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# W. E. P.

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## Würzburg Economic Papers

Nr. 43

### Bank Behavior, Interest Rate Targeting and Monetary Policy Transmission

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# Bank Behavior, Interest Rate Targeting and Monetary Policy Transmission

Oliver Hülsewig\*

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## Abstract

This paper addresses the existence of the credit channel in the transmission of monetary policy in Germany by means of a structural analysis of aggregate bank loan data. The empirical analysis is carried out within a vector error correction (VECM) framework, which allows to identify long-run cointegration relationships that can be interpreted as loan supply and loan demand equations. The short-run dynamics of the VECM is investigated on the basis of impulse response analysis, which sets out the impact of a monetary policy shock on the variables in the system. Empirical evidence in support of the credit channel can be reported.

JEL classifications: E44, E52

Monetary Policy Transmission, Credit Channel, Vector Error Correction Model.

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# 1 Introduction

In recent years the interest in the monetary transmission process has revived. The current debate – see Bernanke and Gertler (1995), Cecchetti (1995), Hubbard (1995) and Mishkin (1995) – focuses on the credit channel, which assigns banks a pivotal 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.<sup>1</sup> 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.

As Bernanke and Gertler (1995) and Hubbard (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.

A number of studies have sought to establish whether the credit channel is operating besides the interest rate channel by employing aggregate data. Using vector autoregression (VAR) analysis, many studies have shown that bank loans decline after a monetary policy contraction, but they have failed to establish whether the drop is driven by loan supply or loan demand effects. While the credit channel emphasizes a shift in loan supply, the interest rate channel stresses a shift in loan demand that stems from a policy-induced decline in real activity. Distinguishing between these predictions is a difficult task, as *"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).

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<sup>1</sup>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. Banks as financial intermediaries are special in gathering and distilling information, which enables them to make loans to these borrowers at more favorable terms.

In light of the ambiguity, several studies have explored heterogeneity across agents by moving from aggregate data to disaggregated data. For the U.S., Gertler and Gilchrist (1993, 1994), Oliner and Rudebusch (1995) and Gilchrist and Zakrajsek (1995) use panel data of a large number of business firms. From this research it appears that firms of different size encounter different financial constraints after a monetary contraction. Kashyap and Stein (1995, 2000) investigate panel data at the individual bank level. They observe that monetary policy particularly affects the lending behaviour of small banks with less liquid balance sheets. Kishan and Opiela (2000) report a similar finding by approximating bank lending activities on the basis of bank size and bank capital.

So far, various studies on the credit channel in Germany – implemented e.g. by Tsatsaronis (1995), Barran, Coudert and Mojon (1997), Guender and Moersch (1997), Worms (1998, 2001a and 2001b), De Bondt (1999a, 1999b), Küppers (2000), Ehrmann (2000), Kakes, Sturm and Maier (2001), von Kalckreuth (2001), Kakes and Sturm (2002) and Holtemöller (2002) – have employed aggregate and disaggregated data, but reported contrary results. While some of these studies find evidence in support of the credit channel, others conclude that the credit channel is ineffective.

This paper aims at exploring the credit channel in Germany by means of a structural analysis of aggregate bank loan data.<sup>2</sup> We begin our analysis by presenting a stylized model of the banking firm, which specifies the loan supply decisions of banks when monetary policy is implemented through an interest rate targeting.<sup>3</sup> 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 loan supply and loan demand relationships by imposing restrictions on cointegrating vectors. The short-run dynamics of the VECM is investigated on the basis of impulse response analysis, which draws out the impact of a monetary policy shock. The main implication of our results is that the credit channel in Germany seems to be effective, as we

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<sup>2</sup>The analysis is based on Hülsewig, Winker and Worms (2001), but differs with regard to the selected variables.

<sup>3</sup>Notice that the conventional framework underpinning the credit channel presumes that monetary policy is conducted in the form of a monetary base control. Since central banks – almost everywhere – implement their policies by steering short-term money market rates, this presumption is a major impediment when analyzing the effects of monetary policy measures.

find that loan supply effects in addition to loan demand effects contribute to the propagation of monetary policy actions.

The remainder of this paper is organized as follows. Section 2 offers a simple model of the banking firm that establishes the basis for our empirical testing. Applying the Johansen procedure, Section 3 sets out a VECM analysis of the German loan market, which takes into account nonstationary time series. After a brief discussion of the methodology, we introduce the data base and present our results. Section 4 provides concluding remarks.

## 2 A Stylized Model of the Banking Firm

Analyzing the behavior of banks in the transmission of monetary policy may hold the key to explaining how monetary policy actions are propagated to the economy. In the following model, we specify the loan supply decisions of banks in the light of expectations about the future course of monetary policy that is implemented through an interest rate targeting. With banks caring about the future trend of monetary policy, the manner they pass on monetary disturbances has a bearing on the propagation of monetary policy measures. The model refers to Bofinger (2001) and Cosimano (1988).<sup>4</sup> Similar approaches have been developed by Elyasiani, Kopecky and van Hoose (1995), Bofinger and Schächter (1995) and Mitusch and Nautz (2001).<sup>5</sup>

### 2.1 Structure of the Model

Suppose there is a banking system with many identical banks that act as price takers. Banks grant loans to nonbanks ( $L_t$ ), which they finance with deposits

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<sup>4</sup>The model extends the approaches of Bofinger (2001) and Cosimano (1988) 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.

<sup>5</sup>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, which gives rise to a 'bank capital channel' by which monetary policy affects bank lending through its impact on bank equity capital.

( $D_t$ ) and central bank credits ( $B_t$ ) after subtracting required reserves ( $R_t$ ). 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  $i$ , profit at time  $t + j$  is given by:

$$\pi_{t+j}^i = r_{t+j}^L L_{t+j}^i - r_{t+j}^D D_{t+j}^i - r_{t+j}^M (B_{t+j}^i - R_{t+j}^i) - C_{t+j}, \quad (1)$$

where:

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

Note that equation (1) is defined for  $j = 0, 1, 2, \dots$

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:

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

where ( $a$ ) is a positive constant. The costs of administering the loan portfolio 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 reshuffle the amount of resources devoted to these activities.<sup>6</sup> Assume the banking sector comprises ( $n$ ) banks with identical cost functions.

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<sup>6</sup>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.

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

$$V_t^i = E_t \sum_{j=0}^{\infty} \beta^j \pi_{t+j}^i, \quad (3)$$

where  $(E_t)$  is the expectation operator conditioned on the information set  $(I_t)$  disposable at time  $t$ , and  $(\beta)$  is the 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:

$$L_{t+j}^i + R_{t+j}^i = D_{t+j}^i + B_{t+j}^i, \quad (4)$$

where minimum reserves are given by:  $R_{t+j}^i = dD_{t+j}^i$ , with  $(d)$  denoting the reserve ratio ( $0 < d < 1$ ). Minimum reserves are remunerated at the policy-controlled money market rate ( $r_{t+j}^M$ ). Following traditional reserve management models, we assume that a single bank takes its level of deposits ( $D_{t+j}^i$ ) as given (see e.g. Klein, 1971; Baltensperger, 1980). Depending on stochastic flows, the bank adjusts its net position on the interbank money market ( $B_{t+j}^i$ ) according to the balance sheet constraint to meet cash withdraws and reserve requirements.<sup>7</sup> Therefore, we expect the deposit rate ( $r_{t+j}^D$ ) to adjust to the interbank money market rate ( $r_{t+j}^M$ ) due to arbitrage conditions (Freixas and Rochet, 1997, p. 57).<sup>8</sup>

## 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

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<sup>7</sup>Note that for a single bank the net position on the interbank market ( $B_{t+j}^i$ ) 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 ( $B_{t+j}$ ) is positive (as regards the liability side of the aggregate bank balance sheet), since the interbank positions of all banks sum up to zero.

<sup>8</sup>At the aggregate level, we assume that the volume of deposits ( $D_{t+j}$ ) of the banking sector is determined by the aggregate stock of loans ( $L_{t+j}$ ) and attached to the amount of central bank refinancing ( $B_{t+j}$ ) via the usual money multiplier (see e.g. Bofinger, 2001 and Mitusch and Nautz, 2001).



and conditional on the set of available information. The first order-condition for optimal loan supply is given by:

$$r_{t+j}^L - a(L_{t+j}^i - L_{t+j-1}^i) + a\beta E_{t+j}(L_{t+j+1}^i - L_{t+j}^i) - r_{t+j}^M = 0, \quad (5)$$

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. Note that the first-order condition is valid for  $j = 0, 1, 2, \dots$ ; when  $j = 0$  the variables refer to the presently observed and expected values.

Since the bank grants loans in the light of expectations about the future course of the loan and the policy rate, optimal loan supply is given by:<sup>9</sup>

$$L_{t+j}^i = L_{t+j-1}^i + a^{-1} \sum_{s=0}^{\infty} \beta^s E_{t+j}(r_{t+j+s}^L - r_{t+j+s}^M), \quad (6)$$

for  $j = 0, 1, 2, \dots$ . Optimal loan supply is raising with an expected increase in the loan rate and falling with an expected increase in the policy rate.<sup>10</sup> 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.

## 2.3 Loan Market Repercussions

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

$$L_t = L_{t-1} + na^{-1} \sum_{s=0}^{\infty} \beta^s E_t(r_{t+s}^L - r_{t+s}^M), \quad (7)$$

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

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<sup>9</sup>The procedure for the solution of the first-order condition is taken from Sargent (1979, pp. 195–200, 333–345). See the Appendix for the details of the technique used to obtain the solution (6) and the other solutions presented in the following.

<sup>10</sup>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:

$$L_t = L_{t-1} + b_0 - b_1 r_t^L + u_t, \quad (8)$$

where  $(b_0)$  is a positive parameter and  $(u_t)$  is a serially uncorrelated random variable, which is white noise with zero mean and variance  $(\sigma_u^2)$ . The parameter  $(b_1)$ , with  $0 < b_1 < \infty$ , is the interest elasticity of aggregate loan demand. A higher  $(b_1)$  means that the demand for loans is less sensitive to changes in the loan rate, i.e. in the borderline case:  $b_1 \rightarrow 0$ , aggregate loan demand is completely inelastic with respect to the interest rate on loans.

The loan market equilibrium is characterized by the equilibrium loan volume and the equilibrium loan rate. The equilibrium in the loan market is described by (for  $j = 0$ ):<sup>11</sup>

$$L_t = L_{t-1} + n(a\beta)^{-1} \left[ (\lambda - 1)^{-1} B_0 - \lambda^{-1} \sum_{s=0}^{\infty} \left( \frac{1}{\lambda} \right)^s E_t r_{t+s}^M \right], \quad (9)$$

where  $B_0 = b_0/b_1$  and  $\lambda = (na^{-1}B_1 + 1)\beta^{-1}$ , with  $B_1 = 1/b_1$ . The equilibrium loan volume decreases with an expected future increase in the policy rate. Substituting the equilibrium loan level (9) into the loan demand equation (8) gives the equilibrium loan rate.

Since banks need time to adjust their loan portfolio, the forecast of the future trend of the policy rate is a crucial factor. Suppose the central bank reverts to an interest rate control rule, which is designed to dampen fluctuations in interest rates (Goodfriend, 1987; Cukierman, 1991). The banks' forecast of the policy rate may then be based upon:

$$r_{t+1}^M = \delta r_t^M + \eta_{t+1}, \quad |\delta| < 1/\beta$$

where the error  $(\eta_{t+1})$  is a serially uncorrelated variable, which is white noise with zero mean and variance  $(\sigma_\eta^2)$ .

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<sup>11</sup>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  $j = 0$ .

Substituting the forecast expression into the loan market equilibrium, gives the reduced form for aggregate loans as:

$$L_t = L_{t-1} + c_0 - c_1 r_t^M, \quad (10)$$

where  $c_0 = B_0 n(a\beta)^{-1}(\lambda - 1)^{-1}$  and  $c_1 = n(a\beta)^{-1}(\lambda - \delta)^{-1}$ .

If the banks forecast an increase in the expected rate of growth of the policy rate ( $\ln(\delta)$ ), then there is an increase in the impact monetary policy has on the volume of loans, since a change in the policy rate is expected to persist for a longer period of time.<sup>12</sup> Substituting expression (10) into the demand for loans equation (8) and rearranging terms, gives the equilibrium loan rate:

$$r_t = B_0 - B_1 c_0 + B_1 c_1 r_t^M, \quad (11)$$

which indicates that the loan rate is tied to the present value of the policy rate and the expected rate of growth of the policy rate. 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.<sup>13</sup>

A final point concerns the role of the business cycle. If aggregate loan demand is assumed to be a function of the level of economic activity, then the loan market equilibrium is dependent upon the present and expected future output level. If economic activity is included in the demand for loans, then the parameter ( $b_0$ ) in equation (8) is replaced by the expectations of all future values of the output level (see e.g. Cosimano, 1988). A forecasted increase in the future level of economic activity then increases the equilibrium loan level and has an ambiguous effect on the equilibrium loan rate.

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<sup>12</sup>This can be seen by rewriting equation (10) according to:

$$L_t = L_0 + t c_0 - c_1 \sum_{s=0}^{t-1} r_{t-s}^M, \quad t \geq 1,$$

which shows that the present equilibrium loan level depends on the initial equilibrium loan level ( $L_0$ ) and the present and previous values of the policy rate. See also Cosimano (1988).

<sup>13</sup>The stickiness of loan rates is well-documented in the literature. Evidence for a sluggish loan rate adjustment has been provided e.g. by Cottarelli and Kourelis (1994), Borio and Fritz (1995), Mojon (2000), Toolsema, Sturm and de Haan (2001), Deutsche Bundesbank (2002) and Weth (2002) for several industrialized countries.

## 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, which stems from the existence of adjustment costs. 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 actions. This prediction is tested in the following section by means of a structural analysis of time series properties of aggregate bank loan data.

## 3 Bank Lending and Monetary Policy Transmission: A VECM Analysis

### 3.1 Methodology

The Johansen (1988) approach provides a statistical framework, which allows to analyze long-term relationships between nonstationary time series in a dynamic specification.<sup>14</sup>

Consider a standard vectorautoregression (VAR) model in levels:

$$X_t = \Pi_1 X_{t-1} + \dots + \Pi_k X_{t-k} + \Phi D_t + \varepsilon_t, \quad (12)$$

with  $t = 1, \dots, T$ ,

where  $X_t$  is a  $p$ -dimensional vector of endogenous variables, which are assumed to be  $I(1)$ , and  $\varepsilon_t$  is a  $p$ -dimensional vector of independent identically distributed error terms with the covariance matrix  $\Lambda$ , i.e.  $\varepsilon_t \sim N(0, \Lambda)$ . The  $\Pi_i$  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

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<sup>14</sup>See Johansen (1988, 1995), Johansen and Juselius (1990, 1994), Lütkepohl (1999), McAleer and Oxley (1999) or Pesaran and Smith (1999) for an illustration and discussion.

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

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \varepsilon_t, \quad (13)$$

where:

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

for  $i = 1, \dots, k-1$

and

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

and  $\Delta = 1-L$ , with  $L$  denoting the lag operator. The  $\Pi$  and  $\Gamma_i$  are parameter matrices.<sup>15</sup> The statistical hypothesis of cointegration is formulated as a reduced rank of the matrix  $\Pi$ :

$$H(r) : \text{rank}(\Pi) = r, \quad r < p.$$

Under this hypothesis,  $\Pi$  can be written as:  $\Pi = \alpha\beta'$ , where  $\alpha$  and  $\beta$  are  $p \times r$  matrices of full rank. Here, the elements of  $X_t$  are  $I(1)$  and cointegrated with  $\text{rank}(\Pi) = r$ , which means there are  $r < p$  linear combinations of  $X_t$  that are  $I(0)$ . The hypothesis  $H(r)$  therefore implies that the process  $\Delta X_t$  is stationary,  $X_t$  is nonstationary, but  $\beta'X_t$  is stationary (Johansen, 1991, pp. 1552–1553). The  $\beta$  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  $\alpha$  represent the factor loadings that measure the average speed of adjustment of each variable in the direction of the long-run equilibrium.<sup>16</sup>

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<sup>15</sup>The  $\Gamma_i$  ( $i = 1, \dots, k-1$ ) are often referred to as the short-term parameters and  $\Pi X_{t-1}$  is sometimes called the long-term part (Lütkepohl, 1999, p. 4).

<sup>16</sup>There are two situations where the VECM representation becomes superfluous. First, if matrix  $\Pi$  has full rank, i.e.  $\text{rank}(\Pi) = p$ , which implies that all variables in  $X_t$  are  $I(0)$ . Here, the appropriate strategy is to estimate the VAR in levels (12), because there is no problem of spurious regression otherwise associated with the analysis of nonstationary variables. Second, if matrix  $\Pi$  is the null matrix, i.e.  $\text{rank}(\Pi) = 0$ , 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 (13) corresponds to a VAR in first differences involving no long-run relationships (Johansen and Juselius, 1990, p. 170).

In a VECM under cointegration (i.e.:  $0 < r < p$ ), an identification problem arises, since the parameters in  $\alpha$  and  $\beta$  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  $\beta^{*'} = P^{-1} \beta'$  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 on 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.<sup>17</sup>

### 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 national accounting data base of 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 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 unification, which is reflected in the data in the second quarter of 1990, causes a shift in both monetary and real aggregates that 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.<sup>18</sup>

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<sup>17</sup>This point has been made clear by Kakes (2000, p. 81).

<sup>18</sup>See the notes in the statistical part of the monthly reports and the banking statistics of the German Bundesbank.

The analysis includes bank loans to domestic private firms and households expressed in real terms (**LOANS**), deflated by the GDP deflator. Supply side factors of the loan market are covered by the banks' equity position (**EQUITY**), also expressed in real terms.<sup>19</sup> 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). 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.<sup>20</sup>

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 suitable data for the interest rate on loans in Germany is unavailable over the sample period covered by our empirical analysis. 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 consist 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).

Since the monetary framework of the German Bundesbank was designed to signal monetary policy intentions by steering short-term money market rates, we use the three-month money market rate ( $r^M$ ) as an indicator for the stance of monetary policy. The real side of the economy is mirrored by the private share 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.

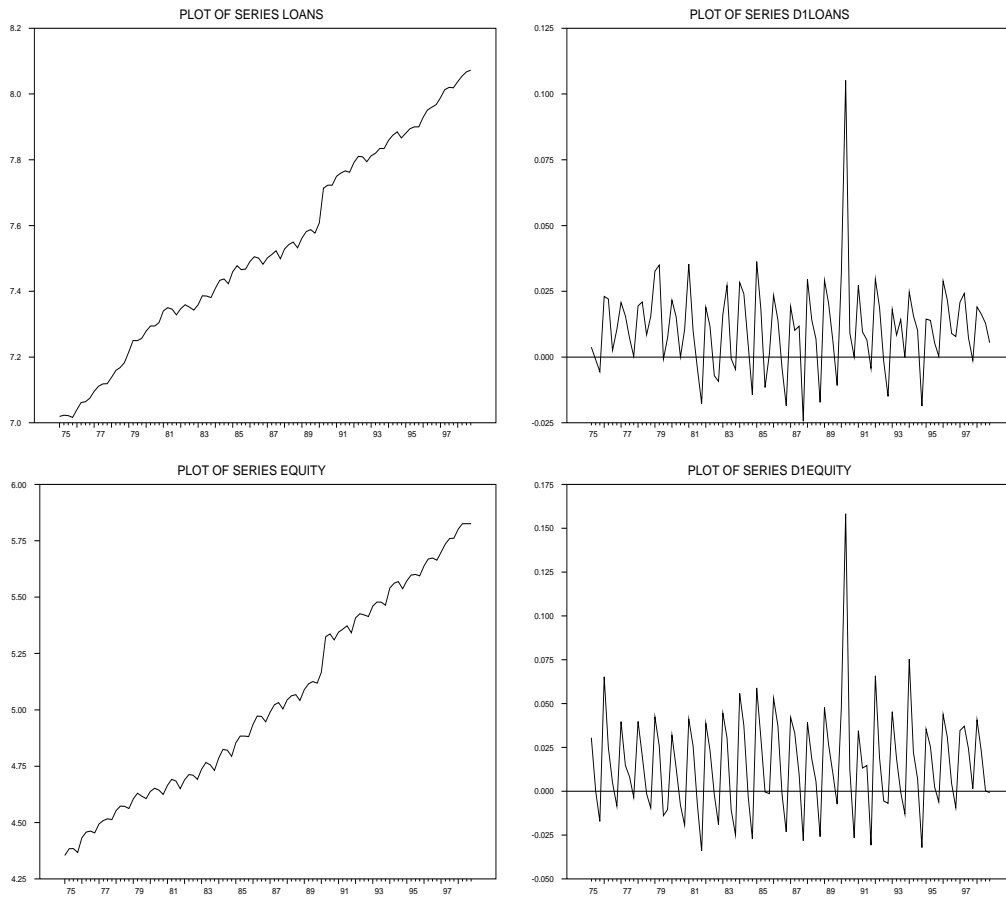
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<sup>19</sup>While equity is an important factor that can be attributed to loan supply rather than loan demand, an alternative approach using the deposit volume instead of equity as a scale variable may at such an aggregate level lead to correlations that are merely due to the balance sheet identity and may therefore not adequately describe structural relationships.

<sup>20</sup>However, it should be borne in mind that the volume bank capital as it appears in the bank balance sheet is solely a rough indicator for the volume of liable equity subject to the Basle Accord (1988).

The time series are summarized in Figure 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. Exploring the time series properties by means of unit root tests shows that all time series can be treated as integrated of order one, i.e.  $I(1)$ . Visual inspection of the levels and first differences seems to support this result.<sup>21</sup>

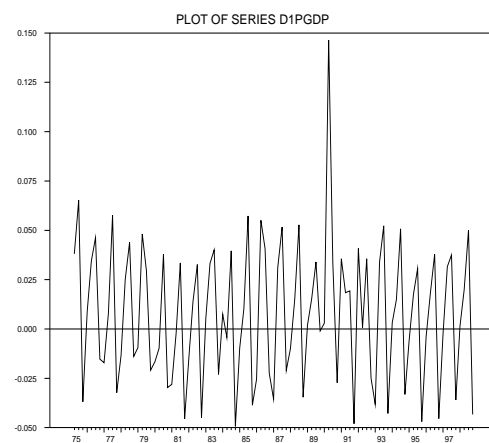
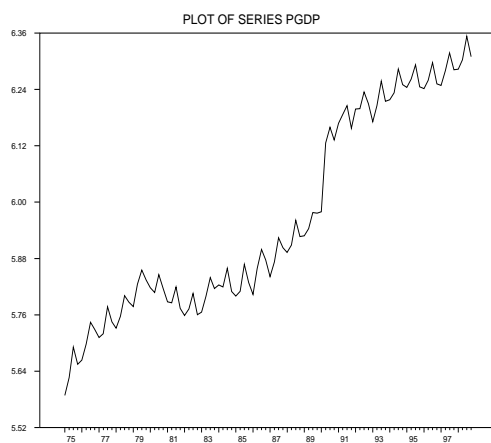
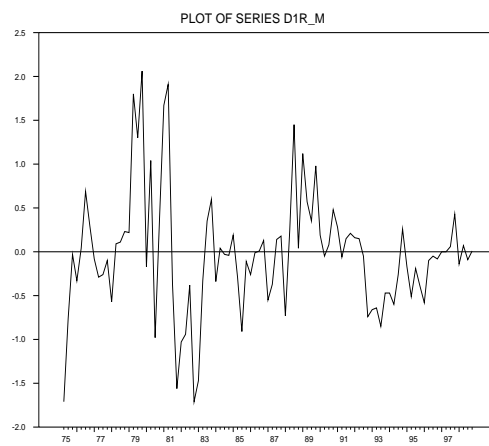
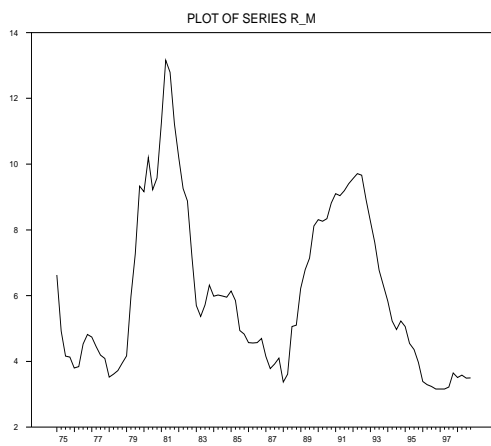
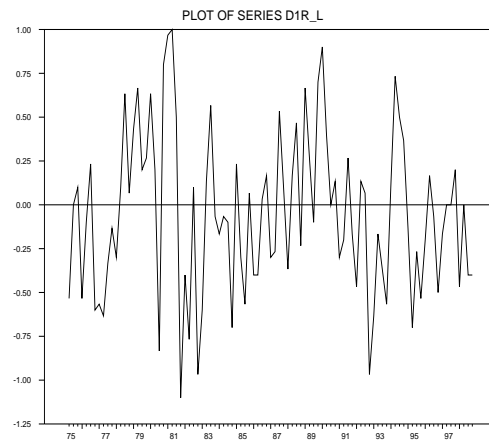
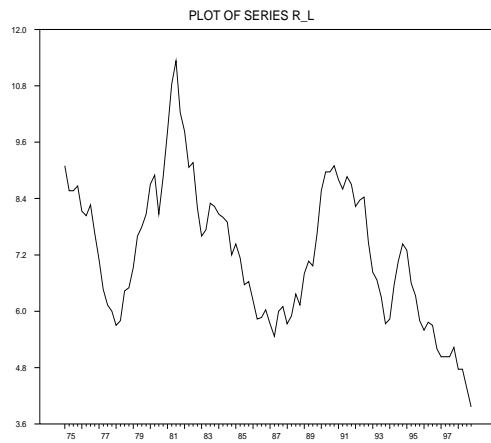
Figure 1: Time Series in Levels and First Differences




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<sup>21</sup>The results of the unit root tests are not reported here, but available from the author upon request.





### 3.3 Results of the VECM Analysis

Our VECM analysis comprises five variables including the credit volume.<sup>22</sup> 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 share 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 potential structural breaks in the data due to the German unification that is reflected in the data in the second quarter of 1990, and due to the new classification scheme of the industrial sector that emerges in the first quarter of 1995.<sup>23</sup> 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 rank test are summarized in Table 1, which shows the reduced rank statistics. Critical values have been taken from Johansen (1995)

Table 1: Test of Cointegration Rank

Rank	Trace	Critical Value 90% Level
0	69.25	64.74
$\leq 1$	45.29	43.83
$\leq 2$	24.88	26.70
$\leq 3$	12.16	13.31

Estimated eigenvalues: 0.2293, 0.1990, 0.1291, 0.0925.

that should be appropriate since the impact of small impulse dummies on the asymptotic distribution of the rank test is usually negligible (Doornik, Hendry and Nielsen, 1999, p. 135).

Based on the trace test, we adopt a rank of  $r = 2$ , which means that we

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<sup>22</sup>All tests presented in the following have been carried out with the software packages CATS in RATS version (1.0) and MALCOLM 2.2.

<sup>23</sup>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.

have to find two independent long-term relationships in order to identify the cointegration space. Table 2 reports the multivariate test statistics, which show that the model is statistically well-specified.<sup>24</sup>

Table 2: 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).

The characteristic roots of the system are all inside the unit circle, which assures that the system is stable, i.e. that it converges to the long-run equilibrium (Hansen and Juselius, 1995, pp. 28–29). The unrestricted cointegration relationships are documented in Table 3.

Table 3: 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 summarizes the outcome after imposing all identifying restrictions.

The rows in Table 4 show the following long-run relationships, which we

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<sup>24</sup>Notice that the tests for misspecification have also been carried out for the restricted vector autoregression model, which have indicated similar results.

Table 4: 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:<sup>25</sup>

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

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

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.

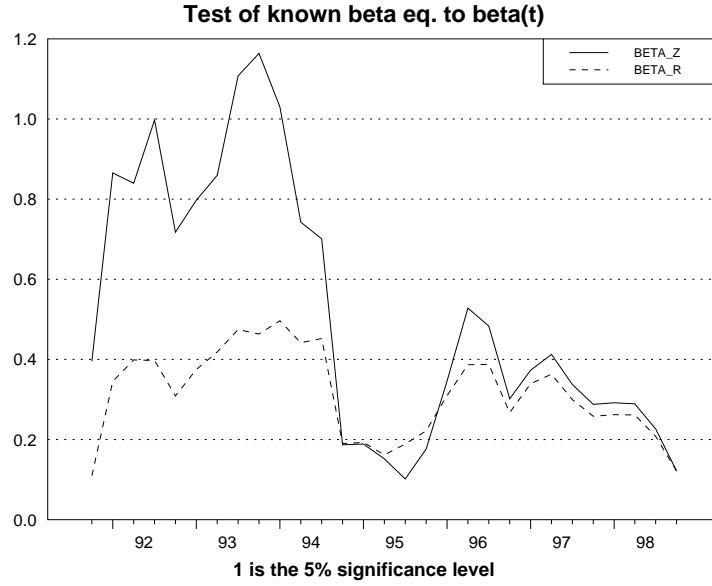
Assessing the stability of the cointegration space throughout time, we have recursively tested the hypothesis that the full sample estimate of  $\hat{\beta}$  with the

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<sup>25</sup>Standard errors are reported in parentheses.

overidentifying restrictions imposed is contained in the space spanned by  $\beta$  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.<sup>26</sup> The results are summarized in Figure 2. While the

Figure 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.

For each variable, Table 5 reports the corresponding factor loadings, which are stored in the loading matrix  $\alpha$ . The loading parameters indicate the speed of adjustment towards the long-run equilibrium relationships if deviations

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<sup>26</sup>Hansen and Juselius (1995) suggest not to chose the smallest possible sample as the base period. In our analysis we have considered different base periods, which have all indicated identical results.

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 5: Loading Matrix

	$\Delta \text{PGDP}$	$\Delta \text{LOANS}$	$\Delta r^L$	$\Delta r^M$	$\Delta \text{EQUITY}$
(I)	0.01 (0.04)	-0.01 (-1.56)	1.05 (3.42)	0.07 (0.18)	-0.01 (-1.16)
(II)	-0.01 (-1.44)	-0.01 (-1.73)	-1.10 (-4.75)	-0.71 (-2.24)	-0.01 (-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  $\alpha$  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  $\beta$ . The likelihood ratio tests on joint zero restrictions on  $\alpha$  are documented in Table 6 and have been carried out (i) without imposing restrictions on  $\beta$  and (ii) with imposing simultaneous overidentifying restrictions on  $\beta$ . The tests show that while the null hypothesis of weak exogeneity can be rejected for aggregate loans and the interest rates, it cannot be rejected for the private share of real GDP and the equity position.<sup>27</sup> However, including PGDP and EQUITY as exogenous variables has no impact on our results.

Our analysis does not precisely indicate how the adjustment process to the

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<sup>27</sup>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 6: Tests on Weak Exogeneity

	$\chi^2(2)$	p-value	$\chi^2(4)$	p-value
$\Delta\text{PGDP}$	2.20	0.33	4.74	0.31
$\Delta\text{LOANS}$	7.63	0.02	12.19	0.02
$\Delta r^L$	10.26	0.01	11.20	0.02
$\Delta r^M$	5.25	0.07	9.05	0.06
$\Delta\text{EQUITY}$	1.51	0.47	4.42	0.35

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

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 drawing out the impact of a monetary policy shock.

### 3.4 Impulse Response Analysis

Within the vectorautoregression (VAR) framework, impulse response 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 assumptions. According to Lütkepohl and Reimers (1992), impulse response analysis is also valuable in cointegrated systems.

Proceeding with our VECM analysis, we generate impulse response functions in order to investigate the reaction of the variables in the system to a

monetary policy shock. We identify the monetary policy shock by imposing a triangular orthogonalization on the short-run dynamics corresponding to the following order: the private share of real GDP, the volume of equity, the short-term interest rate, aggregate bank loans and the long-term interest rate. The ordering of the variables implies that an innovation in the policy instrument affects the private share of real output and the equity position with a lag of one quarter, while the loan volume and the long-term interest rate are possibly affected within the same quarter.<sup>28</sup>

Figure 3 depicts the impulse responses of the variables, which are interpreted as their reaction to an unexpected monetary contraction. 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 is reflected by a significant increase in the short-term interest rate of approximately 60 basis points in the first three quarters. From then on the short-term rate follows a mean reverting process and returns to a level not significantly different from zero within ten quarters.

Aggregate bank loans slightly raise, 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, 2001), who investigate the response of aggregate bank lending in Germany in a similar framework using monthly and quarterly data. The decrease in bank loans continues until the end of the simulation period. From then aggregate loans remain roughly 0.75 percent below the baseline value. The private share of real output slightly exceeds the base level in the first three quarters, then falls and remains approximately 0.5 percent below the baseline value after around eight quarters when the monetary 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.

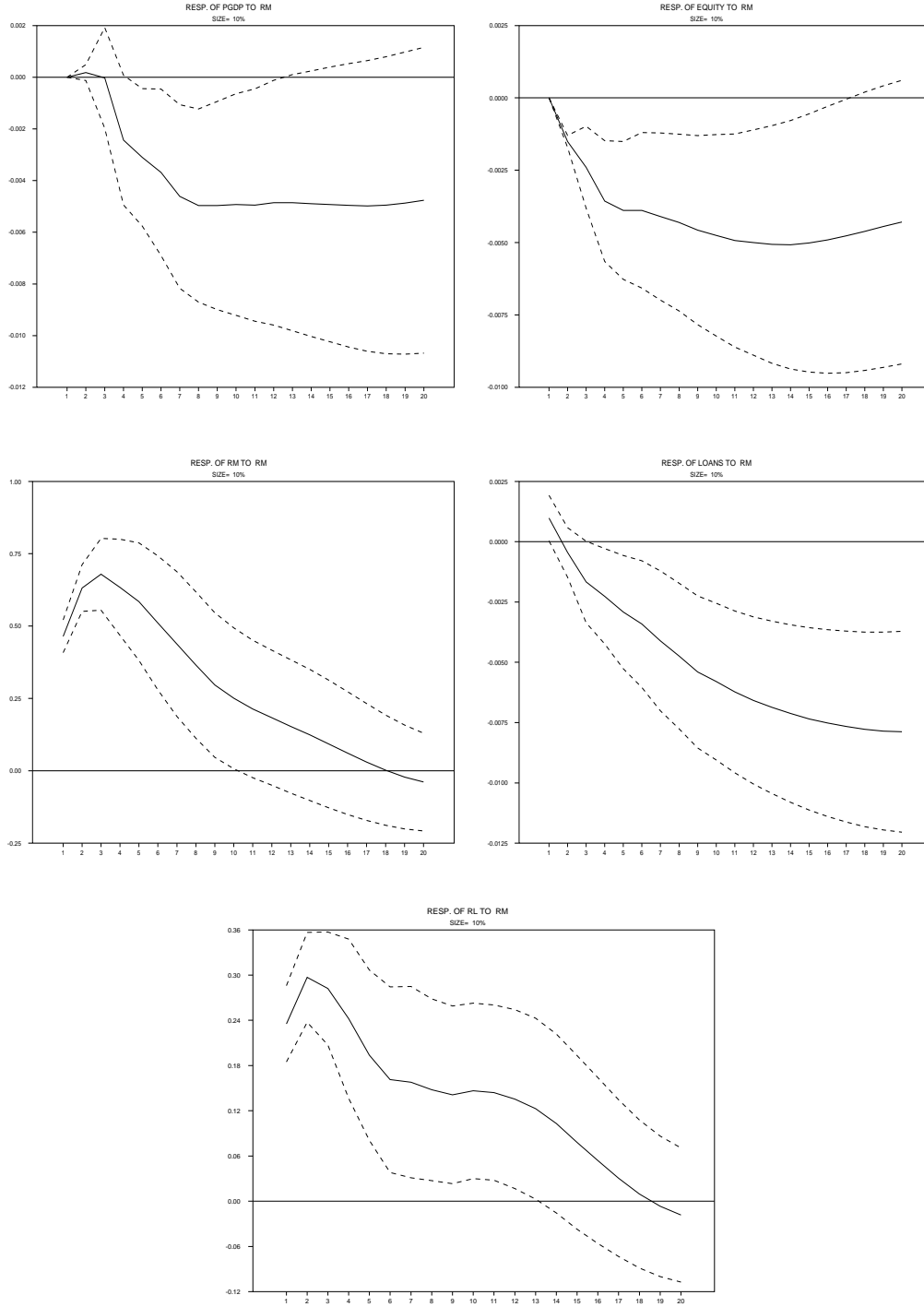
Our findings suggest that bank decrease their loan supply by degrees with

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<sup>28</sup>Notice that the ordering of the variables is based on the results of the tests on weak exogeneity.



Figure 3: Impulse Response Functions



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. Loan demand by firms and households – as captured by movements in the private share of real GDP and the long-term interest rate – declines gradually in the long term, whereas in the short term the adjustment is ambiguous, since PGDP is initially raising 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) – might 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 share of real output.

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 a perverse short-run adjustment of loan demand is not inconsistent with the credit channel, as it does not require that firms and households reduce their borrowing after 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).

## 4 Conclusions

This paper has explored the existence of the credit channel in the transmission of monetary policy 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. 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 share of real output and the loan interest rate. The short-run dynamics of the system has shown that in case aggregate 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.

The main implications of our results is that the credit channel in Germany appears to be operating, 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. Our analysis suggests that banks decrease their loan supply gradually after a restrictive shift in monetary policy, while loan demand by firms and households declines in the long run, but increases in the short run. The initial rise in loan demand might reflect that firms and households seek to reshuffle their structure of indebtedness or to smooth a decline in income during recessions by accessing additional external finance. Since our analysis is 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 facilitate a deeper insight in the transmission mechanism of monetary policy.

## Appendix

### A 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  $x$ .

#### A.1 Optimal Loan Supply of a Single Bank

Optimal loan supply of a single bank is found by rewriting the first-order condition (5) as:

$$\beta E_{t+j}L_{t+j+1}^i - (1 + \beta)L_{t+j}^i + L_{t+j-1}^i = -a^{-1}(r_{t+j}^L - r_{t+j}^M), \quad (\text{A.1})$$

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

$$\beta \left[ 1 - \frac{1+\beta}{\beta} H + \frac{1}{\beta} H^2 \right] E_{t+j} L_{t+j+1}^i = -a_2^{-1} Y_{t+j}, \quad (\text{A.2})$$

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

$$\beta \left( 1 - \frac{1}{\beta} H \right) (1 - H) E_{t+j} L_{t+j+1}^i = -a_2^{-1} Y_{t+j}, \quad (\text{A.3})$$

for  $(j = 0, 1, 2, \dots)$ .

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

The transversality condition is given by  $\lim_{T \rightarrow \infty} E_t \beta^T \{r_T^L - a(L_T^i - L_{T-1}^i) - r_T^M\} = 0$ , 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,  $\{r_{t+j}^L\}_{j=0}^{\infty}$ , and  $\{r_{t+j}^M\}_{j=0}^{\infty}$  are of exponential order less than  $1/\beta$ , i.e. for some  $K > 0$  and  $1 < X < 1/\beta$ ,

$$|E_t r_{t+j}^L| < K(X)^{t+j} \text{ and } |E_t r_{t+j}^M| < K(X)^{t+j}.$$

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

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

for  $j = 0, 1, 2, \dots$ .

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

$$L_{t+j+1}^i = L_{t+j}^i + (a\beta)^{-1} \sum_{s=1}^{\infty} \beta^s E_{t+j+1} Y_{t+j+s}, \quad (\text{A.5})$$

for  $j = 0, 1, 2, \dots$ . Equation (6) follows by substituting in (A.5) the appropriate value for  $Y_{t+j+s}$  and redefining the index from  $t+j+1$  to  $t+j$ .

According to Sargent (1979, pp. 199), a sufficient condition, which assures the transversality condition for loans, is to show that  $\sum_{s=0}^{\infty} \beta^s E_{t+j} Y_{t+j+s}$  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  $1/\beta$ ,

$$\sum_{s=0}^{\infty} \beta^s E_{t+j} Y_{t+j+s} < \sum_{s=0}^{\infty} \beta^s [K(X)^{t+j+s} + K(X)^{t+j+s}], \quad (\text{A.6})$$

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

$$\sum_{s=0}^{\infty} \beta^s E_{t+j} Y_{t+j+s} < \frac{2K}{1 - \beta X} (X)^{t+j}, \quad (\text{A.7})$$

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

## A.2 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 (9) can be derived by means of the following steps. Multiplying equation (A.1) with  $n$  and setting  $j = 0$  gives:

$$\beta E_t L_{t+1} - (1 + \beta) L_t + L_{t-1} = -na^{-1}(r_t^L - r_t^M). \quad (\text{A.8})$$

Next solve the demand for loans equation (8) for the loan rate:

$$r_t^L = B_0 - B_1(L_t - L_{t-1}), \quad (\text{A.9})$$

where  $B_0 = b_0/b_1$  and  $B_1 = 1/b_1$ ,<sup>29</sup> and substitute  $r_t^L$  into equation (A.8), to obtain:

$$\begin{aligned} \beta E_t L_{t+1} &- (\beta + na^{-1}B_1 + 1)L_t \\ &+ (na^{-1}B_1 + 1)L_{t-1} = -na^{-1}(B_0 - r_t^M). \end{aligned} \quad (\text{A.10})$$

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<sup>29</sup>Notice that the random variable  $u_t$  is neglected.

Applying the expectation lag operator yields:

$$\beta \left[ 1 - \left( 1 + \frac{\omega}{\beta} \right) H + \frac{\omega}{\beta} H^2 \right] E_t L_{t+1} = -na^{-1}(B_0 - r_t^M), \quad (\text{A.11})$$

where  $\omega \equiv (na^{-1}B_1 + 1)$ . Now factor the left side of equation (A.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 (A.11) and applying the forward solution as in (A.4) yields:

$$E_t L_{t+1} = L_t + n(a\beta)^{-1} \sum_{s=1}^{\infty} \left( \frac{1}{\lambda} \right)^s E_t (B_0 - r_{t+s}^M). \quad (\text{A.12})$$

Equation (A.12) can be rewritten by expanding the information set from  $I_t$  to  $I_{t+1}$  and noting that  $\sum_{s=1}^{\infty} (1/\lambda)^i = 1/(\lambda - 1)$ , since  $\lambda > 1$ . Equation (9) follows if the index is changed from  $t + 1$  to  $t$ , we have:

$$L_t = L_{t-1} + n(a\beta)^{-1} \left[ (\lambda - 1)^{-1} B_0 - \lambda^{-1} \sum_{s=0}^{\infty} \left( \frac{1}{\lambda} \right)^s E_t r_{t+s}^M \right]. \quad (\text{A.13})$$

Substituting the equilibrium loan level into the demand for loan equation (A.9), gives the equilibrium loan rate:

$$r_t^L = B_0 - B_1 n(a\beta)^{-1} \left[ (\lambda - 1)^{-1} B_0 - \lambda^{-1} \sum_{s=0}^{\infty} \left( \frac{1}{\lambda} \right)^s E_t r_{t+s}^M \right]. \quad (\text{A.14})$$

Assuming that the forecast of the future policy rate depends on the interest rate control rule of the central bank:  $r_{t+1}^M = \delta r_t^M + \eta_{t+1}$ , where  $|\delta| < 1/\beta$ , then expression (A.14) can be written as:

$$r_t^L = B_0 - B_1 c_0 + B_1 c_1 r_t^M, \quad (\text{A.15})$$

where  $c_0 = B_0 n(a\beta)^{-1}(\lambda - 1)^{-1}$  and  $c_1 = n(a\beta)^{-1}(\lambda - \delta)^{-1}$ .

## B 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 share 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.

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