\beta, \end{aligned}$$

where the error terms (η_{t+1}) and (ε_{t+1}) are a serially uncorrelated with zero mean and variance (σ_η^2) and (σ_ε^2).

The equilibrium loan level in consideration of the forecast expressions is given by:

$$L_t^n = L_{t-1}^n + C_1 y_t - C_2 r_t^M, \tag{4.10}$$

[70]Note that the loan market equilibrium is generally characterized by a sequence of the loan volume $\{L_{t+j}\}_{j=0}^{\infty}$ and the loan rate $\{r_{t+j}\}_{j=0}^{\infty}$. This rational expectation equilibrium simultaneously maximizes the banks' present value and clears the loan market (Sargent, 1979, p. 431). Without a loss of generality, we simplify the analysis to the case $j = 0$.

where $C_1 = B_1 n(a\beta)^{-1}(\lambda - \gamma)^{-1}$ and $C_2 = n(a\beta)^{-1}(\lambda - \delta)^{-1}$. Substituting the reduced form for the loan level (4.10) into the demand for loans equation (4.8) and rearranging terms, yields the equilibrium loan rate:

$$r_t^L = c_1 y_t + c_2 r_t^M, \tag{4.11}$$

where $c_1 = B_1(1 - \beta\gamma)\beta^{-1}(\lambda - \gamma)^{-1}$ and $c_2 = B_2 n(a\beta)^{-1}(\lambda - \delta)^{-1}$. The loan rate is tied to the output level and the policy–administered rate. While the loan rate is raising with an expected increase in the rate of growth of the interbank money market rate ($ln(\delta)$),[71] the impact of an expected increase in the rate of growth of the output level ($ln(\gamma)$) is ambiguous.

4.2.4 Implications for Monetary Policy Transmission

Our stylized model implies that banks decide on their loan supply in the light of expectations about the future course of monetary policy. When the banks expect a monetary tightening, they decrease their loan supply with a falling credit margin, but since the adjustment in the loan level is sluggish, the effects of monetary disturbances are passed on solely gradually. Since this suggests that banks are not neutral conveyors of monetary policy – as emphasized by the credit channel – this is equivalent with the notion that bank behaviour can play a meaningful role in the propagation of monetary policy measures. This prediction is tested in the following section by means of a structural analysis of time series properties of aggregate bank loan data.

4.3 Characteristics of the German Loan Market: A VECM Analysis

A number of studies on Germany have sought to establish whether the credit channel is operating. While Worms (1998), De Bondt (1999a), Küppers (2000) and Kakes and Sturm (2002) find evidence in support of the credit

[71] Apparently, this suggests that the loan rate may follow a change in the policy rate, but – owing to adjustment costs – the adjustment is sticky if changes in the policy rate are perceived to be solely temporary. The sluggish adjustment implies that the loan rate may exhibit less frequent, but larger changes over continuously changing policy rates. The stickiness of loan rates is well–documented in the literature. Evidence for a sluggish loan rate adjustment has been provided e.g. by Berger and Udell (1992), Dale and Haldane (1993c), Cottarelli and Kourelis (1994), Borio and Fritz (1995), Winker (1996), Mojon (2000), Toolsema, Sturm and de Haan (2001), Deutsche Bundesbank (2002) and Weth (2002) for several industrialized countries.

channel by employing aggregate and disaggregated data, Tsatsaronis (1995), Guender and Moersch (1997), Barran, Coudert and Mojon (1997) and Kakes, Sturm and Maier (2001) conclude that the credit channel is ineffective.[72] The different results reflect the problem to distinguish between the loan supply effects and the loan demand effects that may arise following a monetary contraction.

Addressing heterogeneity across agents, De Bondt (1999b), Worms (2001a, 2001b), Ehrmann, Gambacorta, Martinez-Pages, Sevestre and Worms (2001), Ehrmann (2000), von Kalckreuth (2001), Chatelain, Generale, Hernando, von Kalckreuth and Vermeulen (2001), Grössl, Stahlecker and Wohlers (2001) and Kirchesch, Sommer and Stahlecker (2001) examine cross–sectional bank and firm level data. These studies show that banks of different size depart in their lending activities after a monetary contraction, while firms of different size are differently affected by restrictive monetary policy measures. By disclosing the distributional effects of monetary policy, these findings can be reconciled with the presence of financial frictions.

In this section, we address the credit channel in Germany on the basis of a structural analysis of aggregate bank loan data. The empirical analysis is carried out within a VECM framework – as suggested by Johansen (1988, 1995) – that takes into account nonstationary time series. We identify supply and demand relationships in the German loan market by imposing restrictions on cointegration vectors, which reveal the systematic impact of monetary policy actions.[73] The analysis begins in 1975, after the effects of the breakdown of the Bretton Woods regime have settled down and ends in 1998 with the launch of the European monetary union. Before we present our results, we will give a brief discussion of the Johansen procedure and describe the data base and time series properties.

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[72] In addition, Kashyap and Stein (1997b) and Cecchetti (2001) conclude from a number of qualitative indicators that the credit channel in Germany is likely relevant. These qualitative indicators include data on the size and concentration of the banking system, along with measures of banking system health, importance of bank financing and firm size.

[73] As pointed out by McCallum (1999), the analysis of the systematic component of monetary policy actions should be regarded more substantial than the analysis of monetary policy shocks, which sets out the unsystematic component of monetary policy measures: *"[...] in studying the monetary policy transmission mechanism, more emphasis should be given to the systematic portion of policy behavior and correspondingly less to random shocks – basically because shocks account for a very small fraction of policy–instrument variability. Analysis of the effects of the systematic part of policy requires structural modeling, rather than VAR procedures, because the later do not give rise to behavioral relationships that can plausibly be regarded as policy–invariant."* (McCallum, 1999, p. 33). See also Friedman (1995) for a discussion.

4.3.1 The Johansen Procedure

The Johansen (1988) approach provides a statistical framework, which allows to analyze long–term relationships between nonstationary time series in a dynamic specification. The following illustration of the Johansen procedure refers to Johansen (1991, 1995) and Johansen and Juselius (1990). See also Johansen (1992), Johansen and Juselius (1994), Banerjee, Dolado, Galbraith and Hendry (1993), Harris (1995), Lütkepohl (1999), McAleer and Oxley (1999), Pesaran and Smith (1999) and Doornik, Hendry and Nielsen (1999) for a survey and discussion.

Consider a standard vectorautoregression (VAR) model in levels:

$$X_t = \Pi_1 X_{t-1} + ... + \Pi_k X_{t-k} + \Phi D_t + \varepsilon_t, \tag{4.12}$$

$$\text{with } t = 1, ..., T,$$

where X_t is a p–dimensional vector of endogenous variables, which are assumed to be $I(1)$, and ε_t is a p–dimensional vector of independent identically distributed error terms with the covariance matrix Λ, i.e. $\varepsilon_t \sim N(0, \Lambda)$. The Π_i describe the corresponding $p \times p$ coefficient matrices and k specifies the number of lags. The D_t are deterministic terms, such as a constant, a linear trend, centered seasonal dummies, or other regressors that are considered fixed and non–stochastic. The seasonal dummies are centered, i.e. they sum to zero over a full year.

The VAR model (4.12) can be reformulated into a vector error correction model (VECM) of the form:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t, \tag{4.13}$$

with:

$$\Gamma_i = -(I - \Pi_1 - ... - \Pi_i),$$

$$\text{for } i = 1, ..., k-1$$

and

$$\Pi = -(I - \Pi_1 - ... - \Pi_k),$$

and $\Delta = 1 - L$, where L is the lag operator. The Π and Γ_i are parameter matrices.[74] The statistical hypothesis of cointegration is formulated as a

[74] The Γ_i $(i = 1, ..., k-1)$ are often referred to as the short–term parameters and ΠX_{t-1} is sometimes called the long–term part (Lütkepohl, 1999, p. 4).

reduced rank of the matrix Π:

$$H(r) : rank(\Pi) \leq r.$$

Under this hypothesis, Π can be written as: $\Pi = \alpha\beta'$, where α and β are $p \times r$ matrices of full rank. Here, the elements of X_t are $I(1)$ and cointegrated with $rank(\Pi) = r$, which means there are $r < p$ linear combinations of X_t that are $I(0)$. The hypothesis $H(r)$ therefore implies that the process ΔX_t is stationary, X_t is nonstationary, but $\beta' X_t$ is stationary (Johansen, 1991, pp. 1552–1553). The β vectors are the cointegration vectors and the term $\beta' X_t$ describes r stationary linear combinations of the variables in X_t that can be given a long–run equilibrium interpretation. The elements in α represent the factor loadings that measure the average speed of adjustment of each variable in the direction of the long–run equilibrium.[75]

Following Johansen (1991, 1995) and Johansen and Juselius (1990), the maximum likelihood approach can be illustrated by rewriting the vector error correction model (4.13) in reduced form according to:

$$Z_{0t} = \alpha\beta' Z_{1t} + \Gamma Z_{2t} + \varepsilon_t, \tag{4.14}$$

$$\text{with } t = 1, ..., T,$$

using the notation $Z_{0t} = \Delta X_t$, $Z_{1t} = X_{t-1}$ and Z_{2t} for the stacked variables $\Delta X_{t-1}, ..., \Delta X_{t-k+1}$ and D_t. Γ is the matrix of parameters corresponding to Z_{2t}, i.e. the matrix consisting of $\Gamma_1, ..., \Gamma_{k-1}$ and Φ. The procedure begins by regressing ΔX_t and X_{t-1} on the lagged differences $\Delta X_{t-1}, ..., \Delta X_{t-k+1}$ and D_t, which gives the residuals R_{0t} and R_{1t}. The likelihood function concentrated with respect to the parameters $\Gamma_1, ..., \Gamma_{k-1}$ and Φ is

$$L(\alpha, \beta, \Lambda) = \\ |\Lambda|^{-T/2} \exp\left\{ -\frac{1}{2} \sum_{t=1}^{T} (R_{0t} - \alpha\beta' R_{1t})' \Lambda^{-1} (R_{0t} - \alpha\beta' R_{1t}) \right\}. \tag{4.15}$$

[75] There are two situations where the VECM representation becomes superfluous. First, if matrix Π has full rank, i.e. $rank(\Pi) = p$, which implies that all variables in X_t are $I(0)$. Here, the appropriate strategy is to estimate the VAR in levels (4.12), because there is no problem of spurious regression otherwise associated with the analysis of nonstationary variables. Second, if matrix Π is the null matrix, i.e. $rank(\Pi) = 0$, which means that there are no linear combinations between the variables in X_t that are $I(0)$. Since the elements of X_t are $I(1)$, but there is no cointegration, model (4.13) corresponds to a VAR in first differences involving no long–run relationships (Johansen and Juselius, 1990, p. 170; Harris, 1995, pp. 78–79).

For fixed β it is possible to estimate α and Λ by regressing R_{0t} on $\beta' R_{1t}$, which gives

$$\hat{\alpha}(\beta) = S_{01}\beta(\beta' S_{11}\beta)^{-1}, \tag{4.16}$$

and

$$\hat{\Lambda}(\beta) = S_{00} - S_{01}\beta(\beta' S_{11}\beta)^{-1}\beta' S_{10}, \tag{4.17}$$

where

$$S_{ij} = \Gamma^{-1}\sum_{t=1}^{T} R_{it}R'_{jt} \quad i,j = 0,1. \tag{4.18}$$

The likelihood function is then reduced to (Johansen, 1995, pp. 91–92)

$$\begin{aligned} L_{max}^{-2/T}(\beta) &= |\hat{\Lambda}(\beta)| \\ &= |S_{00} - S_{01}\beta(\beta' S_{11}\beta)^{-1}\beta' S_{10}| \\ &= |S_{00}||\beta' S_{11}\beta - \beta' S_{10}S_{00}^{-1}S_{01}\beta|/|\beta' S_{11}\beta|. \end{aligned} \tag{4.19}$$

This likelihood function is maximized by the choice of $\hat{\beta} = (\hat{v}_1, ..., \hat{v}_r)$, where $\hat{V} = (\hat{v}_1, ..., \hat{v}_p)$ are the eigenvectors of the equation

$$|\lambda S_{11} - S_{10}S_{00}^{-1}S_{01}| = 0, \tag{4.20}$$

which are normalized by $\hat{V}' S_{11}\hat{V} = I$, and ordered by decreasing size of the corresponding eigenvalues $1 > \hat{\lambda}_1 > ... > \hat{\lambda}_p > 0$.[76] The maximized likelihood function is given by

$$L_{max}^{-2/T}(r) = |S_{00}|\prod_{i=1}^{r}(1-\hat{\lambda}_i). \tag{4.21}$$

The estimates of the other parameters are found by inserting $\hat{\beta}$ into the above equations, which gives $\hat{\alpha} = S_{01}\hat{\beta}$ and $\hat{\Lambda} = S_{00} - \hat{\alpha}\hat{\alpha}'$.

The likelihood ratio test statistic for the hypotheses $H(r)$ in $H(p)$ is

$$-\ln Q(H(r)|H(p)) = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i), \tag{4.22}$$

which is called the trace statistic. The likelihood ratio test statistic for testing $H(r)$ in $H(r+1)$ is given by

$$-\ln Q(H(r)|H(r+1)) = -T\ln(1-\hat{\lambda}_{r+1}), \tag{4.23}$$

[76]Note that the maximization of the likelihood function is equivalent to the minimization of the factor $|\beta' S_{11}\beta - \beta' S_{10}S_{00}^{-1}S_{01}\beta|/|\beta' S_{11}\beta|$ with respect to the matrix β (Johansen, 1995, p. 92).

which is denoted as the maximum eigenvalue statistic. The asymptotic distribution of the test statistics is derived in Johansen and Juselius (1990) and Johansen (1991) and differs depending on the deterministic components included in the model.[77] These distributions follow a non–standard distribution and have to be tabulated by simulation. Tables are provided in Johansen and Juselius (1990), Osterwald-Lenum (1992) and Johansen (1995). A discussion of the calculation of the maximum likelihood estimators and likelihood ratio tests in the model for cointegration under linear restrictions on the cointegration vectors β and weights α is given in Johansen and Juselius (1990).

In a VECM under cointegration (i.e.: $0 < r < p$), an identification problem arises, since the parameters in α and β are not uniquely determined. For any nonsingular matrix P it is possible to define $\Pi = \alpha P P^{-1} \beta'$ and $\alpha^* = \alpha P$ and $\beta^{*\prime} = P^{-1}\beta'$ would be equivalent matrices of adjustment coefficients and cointegrating vectors. This identification problem can be solved by imposing identifying restrictions on the cointegrating vectors (Pesaran and Smith, 1999, p. 65). These restrictions can be provided by using economic theory, which allows the cointegrating vectors to be interpreted as long–run economic relations. Johansen and Juselius (1994) provide a discussion of the conditions for identification.

An advantage of the VECM framework is that interesting long–run relationships between a limited set of variables can be analyzed. Provided that the model is statistically well specified, the identified long–run structure that is found also applies in a more extended model. Hence, in the subsequent analysis we can restrict ourselves to a fairly small number of variables, which we assume to adequately describe the market for bank loans.[78]

4.3.2 Data Base and Time Series Properties

Our VECM analysis of the German loan market is based on quarterly data taken from the statistics of the German Bundesbank and the German Institute for Economic Research (DIW). The time period under consideration starts with the first quarter of 1975, i.e. after the effects of the breakdown of

[77] It should be noted that not only the trends change the asymptotic distributions, but almost any type of dummy variable – except for centered seasonal dummies – may have this effect (Hansen and Juselius, 1995, p. 8). This means that the critical values provided might only be indicative if dummy variables are included in the model. See Johansen and Nielsen (1993), Doornik et al. (1999) and Johansen, Mosconi and Nielsen (2000) for a discussion.

[78] This point has been made clear by Kakes (2000, p. 81).

the Bretton Woods regime have settled down, and ends with the last quarter of 1998 due to the expected structural break associated with the European monetary union. Within this sample period, the German monetary and social union, which is reflected in the data in the second quarter of 1990, causes a shift in both monetary and real aggregates, which has to be taken into account in the empirical modeling. Similarly, there is a potential structural break in the first quarter of 1995, when the German Bundesbank has based the aggregate loan data on the classification of the industrial sectors of the German Federal Statistical Office.[79]

Our VECM analysis includes loans granted by banks to domestic private firms and households, which represent 77% on average of the total loan level extended within the sample period. The loan volume is expressed in real terms (`LOANS`), deflated by the GDP deflator. Supply side factors of the loan market are covered by the banks' equity position, also expressed in real terms, i.e. deflated by the GDP deflator (`EQUITY`).[80] Following Hancock, Laing and Wilcox (1995) and Van den Heuvel (2000), the inclusion of equity is based on the assumption that the capital position of banks might reflect substantial economic effects, such as signaling for solvency and regulatory constraints, which have been effective in Germany prior to the Basle Accord (1988) since 1962 (Winker, 1996, pp. 159–160).[81] The volume of liable equity is approximated by the banks' capital position as it appears in the balance sheet, which includes the subscribed capital, reserves, capital represented by participation rights and the fund for general banking risks.[82]

The loan interest rate is approximated by a medium–term capital market rent, i.e. the yield on bonds outstanding issued by domestic residents (r^L). This stems from the flaw that there exists no suitable data for the interest rate on loans in Germany over the sample period covered by our empirical anal-

[79]See the notes in the statistical part of the monthly reports and the banking statistics of the German Bundesbank.

[80]While equity is an important factor that can be attributed to loan supply rather than loan demand, an alternative approach using the deposit volume instead of equity may at such an aggregate level lead to correlations that are merely due to the balance sheet identity and may therefore not adequately describe structural relationships.

[81]Of course, the equity position of banks may also indirectly reflect previous activities in the credit business. Note that the role of equity in financial institutions has recently received growing attention in the theoretical and empirical literature. See for example Bernanke and Lown (1991), Peek and Rosengreen (1992, 1995), Blum (1999) or the special issue of the Journal of Banking and Finance (Berger, Herring and Szegoe, 1995).

[82]However, it should be borne in mind that the volume of bank capital as it appears in the balance sheet is solely a rough indicator for the volume of liable equity subject to the Basle Accord (1988).

ysis. Other studies on the German loan market implemented by Möller and Jarchow (1982), Gischer (1992) and Winker (1996) use the interest rate on current account loans as a proxy. Winker (1996) provides some rationale for this choice on the basis of a comparison of different interest rates. However, since `LOANS` mainly consists of medium– and long–term loans, we consider the capital market rent as a more accurate indicator for the loan interest rate rather than the short–term current account interest rate. This is also supported by related studies (see e.g. Vathje, 1998; Holtemöller, 2003).[83]

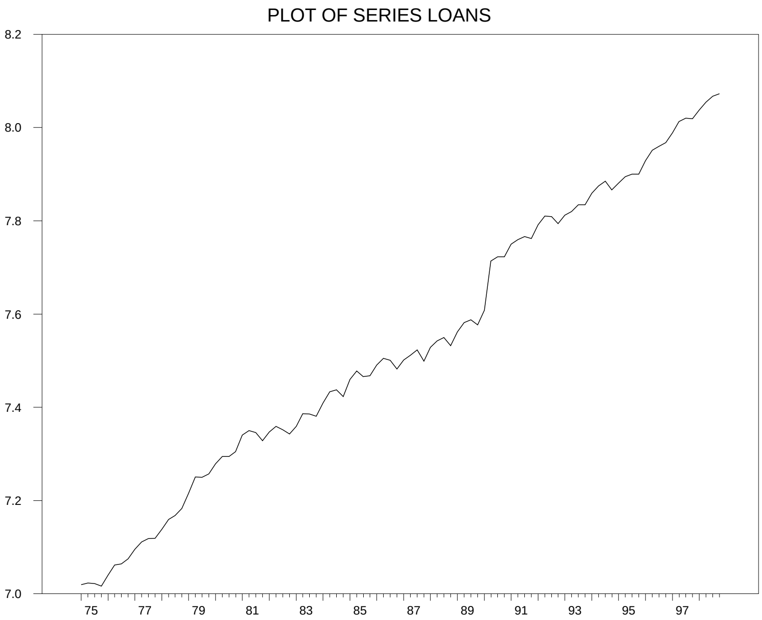
Since the monetary framework of the German Bundesbank was designed to control short–term interest rates in the money market, we use the three–month money market rate (r^M) as an indicator for the stance of monetary policy.[84] The real side of the economy is mirrored by the private part of real German GDP (`PGDP`) – private investment and consumption – which we consider – in line with De Bondt (1999a) and Kakes (2000) – as a proxy for loan demand factors.

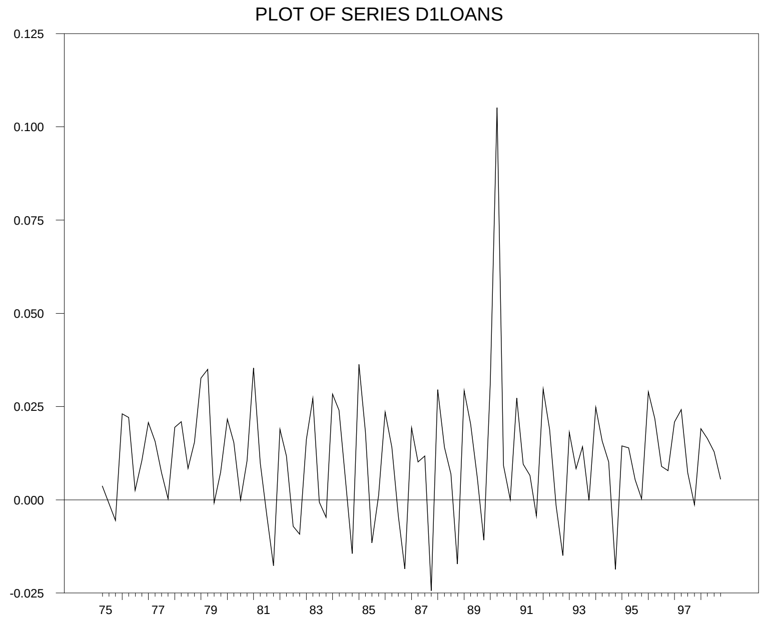
The time series are summarized in Figure 4.1, which shows the levels and first differences. `LOANS`, `EQUITY` and `PGDP` are expressed in logarithms and real terms, while r^L and r^M are in decimals.

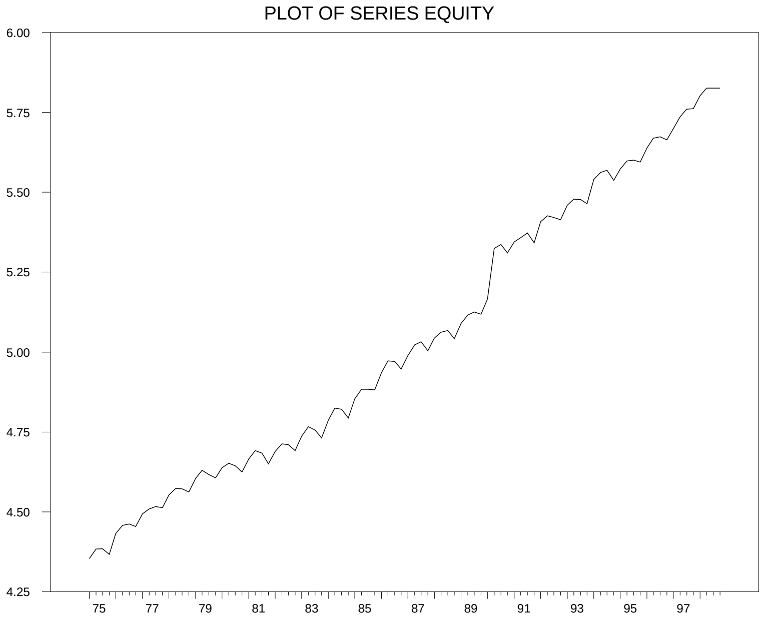
[83]We have also used the commercial paper rate and the interest rate on mortgage loans as alternative proxies for the loan interest rate. Since our qualitative findings are robust against these changes, we restrict the following presentation of our results on the outcome obtained by using the medium–term capital market rent. Note that within our sample period the spreads between the medium capital market rent, the commercial paper rate and the interest rate on mortgage loans are stationary, and bivariate cointegration tests – suggested by Banerjee et al. (1998) – imply that these interest rates are cointegrated. Note further, that the interest rate on mortgage loans exhibits a structural break in the second quarter of 1982, and may therefore generate some distortion on the outcome.

[84]See e.g. Borio (1997) and Schächter (1999), for a discussion.

Figure 4.1: Time Series in Levels and First Differences






PLOT OF SERIES EQUITY
6.00
5.75
5.50
5.25
5.00
4.75
4.50
4.25
75
77
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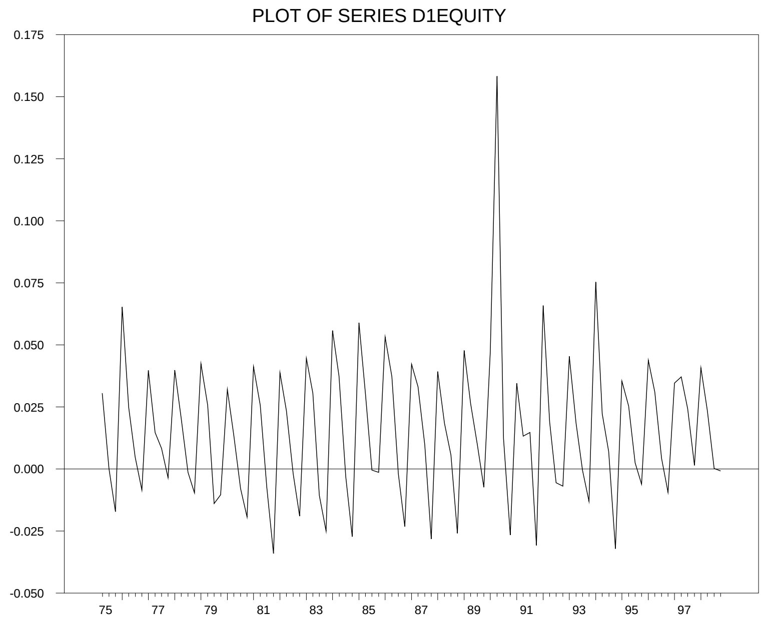
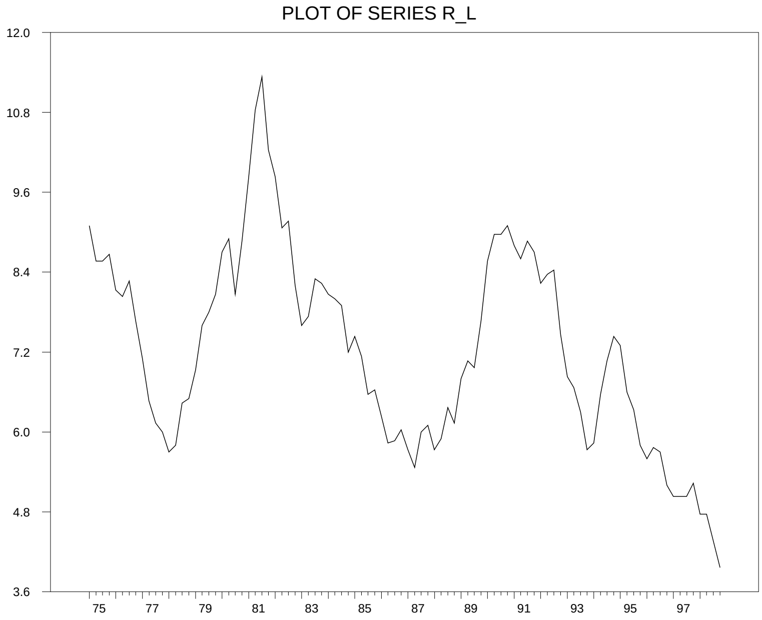
85
87
89
91
93
95
97


PLOT OF SERIES D1EQUITY
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
-0.025
-0.050
75
77
79
81
83
85
87
89
91
93
95
97


PLOT OF SERIES R_L
12.0
10.8
9.6
8.4
7.2
6.0
4.8
3.6
75
77
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81
83
85
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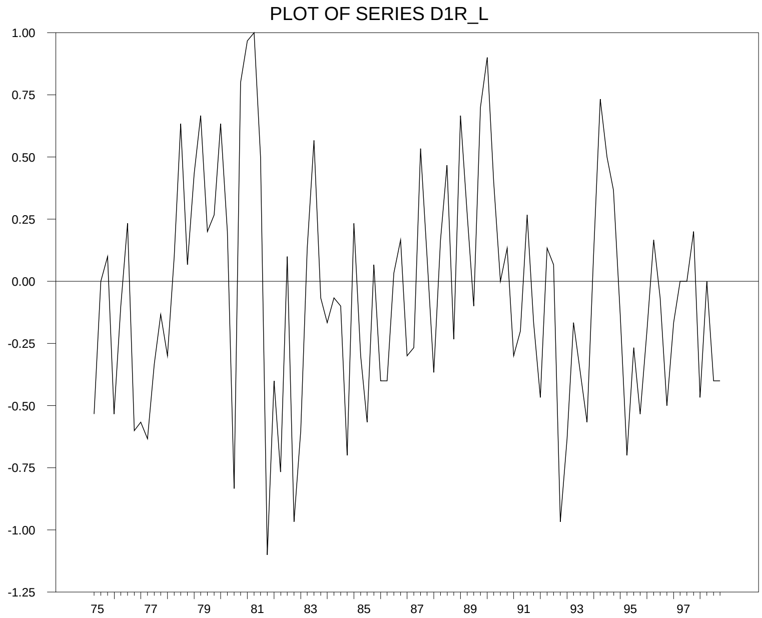
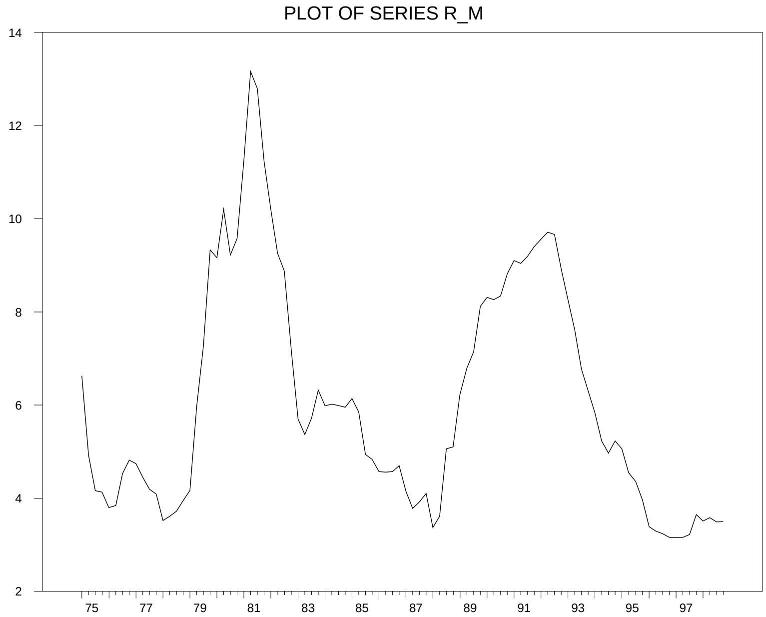
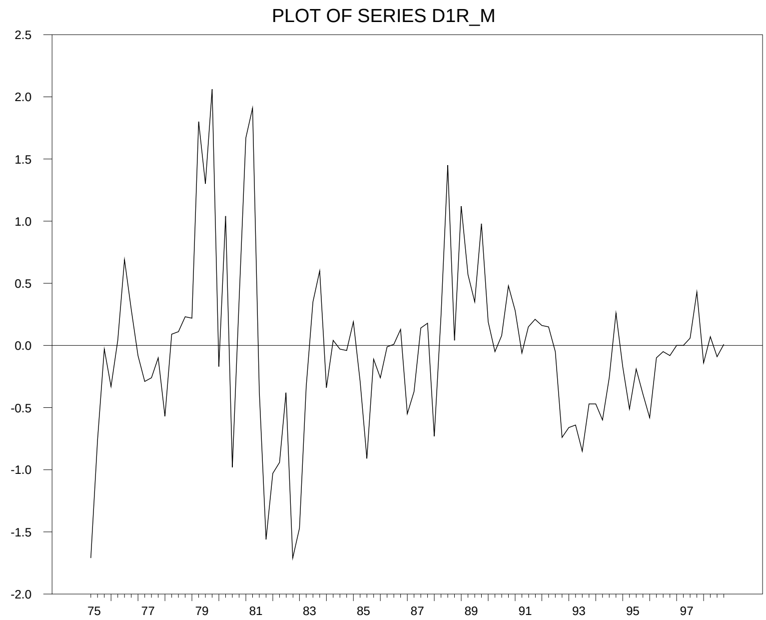
89
91
93
95
97


PLOT OF SERIES D1R_L
1.00
0.75
0.50
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
75
77
79
81
83
85
87
89
91
93
95
97


PLOT OF SERIES R_M
14
12
10
8
6
4
2
75
77
79
81
83
85
87
89
91
93
95
97


PLOT OF SERIES D1R_M
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2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
75
77
79
81
83
85
87
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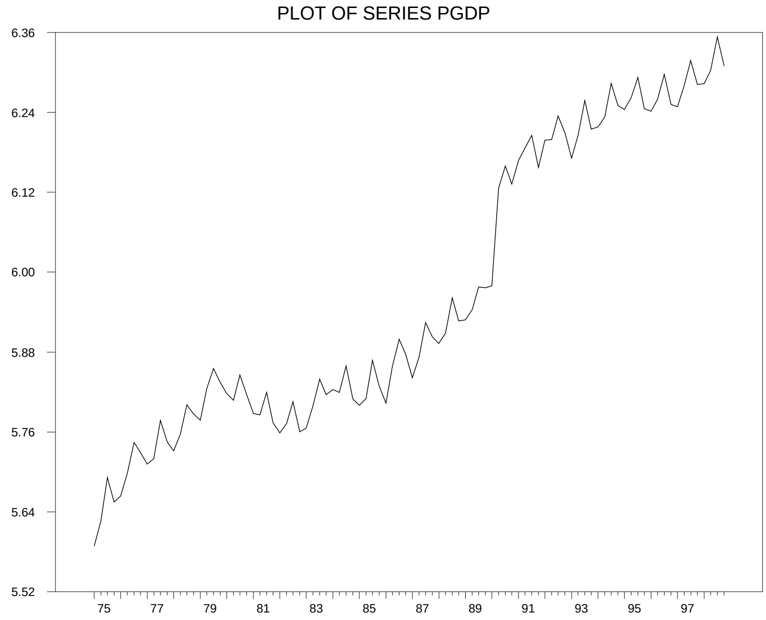
93
95
97


PLOT OF SERIES PGDP
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6.24
6.12
6.00
5.88
5.76
5.64
5.52
75
77
79
81
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85
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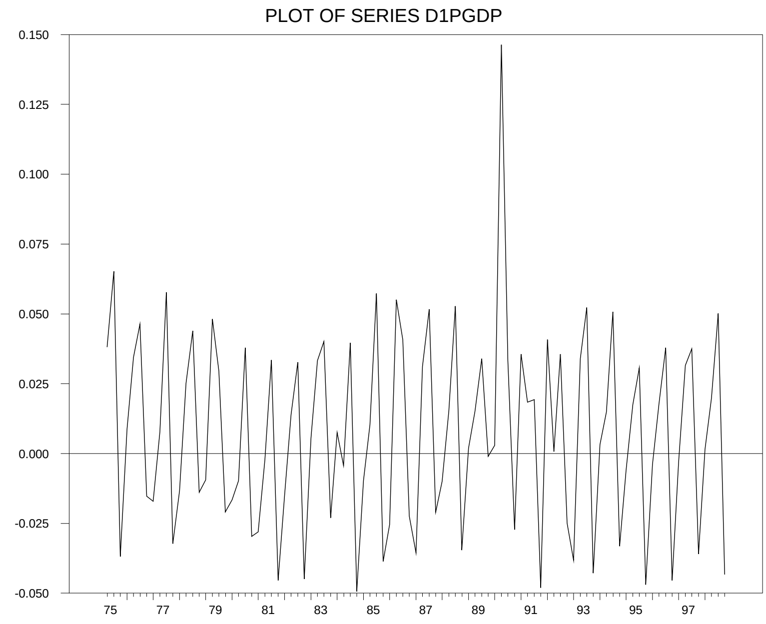
89
91
93
95
97


PLOT OF SERIES D1PGDP
0.150
0.125
0.100
0.075
0.050
0.025
0.000
-0.025
-0.050
75
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The time series properties are documented in Table 4.1, which reports the results of the ADF tests for the levels and first differences of the variables. Besides the test statistic of the unit root tests ($t(\hat{\rho})$), the table also shows whether a trend and a constant (t) or just a constant (c) is included in the regressions.[85] The lag length is reported in the columns with heading k. This lag order has been determined by choosing the smallest lag length such that the residuals of the regressions are free of autocorrelation, which has been measured by means of the Ljung–Box Q test.

Table 4.1: Unit Root Tests

	Levels			First differences		
Variable	$t(\hat{\rho})$	trend	k	$t(\hat{\rho})$	trend	k
LOANS	−2.92	t	4	−3.64	c	3
PGDP	−2.12	t	4	−3.49	c	3
EQUITY	−1.99	t	4	−3.83	c	3
r^L	−1.58	c	1	−5.81	–	1
r^M	−2.19	c	1	−4.98	–	1

Notes: The MacKinnon (1991) critical values for the ADF statistic at the 10% level are −3.15 (trend and constant), −2.58 (constant) and −1.62 (no constant).

For the ADF statistic, the critical values are −3.15 (trend and constant), −2.58 (constant) and −1.62 (no constant) as regards the 10% level. The results indicate that the levels of the variables are nonstationary, while the first differences are stationary, which suggests that the variables can be treated as integrated of order one, i.e. $I(1)$.[86]

4.3.3 Results of the VECM Analysis

Our VECM framework comprises five variables including the credit volume. Equity and the two interest rates r^L and r^M mirror factors driving loan supply, where r^M is the monetary policy instrument. Loan demand is covered by the private part of real GDP and the long–term interest rate r^L, which serves as a proxy for the interest rate on loans. The model further includes centered seasonal dummies, an unrestricted constant, i.e. a linear trend in the levels, and two unrestricted jump dummies – D902 and D951 – for the

[85] The decision to include deterministic terms has been based on the 10% level.

[86] Anyway, it should be noted that not all variables included in a VECM need to be I(1) (Hansen and Juselius, 1995, p. 1).

potential structural breaks in the data due to the German unification, which is reflected in the data in the second quarter of 1990, and due to the new classification scheme of the industrial sector, which emerges in the first quarter of 1995.[87] Consequently, D902 is one for the second quarter of 1990 and zero for all other dates, while D951 is one for the first quarter of 1995 and zero in all other periods. For the underlying vector autoregressive model we decided to implement a lag length of four, which is based on the outcome of various tests for misspecification.

The results of the trace test are summarized in Table 4.2 that shows the reduced rank statistics. Critical values have been taken from Johansen (1995)[88], which should be appropriate since the impact of small impulse dummies on the asymptotic distribution of the rank test is usually negligible (Doornik et al., 1999, p. 135).[89]

Based on the trace test, we adopt a rank of $r = 2$, which means that we have to find two independent long–term relationships in order to identify the cointegration space. Table 4.3 reports the multivariate test statistics, which show that the model is statistically well–specified.[90]

The characteristic roots of the system are all inside the unit circle assuring that the system is stable, i.e. that it converges to the long–run equilibrium

[87] The following tests have been carried out with the software packages CATS in RATS, version (1.0), and MALCOLM 2.2. Both programs yield identical results. The specification of deterministic components is based on the so–called Pantula principle as described in Hansen and Juselius (1995). The Pantula procedure works as follows: Start with the most restricted model and a cointegration rank of zero, compare the rank test statistic with the chosen quantile of the corresponding table. If this model is rejected, the next step is to look at the second most restricted model, keeping the rank assumption. If this model is rejected go to the next model, and so on. If all models reject $r = 0$, then repeat this procedure for $r = 1, 2, 3, ...$ until the first time a model cannot be rejected. In our analysis we have focused on two different specifications, denoted by Johansen (1995) as: *model 2*, which includes an intercept in the cointegration space and *model 3*, which includes an unrestricted constant, i.e. a linear trend in the levels. Applying the Pantula principle suggests to choose $r = 2$ and *model 3* based on the 90% quantile.

[88] See Johansen (1995) Table 15.3, page 215.

[89] With respect to this issue Doornik et al. (1999, p. 135) point out: *"A dummy which is unity at a few points and zero otherwise may give a persistent shock to the non-stationary components of the process, but is usually asymptotically negligible."* See also Hubrich (2001, p. 78): *"The introduction of an impulse dummy does not influence the asymptotic distribution of the test statistic since it only excludes a single observation from the sample."* However, it should be noted that generally the determination of the cointegration rank remains a subtle task.

[90] Notice that the tests for misspecification have also been carried out for the unrestricted vector autoregression model. These have indicated very similar results.

Table 4.2: Test of Cointegration Rank

Rank	Trace Statistic	Critical Value 90% Level
0	69.25	64.74
≤ 1	45.29	43.83
≤ 2	24.88	26.70
≤ 3	12.16	13.31
≤ 4	3.24	2.71

Estimated eigenvalues: 0.2293, 0.1990, 0.1291, 0.0925, 0.0346.

Table 4.3: Tests for Misspecification

	Test	Statistic	p-value
Autocorrelation	$LM(1)$	$\chi^2(25) = 22.68$	0.60
	$LM(4)$	$\chi^2(25) = 19.92$	0.75
Normality		$\chi^2(10) = 8.14$	0.62

Notes: The test on normality is based on Doornik and Hansen (1994). See also the Appendix in Hansen and Juselius (1995).

(Hansen and Juselius, 1995, pp. 28–29). Table 4.4 documents the two unrestricted cointegration relationships.

Table 4.4: Unrestricted Cointegration Vectors

PGDP	LOANS	r^L	r^M	EQUITY
-4.51	-9.68	-1.93	0.99	6.56
-12.97	0.47	-0.05	0.53	6.17

The credit channel implies that banks' loan supply should depend positively on r^L and EQUITY and negatively on the policy instrument r^M, while loan demand should depend positively on PGDP and negatively on r^L. Normalizing the cointegration vectors with respect to LOANS, Table 4.5 summarizes the outcome after imposing all identifying restrictions.

The rows in Table 4.5 show the following long–run relationships, which we

Table 4.5: Identified Cointegration Vectors

PGDP	LOANS	r^L	r^M	EQUITY
–	1	-0.121	0.121	-0.827
-0.924	1	0.183	–	–

interpret as loan supply and loan demand equations:[91]

$$\texttt{LOANS}^S = \underset{(0.022)}{0.121} \; (r^L \text{-} \; r^M) + \underset{(0.090)}{0.827} \; \texttt{EQUITY} \qquad \text{(I)}$$

$$\texttt{LOANS}^D = \underset{(0.231)}{0.924} \; \texttt{PGDP} - \underset{(0.029)}{0.183} \; r^L \qquad \text{(II)}$$

For identification of the cointegration space we have imposed four restrictions – three exclusion restrictions and one equality restriction – while exact identification would have only required two restrictions for identifying the cointegration space. However, the overidentifying restrictions cannot be rejected by a LR–Test: $\chi^2(2) = 1.53$, with a p-value of 0.47.

In the loan supply equation (I), the elasticity of the interest rate differential can be calculated as the product of the estimated coefficient 0.121 – that is a semi–elasticity – and the sample mean of the interest spread 1.15, which gives an elasticity of 0.14. The equity elasticity is around 0.83, which indicates that loan supply is sensitive to shifts in equity, albeit the reaction occurs less than proportionally. The loan demand equation (II) reports an income elasticity of 0.924, which is close to unity and in line with related analyses (see e.g. Vathje, 1998; Calza, Gartner and Sousa, 2001). The interest elasticity of loan demand is derived by multiplying the estimated coefficient -0.183 and the sample mean of the medium term capital market rent 7.22, which provides a value of -1.32. Other empirical studies (see e.g. Kakes, 2000; Calza et al., 2001) report interest rate elasticities fluctuating in an absolute range between 0.2 – 1.1. This divergency might result from using different types of loan aggregates, in particular different maturities and different sample periods, which implies that it might be difficult to find a robust benchmark within these figures.[92]

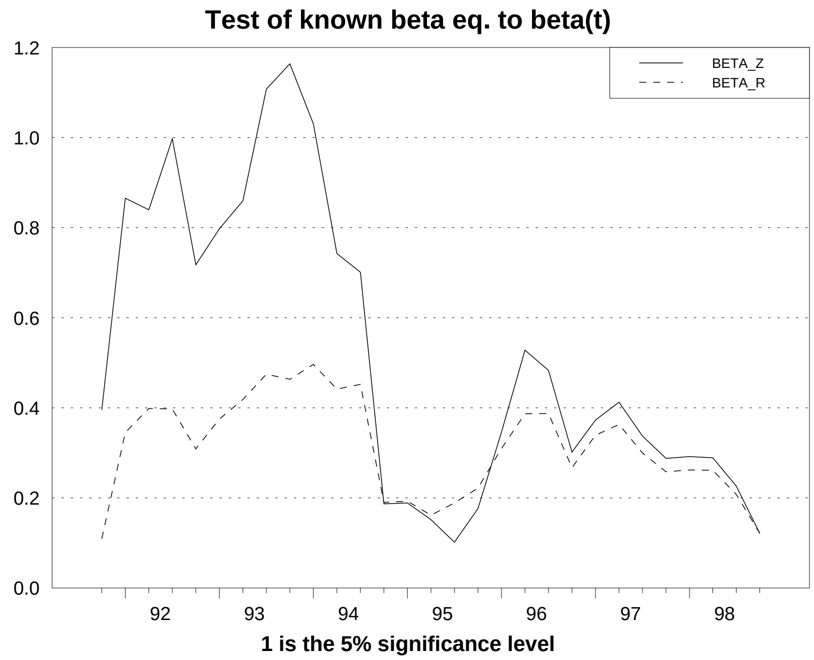
Assessing the stability of the cointegration space throughout time, we have recursively tested the hypothesis that the full sample estimate of $\hat{\beta}$ with the

[91] Standard errors are reported in parentheses.

[92] Notice that including the commercial paper rate or the interest rate on mortgage loans instead of the medium term capital market rent does not qualitatively affect the outcome.

overidentifying restrictions imposed is contained in the space spanned by β in each sub–sample. Following Hansen and Johansen (1993), the analysis is carried out within both the *Z-model* and the *R-model*. While in the *Z-model* all the parameters, including those related to the short–run dynamics, are estimated for each sample size, in the *R-model*, the short–run parameters are considered as fixed, and estimated only once in the full sample (Mosconi, 1998, p. 84). For the recursive analysis the base period has been set to 1975Q1 - 1991Q4.[93] The results are summarized in Figure 4.2. While the

Figure 4.2: Stability of the Cointegration Space



hypothesis of parameter stability is not rejected in the *R-model*, it is partly rejected in the *Z-model*. However, in case of conflicting results Hansen and Johansen (1993) suggest to prefer the *R-model*, which implies support in favor of the hypothesis of parameter constancy within the time period under consideration.[94]

[93]Hansen and Juselius (1995) suggest not to choose the smallest possible sample as the base period. In our analysis we have considered different base periods, which have all indicated identical results.

[94]With regard to the applied test for constancy of the parameters, Vlaar and Schuberth (1999) note that the recursive test suggested by Hansen and Johansen (1993) sequentially assumes a known breakpoint and may therefore rest on confidence levels far above the one implied by the 5% nominal size, i.e. the applied test might be too conservative.

For each variable, Table 4.6 reports the corresponding factor loadings, which are stored in the loading matrix α. The loading parameters indicate the speed of adjustment towards the long–run equilibrium relationships if deviations occur. Looking at the loadings of aggregate loans, it appears that the loan volume adjusts only slowly and slightly significant in the directions of the long–run loan supply and loan demand equations. This suggests that – given the endogeneity of the variables in the system – the adjustment to each equilibrium relationship might also be triggered by adjustments in the other variables.

Table 4.6: Loading Matrix

	ΔPGDP	ΔLOANS	Δr^L	Δr^M	ΔEQUITY
(I)	0.01	−0.01	1.05	0.07	−0.01
	(0.04)	(-1.56)	(3.42)	(0.18)	(-1.16)
(II)	−0.01	−0.01	−1.10	−0.71	−0.01
	(-1.44)	(-1.73)	(-4.75)	(-2.24)	(-0.54)

Notes: t-values in parentheses. The rows (I) and (II) refer to the long–run loan supply and loan demand relationships.

Hence, for a deeper insight in the adjustment process we have performed likelihood ratio tests on restrictions on the loading matrix α in order to see whether there is any evidence that some variables are weakly exogenous. A variable can be treated as weakly exogenous if its coefficients of all error correction terms are zero, implying that the respective equation in the first difference does not contain information about the long–run parameters β. The likelihood ratio tests on joint zero restrictions on α are documented in Table 4.7 and have been carried out (i) without imposing restrictions on β and (ii) with imposing simultaneous overidentifying restrictions on β. The tests show that while the null hypothesis of weak exogeneity can be rejected for the loan volume and the interest rates, it cannot be rejected for the private part of real GDP and the equity position.[95] However, including PGDP and EQUITY as exogenous variables has no qualitative impact on our results.

[95] For LOANS and the long–term interest rate r^L, the null hypothesis of weak exogeneity can be rejected at the 5% significant level, whereas for the interbank money market rate r^M, the null hypothesis of weak exogeneity can only be rejected at the 10% significant level. This borderline case might denote that the corresponding equation for the first difference of the short–term interest rate in the VECM may not be interpreted as the central bank's reaction function, since the policy targets – inflation and the output gap – are excluded from the analysis.

Table 4.7: Tests on Weak Exogenity

	$\chi^2(2)$	p-value	$\chi^2(4)$	p-value
ΔPGDP	2.20	0.33	4.74	0.31
ΔLOANS	7.63	0.02	12.19	0.02
Δr^L	10.26	0.01	11.20	0.02
Δr^M	5.25	0.07	9.05	0.06
ΔEQUITY	1.51	0.47	4.42	0.35

Notes: $\chi^2(2)$ refers to likelihood ratio tests of joint zero restrictions on α without overidentifying restrictions on β; $\chi^2(4)$ refers to likelihood ratio tests of joint zero restrictions on α with simultaneous overidentifying restrictions on β. Weak exogeneity is rejected if the empirical significance level (p-value) is smaller than 10%.

Our analysis does not precisely indicate how the adjustment process to the long–run equilibrium takes place since it is difficult to interpret the dynamic adjustment solely on the basis of the loading factors without taking into account the short–run dynamic parameters of the system (Johansen, 1995, p. 55). Nevertheless, the results suggest that in case aggregate loans deviate from equilibrium the return to it is not prompted only by adjustments in loans themselves, but also by movements in the interest rates. For more information on the dynamics of the system the following section presents impulse response analysis, which generates some stylized facts about the monetary transmission mechanism by setting out the impact of a monetary policy shock.

4.4 Concluding Remarks

This chapter has explored the existence of the credit channel in Germany on the basis of a structural analysis of aggregate bank loan data. Within a VECM framework, we have identified two cointegration vectors that we interpret as loan supply and loan demand equations. In accordance with the credit channel, our findings suggest that banks base their loan supply on their credit margin – that is affected by monetary policy actions – and their capital position, while loan demand by firms and households is related to the private part of real output and the loan interest rate. From the short–run dynamics of the VECM we conclude that in case aggregate bank loans deviate from equilibrium the return to it is not prompted solely by the adjustment of loans themselves, but also by the adjustment in the interest rates.

For deeper insight in the dynamics of the system, the following chapter presents innovation analysis – i.e. impulse response functions and variance decompositions – which generates some stylized facts about the transmission mechanism of monetary policy by displaying the reaction of the variables in the system to a monetary shock.

Appendix: A Stylized Model of the Banking Firm

This appendix provides the steps used to derive the optimal loan supply of a single bank and the loan market equilibrium. For notational convenience, let H denote the expectation lag operator, such that $H^{-j}E_{s-1}x_s = E_{s-1}x_{s+j}$, for all integers j, and variable x.

4.A Optimal Loan Supply of a Single Bank

Optimal loan supply of a single bank is found by rewriting the first–order condition (4.6) as:

$$\beta E_{t+j}L_{t+j+1} - (1+\beta)L_{t+j} + L_{t+j-1} = -a^{-1}(r^L_{t+j} - r^M_{t+j}), \tag{B.1}$$

for $(j = 0, 1, 2, ...)$, or:

$$\beta \left[1 - \frac{1+\beta}{\beta}H + \frac{1}{\beta}H^2\right] E_{t+j}L_{t+j+1} = -a^{-1}Y_{t+j}, \tag{B.2}$$

for $(j = 0, 1, 2, ...)$, where $Y_{t+j} \equiv r^L_{t+j} - r^M_{t+j}$. Using the procedure established by Sargent (1979, pp. 197–199), the left–hand side of equation (B.2) may be factored to obtain:

$$\beta(1 - \frac{1}{\beta}H)(1 - H)E_{t+j}L_{t+j+1} = -a^{-1}Y_{t+j}, \tag{B.3}$$

for $(j = 0, 1, 2, ...)$. The forward solution to equation (B.3) may be found by recognizing that $(1-\zeta H)^{-1}E_{t+j}x_{t+j} = -\sum_{i=1}^{\infty}\left(\frac{1}{\zeta}\right)^i E_{t+j}X_{t+j+i}$, if $\zeta > 1$ and $\{x_t\}$ is bounded (Sargent, 1979, p. 173). Here, $\zeta = 1/\beta > 1$ and $x_{t+j} = Y_{t+j}$ is bounded, if the transversality condition is satisfied.

The transversality condition is given by $\lim_{T\to\infty} E_t\beta^T\{r^L_T - a(L_T - L_{T-1}) - r^M_T\} = 0$, where T denotes the terminal period. According to Sargent (1979, pp. 197–200 and 335–336), the transversality condition holds if it is assumed that the stochastic processes for the interest rates, $\{r^L_{t+j}\}^{\infty}_{j=0}$, and $\{r^M_{t+j}\}^{\infty}_{j=0}$ are of exponential order less than $1/\beta$., i.e. for some $K > 0$ and $1 < x < 1/\beta$,

$$|E_t r^L_{t+j}| < K(X)^{t+j} \text{ and } |E_t r^M_{t+j}| < K(X)^{t+j}.$$

The forward solution to the bank's problem is (Sargent, 1979, p. 336):

$$E_{t+j}L_{t+j+1} = L_{t+j} + (a\beta)^{-1}\sum_{i=1}^{\infty}\beta^i E_{t+j}Y_{t+j+i}, \tag{B.4}$$

for $(j = 0, 1, 2...)$. Next, expanding the information set from I_{t+j} to I_{t+j+1} in (B.4), which is the information the bank has to make its decision on L_{t+j+1}, and redefining the index from $t+j+1$ to $t+j$, gives (Cosimano, 1988, p. 135):

$$L_{t+j} = L_{t+j-1} + a^{-1} \sum_{i=0}^{\infty} \beta^i E_{t+j} Y_{t+j+i}, \tag{B.5}$$

for $(j = 0, 1, 2...)$. Equation (4.5) follows by substituting in (B.5) the appropriate value for Y_{t+j+i}.

According to Sargent (1979, pp. 199), a sufficient condition, which assures the transversality condition for loans, is to show that $\sum_{i=0}^{\infty} \beta^i E_{t+j} Y_{t+j+i}$ is of exponential order less than $1/\beta$. Since r_{t+j}^L and r_{t+j}^M are assumed to be of exponential order less than $1/\beta$,

$$\sum_{i=0}^{\infty} \beta^i E_{t+j} Y_{t+j+i} < \sum_{i=0}^{\infty} \beta^i \left[K(X)^{t+j+i} + K(X)^{t+j+i} \right], \tag{B.6}$$

where the right hand side in (B.6) may be written as $2K(X)^{t+j} \sum_{i=0}^{\infty} (\beta X)^i$. From $0 < \beta X < 1$ follows $\sum_{i=0}^{\infty} (\beta X)^i = 1/(1-\beta X)$. Thus, equation (B.6) may be written as (Cosimano, 1988, p. 136):

$$\sum_{i=0}^{\infty} \beta^i E_{t+j} Y_{t+j+i} < \frac{2K}{1-\beta X} (X)^{t+j}, \tag{B.7}$$

which shows that L_{t+j} is of exponential order less than $1/\beta$.

4.B Loan Market Equilibrium

The loan market equilibrium is characterized by the equilibrium values of the loan level and the loan rate.

The equilibrium loan level (4.9) can be derived by means of the following steps. Multiplying equation (B.1) with n and setting $j = 0$ gives:

$$\beta E_t L_{t+1}^n - (1+\beta) L_t^n + L_{t-1}^n = -na^{-1}(r_t^L - r_t^M). \tag{B.8}$$

Next solve the demand for loans equation (4.8) for the loan rate:

$$r_t^L = B_1 y_t - B_2 (L_t^n - L_{t-1}^n), \tag{B.9}$$

where $B_1 = b_1/b_2$ and $B_2 = 1/b_2$,[96] and substitute r_t^L into equation (B.8), to obtain:

$$\begin{aligned}\beta E_t L_{t+1}^n &- (\beta + na^{-1}B_2 + 1)L_t^n \\ &+ (na^{-1}B_2 + 1)L_{t-1}^n = -na^{-1}(B_1 y_t - r_t^M). \end{aligned} \tag{B.10}$$

Applying the expectation lag operator yields:

$$\beta \left[1 - \left(1 + \frac{\omega}{\beta} \right) H + \frac{\omega}{\beta} H^2 \right] E_t L_{t+1}^n = -na^{-1}(B_1 y_t - r_t^M), \tag{B.11}$$

where $\omega \equiv (na^{-1}B_2 + 1)$. Now factor the left side of equation (B.11) using the procedure suggested by Sargent (1979, pp. 339–342):

$$\left[1 - \left(1 + \frac{\omega}{\beta} \right) H + \frac{\omega}{\beta} H^2 \right] = (1 - H)(1 - \lambda H),$$

where $\lambda \equiv \omega/\beta > 1$, since $\omega > 1$. Substituting this expression into (B.11) and applying the forward solution as in (B.4) yields:

$$E_t L_{t+1}^n = L_t^n + n(a\beta)^{-1} \sum_{i=1}^{\infty} \left(\frac{1}{\lambda} \right)^i E_t (B_1 y_{t+i} - r_{t+i}^M). \tag{B.12}$$

Equation (B.12) can be rewritten by expanding the information set from I_t to I_{t+1}, which gives:

$$L_t^n = L_{t-1}^n + n(a\beta)^{-1}\lambda^{-1} \sum_{i=0}^{\infty} \left(\frac{1}{\lambda} \right)^i E_t \left(B_1 y_{t+i} - r_{t+i}^M \right), \tag{B.13}$$

after changing the time index from $t+1$ to t.

Suppose the banks forecast the future development of the output level and the policy rate according to:

$$\begin{aligned} r_{t+1}^M &= \delta r_t^M + \eta_{t+1} \\ y_{t+1} &= \gamma y_t + \varepsilon_{t+1}, \end{aligned}$$

where $|\delta|, |\gamma| < 1/\beta$. The reduced form for the loan level can be derived by inserting the forecast expression into equation (B.13):

$$L_t^n = L_{t-1}^n + n(a\beta)^{-1}\lambda^{-1} \sum_{i=0}^{\infty} \left(\frac{1}{\lambda} \right)^i \left(B_1 \gamma^i y_t - \delta^i r_t^M \right), \tag{B.14}$$

[96] Notice that the random variable u_t is neglected.

and by recognizing that $\sum_{i=0}^{\infty}(1/\lambda)^i = \lambda/(\lambda-1)$, since $\lambda > 1$, which gives

$$L_t = L_{t-1} + C_1 y_t + C_2 r_t^M, \tag{B.15}$$

where $C_1 = B_1 n(a\beta)^{-1}(\lambda-\gamma)^{-1}$ and $C_2 = n(a\beta)^{-1}(\lambda-\delta)^{-1}$. The equilibrium loan rate (4.11) is found by inserting equation (B.15) into equation (B.9) and rearranging terms:

$$r_t^L = c_1 y_t - c_2 r_t^M, \tag{B.16}$$

where $c_1 = B_1(1-\beta\gamma)\beta^{-1}(\lambda-\gamma)^{-1}$ and $c_2 = B_2 n(a\beta)^{-1}(\lambda-\delta)^{-1}$.

Appendix: Data Base

All the data used for the VECM analysis is taken from the German Bundesbank and the German Institute for Economic Research (DIW).

1. `LOANS`: Loans to domestic firms and private households (all banks) in billions of DM, seasonally unadjusted. 1975:1–1990:1 West-Germany, and 1990:2–1998:4 Germany. Quarterly data end of period, German Bundesbank: PQA350.

2. `EQUITY`: Banks overall equity position in billions of DM, seasonally unadjusted. 1975:1–1990:1 West-Germany, and 1990:2–1998:4 Germany. Monthly data converted in quarterly data, end of period, German Bundesbank: OU0322.

3. `PGDP`: Private part of GDP in prices from 1991: private investment and consumption, seasonally unadjusted. 1975:1–1990:1 West Germany, German Institute for Economic Research: WH3201, WH3204, WH3205 and WH3208, and 1990:2–1998:4 Germany, German Institute for Economic Research: GH3201, GH3204, GH3205 and GH3208.

4. Short–term interest rate r^M: Three–month money market rate, Frankfurt/Main, monthly averages, German Bundesbank: SU0107. Converted in quarterly data.

5. Long–term interest rate r^L: Yield on bonds outstanding issued by domestic residents, monthly average, German Bundesbank: WU0017. Converted in quarterly data.

6. Commercial paper rate: monthly averages, German Bundesbank: WU0022. Converted in quarterly data. Interest rate on mortgage loans: monthly averages, German Bundesbank: 1975:1–1982:1: SU0010 and 1982:2–1998:4: SU0043. Converted in quarterly data.

5 Bank Lending in the Transmission of Monetary Policy in Germany

5.1 Introduction

Within the vector autoregression (VAR) framework, innovation analysis has become a popular tool in monetary policy research. The approach – that has been originally introduced by Sims (1980) – allows to investigate the dynamic responses of macroeconomic variables to various innovations by relying on a minimal set of identifying restrictions.[97] According to Lütkepohl and Reimers (1992), this methodology is also valuable in cointegrated systems.[98]

Based on our VECM framework, this chapter examines the existence of the credit channel in Germany by means of innovation analysis, i.e. impulse response functions and forecast error variance decompositions. The analysis draws on the assumption that banks relate their loan supply to their credit margin[99], while loan demand by firms and households is determined by the level of real activity – as captured in terms of the private part of real GDP – and the loan interest rate. Our analysis extends the approaches of Worms (1998), De Bondt (1999a), Küppers (2000) and Kakes and Sturm (2002), who explore the relevance of the credit channel on the basis of aggregate and disaggregated data, and may be seen complementary to the approaches of De Bondt (1999b), Worms (2001a, 2001b), Ehrmann et al. (2001), Ehrmann (2000), von Kalckreuth (2001), Chatelain et al. (2001), Grössl et al. (2001) and Kirchesch et al. (2001), who address heterogeneity across agents by examining cross–sectional bank and firm level data.

The main implication of our results is that the credit channel in Germany appears to be effective. Following a monetary contraction, banks seem to decrease their loan supply gradually with a falling credit margin, while loan

[97]In general, a VAR is a multivariate model in which each endogenous variable is regressed on its own past values and the current and past values of all other variables in the system. See e.g. Enders (1995), Lütkepohl and Breitung (1997) and Amisano and Giannini (1997) for a survey and discussion of the VAR methodology.

[98]VARs have been used by Bernanke and Blinder (1992), Sims (1992), Christiano, Eichenbaum and Evans (1996), Dornbusch, Favero and Giavazzi (1998), Bernanke and Mihov (1998) or Peersman and Smets (2003) – among others – for assessing the monetary transmission mechanism.

[99]That is, the spread between the loan interest rate – as approximated by the yield on bonds outstanding issued by domestic residents – and the three–month money market rate, which describes the monetary policy instrument.

demand by firms and households seems to react ambiguously. In the long term, loan demand declines with a drop in the private part of real output and an increase in the loan interest rate, but in the short term, loan demand is raising even if credit conditions are tightening. The primary increase in loan demand – that is also documented by Worms (1998) and De Bondt (1999a) for Germany – might denote that firms and households use short–term credit to smooth a decline in income during a policy–induced recession (see e.g. Gertler and Gilchrist, 1993) or to shorten the maturity of their debts as a reaction to increases – and in anticipation of future decreases – in the loan interest rate (see e.g. Kakes, 2000).

The chapter is organized as follows. Section 5.2 gives a brief introduction of the methodology applied. Section 5.3 presents our results, which are based on our preceding VECM framework, including the same set of variables, a lag length of four, an unrestricted constant, centered seasonal dummies, and the two jump dummies that deal with the German unification in the second quarter of 1990 and the potential structural break in the loan data that emerges from the new classification of the industrial sector in the first quarter of 1995. In line with the identified system the cointegrating restrictions and all overidentifying restrictions on the cointegrating vectors are imposed. Section 5.4 offers concluding remarks.

5.2 Innovation Analysis in Cointegrated VARs

Following Lütkepohl and Reimers (1992), consider a standard VAR model in levels dropping the constant term for notational convenience:

$$X_t = \Pi_1 X_{t-1} + ... + \Pi_k X_{t-k} + \varepsilon_t, \tag{5.1}$$

where X_t is a p–dimensional vector of endogenous variables that are integrated of order one, i.e. $I(1)$ and ε_t is a p–dimensional vector of error terms, which are assumed to be white noise with $E(\varepsilon_t) = 0$ and $E(\varepsilon_t \varepsilon_t') = \Sigma_\varepsilon$. The Π_i describe $p \times p$ coefficient matrices.

The VAR model (5.1) can be reformulated into a vector error correction model (VECM) of the form:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t, \tag{5.2}$$

where:

$$\Gamma_i = -(I - \Pi_1 - ... - \Pi_i),$$

$$\text{for } i = 1, ..., k-1$$

and

$$\Pi = -(I - \Pi_1 - ... - \Pi_k),$$

if the variables in X_t are cointegrated. In cointegrated models the matrix Π has reduced rank $r = rank(\Pi) < p$ and can be decomposed as $\Pi = \alpha\beta'$, where α and β are $p \times r$ matrices of full column rank containing the factor loadings and the cointegration vectors. Applying the Johansen (1988, 1995) procedure, the model can be estimated by maximum likelihood (see Chapter 4, Section 4.3.1).

According to Lütkepohl and Reimers (1992) and Lütkepohl (1993), impulse responses can be derived from the VAR representation (5.1) and may be defined as:

$$\Phi_h = (\varphi_{il,h}) = \sum_{j=1}^{h} \Phi_{h-j}\Pi_j, \qquad h = 1, 2, ..., \tag{5.3}$$

where $\Phi_0 = I$ and $\Pi_j = 0$ for $j > k$. The impulse responses $\Phi_h = (\varphi_{il,h})$ describe the impact of shocks in the variables of the system, implying that $\varphi_{il,h}$ represents the response of variable i to a shock in variable l, h periods ago. Responses to orthogonalized impulses may be defined as:

$$\Theta_h = (\theta_{il,h}) = \Phi_h P = \sum_{j=1}^{h} \Phi_{h-j}\Pi_j P, \qquad h = 1, 2, ...,$$

where P is a lower triangular matrix such that $PP' = \Sigma_\varepsilon$, i.e. a Cholesky decomposition of the covariance matrix Σ_ε. The orthogonalized impulses can be regarded as transformed residuals of the form:

$$e_t = P^{-1}\varepsilon_t,$$

which have identity covariance matrix, i.e. $\Sigma_e = E(e_t e_t') = I$.

As Lütkepohl and Reimers (1992) point out, in VAR models under cointegration the effect of an impulse in one of the variables may in general not die out in the long run, which means that the variables may not necessarily return to their initial values even if no further shocks occur.[100] Consequently, a single impulse may have a permanent effect in the sense that it shifts the system to a new equilibrium (Lütkepohl and Reimers, 1992, pp. 54–55).

[100] In this manner, the non–stationary case departs from the stationary case. See e.g. Lütkepohl (1993) for VARs including stationary variables.

In addition, the dynamic properties of the system can be analyzed by variance decompositions – as proposed by Sims (1980) – that decompose each variable's forecast error variance into the parts that are attributable to itself and to all other variables for different horizons. The forecast error variance decompositions are obtained by:

$$\omega_{lj,s} = \sum_{h=0}^{s-1} \frac{\theta_{lj,h}^2}{MSE_l(s)}, \qquad s = 1, 2, ..., \tag{5.4}$$

where $\theta_{lj,h}$ is the ljth element of Θ_h and $MSE_l(s)$ is the lth diagonal element of

$$MSE(s) = \Sigma_\varepsilon + \sum_{h=1}^{s-1} \Phi_h \Sigma_\varepsilon \Phi_h',$$

the mean squared error matrix of the optimal s–step–ahead forecast of the X_t process. The asymptotic distribution of the impulse response functions and the forecast error variance decompositions is given in Lütkepohl and Reimers (1992).

As pointed out by Enders (1995), the idea of imposing a recursive structure to obtain independent innovations is to some extent arbitrary, since many matrices P exist, which satisfy $PP' = \Sigma_\varepsilon$.[101] Even if P is found by a lower triangular Cholesky decomposition, applying a different ordering of the variables in the vector X_t may lead to different shocks, which means that the effects of a shock may depend on the way the variables are arranged in the vector X_t (Lütkepohl, 1999, p. 21). A natural way to deal with this difficulty is to apply several orderings of the variables and to compare the results with respect to discrepancies. However, in a system with p variables there are $p!$ orderings possible, which implies that it might be difficult to make a particular choice.[102] In light of this difficulty alternative decomposition methods have been suggested, for instance by Sims (1986) and Bernanke (1986), in which the contemporaneous relationships between the variables are explicitly derived from economic theory. These approaches are denoted as structural VAR analysis (SVAR), which in fact include the triangular system as a special case.

It should be noted that the orthogonalization procedure is not likely to be important if the correlation between the estimated innovations ε_t is low,

[101] This criticism has been emphasized e.g. by Cooley and LeRoy (1985).

[102] With regard to this issue, Sims (1981) points out: *"When results are sensitive to the ordering of the variables, one may make some progress by using a priori hypotheses about the structure."* (Sims, 1981, p. 288).

which is the case if the off–diagonal elements of the correlation matrix of ε_t are close to zero, implying that the system is nearly orthogonal (Enders, 1995, p. 309).[103] As a consequence, the identification scheme – or in case of a Cholesky decomposition, the ordering of the variables – should not matter much for the analysis.

Recent modifications of the structural VAR approach have been introduced by Blanchard and Quah (1989), King, Plosser, Stock and Watson (1991) and Vlaar (1998), which include long–term restrictions besides the short–term constraints on the disturbance terms. Likewise, Pesaran and Shin (1996, 1998) have suggested generalized impulses, which represent a theoretically neutral way of deriving impulse responses that accounts for the difficulties associated with the identification of shocks.[104]

5.3 Results

5.3.1 Innovation Analysis

Based on our VECM framework, we generate impulse response functions and forecast error variance decompositions in order to examine the reaction of the variables in the system to a monetary policy shock.[105] Following Sims (1980) and Lütkepohl and Reimers (1992), we identify the policy shock by imposing a triangular orthogonalization on the short–run dynamics corresponding to the following order:[106] the private part of real output (`PGDP`), equity (`EQUITY`), the short–term interest rate (r^M), aggregate bank loans (`LOANS`) and the long–term interest rate (r^L). The ordering of the variables

[103]According to Enders (1995), the importance of the ordering of the variables depends on the magnitude of the correlation coefficient ρ between the estimated innovations. *"[...] as a rule of thumb, if* $|\rho| > 0.2$*, the usual procedure is to obtain the impulse response function using a particular ordering. Compare the results to the impulse function obtained by reversing the ordering. If the implications are quite different, additional investigation into the relationships between the variables is necessary."* (Enders, 1995, p. 309)

[104]It should be mentioned that the VAR–based identification of monetary policy has been criticized by Rudebusch (1996), who doubts the plausibility and robustness of this type of analysis. Indeed, VAR models are only able to produce estimates of an unanticipated monetary policy shock but fail to analyze changes in the systematic component of monetary policy, which are likely to be more important.

[105]Impulse response simulations and forecast error variance decompositions have been calculated with the MALCOLM package developed by Mosconi (1998).

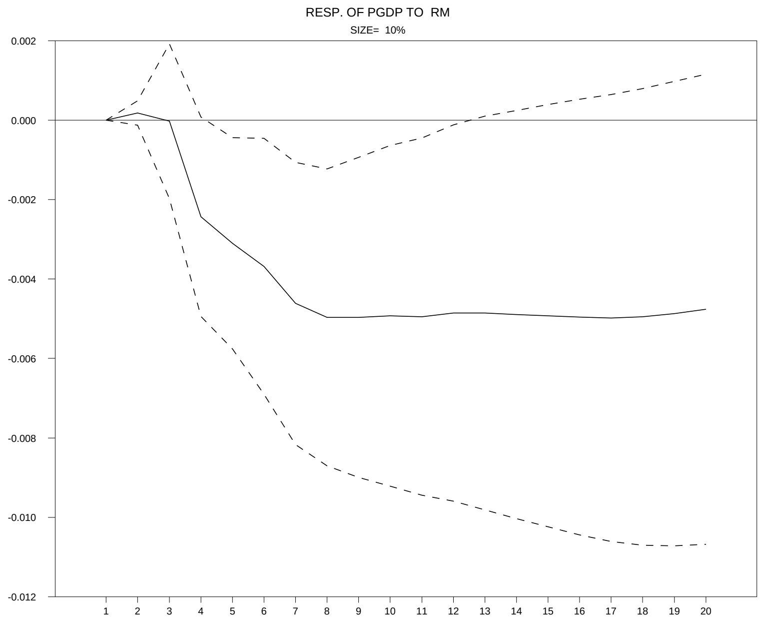
[106]Similar identification schemes have been chosen e.g. by Bernanke and Blinder (1992), Kashyap and Stein (1994), Dale and Haldane (1993b, 1995), Tsatsaronis (1995), De Bondt (1999a), Küppers (2000), Kakes (2000) and Kakes and Sturm (2002).

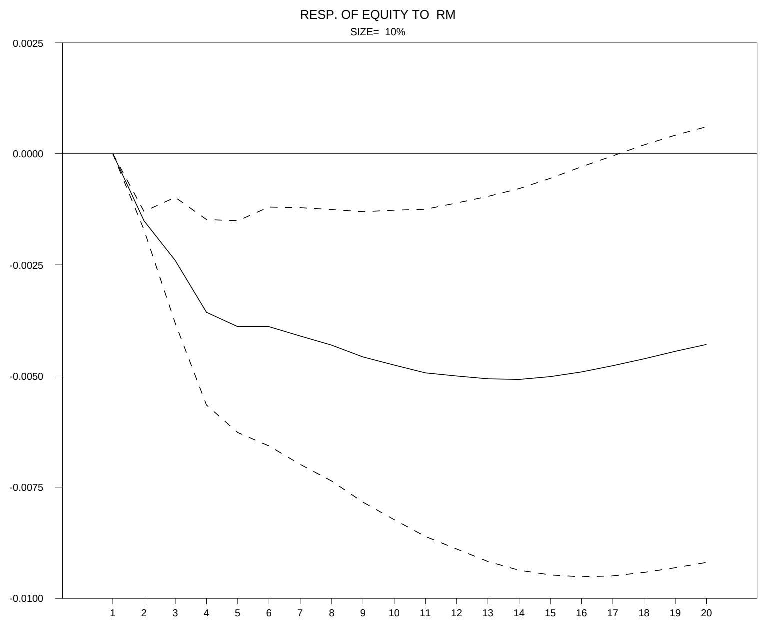
– that is in line with related studies (see e.g. Guender and Moersch, 1997; Ehrmann and Worms, 2001) – implies that an innovation in the monetary policy instrument affects the private part of real output and the equity position with a lag of one quarter, while aggregate loans and the long–term interest rate are possibly affected within the same quarter.[107]

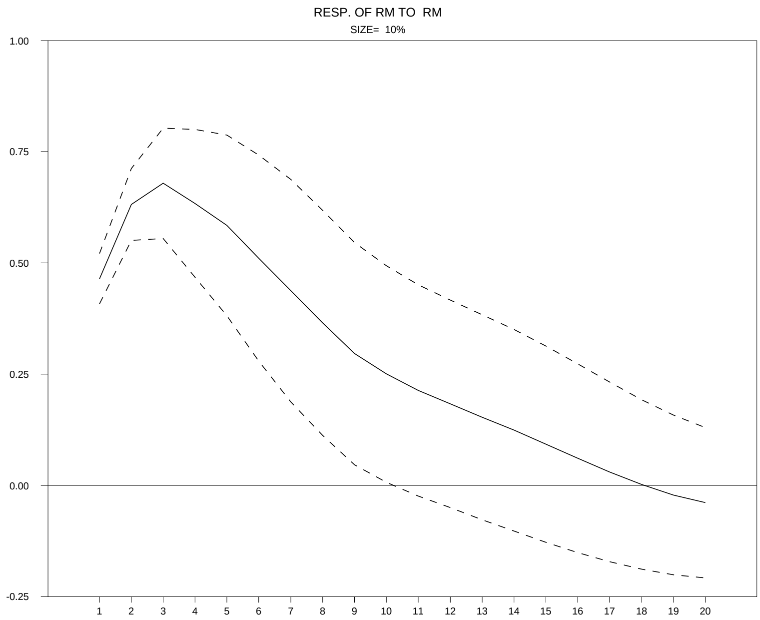
For each variable, Figure 5.1 plots the impulse responses, which are interpreted as their reaction to an unexpected monetary tightening that is reflected by a one–standard deviation short–term rate shock. The simulation period covers a horizon of 20 quarters. The solid lines denote impulse responses. The dotted lines are 90% error bounds, based on asymptotic calculation. Within the simulation, the monetary policy shock leads to an increase in the policy rate of approximately 60 basis points in the first three quarters. From then on the short–term interest rate follows a mean reverting process and returns to a level not significantly different to zero within ten quarters.

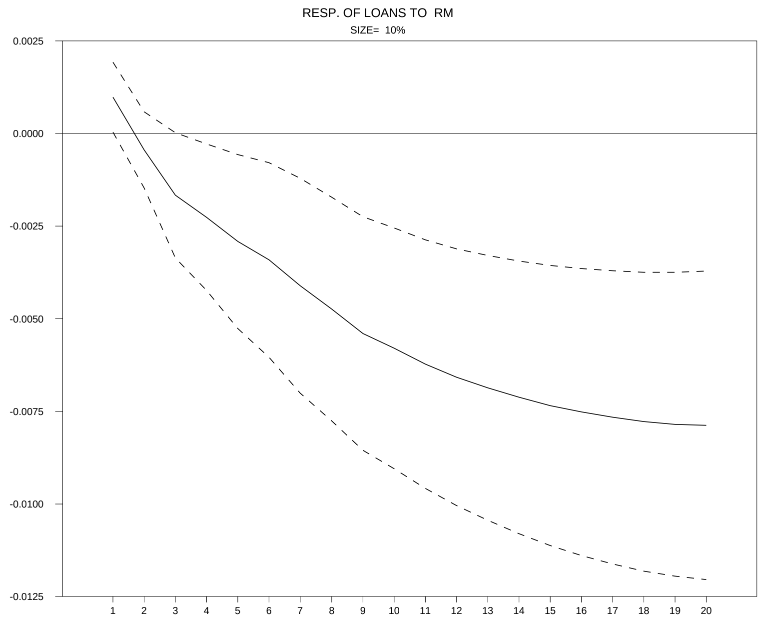
[107]Notice that the ordering of the variables is based on the outcome of the tests of weak exogeneity. We have also investigated alternative orderings, but these have hardly affected the qualitative outcome and have not led to different conclusions. In addition, we have performed generalized impulse responses, as proposed by Pesaran and Shin (1996, 1998), which have also given very similar results. The Appendix shows the generalized impulse responses to one–standard–deviation short–term rate shock, which have been estimated with the software package EViews 4.0.

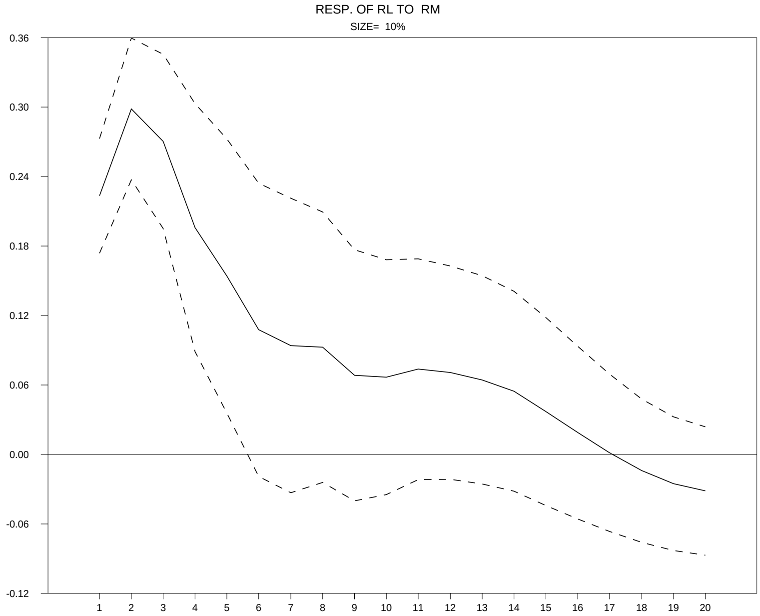
Figure 5.1: Impulse Response Functions






RESP. OF RM TO RM
SIZE= 10%


RESP. OF LOANS TO RM
SIZE= 10%



Notes: Impulse responses to a monetary policy shock.

Aggregate bank loans slightly rise, but then fall immediately after the monetary policy shock. This corroborates the results of Tsatsaronis (1995), Barran et al. (1997), Worms (1998), De Bondt (1999a) and Küppers (2000), who investigate the response of aggregate bank lending in Germany in a similar framework using monthly and quarterly data.[108] The decrease in bank loans continues until the end of the simulation period. From then on aggregate loans remain roughly 0.75 percent below the baseline value. The private part of real output slightly raises in the first three quarters then falls and remains approximately 0.5 percent below the baseline value around eight quarters after the monetary policy shock has been initialized. The equity position drops instantly to around 0.5 percent below the baseline value, but recovers slightly until the end of the simulation period. Finally, the long–term interest rate shows an immediate positive response of roughly 30 basis points in the first three quarters. From then on the long–term interest rate is gradually declining following a somewhat similar pattern as the short–term interest rate but at a lower level.

[108]Interestingly, Kakes et al. (2001) observe a positive response of aggregate bank loans after an unexpected monetary tightening that persists till the end of their simulation period.

Our findings suggest that banks decrease their loan supply gradually with a drop in their credit margin and their capital position after a monetary contraction, which is in line with Worms (1998) and De Bondt (1999a), who draw similar conclusions.[109] Loan demand by firms and households – as captured by movements in the private part of real GDP and long–term interest rate – declines by degrees in the long term, whereas in the short term the adjustment is ambiguous, since real output is initially rising after the short–term interest rate shock has been initialized. According to Bernanke and Gertler (1995) a primary increase in loan demand – that is also documented by Worms (1998) and De Bondt (1999a) for Germany – may arise from the desire of firms and households to smooth a decline in income after a policy–induced recession or to shorten the maturity of their debt structure as a reaction to an increase – and in anticipation to a future decrease – in the long–term interest rate (see e.g. Kakes, 2000). After three quarters loan demand begins to fall in conjunction with the decline in the private part of real output.[110]

Our findings are complemented in Table 5.1, which presents for each variable the part of the forecast error variance decomposition that can be attributed to innovations in the policy rate throughout the simulation horizon.

[109] Possibly, the sluggish decline in bank loans may be attributed to the fact that banks in Germany maintain close relationships with their clients, which shelters borrowers from short–term liquidity squeezes possibly associated with restrictive monetary policy. See Harhoff and Körting (1998) and Elsas and Krahnen (1998) for a discussion.

[110] In so far as monetary policy disturbances deteriorate the creditworthiness of some borrowers, credit rationing may also be a relevant phenomena, which, however, is difficult to account for while using aggregate data.

Table 5.1: Forecast Error Variance Decompositions

	PGDP	EQUITY	r^M	LOANS	r^L
1 quarter	0.00	0.00	0.979	0.025	0.471
2 quarters	0.001	0.015	0.950	0.015	0.490
4 quarters	0.014	0.072	0.851	0.044	0.492
8 quarters	0.079	0.136	0.718	0.141	0.459
12 quarters	0.109	0.167	0.656	0.276	0.431
16 quarters	0.120	0.181	0.624	0.393	0.418
20 quarters	0.126	0.183	0.603	0.475	0.407

Notes: For each simulation The figures denote, for each simulation step, the part of each variable's forecast error variance that can be attributed to innovations in the short–term interest rate.

Innovations in the policy rate appear to have a substantial impact on the long–term rate, while the impact on the private part of real output, aggregate loans and equity initially appears limited, but is subsequently increasing. This suggests that changes in the stance of monetary policy are temporarily less effective, but their impact is raising across the simulation horizon.

On the basis of our results, we conclude that the credit channel in Germany appears to be effective, as we find that loan supply effects in addition to loan demand effects contribute to the propagation of monetary policy measures. In this regard, it is worth noting that the perverse short–run adjustment of loan demand is not inconsistent with the credit channel, as it does not require that households and firms necessarily reduce their borrowing following a monetary contraction; the credit channel predicts only that firms and households will borrow and spend less than they would if credit markets were perfect (Bernanke and Gertler 1995, p. 44).

5.3.2 Related Findings

Our findings are in line with a number of studies on Germany that employ aggregate and disaggregated data. Worms (1998) and De Bondt (1999a) find evidence in support of the credit channel by showing that a decline in aggregate bank loans following a monetary contraction can be attributed to loan supply and loan demand effects. Küppers (2000) and Kakes and Sturm (2002) investigate the lending activities of different banking groups on the basis of disaggregated bank balance sheet data. They observe that these banking groups depart in their lending activities after a monetary tightening, which suggests that bank behavior can play a meaningful role in the propagation of monetary policy shocks.

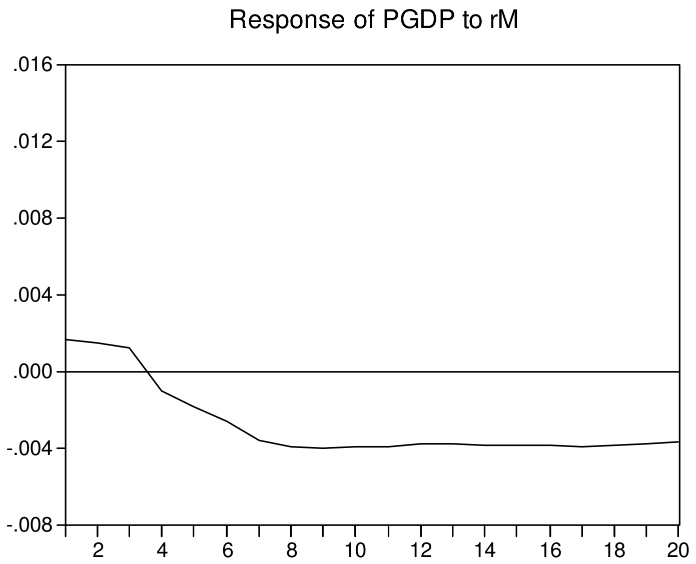
Our results can be interpreted along the findings obtained for Germany by De Bondt (1999b), Ehrmann et al. (2001), Worms (2001a, 2001b), Ehrmann (2000) and von Kalckreuth (2001) on the basis of individual bank and firm level data. The conclusion of these studies is that German banks differ in their lending activities after a shift in monetary policy, while German firms depending on their size are differently affected in the access of external finance, which is consistent with the existence of financial imperfections. By focusing on heterogeneity across agents, these approaches surpass our aggregate approach in disclosing the distributional effects of monetary policy actions; but, regarding the macro level they are attached to an aggregation problem, which is a major impediment for the interpretation of the estimation results obtained at the micro level. While sticking to the aggregate level allows to draw conclusions about the transmission mechanism of monetary policy, our aggregate approach and the microbased approaches may be regarded complementary.

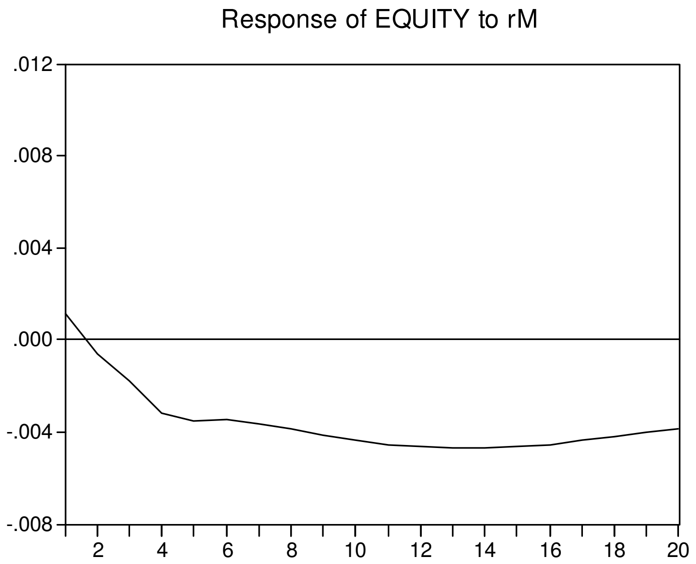
5.4 Concluding Remarks

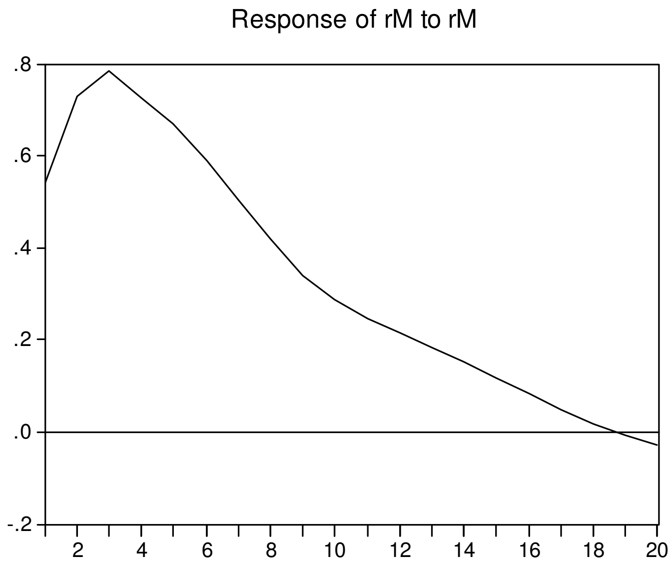
This chapter has examined the existence of the credit channel in Germany by means of innovation analysis, i.e. impulse response functions and forecast error variance decompositions. Our results suggest that banks decrease their loan supply gradually following a monetary contraction, while loan demand by firms and households declines in the long run, but raises in the short run even if credit conditions are tightening. The initial increase in loan demand may reflect that firms and households seek to smooth a decline in income during a policy–induced recession or to shorten the maturity of their debt structure as a reaction to increases – and in anticipation of future decreases – in the loan interest rate.

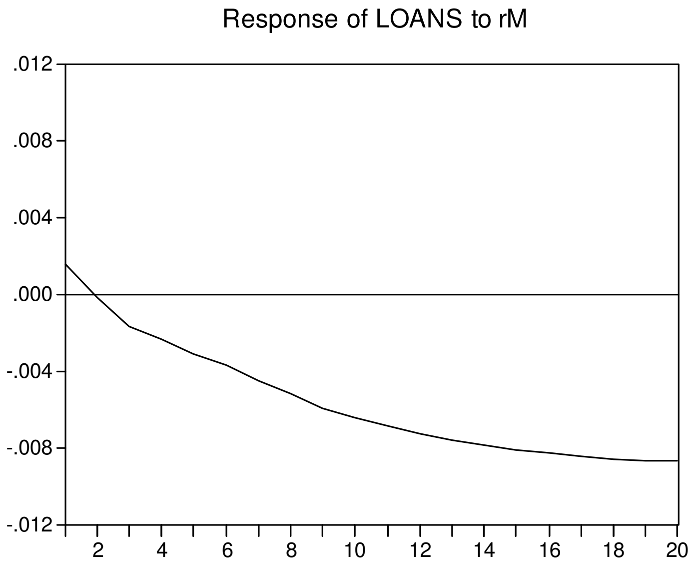
The main implication of our results is that the credit channel in Germany appears to be effective, as we find that loan supply effects next to loan demand effects seem to shape the consequences of monetary policy measures. This is consistent with the conclusions drawn by Worms (1998), De Bondt (1999a), Küppers (2000) and Kakes and Sturm (2002) on the basis of aggregate and disaggregated bank balance sheet data. Since our findings are based on aggregate bank loan data, a natural extension for future research would be to examine different loan categories broken down into sectors and maturities, which may allow for a deeper insight in the transmission mechanism of monetary policy.

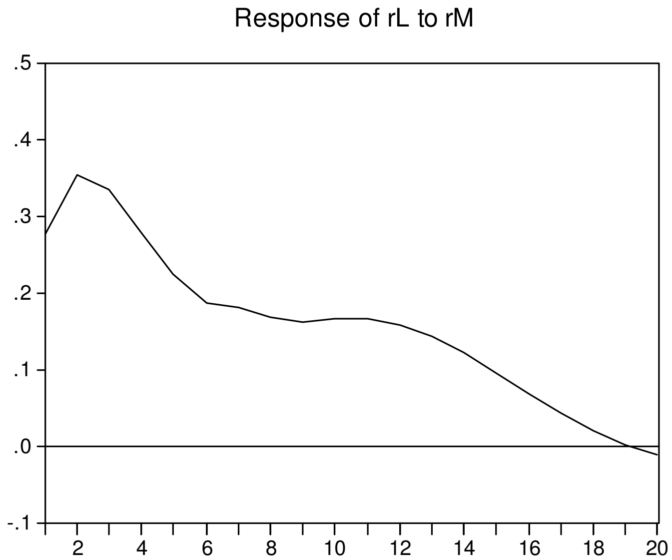
Appendix: Generalized Impulse Response Functions






Response of rM to rM
.8
.6
.4
.2
.0
-.2
2
4
6
8
10
12
14
16
18
20


Response of LOANS to rM
.012
.008
.004
.000
-.004
-.008
-.012
2
4
6
8
10
12
14
16
18
20



Notes: Responses to a Generalized Policy Innovation

6 Concluding Remarks

This study has addressed the credit channel in Germany with special attention concerning the way monetary policy is implemented. Policy implementation by the Eurosystem – following the prior example of the German Bundesbank – is based on an operational framework, which is designed to signal monetary policy intentions by steering short–term money market rates. Banks play a meaningful part in the transmission of monetary policy, since their behavior in passing on policy–induced changes in short–term money market rates has important implications for the propagation of monetary policy actions.

With this in mind, this study has explored the existence of the credit channel in Germany on the basis of a structural analysis of aggregate bank loan data. Within a VECM framework, we have identified long–run loan supply and loan demand relationships by imposing restrictions on cointegration vectors. The short–run dynamics of the VECM has been investigated on the basis of innovation analysis, which has displayed some stylized facts about the transmission mechanism of monetary policy by assessing the impact of a monetary policy shock. The main conclusion of our results is that the credit channel in Germany appears to be effective, as we find evidence that loan supply effects in addition to loan demand effects contribute to the transmission of monetary policy measures.

With the launch of the single monetary policy, studying the transmission mechanism of monetary policy remains an important task. Since our analysis is based on data from before the creation of the euro, a natural continuation would be to update the data base. Such research will become valuable with sufficient data availability.

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Kurzlebenslauf
von Oliver Hülsewig

18. November 1970	geboren in Bad Neustadt a. d. Saale
September 1977 – Juli 1981	Grundschule Würzburg
September 1981 – Juli 1991	Schönborn Gymnasium Würzburg
September 1988 – August 1989	Fairport High School, N.Y., USA
Juli 1991	Abitur
Juli 1991 – Juni 1992	Grundwehrdienst
Oktober 1992 – November 1997	Studium der Volkswirtschaftslehre, Universität Würzburg
November 1997	Diplom– Volkswirt
August 1998 – Dezember 2003	Wissenschaftlicher Mitarbeiter am Lehrstuhl für Geld und internationale Wirtschaftsbeziehungen, Universität Würzburg
Januar 1999 – Mai 2004	Promotion im Fach Volkswirtschaftslehre
November 2003	Abgabe der Dissertation
Mai 2004	Abschluss des Promotionsverfahrens
seit Mai 2004	Ifo Institut für Wirtschaftsforschung, München