Bank Loan Supply and Monetary Policy Transmission in Germany:

An Assessment based on Matching Impulse Responses[*]

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Abstract

This paper addresses the credit channel in Germany by using aggregate data. We present a stylized model of the banking firm, in which banks decide on their loan supply in the light of uncertainty about the future course of monetary policy. Applying a vector error correction model (VECM), we estimate the response of bank loans after a monetary policy shock in consideration of the reaction of the output level and the loan rate. We estimate our model to characterize the response of bank loans by matching the theoretical impulse responses with the empirical impulse responses to a monetary policy shock. Evidence in support of the credit channel can be reported.

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1   Introduction

The credit channel assigns banks a pivotal role in the transmission of monetary policy, which stems from the notion that financial markets are characterized by imperfections.[1] Banks are special in extending credit to borrowers – that cannot access other types of credit – because of their expertise in mitigating 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 some borrowers have to rearrange their expenditure decisions.[2]

As Bernanke and Gertler (1995) and Hubbard (1995) point out, the credit channel is 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, the credit channel and the interest rate channel diverge in assessing the relevance of financial considerations, they are deemed complementary, with the implication that monetary policy can be effective through these transmission channels simultaneously.

In the spirit of Bernanke and Blinder (1992), a number of studies based on vectorautoregression (VAR) analysis have examined whether the credit channel is operating besides the interest rate channel by using aggregate data. Many studies have shown that bank loans decline after a monetary policy shock, but these findings are plagued by a severe identification problem, as it remains unclear 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, which 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).

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), Gilchrist and Zakrajsek (1995) and Oliner and Rudebusch (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 tightening. Kashyap and Stein (2000) investigate panel data at the individual bank level. They observe that monetary policy particularly affects the

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[1]See Bernanke and Gertler (1995), Cecchetti (1995) or Hubbard (1995) for a survey of the credit channel of monetary policy transmission.

[2]This idea centers on the assumption 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 specialize in gathering and distilling information, which enables them to make loans to these borrowers at more favorable terms.

lending behavior 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, much work on the credit channel in Germany – implemented by Barran, Coudert, and Mojon (1997), De Bondt (2000), Ehrmann (2004), Ehrmann and Worms (2004), Holtemöller (2003), Hülsewig, Winker, and Worms (2004), Kakes and Sturm (2002), Küppers (2001), Von Kalckreuth (2003) and Worms (2003) – has 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. The vagueness in the results reflects in part the difficulty to separate the loan supply effects from the loan demand effects that follow a monetary contraction.

This paper addresses the credit channel in Germany by using aggregate data. We present a stylized model of the banking firm, which specifies the loan supply decision of banks in the light of uncertainty about the future course of monetary policy. Applying a vector error correction model (VECM), we estimate the response of bank loans to a monetary policy shock in consideration of the reaction of the output level and the loan rate. We use our model as a guide to characterize the response of bank loans – i.e. to decompose the adjustment of bank loans into the parts that can be attributed to loan supply and loan demand – by matching the theoretical impulse responses with the empirical impulse responses to a monetary policy shock. In this vein, the identification problem inherent in reduced–form approaches based on aggregate data is explicitly addressed.[3]

Our findings suggest that the credit channel is operating besides the interest rate channel. Banks decrease their loan supply with an expected drop in their credit margin after a monetary policy shock, while loan demand declines with a drop in the output level and a rise in the loan rate. The decrease in loan supply occurs instantly and bottoms out gradually. The decrease in loan demand proceeds by degrees and continues persistently.

The remainder of this paper is organized as follows. Section 2 presents our model of the banking firm, which establishes the basis for our testing. Section 3 sets out the empirical results, which are derived by adopting a two step procedure. First, we estimate a VECM to generate impulse responses to a monetary policy shock. Second, we estimate our model by using a limited distance estimation, which matches the theoretical impulse responses with the empirical impulse responses. Section 4 provides concluding remarks.

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[3]To our knowledge separating loan supply effects from loan demand effects by matching impulse responses has not yet been proposed in the literature.

2   A Model of the Banking Firm

We base our analysis of the credit channel on a stylized model of the banking firm, in which banks decide on their loan supply when future monetary policy is uncertain. The model refers to Cosimano (1988). Similar approaches have been developed by Bofinger (2001), Elyasiani, Kopecky, and van Hoose (1995) and Mitusch and Nautz (2001).

2.1   Structure of the Model

Consider a banking system with many identical banks that act as price takers. Banks grant loans to nonbanks (L_t), which they finance with deposits (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.[4]

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

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

where:

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

Note that equation (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 adjusting the loan portfolio (C_{t+j}), which are represented by (see e.g. Cosimano, 1988):

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

where (a) is a positive constant. The costs of adjusting the loan portfolio can be thought of reflecting the allocation of resources necessary to evaluate the credit-worthiness of customers and to monitor loans during the duration. If the bank

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[4]Notice that throughout the paper we presume that monetary policy is implemented by the central bank in the form of an interest rate targeting procedure.

realizes a change in the size of its loan portfolio, this requires to reshuffle the amount of resources devoted to these activities. 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:

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

where (E_t) is the expectation operator conditioned on the information set (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. $E_t(x_{t+j}) \equiv E(x_{t+j}|I_t)$.

The maximization is subject to the balance sheet constraint:

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

where minimum reserves (R_{t+j}^i) are determined by: $R_{t+j}^i = dD_{t+j}^i$, with (d) denoting the minimum reserve ratio $(0 < d < 1)$. For a single bank the level of deposits (D_{t+j}^i) is assumed to be exogenously given (see e.g. Baltensperger (1980); Klein (1971)). Depending on stochastic flows, the bank adjusts its net position on the interbank money market (B_{t+j}^i) to meet the balance sheet constraint.[5] The deposit rate (r_{t+j}^D) is presumed to adjust to the interbank money market rate (r_{t+j}^M) in consideration of the minimum reserve ratio due to arbitrage conditions (Freixas and Rochet, 1997, p. 57).

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:[6]

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

which is raising with an expected increase in the loan rate and falling with an expected increase in the policy rate. 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.

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[5]Hence, for a single bank (B_{t+j}^i) can either be positive or negative depending on whether the bank borrows or lends on net at the prevailing interbank money market rate.

[6]The procedure used for deriving optimal loan supply is taken from Sargent (1979). See Appendix A for details.

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

$$r^L_{t+j} - a(L^i_{t+j} - L^i_{t+j-1}) + a\beta E_{t+j}(L^i_{t+j+1} - L^i_{t+j}) - r^M_{t+j} = 0, \tag{6}$$

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.

2.3 Loan Market Repercussions

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

$$L_t = L_{t-1} + na^{-1}\sum_{s=0}^{\infty} \beta^s E_t(r^L_{t+s} - r^M_{t+s}), \tag{7}$$

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

Aggregate loan demand is assumed to be given by:

$$L_t = b_1 y_t - b_2 r^L_t, \tag{8}$$

where (y_t) is the output level and (b_1) and (b_2) are positive parameters.[7] The demand for loans is raising with the output level and falling with the loan rate. The parameters (b_1) and (b_2) denote the income elasticity and the interest elasticity of aggregate loan demand.

The equilibrium in the loan market is characterized by the equilibrium loan level and the equilibrium loan rate. The equilibrium loan volume that maximizes the banks' present value is (for $j = 0$):[8]

$$L_t = \lambda_1 L_{t-1} + \lambda_1 na^{-1}\sum_{s=0}^{\infty} \lambda_2^{-s} E_t(B_1 y_{t+s} - r^M_{t+s}), \tag{9}$$

where λ_1 and λ_2 are positive characteristic roots, with $\lambda_1 < 1 < 1/\beta < \lambda_2$, and $B_1 = b_1/b_2$. The equilibrium loan volume increases with an expected future increase in the output level and decreases with an expected future increase in

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[7]Modelling loan demand in dependency of the output level and the loan rate is commonly accepted. See Bofinger (2001), Calza, Gartner, and Sousa (2003) or Kakes (2000) among others.

[8]Since the credit channel does not imply credit rationing, we assume – for the sake of simplicity – that the loan market clears by price (see e.g. Gertler and Gilchrist (1993)).

the policy rate. Substituting the equilibrium loan level (9) into the loan demand equation (8) yields the equilibrium loan rate:

$$r_t^L = B_1 y_t - B_2 \lambda_1 L_{t-1} - B_2 \lambda_1 n a^{-1} \sum_{s=0}^{\infty} \lambda_2^{-s} E_t(B_1 y_{t+s} - r_{t+s}^M), \qquad (10)$$

where $B_2 = 1/b_2$. The loan rate is raising with an expected increase in policy rate and falling with an expected increase in the output level.

2.4 Implications for Monetary Policy Transmission

Our stylized model implies that banks decide on their loan supply in the light of uncertainty about the future course of monetary policy. Loan supply by the banks declines with an expected fall in the credit margin after a monetary tightening, 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 predicted by the credit channel – this is equivalent with the notion that bank behavior can play a meaningful role in the propagation of monetary policy actions. We explore this prediction in the following section by assessing impulse responses to a monetary policy shock.

3 Empirical Results

As in Rotemberg and Woodford (1998) and Christiano, Eichenbaum, and Evans (2004), we estimate our model to evaluate the adjustment of bank loans to a monetary policy shock by using a two step procedure. In the first step, we estimate a VECM to derive empirical impulse responses. In the second step, we estimate the model by matching the theoretical impulse responses with the empirical impulse responses. The reaction of loan supply and loan demand to a monetary policy shock is determined on the basis of the estimated model parameters.

3.1 Empirical Impulse Responses

Following Johansen (1995) and Johansen and Juselius (1990), we employ a vector error correction model (VECM) of the form:

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{k=1}^{n-1} \Gamma_k \Delta Z_{t-k} + \Phi D_t + \varepsilon_t, \qquad (11)$$

where Z_t is a vector of endogenous variables, which are integrated of order one, i.e. $I(1)$, D_t is a vector of constant terms and ε_t is a vector of error terms that

are assumed to be white noise. The variable vector Z_t comprises four variables:

$$Z_t = (\text{GDP}_t, r_t^M, \text{LOANS}_t, r_t^L)',$$

where GDP stands for real output, r^M for the policy–controlled short–term rate, LOANS for real aggregate bank loans and r^L for the loan rate.[9] Loan supply by the banks should depend on the credit margin, i.e. the spread between r^L and r^M, while loan demand should depend on real output and the loan rate. The sample period starts in 1991Q1, after the German unification, and ends in 2003Q2.[10] GDP and LOANS are in logs and r^M and r^L are in decimals. The vector D_t contains an unrestricted constant and centered seasonal dummies. The lag length is set to $n = 3$, which ensures that the error terms are free of autocorrelation and normally distributed.

Testing for cointegration, Table 1 reports the trace test statistic. Critical values are taken from Mackinnon, Haug, and Michelis (1999), which have been derived in response surface regressions based on simulation experiments. The

Table 1: Cointegration Test

Rank	Trace Statistic	Critical Values* 95% Level
0	62.09	49.64
≤ 1	33.96	31.88
≤ 2	15.80	18.11
≤ 3	4.91	8.19

Notes: *Mackinnon, Haug, and Michelis (1999), Table 4, Case III.

outcome of the trace test suggests that two cointegration vectors span the cointegration space. Table 2 documents multivariate test statistics, which show that the model is statistically well–specified.

Based on the VECM specification with the two cointegration vectors, we generate impulse responses of the variables in Z_t to a monetary policy shock, which is identified by imposing a triangular orthogonalization. The ordering of the variables implies that an innovation in the short–term rate affects real output with

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[9]See Appendix B for a description of the variables used in the analysis. The results of unit root tests show that all variables are integrated of order one, i.e. $I(1)$, which implies that the cointegration approach should be applied. The unit root rests are not reported here, but are available from the authors upon request.

[10]Notice that the end of our sample period is determined by the switch to the new MFI interest rate statistics of the European Central Bank (ECB), which entails a structural break in the data. See Deutsche Bundesbank (2004) for details.

Table 2: Tests for Misspecification

	Test	Statistic	p-value
Autocorrelation:	LM(1)	$\chi^2(16) = 15.76$	0.47
	LM(4)	$\chi^2(16) = 13.20$	0.66
Normality:		$\chi^2(8) = 10.30$	0.24

a lag of one quarter, while the loan volume and the loan rate are affected within the same quarter. Figure 1 displays the impulse responses of the variables after a monetary policy shock, which is reflected by a one–standard–deviation shock to the short–term rate. The simulation horizon covers 20 quarters. The solid lines denote impulse responses. The dotted lines are 95% error bounds based on asymptotic calculation.[11]

Following a monetary policy shock, bank loans decline gradually. This corroborates the results of De Bondt (2000), Holtemöller (2003) and Hülsewig, Winker, and Worms (2004), who investigate the response of aggregate bank lending in Germany in a similar framework using monthly and quarterly data. The drop in bank loans continues for around sixteen quarters until it breaks off. The output level raises in the first two quarters and then declines persistently.[12] The loan rate and the short–term rate increase for about four quarters and decrease afterwards. The loan rate is following a similar pattern as the short-term rate, but generally remaining on a lower level.

As Bernanke and Gertler (1995) and Cecchetti (1995) point out, the decline in bank loans after a monetary tightening is consistent with the credit channel, but since the adjustment can be interpreted as being induced by loan supply and loan demand, clear predictions are difficult to establish. For an insight, we estimate our model in an attempt to reveal the reaction of loan supply and loan demand by adopting a minimum distance estimation, which matches the theoretical impulse responses with the empirical impulse responses to a monetary policy shock. Before we present the results, we briefly discuss the methodology applied.

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[11]For each variable the horizontal axis shows the number of quarters after the monetary policy shock has been initialized. The vertical axis measures the response of the relevant variables. In case of LOANS and GDP a value of 0.001 corresponds to a 0.1 percent change of the baseline value, while in case of the interest rates a value of 0.1 corresponds to a change of 10 basis points.

[12]The primary reaction of the output level after the monetary policy shock is surprising. The shift in GDP – that is also documented for Germany by Ehrmann and Worms (2004) and Mojon and Peersman (2003)– is possibly related to the structural distortions in the data that emerge right after the German reunification.

Figure 1: Impulse Response Functions
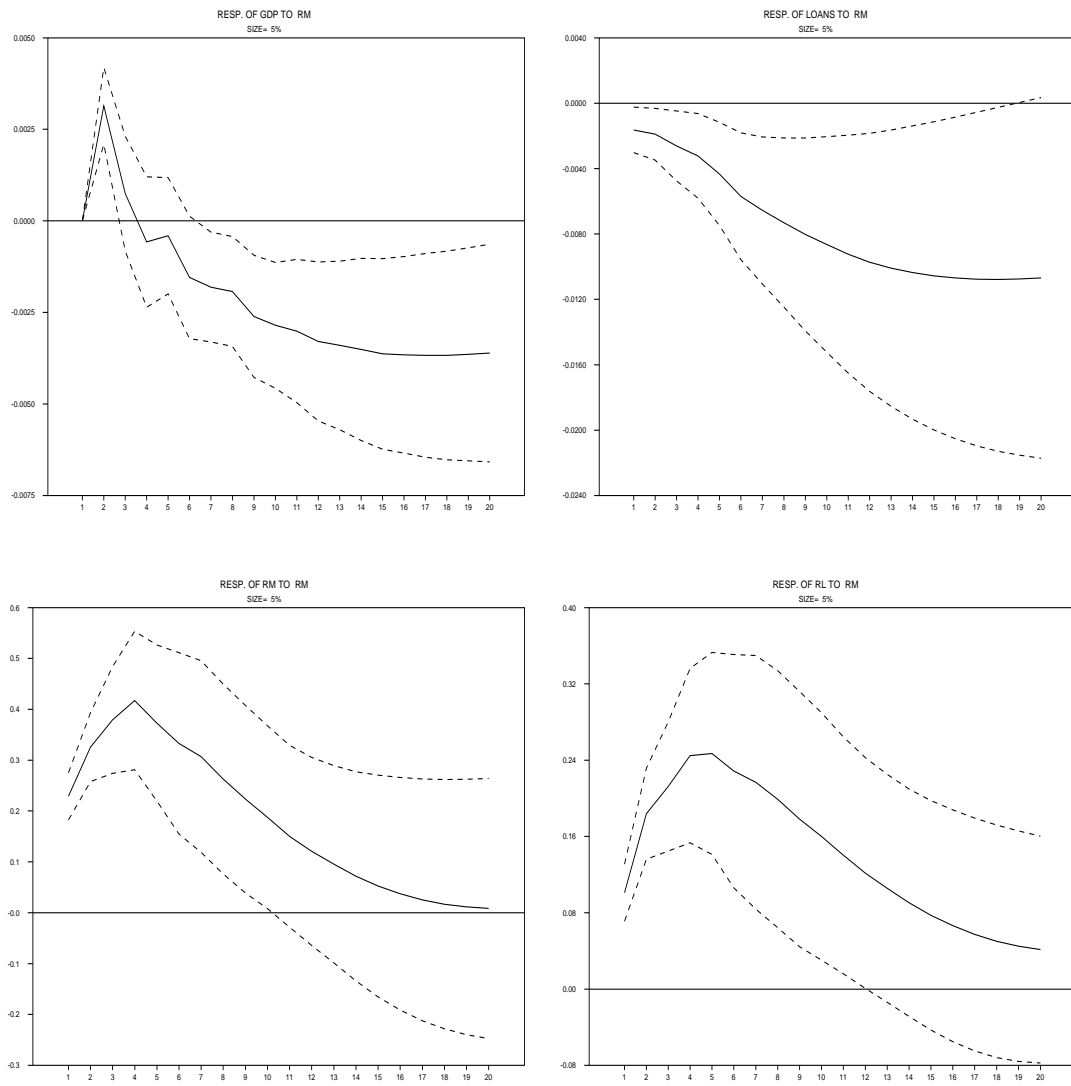
3.2 Methodology

The estimation of our model is based on the following state space representation:

$$A_0 X_{t+1} = A_1 X_t + \upsilon_{t+1}, \tag{12}$$

where X_t is the state vector, which is composed of a vector $X_{1,t}$ of backward–looking variables and a vector $X_{2,t}$ of forward–looking variables, A_0 and A_1 are coefficient matrices and υ_{t+1} is a vector of shocks:

$$A_0 \begin{bmatrix} X_{1,t+1} \\ E_t X_{2,t+1} \end{bmatrix} = A_1 \begin{bmatrix} X_{1,t} \\ X_{2,t} \end{bmatrix} + \begin{bmatrix} \upsilon_{1,t+1} \\ 0 \end{bmatrix}.$$

The state space representation comprises the equations:

$$L_t = \psi^{-1}\beta E_t L_{t+1} + \psi^{-1}L_{t-1} + B_1 na^{-1}\psi^{-1}y_t - na^{-1}\psi^{-1}r_t^M \tag{13}$$

$$r_t^L = B_1 y_t - B_2 L_t \tag{14}$$

$$y_{t+1} = \gamma_1 y_t + \gamma_2 r_t^L + \gamma_3 r_{t-1}^L \tag{15}$$

$$r_{t+1}^M = \delta_1 r_t^M + \delta_2 r_{t-1}^M + \eta_{t+1}, \tag{16}$$

where $\psi \equiv (\beta + na^{-1}B_2 + 1)$, $B_1 = b_1/b_2$ and $B_2 = 1/b_2$. The first two equations are derived from the model and specify the evolution of the loan volume and the loan rate.[13] The last two equations characterize the development of the output level and the short–term rate. The output level is assumed to depend on its own lagged value and the lagged loan rate, while the short–term rate is supposed to depend on its own lagged values. The monetary policy shock is reflected by the shock term η_{t+1}. Summarizing these equations in matrix form gives:

$$X_{1,t} = \begin{bmatrix} y_t \\ r_t^M \\ r_{t-1}^M \\ r_{t-1}^L \\ L_{t-1} \end{bmatrix}, X_{2,t} = \begin{bmatrix} L_t \end{bmatrix}, A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & \beta\psi^{-1} \end{bmatrix}, \upsilon_{1,t+1} = \begin{bmatrix} 0 \\ \eta_{t+1} \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

$$A_1 = \begin{bmatrix} \gamma_1 + B1\gamma_2 & 0 & 0 & \gamma_3 & 0 & -B_2\gamma_2 \\ 0 & \delta_1 & \delta_2 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ B_1 & 0 & 0 & 0 & 0 & -B_2 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ -B_1 na^{-1}\psi^{-1} & na^{-1}\psi^{-1} & 0 & 0 & -\psi^{-1} & 1 \end{bmatrix}.$$

[13]The identity of the equations (13) and (9) is shown in Appendix A.2.

The closed loop dynamics of the model, which serves as a starting point to generate impulse responses, are given by:

$$
\begin{aligned}
X_{1,t+1} &= (A_{11} + A_{12}C) X_{1,t} + v_{1,t+1} \\
X_{2,t} &= CX_{1,t},
\end{aligned}
\tag{17}
$$

where A_{11} and A_{12} are sub–matrices of $A = A_0^{-1}A_1$, which have been partitioned conformably with $X_{1,t}$ and $X_{2,t}$.[14] Using the algorithms as described in Söderlind (1999), the matrix C is determined numerically.

For the matching of impulse responses, we estimate the set of parameters:

$$
\xi \equiv (b_1, b_2, na^{-1}, \delta_1, \delta_2, \gamma_1, \gamma_2, \gamma_3),
$$

by minimizing a measure of distance between the theoretical impulse responses and the empirical impulse responses. The discount factor is calibrated to: $\beta = 0.99$. The optimal estimator of ξ minimizes the corresponding distance measure $J^{opt}(\xi)$ (see e.g. Christiano, Eichenbaum, and Evans (2004)):

$$
J = \min_{\xi} \left(\hat{\Psi} - \Psi(\xi) \right)' V^{-1} \left(\hat{\Psi} - \Psi(\xi) \right),
\tag{18}
$$

where $\hat{\Psi}$ denote the empirical impulse responses, $\Psi(\xi)$ describe the mapping from ξ to the theoretical impulse responses and V is the weighting matrix with the variances of $\hat{\Psi}$ on the diagonal.[15] The minimization of the distance implies that those point estimates with a smaller standard deviation are given a higher priority.

3.3 Minimum Distance Estimation

In estimating our model, we aim at evaluating the adjustment of bank loans to a monetary policy shock. Figure 2 displays the impulse responses together with the error bounds. The theoretical responses conform quite closely with the empirical responses and fall generally – except for the primary shift in GDP – within the confidence interval. Following a monetary policy shock, bank loans decline by degrees. The output level raises slightly and then falls. The loan rate and short–term rate increase initially and decrease afterwards.

Table 3 summarizes the estimated set of parameters $\hat{\xi}$ that minimize the distance measure. The parameter for the degree of stickiness na^{-1} is 0.001. The

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[14]Notice that $A_0^{-1} \begin{bmatrix} v_{1,t+1} \\ 0 \end{bmatrix} = \begin{bmatrix} v_{1,t+1} \\ 0 \end{bmatrix}$ since A_0 is block diagonal with an identity matrix as its upper left block and the lower block of the shock vector is zero.

[15]If ξ is normally distributed, then J has a χ^2–distribution with $N - m$ degrees of freedom, where N is the number of observations on the impulse responses and m is the number of coefficients (see e.g. Smets and Wouters (2002)).
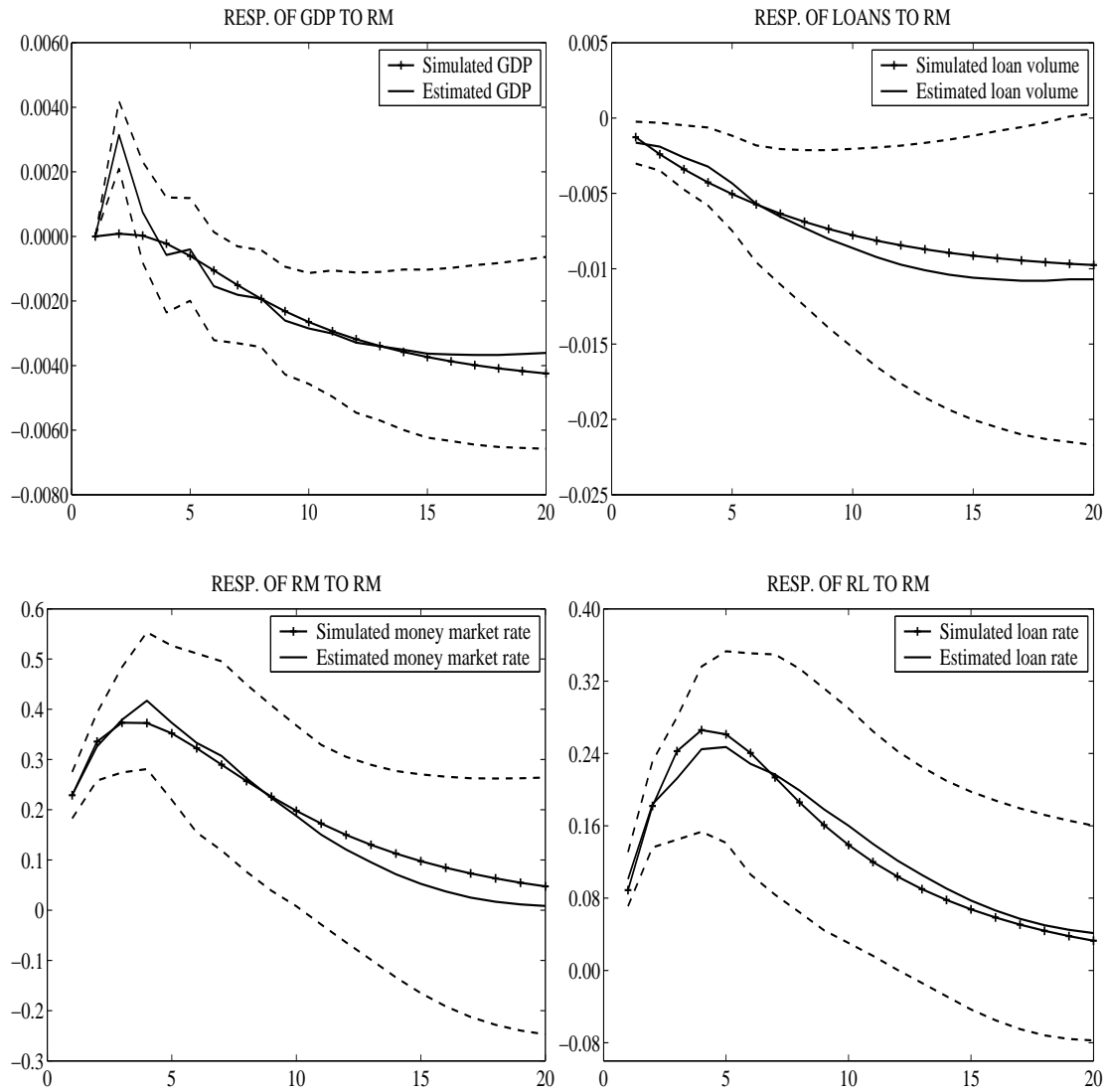
Figure 2: Implied Impulse Responses

Table 3: Parameter Estimates

Parameter	Estimate	Standard Error
b_1	2.1887	0.2474
b_2	0.0142	0.0013
na^{-1}	0.0010	0.0001
δ_1	1.4665	0.0299
δ_2	-0.5204	0.0310
γ_1	0.9985	0.0161
γ_2	0.0009	0.0004
γ_3	-0.0026	0.0005

Notes: The value function is 42.08 with a probability of 0.99. The probability is calculated by using a Chi–Squared distribution with 72 degrees of freedom. The standard errors are calculated as the square root of the diagonal elements of the inverted Hessian matrix resulting from the optimization of the value function.

income elasticity b_1 and the interest elasticity b_2 are 2.19 and 0.014, which is in line with other reported elasticities that range between $1.1 - 2.5$ and $0.01 - 0.60$ (see e.g. Calza, Gartner, and Sousa (2003), Calza, Manrique, and Sousa (2003), Fase (1995) Hülsewig, Winker, and Worms (2004) and Kakes (2000)).[16]

Our model implies that the adjustment of bank loans is determined jointly by the response of loan supply and loan demand to a monetary policy shock. Recall that loan supply depends on the expected credit margin:

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

while loan demand depends on the output level and the loan rate:

$$L_t = b_1 y_t - b_2 r_t^L.$$

Figure 3 displays the development of the components that drive loan supply and loan demand, which are calculated on the basis of the estimated and calibrated model parameters.[17]

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[16]The divergency in the estimated elasticities of loan demand might result from using different types of loan aggregates, in particular different categories and different maturities, which implies that it might be difficult to find a robust benchmark within these ranges. According to Calza, Gartner, and Sousa (2003), a possible explanation for an income elasticity above unity is that GDP might capture the effect of omitted variables, such as wealth, which are also relevant to explain loan demand.

[17]Since the simulation horizon covers 20 quarters, we set $T = 20$ for the calculation of the expected credit margin.

Figure 3: Loan Supply and Loan Demand Components
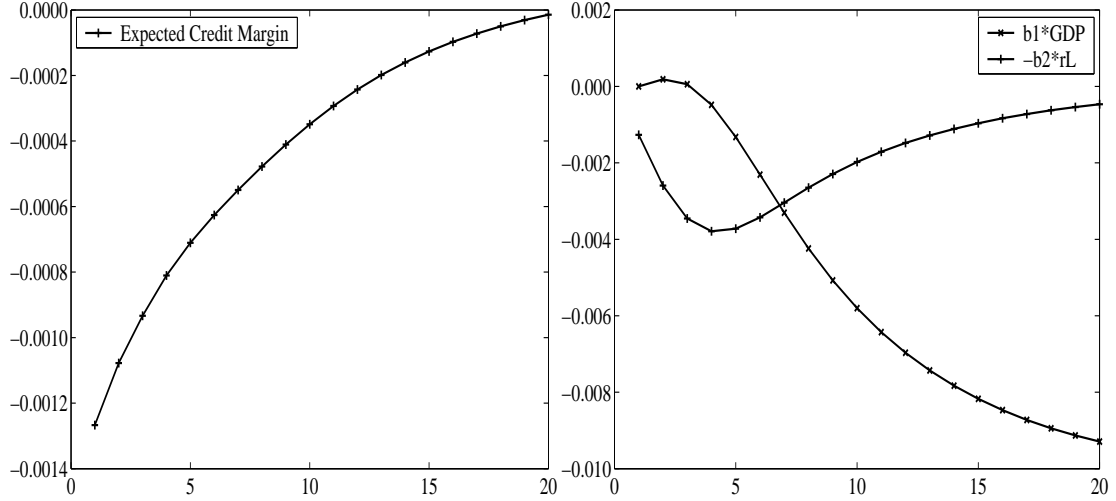
The findings suggest that loan supply by the banks declines with an expected fall in the credit margin after a monetary policy shock. The drop in the credit margin occurs instantly and bottoms out gradually. Loan demand declines with the decrease in the output level and the increase in the loan rate. The fall proceeds promptly despite the primary shift in the output level that is surpassed by the primary shift in the loan rate.

In conclusion, our findings imply that the adjustment of bank loans is characterized by the mutual drop in loan supply and loan demand following a monetary contraction. The decrease in loan supply emerges instantly and fades gradually, while the decrease in loan demand proceeds by degrees and lasts persistently.

4   Concluding Remarks

This paper has addressed the credit channel in Germany by using aggregate data. We have developed a stylized model of the banking firm, in which banks decide on their loan supply in the light of uncertainty about the future course of monetary policy. We have estimated the reaction of bank loans to a monetary policy shock in consideration of the response of the output level and the loan rate. Using our model as a guide, we have evaluated the reaction of bank loans – i.e. disclosing the parts that can be attributed to loan supply and loan demand – by matching the theoretical impulse responses with the empirical impulse responses to a monetary policy shock.

Our findings suggest that the credit channel in Germany is working besides

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the interest rate channel, which is consistent with De Bondt (2000), Holtemöller (2003), Hülsewig, Winker, and Worms (2004), Küppers (2001), Kakes and Sturm (2002) and Worms (2003), who draw similar conclusions. Our results imply that loan supply by the banks declines with an expected fall in the credit margin after a monetary policy shock, while loan demand drops with a fall in the output level and a raise in the loan rate. The decrease in loan supply occurs promptly and bottoms out gradually. The decrease in loan demand proceeds by degrees and continues persistently.

Appendix

A A Stylized Model of the Banking Firm

This appendix provides the steps used to derive a single bank's optimal loan supply and the loan market equilibrium. Define the lag operator by H such that $HX_t = X_{t-1}$.

A.1 Optimal Loan Supply of a Single Bank

Optimal loan supply of a single bank is found by rewriting the first–order condition (6) as:

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

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

$$\beta \left[1 - \frac{1+\beta}{\beta} H + \frac{1}{\beta} H^2 \right] E_{t+j} L_{t+j+1}^i = -a^{-1}(r_{t+j}^L - r_{t+j}^M), \qquad (A.2)$$

for $(j = 0, 1, 2, ...)$. Using the procedure established by Sargent (1979, pp. 197–199), the left–hand side of equation (A.2) may be factored to obtain:

$$\beta(1 - \frac{1}{\beta} H)(1 - H) E_{t+j} L_{t+j+1}^i = -a^{-1}(r_{t+j}^L - r_{t+j}^M), \qquad (A.3)$$

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

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 $x_{t+j} = (r_{t+j}^L - r_{t+j}^M)$ is bounded, if the transversality condition is satisfied.

The transversality condition is given by $\lim_{T \to \infty} E_t \beta^T \{r_T^L - a(L_T^i - L_{T-1}^i) - r_T^M\} = 0$, 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, $\{r^L_{t+j}\}^\infty_{j=0}$, 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):

$$E_{t+j} L^i_{t+j+1} = L^i_{t+j} + (a\beta)^{-1} \sum_{s=1}^\infty \beta^s E_{t+j}(r^L_{t+j+s} - r^M_{t+j+s}), \qquad (\text{A.4})$$

for $(j = 0, 1, 2...)$. Next, expand the information set from I_{t+j} to I_{t+j+1} in (A.4), which is the information the bank has when taking the decision on L_{t+j+1}, and redefine the index from $t + j + 1$ to $t + j$ (Cosimano, 1988, p. 135):

$$L^i_{t+j} = L^i_{t+j-1} + a^{-1} \sum_{s=0}^\infty \beta^s E_{t+j}(r^L_{t+j+s} - r^M_{t+j+s}), \qquad (\text{A.5})$$

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

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:

$$\beta E_t L_{t+1} - (1 + \beta)L_t + L_{t-1} = -na^{-1}(r^L_t - r^M_t). \qquad (\text{A.6})$$

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

$$r^L_t = B_1 y_t - B_2 L_t, \qquad (\text{A.7})$$

where $B_1 = b_1/b_2$ and $B_2 = 1/b_2$, and substitute r^L_t into equation (A.6), to obtain:

$$\beta E_t L_{t+1} - (\beta + na^{-1}B_2 + 1)L_t + L_{t-1} = -na^{-1}(B_1 y_t - r^M_t). \qquad (\text{A.8})$$

Applying the expectation lag operator yields:

$$\beta \left[1 - \frac{\psi}{\beta}H + \frac{1}{\beta}H^2 \right] E_t L_{t+1} = -na^{-1}(B_1 y_t - r^M_t), \qquad (\text{A.9})$$

where $\psi \equiv (\beta + na^{-1}B_2 + 1)$. Now factor the left side of equation (A.9) using the procedure suggested by Sargent (1979, pp. 339–342):

$$\left[1 - \frac{\psi}{\beta}H + \frac{1}{\beta}H^2 \right] = (1 - \lambda_1 H)(1 - \lambda_2 H), \qquad (\text{A.10})$$

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where λ_1 and λ_2 are positive characteristic roots, with $\lambda_1 < 1 < 1/\beta < \lambda_2$.

Substituting expression (A.10) into (A.9) and applying the forward solution as in (A.4) yields:

$$E_t L_{t+1} = \lambda_1 L_t + n(a\beta)^{-1} \sum_{s=1}^{\infty} \lambda_2^{-s} E_t(B_1 y_{t+s} - r_{t+s}^M). \qquad (A.11)$$

Equation (A.11) can be rewritten by expanding the information set from I_t to I_{t+1}, which gives:

$$L_t = \lambda_1 L_{t-1} + \lambda_1 n a^{-1} \sum_{s=0}^{\infty} \lambda_2^{-s} E_t(B_1 y_{t+s} - r_{t+s}^M), \qquad (A.12)$$

after changing the index from $t+1$ to t and recognizing that $\lambda_1 = 1/(\beta \lambda_2)$.

The equilibrium loan rate (10) is found by inserting equation (A.12) into equation (A.7) and rearranging terms.

B   Data Base

All the data used for the VECM analysis is taken from the German Bundesbank (www.bundesbank.de) and the German Federal Statistical Office (www.destatis.de).

1. `LOANS`: Loans to domestic firms and private households (all banks), seasonally unadjusted. German Bundesbank: PQA350; deflated with the Consumer Price Index: UUFA01.

2. `GDP`: Real German GDP in prices from 1995, seasonally unadjusted. German Federal Statistical Office.

3. Loan rate r^L: Average of the rate on mortgage loans and the rates of current account loans. German Bundesbank: SU0001, SU0004 and SU0049. Converted into quarterly data.

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

Figure 4 displays the time series in levels and first differences.

Figure 4: Data in Levels and First Differences
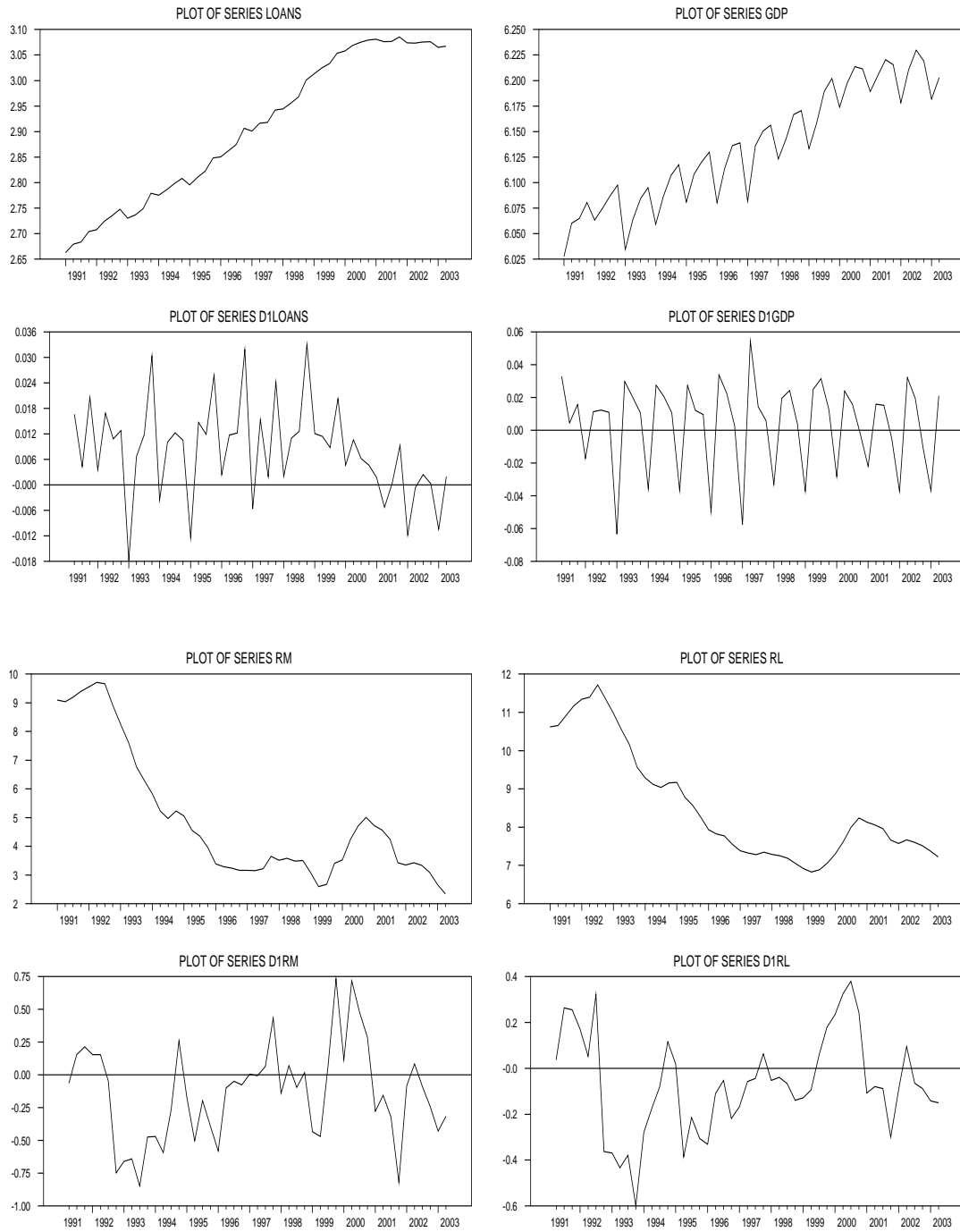
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