Bank Behavior and the Cost Channel of Monetary Transmission*

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Abstract

This paper provides a micro-foundation of the behavior of the banking industry in a Stochastic Dynamic General Equilibrium model of the New Keynesian style. The role of banks is reduced to the supply of loans to firms that must pay the wage bill before they receive revenues from selling their products. This leads to the so-called cost channel of monetary policy transmission. Our model is based on the existence of a bank–client relationship which provides a rationale for monopolistic competition in the loan market. Using a Calvo-type staggered price setting approach, banks decide on their loan supply in the light of expectations about the future course of monetary policy, implying that the adjustment of loan rates to a monetary policy shock is sticky. This is in contrast to Ravenna and Walsh (2006) who focus primarily on banks operating under perfect competition, which means that the loan rate always equals the money market rate. The structural parameters of our model are determined using a minimum distance estimation, which matches the theoretical impulse responses to the empirical responses of an estimated VAR for the euro zone to a monetary policy shock.

JEL classifications: E44, E52, E58

Key words: New Keynesian Model, monetary policy transmission, bank behavior, cost channel, minimum distance estimation

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1 Introduction

In the cost channel, banks play a pivotal role in the transmission of monetary policy. Banks extent credit to firms that depend on external finance for funding production cost. Changes in credit conditions induce changes in production cost, which have an impact on the firms' price setting behavior (Barth and Ramey, 2000). The cost channel is seen as working in addition to the interest rate channel, according to which monetary policy affects spending by inducing changes in the cost of capital and yield on savings.

This paper presents a Stochastic Dynamic General Equilibrium model of the New Keynesian style that highlights the role of banks in the cost channel of monetary policy. As banks decide on their loan supply in the light of expectations about the future course of monetary policy, this implies that bank behavior occupies a meaningful part in the propagation of monetary policy shocks. Banks care about future monetary policy because changes in the loan stock are associated with adjustment cost. This is in contrast to Ravenna and Walsh (2006) who focus primarily on banks operating costlessly, which means that the loan rate equals the money market rate – i.e. the policy rate – in each period. Our motivation stems from the empirical observations from a VAR model for the euro area that the loan rate follows the policy rate after a monetary policy shock, but the adjustment is less pronounced.

We estimate the model by applying a minimum distance estimation – as proposed by Rotemberg and Woodford (1998) and Christiano, Eichenbaum, and Evans (2005) – which matches the theoretical impulse responses to the empirical responses of an estimated VAR model to a monetary policy shock. Our results reveal that the banking industry plays a meaningful role in propagating and amplifying monetary shocks as the adjustment of bank loans in the light of future changes in the monetary policy rate and changing economic conditions amplify the initial monetary impulse. In particular the findings emphasize that the cost channel in the inflation adjustment equation are not only driven by loan demand, but in addition by loan supply factors. This result can be considered as a contribution to literature as we extend earlier findings by Ravenna and Walsh (2006) who only model the banking industry as a neutral conveyor of monetary shocks.

2 The Model

We present a New Keynesian model in which banks decide on their loan supply in the light of expectations about the future course of monetary policy. The model builds on Gali, Gertler, and Lopez–Salido (2001), Christiano, Eichenbaum, and Evans (2005) and Ravenna and Walsh (2006), but yields richer implications for the evolution of the loan market equilibrium.

2.1 Households

There is a continuum of households, indexed by $j \in (0,1)$, deciding on consumption, labor supply, cash holdings and deposits. The jth household maximizes its expected lifetime utility:

$$E_{t-1}\sum_{i=0}^{\infty}\beta^i U_{j,t+i}, \tag{1}$$

where E_{t-1} denotes the expectation operator, conditional on aggregate and household j's idiosyncratic information up to – and including – time $t-1$[1], and $\beta \in (0,1)$ is a discount factor. Period utility $U_{j,t}$ is described by the following function:

$$U_{j,t} = \xi_t \frac{(C_{j,t} - H_t)^{1-\sigma}}{1-\sigma} - \frac{N_{j,t}^{1+\eta}}{1+\eta} + \frac{(M_{j,t}/P_t)^{1-\nu}}{1-\nu}, \tag{2}$$

where $C_{j,t}$ is household j's consumption in period t, ξ_t is a taste shock, σ is the coefficient of relative risk aversion, $N_{j,t}$ is household j's labor supply, η is the elasticity of marginal disutility of labor, $M_{j,t}/P_t$ are real cash balances, and ν is the elasticity of marginal utility of money. H_t denotes an external habit variable which depends positively on consumption of the aggregate household sector in period $t-1$, $H_t = hC_{t-1}$.

Households maximize their expected lifetime utility (1) by choosing optimal consumption subject to an intertemporal budget constraint:

$$P_t C_{j,t} + D_{j,t} + M_{j,t} = M_{j,t-1} + W_t N_{j,t} + R_t^D D_{j,t-1} + \Pi_{j,t}, \tag{3}$$

[1]The assumption that the household's decisions for time t and later are taken on the basis of the information set in time $t-1$ implies that decisions for time t are predetermined. This is consistent with the identifying restrictions of the VAR model considered below, according to which output and inflation are prevented from responding contemporaneously to a monetary policy shock.

where $D_{j,t}$ are deposits hold at banks at the gross deposit rate R_t^D, W_t is the nominal wage rate, and $\Pi_{j,t}$ are aggregate profits from the firms and banks distributed at the end of period t.

The relevant first–order conditions are:

$$E_{t-1}\lambda_{j,t} = \beta E_{t-1}\left(\lambda_{j,t+1}\frac{R_t^D P_t}{P_{t+1}}\right) \tag{4}$$

$$E_{t-1}\lambda_{j,t} = E_{t-1}\left[\xi_t(C_{j,t} - H_t)^{-\sigma}\right], \tag{5}$$

where the Lagrange multiplier on the intertemporal budget constraint $\lambda_{j,t}$ denotes household j's marginal utility of consumption. We assume that financial markets are complete, and that households insure themselves against all idiosyncratic risk. Thus, households are homogeneous with respect to consumption and asset holdings, implying that the first–order conditions are equal for all households (Christiano, Eichenbaum, and Evans, 2005).

2.2 Firms

2.2.1 Final Good Producers

The final good Y_t which is entirely used for consumption C_t is produced by a continuum of wholesale producers in an environment of perfect competition. Final goods are bundles of differentiated goods $Y_{j,t}$ which are provided by a continuum of monopolistically competitive intermediate good producers. The technology to produce the aggregate final good is:

$$Y_t = \left[\int_0^1 (Y_{j,t})^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{6}$$

where $\epsilon > 1$ governs the price elasticity of demand for the individual goods. The optimal allocation of households' expenditure across differentiated goods implies a downward sloping demand function:

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} Y_t, \text{ for all } j \in (0,1), \tag{7}$$

where $P_{j,t}$ denotes the price of good $Y_{j,t}$ and P_t is the price index of final goods given by:

$$P_t = \left[\int_0^1 (P_{j,t})^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}. \tag{8}$$

2.2.2 Intermediate Good Producers

Firms indexed by $j \in (0,1)$ produce a continuum of goods in monopolistically competitive markets. The production function of a firm is given by:

$$Y_{j,t} = A_t N_{j,t}^{\alpha} \tag{9}$$

where $Y_{j,t}$ is the amount of intermediate good j, $N_{j,t}$ is employment, α is the output elasticity with respect to labor, and A_t is an aggregate productivity shock.

Firms face price frictions as in Calvo (1983), which implies a staggered price setting. The price level P_t evolves each period as a weighted average of a fraction of firms θ that stick with last periods price level P_{t-1} and a fraction of firms $1-\theta$ that are allowed to change prices:

$$P_t^{1-\epsilon} = (1-\theta)(P_t^*)^{1-\epsilon} + \theta P_{t-1}^{1-\epsilon}. \tag{10}$$

Prices that are reset in the current period P_t^* can be decomposed into a component $1-\omega$ resulting from optimizing (forward-looking) firms and a component ω resulting from backward looking firms that apply a simple rule of thumb:

$$P_t^* = (P_t^f)^{1-\omega}(P_t^b)^{\omega}. \tag{11}$$

Gali, Gertler, and Lopez–Salido (2001) propose the following pricing scheme for backward looking firms:

$$P_t^b = P_{t-1}^* \frac{P_{t-1}}{P_{t-2}}. \tag{12}$$

The fraction of forward-looking firms maximizes an intertemporal profit function

$$E_{t-1} \sum_{i=0}^{\infty} \theta^i \Delta_{i,t+i} \Pi_{j,t+i}^f \tag{13}$$

subject to the households' aggregate demand given by equation (7). Share holders to which profits are redeemed discount cash flows in i periods to come with a stochastic factor equal to $\theta^i \Delta_{i,t+i}$, where $\Delta_{i,t+i}$ denotes the intertemporal marginal rate of substitution of a representative household. Again we assume that pricing decisions occur prior to the realization of any aggregate time t disturbance. Time $t+i$ profits by firm j which reset prices at time t are:

$$\Pi_{j,t+1}^f = \left(P_{j,t}^f - \alpha P_{t+i}\varphi_{j,t+i}\right) Y_{j,t+i}, \tag{14}$$

where $\varphi_{j,t+i}$ are the real marginal cost. The solution to the optimization problem of the forward-looking intermediate firms can be shown to satisfy the following first–order condition:

$$E_{t-1}\sum_{i=0}^{\infty}\theta^i\Delta_{i,t+i}\left[(1-\epsilon)+\epsilon\alpha\frac{P_{t+i}}{P^f_{j,t}}\varphi_{j,t+i}\right]\left(\frac{P^f_{j,t}}{P_{t+i}}\right)^{-\epsilon}Y_{t+i}=0, \tag{15}$$

where $P^f_{j,t}$ is the optimal price of forward-looking firm j.

Firms rent labor in perfectly competitive markets. Profits are distributed to households at the end of each period. As firms are obliged to pay the wage bill in advance of production, they have to take up loans from the banks at the beginning of each period amounting to $W_tN_{j,t}$. Repayment by the firms occurs at the end of each period at the gross lending rate R^L_t. Production costs of firm j are therefore given by $R^L_tW_tN_{j,t}$. Cost minimization implies that real marginal cost of firm j at time $t+i$ are equal to:

$$\varphi_{j,t+i}=\frac{1}{\alpha}R^L_{t+i}\frac{w_{t+i}N_{j,t+i}}{Y_{j,t+i}}=\frac{1}{\alpha}R^L_{t+i}S_{j,t+i}, \tag{16}$$

where $w_t=W_t/P_t$ is the real wage and $S_{j,t}$ are real unit labor costs. When the production is subject to diminishing returns to scale ($\alpha<1$), firms with different production levels face different marginal costs. Relating $\varphi_{j,t+i}$ to average real marginal costs, $\varphi_{t+i}=\frac{1}{\alpha}R^L_{t+i}S_{t+i}$, yields

$$\varphi_{j,t+i}=\varphi_{t+i}\left(\frac{S_{j,t+i}}{S_{t+i}}\right)=\varphi_{t+i}\left(\frac{Y_{j,t+i}}{Y_{t+i}}\right)^{\frac{1-\alpha}{\alpha}}=\varphi_{t+i}\left(\frac{P_{j,t}}{P_{t+i}}\right)^{\frac{\epsilon(\alpha-1)}{\alpha}}, \tag{17}$$

where we made use of equations (7) and (9).

2.3 Banks

The individual bank j, which operates in an environment of monopolistic competition, faces the following loan demand function

$$L_{j,t}=\left(\frac{R^L_{j,t}}{R^L_t}\right)^{-\zeta}L_t, \tag{18}$$

where $\zeta>1$ is the interest rate elasticity of demand for the individual loan, and $R^L_{j,t}$ is the gross interest rate of the loan $L_{j,t}$ provided by bank j.

Banks face nominal frictions as in Calvo (1983). Each bank resets its loan rate only with a probability $1-\tau$ each period, independently of the time elapsed since the last adjustment. Thus, each period a measure $1-\tau$ of banks reset their loan rates, while a fraction τ keep their rates unchanged. The aggregate loan rate then satisfies

$$(R_t^L)^{(1-\zeta)} = (1-\tau)(R_t^{L*})^{(1-\zeta)} + \tau(R_{t-1}^L)^{(1-\zeta)}, \tag{19}$$

where R_t^{L*} is the newly set loan rate.

A bank that is able to reset in period t chooses the loan rate so as to maximize the expected present value of its profit flow:

$$E_t \sum_{i=0}^{\infty} \tau^i \Delta_{i,t+i} \Pi_{t+i}^{bank}. \tag{20}$$

As profits are redeemed to households at the end of each period, the stochastic discount factor equals the intertemporal marginal rate of substitution of a representative household. In contrast to households and firms, the optimization is conditional on the set of information available at time t.[2] The banks grant loans to firms L_t, which are financed by deposits D_t and central bank credits B_t. Time $t+i$ profit by bank j, which resets loan rates in period t, is given by:

$$\Pi_{j,t+i}^{bank} = R_{j,t}^L L_{j,t+i} - R_{t+i}^D D_{j,t+i} - R_{t+i}^M B_{j,t+i}. \tag{21}$$

The central bank administers the policy rate R_t^M, which determines the interest rate on the interbank money market. The deposit rate R_t^D is assumed to adjust in accordance with the policy rate R_t^M due to arbitrage conditions (Freixas and Rochet, 1997, p. 57) and is therefore exogenous for the individual bank. Given the balance sheet constraint:

$$L_t = D_t + B_t, \tag{22}$$

which implies that the loan volume equals the level of deposits – that is chosen by households – and a cash injection taken up in the form of central bank credits at the prevailing policy rate, profit function (21) can be rewritten as

$$\Pi_{j,t+i}^{bank} = (R_{j,t}^L - R_{t+i}^M) L_{j,t+i}. \tag{23}$$

[2]This assumption is consistent with the identifying restrictions of the VAR model considered below, according to which the loan rate reacts contemporaneously to a monetary policy shock.

The maximization of the intertemporal profit function, which is subject to the firms' loan demand function (18), yields the following first–order condition:

$$E_t \sum_{i=0}^{\infty} \tau^i \Delta_{i,t+i} \left[(1-\zeta) + \zeta \frac{R^M_{t+i}}{R^{L*}_{j,t}} \right] \left(\frac{R^{L*}_{j,t}}{R^L_{t+i}} \right)^{-\zeta} L_{t+i} = 0, \tag{24}$$

where $R^{L*}_{j,t}$ is the optimal reset price of bank j.

2.4 The Linearized Model

For the empirical analysis we use a log–linearized version of the model, where the equations are linearized around their steady states. We employ the following conventions: assume that X_t is a strictly positive variable and $\bar{X}$ denotes the steady state, then the variable $\hat{X}_t$ is the logarithmic deviation of the variable from its steady state, $\hat{X}_t = ln(X_t) - ln(\bar{X})$.

The consumption Euler–equation with habit formation is given by:

$$\hat{Y}_t = \frac{1}{1+h} E_{t-1} \hat{Y}_{t+1} + \frac{h}{1+h} \hat{Y}_{t-1} - \frac{1-h}{(1+h)\sigma} E_{t-1} (\hat{R}^M_t - \pi_{t+1}), \tag{25}$$

where the log–linearized income identity $\hat{Y}_t = \hat{C}_t$ is applied to substitute out consumption by income. $\hat{Y}_t$ denotes the output gap; the inflation rate π_t is defined as $\pi_t = \hat{P}_t - \hat{P}_{t-1}$. In the absence of habit formation, i.e. $h = 0$, equation (25) collapses to a purely forward–looking IS–equation.

The inflation adjustment equation is given by a hybrid New Keynesian Phillips curve (Gali, Gertler, and Lopez–Salido, 2001):

$$\pi_t = \gamma_f E_{t-1} \pi_{t+1} + \gamma_b \pi_{t-1} + \kappa E_{t-1} (\hat{R}^L_t + \hat{S}_t), \tag{26}$$

where $\gamma_f = \frac{\beta\theta}{\theta + \omega[1-\theta(1-\beta)]}$, $\gamma_b = \frac{\omega}{\theta+\omega[1-\theta(1-\beta)]}$ and $\kappa = \frac{(1-\theta)(1-\beta\theta)(1-\omega)}{\theta+\omega[1-\theta(1-\beta)]} \frac{\alpha}{1+(1-\alpha)(\epsilon-1)}$. The dynamics of the inflation rate depends on the size of γ_b in relation to γ_f, where it holds that $\gamma_f + \gamma_b = 1$. The parameter κ is the sensitivity of inflation with respect to the gross loan rate $\hat{R}^L_t$ and the real unit labor cost $\hat{S}_t$. The innovation compared to a standard New Keynesian Phillips curve is the introduction of the gross loan rate, which implies the existence of a cost channel as deviations of the nominal gross loan rate from its steady state are a source of cyclical movements in the inflation process.

The behavior of the banking industry is governed by the following equation:

$$\hat{R}_t^L = \frac{\beta\tau}{1+\beta\tau^2} E_t \hat{R}_{t+1}^L + \frac{\tau}{1+\beta\tau^2} \hat{R}_{t-1}^L + \frac{(1-\beta\tau)(1-\tau)}{1+\beta\tau^2} \hat{R}_t^M, \tag{27}$$

which implies that the loan rate is a function of the expected future course of monetary policy. If the fraction of banks τ that stick with the last period's loan rate goes to zero, $\hat{R}_t^L = \hat{R}_t^M$ at all times t. This corresponds to the approach chosen by Ravenna and Walsh (2006) who focus on banks operating under perfect competition.

The real unit labor cost evolves according to:

$$\hat{S}_t = \left(\frac{1-\alpha+\eta}{\alpha} + \frac{\sigma}{1-h} \right) \hat{Y}_t - \frac{h\sigma}{1-h} \hat{Y}_{t-1}, \tag{28}$$

where we used the definition of real unit labor cost $\hat{S}_t = \hat{w}_t + \hat{N}_t - \hat{Y}_t$ and the log–linearized technology $\hat{Y}_t = \alpha \hat{N}_t$.

The model is closed by the central bank's reaction function. The central bank sets the short–term interest rate according to a forward-looking Taylor–type policy rule:

$$\hat{R}_t^M = \delta \hat{R}_{t-1}^M + (1-\delta)[\phi_\pi E_t \pi_{t+1} + \phi_{\hat{Y}} \hat{Y}_t] + z_t^M, \tag{29}$$

where δ captures the degree of interest rate smoothing, ϕ_π and $\phi_{\hat{Y}}$ are the central bank's reaction coefficients with respect to the expected inflation rate and the output gap and z_t^M denotes the monetary policy shock.

Equations (25) to (29) determine the set of endogenous variables: $\hat{Y}_t$, $\hat{S}_t$, $\hat{R}_t^L$, $\hat{R}_t^M$ and π_t. By assumption the linear rational expectations model is only driven by a monetary policy shock z_t^M.

3 Empirical Results

3.1 Empirical Impulse Responses

As in Peersman and Smets (2003), we employ a VAR model for the euro area of the form:

$$Z_t = A(L) Z_{t-1} + \mu + \varepsilon_t, \tag{30}$$

where Z_t is a vector of endogenous variables, μ is a vector of constant terms and ε_t is a vector of error terms that are assumed to be white noise. The vector Z_t comprises the variables:

$$Z_t = (\mathtt{GDP}_t, \mathtt{INF}_t, \mathtt{STR}_t, \mathtt{LR}_t)',$$

where $\mathtt{GDP}_t$ stands for real output, $\mathtt{INF}_t$ for the inflation rate, $\mathtt{STR}_t$ for the policy rate of the central bank, which is approximated by a short–term money market rate, and $\mathtt{LR}_t$ for the loan rate.

The VAR model is estimated in levels to allow for implicit cointegration relationships between the variables. The sample period starts in 1990Q1 and ends in 2002Q4.[3] The output level is expressed in logs, while the inflation rate and the interest rates are in decimals. The vector of constant terms comprises a trend and a constant. Choosing a lag length of two ensures that the error terms dismiss signs of autocorrelation and conditional heteroscedasticity.[4]

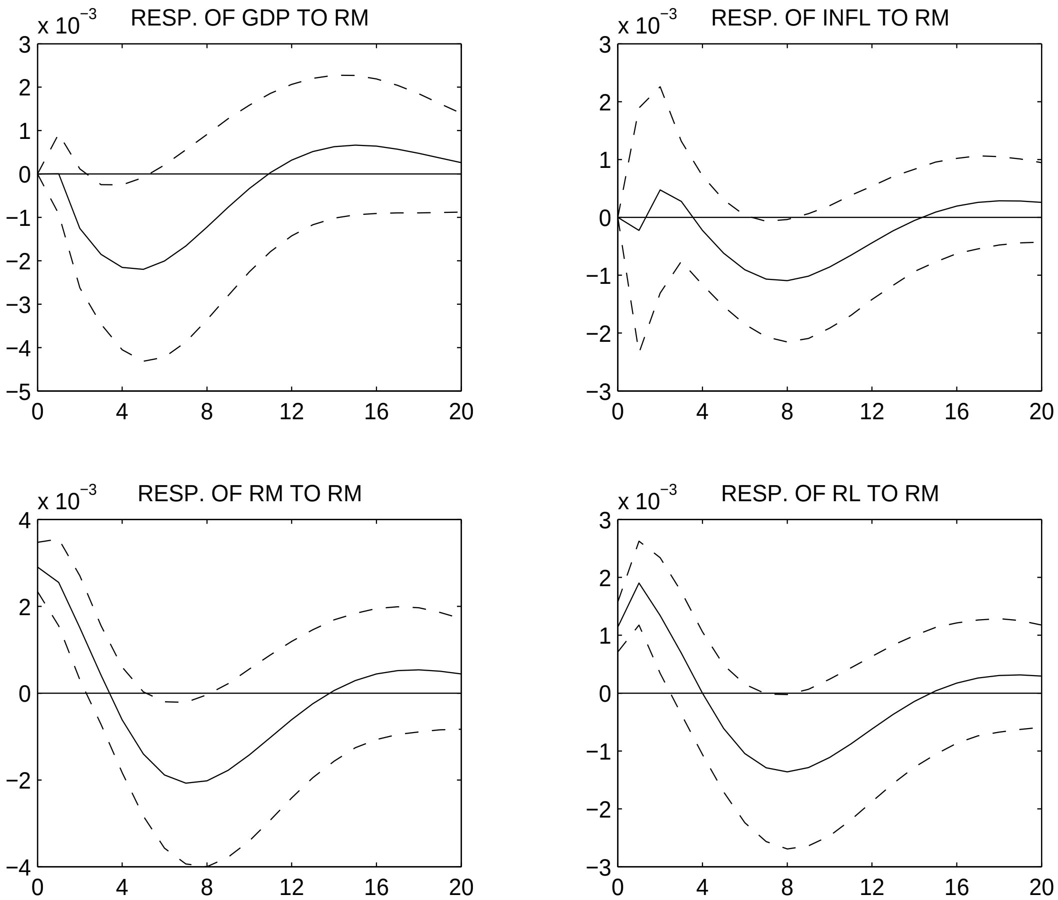
Based on the VAR model, we generate impulse responses of the variables in Z_t to a monetary policy shock, which is identified by imposing a triangular orthogonalization. The ordering of the variables implies that an innovation in the money market rate affects the output level and the inflation rate with a lag of one quarter, while the loan rate is affected within the same quarter. Figure 1 displays the impulse responses of the variables to a monetary policy shock. The simulation horizon covers 20 quarters. The solid lines denote impulse responses. The dotted lines are approximate 95% error bands that are derived from a bootstrap routine with 5000 replications.

Our findings conform with the impulse responses reported by Peersman and Smets (2003) and Smets and Wouters (2002) to a monetary policy shock. The output level declines by degrees, reaches a trough after four quarters, and returns to the baseline value subsequently. The reaction of the output level corresponds with the evolution of the output gap. The inflation rate falls slowly and shows a

[3]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 interest rate data.

[4]The VAR is estimated with JMulti by Lütkepohl and Krätzig (2004), which allows to conduct a variety of test for misspecification and stability. The outcome of the tests – not reported here, but available upon request – have shown that the model is well–specified.

Figure 1: Empirical Impulse Responses



Notes: Orthogonalized impulse responses to a monetary policy shock. The solid lines display impulse responses. The dashed lines are 95% error bands. The horizontal axis is in quarters.

significant decline only after five quarters. Following the trough, which is reached after around eight quarters, it gradually reverts to baseline. The money market rate increases immediately, then declines temporally, and returns to the baseline value subsequently. The loan rate follows a similar pattern as the money market rate, but the reaction is less pronounced.

3.2 Methodology

As in Rotemberg and Woodford (1998) and Christiano, Eichenbaum, and Evans (2005) we estimate the parameters of the log–linearized model by matching its theoretical impulse responses to a monetary policy shock with the empirical impulse responses. The theoretical model can be summarized by the following matrix representation:

$$\Gamma_0 X_t = \Gamma_1 X_{t-1} + \Omega_z z_t + \Omega_\vartheta \vartheta_t, \tag{31}$$

where X_t is the state vector, z_t is a vector of shocks and ϑ_t is a vector of expectational errors that satisfy $E_t\vartheta_{t+1} = 0$ for all t. The matrices Γ_0, Γ_1, Ω_z and Ω_ϑ contain the structural parameters of the model (Sims, 2001).

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

$$X_t(\varrho) = \Theta_X(\varrho) X_{t-1} + \Theta_z(\varrho) z_t, \tag{32}$$

where the rational expectations equilibrium is solved by using the method developed by Sims (2001). For the matching of the impulse responses, we estimate the following set of parameters:

$$\varrho = (h\ \theta\ \omega\ \tau\ \delta\ \phi_\pi\ \phi_{\hat{Y}}),$$

by minimizing a distance measure between the theoretical impulse responses and the empirical impulse responses. The remaining parameters were calibrated according to estimates typically found in the literature (see table 1). The distinction between calibrated and estimated parameters is motivated by the fact that we wanted to estimate only those parameters, which are either sources of real rigidities (h) and nominal frictions (θ, ω, τ), or policy rule parameters (δ, ϕ_π, $\phi_{\hat{Y}}$).

Table 1: Calibrated Parameters

Parameter	Symbol	Calibration
Discount factor	β	0.99
Risk aversion	σ	1.00
Monopoly power of firms	$1/\epsilon$	1/11
Production function	α	0.75
Labor supply elasticity	η	2.00

The optimal estimator of ϱ minimizes the corresponding distance measure $J^{opt}(\varrho)$ (Christiano, Eichenbaum, and Evans, 2005):

$$J = \min_{\varrho} \left(\hat{\Psi} - \Psi(\varrho) \right)' V^{-1} \left(\hat{\Psi} - \Psi(\varrho) \right), \tag{33}$$

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

3.3 Minimum Distance Estimation

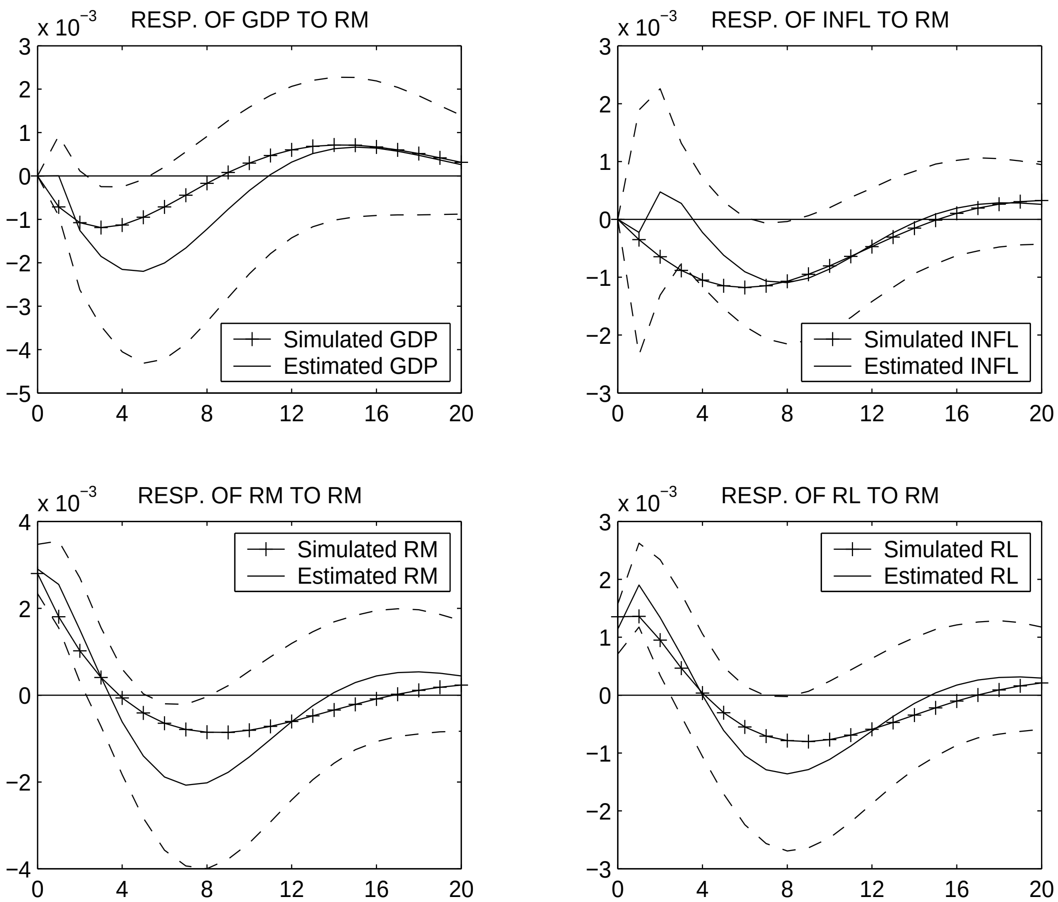
Table 2 summarizes the estimated set of parameters $\hat{\Psi}$ that minimize the distance measure. The corresponding impulse responses are shown in Figure 2 together with the empirical impulse responses.

Concerning the Taylor rule, we find that interest rate smoothing is important, that the output gap turns out to be insignificant and that the central bank positively reacts to the expected inflation rate in $t+1$.

The estimated degree of habit formation is very substantial and seems to indicate that the hump shaped response in the output gap to a monetary shock seems to be mainly driven by habit in consumption itself. This estimate seems to validate the claim of Rudebusch and Fuhrer (2005) that the degree of forward–lookingness in consumption is small.

The degree of Calvo pricing is - compared with other studies - relatively low and implies that prices are fixed on average for half a year. Rule-of-thumb price

Figure 2: Theoretical Impulse Responses



Notes: Orthogonalized impulse responses to a monetary policy shock. The solid lines display impulse responses. The dashed lines are 95% error bands. The horizontal axis is in quarters.

Table 2: Parameter Estimates

Parameter	Symbol	Estimate	t-value
Habit formation	h	0.89	47.32
Price stickiness	θ	0.41	1.98
Rule-of-thumb pricing	ω	0.75	18.03
Loan rate stickiness	τ	0.40	11.54
Taylor rule: smoothing	δ	0.72	13.57
Taylor rule: output gap	$\phi_{\hat{Y}}$	0.02	0.13
Taylor rule: inflation	ϕ_{π}	1.07	5.25

Notes: The value function is 44.20 with a probability of 0.99824. The probability is calculated by employing a Chi–Squared distribution with 75 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.

setters amount to 75 percent of the firms.

The significant estimate for τ reveals that the banking industry plays a meaningful role in propagating monetary shocks via the cost channel. The degree of loan rate stickiness τ was estimated to be 0.40, which implies that loan rates are fixed on average for half a year. This result can be considered as a contribution to literature as we extend earlier findings by Ravenna and Walsh (2006) who only model the banking industry as a neutral conveyor of monetary shocks. Their model of the banking industry can be regardedas a special case of our model with $\tau = 0$.

Additionally, the significant estimate of κ is evidence for the existence of a cost channel in the euro area.

4 Conclusion

This paper has addressed the cost channel of monetary transmission and the role of the banking industry in the euro–area by using aggregate data. Our motivation originates from two sources. Empirically, VAR models show that the loan rate follows the policy rate after a monetary policy shock, but the adjustment is less pronounced. Theoretically, the standard New Keynesian model (as for example presented in Woodford, 2003, ch. 4) does not explicitly model a banking industry.

Therefore we have extended a New Keynesian model including habit formation and rule–of–thumb setters to allow for a more realistic description of financial intermediation. Related literature is in particular Ravenna and Walsh (2006) and Chowdhury, Hoffmann, and Schabert (2006). Empirically, we have evaluated the existence of a cost channel and the role of the banking industry by matching the theoretical impulse responses with the empirical impulse responses to a monetary shock. Our findings suggest that there is clear evidence for the existence of a cost channel in Europe working alongside the interest rate channel. This result is consistent with Chowdhury, Hoffmann, and Schabert (2006), who draw similar conclusions based on single equation GMM estimates for the G7 countries.

Additionally our findings suggest that the cost channel in the inflation adjustment equation are not only driven by loan demand, but additionally by loan supply factors. This result is a contribution to literature and extends earlier findings by Ravenna and Walsh (2006) who only model the banking industry as a neutral conveyor of monetary shocks.

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