Competition among banks and the pass-through of monetary policy

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Competition among banks
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Abstract

Empirically, stiffer competition among commercial banks implies that (i) loan rates and deposit rates correlate more tightly with the policy rate, (ii) loan rates exceed the policy rate less, and (iii) deposit rates undercut the policy rate more. I find that a New Keynesian model with monopolistically competitive banks can account for the first two of these empirical facts. The model predicts that increased competition in the banking sector reduces the spread between the steady-state policy rate and the loan rate. Furthermore, augmented competition among banks amplifies the pass-through of monetary policy to the real economy.

Keywords: Monopolistically competitive banks; Collateral; External finance premium; Inside money premium

JEL Classification: C61; E32; E43; E51

1 Introduction

Despite the fact that commercial banks are the scapegoats of the deep financial crisis which started in August 2007 and persists to this day, their importance in the clearing up must not be forgotten, now. Jürgen Stark, Member of the Executive Board and the Governing Council of the ECB, emphasises that "In contrast to other regions, the banking sector plays an important role in the transmission process of monetary policy impulses in the euro area."[1].

Hence, this paper continues the consideration of banking and interest rates in monetary policy analysis by Goodfriend and McCallum (2007), extending their work in an important direction. In my model, the products of two different banks are imperfect substitutes. Like price-making goods producers, commercial banks can thus determine the interest rate they pay on deposits and the rate they demand on loans.

At the same time, it is a first attempt to develop a micro-founded general equilibrium model that is able to reproduce a few empirically observed features related to private banking. Van Leuvensteijn et al. (2008) analyse the impact of loan market competition on bank rates in the euro area between 1994 and 2004. They find evidence that stronger competition implies lower interest differentials between bank and market rates for most loan products, while banks seem to compensate for this by increasing the spread on current and deposit accounts. Furthermore, the responsiveness of bank rates to changes in market interest rates is positively correlated with the extent of competition.

The introduction of interest-rate rigidity into a New Keynesian DSGE model with a banking sector has two implications. In the long run, monopolistic competition among banks leads to an under-provision of deposits and credit contracts relative to a perfect competition scenario. As a consequence, steady-state economic activity decreases.

In the short run, imperfect pass-through from the policy rate to deposit and loan rates affects the fluctuations of real variables. Banks with deposit rate setting power amplify the responses to unforeseen monetary disturbances. Sluggish adjustment of deposit rates enhances any change in the opportunity cost of consumption and thus the behaviour of output, consumption, and employment at business cycle frequencies.

On the contrary, banks that control the loan rate have a moderating effect on the fluc-

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[1]Translated from a speech delivered in German at the Franz-Böhm-Kolleg, Siegen, April 29th 2009

tuations in real variables. Imperfect adjustment of loan rates cushions the deviations of investment and employment from their respective steady-states. The loan market effect clearly dominates the deposit market effect.

Overall, monopolistic competition among private banks can thus be considered a significant bottleneck in this model. It attenuates the efficiency of monetary policy. My theoretical results imply the same policy suggestions as the empirical findings by van Leuvensteijn et al. (2008). Structural reforms that enforce competition among the providers of financial services are likely to promote long-run economic activity and seem to improve the pass-through of central bank policy measures to the real economy.

Building on Goodfriend and McCallum (2007), my model evolves from an economy with a goods-producing and a banking sector. Firms use labour and capital to produce a diversified output good which is sold in a monopolistically competitive market. They cannot retain earnings, but accumulate productive capital through investment. Returns accrue at the end of period, while the wage bill and investment are paid up front. Firms must therefore finance their production costs by a one-period bank loan.

Commercial banks provide two types of financial intermediation. To produce loans, they combine collateral, consisting of a borrower's productive capital stock and end-of-period profits, with monitoring effort. Since monitoring is costly, banks demand an *external finance premium (EFP)* on top of the risk-free reference rate.

Moreover, banks take deposits from private households. Due to administrative costs, these accounts pay a return below that of a risk-free asset. Nevertheless, households hold deposits, as they face a deposit-in-advance constraint. Accordingly, I refer to this interest rate differential as the *liquidity premium* or *inside money premium (IMP)*.

Financial contracts are heterogeneous between banks. This generates an imperfectly competitive market pattern, where banks expand the spread between the reference rate and the interest rate on deposit and loans, respectively, beyond the costs of provision. This paper focuses on the particularities of a monopolistically competitive banking sector with endogenous costs of deposit and loan provision. Allowing financial intermediaries to set the respective interest rates, subject to quadratic adjustment costs à la Rotemberg (1982), I add a micro-founded imperfection to the transmission mechanism of monetary policy and generalise the theoretical findings in Scharler (2008).

The rest of the paper is organised as follows. In section 2, I give a short overview of the recent related literature. Section 3 introduces the main actions and timing as well as the agents of my model economy. In section 4, I derive the intertemporally optimal behaviour of agents and the symmetric equilibrium. The calibration of parameters and steady-state results are presented in section 5. In section 6, I analyse the reactions of selected variables to the 5 different shocks, and perform a sensitivity analysis of impulse responses to an expansionary monetary policy shock with respect to the bank competition parameters. Section 7 concludes.

2   Review of the Recent Related Literature

The past decade has bred an enormous amount of research trying to reproduce the qualitative and quantitative features of business cycles and to evaluate the potential of monetary policy in steering economic activity. Recent theoretical approaches use micro-founded models based on intertemporally optimising agents whose decisions are subjected to budget or other constraints and affected by various types of exogenous shocks.[2] Popular examples of these state-of-the-art DSGE models are discussed in Woodford (2003) and Smets and Wouters (2003, 2005, 2007).

However, the fact that most models are fundamentally non-monetary remains indeed a reason for unease, as Goodfriend and McCallum (2007) put it. In the light of the current financial crisis which spilled over to the real economy, a standard framework without broad monetary aggregates, commercial banks or endogenous interest rates seems increasingly incomplete.

Opponent authors like Woodford (2003) in his celebrated volume Interest and Prices, Ireland (2004), or Woodford (2009) suggest that money plays a minimal role in the business cycle, at best. Yet, these contributions do not incorporate any kind of credit market imperfection.

Consequently, this paper follows prior research to implement a banking sector in an otherwise standard DSGE model with nominal and real rigidities. It is thus an attempt to continue a line of work that includes Bernanke and Gertler (1989, 1995), Christiano and Eichenbaum (1995), Carlstrom and Fuerst (1997), Bernanke et al. (1999), Ireland

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[2]Many economists have agreed upon what Goodfriend and King (1997) call *The New Neoclassical Synthesis.*

(2003), Goodfriend (2005), and more recently Goodfriend and McCallum (2007), Stracca (2007), as well as Gerali et al. (2008, 2009). While all these studies set out to illuminate "the black box" of the credit channel, Ireland (2003) is the first to incorporate a demand for money that facilitates transactions.

Goodfriend (2005) pursues the distinction between narrow money, made up of currency and bank reserves, and broad money, including bank deposits and highly liquid assets. The former accommodates automatically when monetary policy targets the interest rate. According to the author, broad money must not be ignored either in a model destined to guide monetary policy.

The approach is rendered dynamical in the subsequent paper by Goodfriend and McCallum (2007). In their model, the provision of loans requires collateral as well as monitoring effort. At the same time, broad money or bank deposits are required for transactions. Accordingly, the authors identify two opposing effects of an explicit banking sector: On the one hand, the well-known "financial accelerator", resulting from a drop in the value of collateral under adverse economic conditions. This increases the *EFP* and intensifies the responses to a given initial disturbance. On the other hand a "banking attenuator" which arises from the tendency of consumption to fall during recession, lowering thereby the demand for bank deposits. This redirects part of the borrowers' net worth into collateral-eligible assets and reduces the *EFP*.

3   The Model

The economic environment contains five types of agents: A representative private household, a representative final goods producer, a continuum of intermediate goods-producing firms, a continuum of financial intermediaries, and a monetary authority. Time t is discrete.

At the beginning of every period, intermediate goods producers take out a loan from one of the private banks to hire labour and to invest into new capital which is productive as of period $t+1$. With the borrowed funds, firms produce a differentiated intermediate output that is traded in a monopolistically competitive market.

Banks produce these loans from two substitutable input factors: labour to screen and monitor borrowers and collateral. Since only monitoring is costly, more collateral reduces

the cost of providing a loan and thus the loan interest rate demanded by the bank.

A representative final goods producer combines the continuum of intermediate goods to a final good that can be invested by firms or consumed by the household. The market for final output is perfectly competitive and the representative final goods producer earns zero profit.

The central bank's monetary policy follows a simple Taylor rule. It provides private banks with high-powered money in exchange for risk-free bank bonds. The latter yield an interest equal to the central bank-determined policy rate.

A representative household supplies two types of homogeneous labour - work and monitoring effort - to firms and banks. It earns the same real wage in both sectors. A deposit-in-advance constraint forces households to support a share of consumption expenditure with deposits.

Imperfectly competitive agents extract a monopolistic rent which is redistributed to the owner, the representative household, as a dividend at the end of period. Likewise, the central bank transfers its seignorage proceeds to the private household. These resources are also consumed or saved for future periods in the form of deposits and to provide liquidity services.

3.1 The Representative Household

The infinitely-lived representative household derives utility from final goods consumption c_t and from the consumption of leisure time. It maximises discounted lifetime utility

$$E_t \sum_{v=0}^{\infty} \beta^v U_{t+v}, \text{ where } U_t = ln\ c_t - \phi(n_t + s_t). \tag{1}$$

Above, β is the private discount factor. n_t and s_t are the shares of total time endowment, normalised to 1, the household spends working in the firm and the bank, respectively.[3] Due to asymmetric information in the consumer market, the final goods producer requires an evidence of solvency before delivery. Thus, households must secure an exogenously varying share of consumption by bank deposits d. This additional restriction is implemented by means of a deposit-in-advance (DIA) constraint in the sense of a standard cash-in-advance (CIA) constraint.

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[3]Accordingly, $1 - n_t - s_t$ measures the consumption of leisure. Its natural logarithm is approximately $-(n_t + s_t)$.

Consumption expenditure is financed out of labour income and dividends - distributed either by firms or banks - seignorage proceeds transferred by the central bank, or private saving. The latter either takes the form of deposit accounts at a bank or of financial investment in the risk-free bond b. Household income that has not been consumed, can be saved in either asset to raise private wealth. Maximisation is thus subjected to the budget constraint,

$$c_t + b_t + d_t + \frac{\phi_d}{2}\left(\frac{d_t}{d_{t-1}} - 1\right)^2 d_{t-1} \leq w_t(n_t + s_t) + \frac{d_{t-1}R_{t-1}^d}{\pi_t} + \frac{b_{t-1}R_{t-1}}{\pi_t} + g_t + g_t^f + g_t^{cb}, \quad (2)$$

on the one hand, and to the deposit-in-advance constraint, $\alpha_t c_t \leq d_t$, on the other hand. The DIA constraint embeds a mean reverting AR(1) process, $\alpha_t = \rho_\alpha \alpha_{t-1} + (1-\rho_\alpha)\alpha + \epsilon_t^\alpha$, that swings around a long-run share of consumption α to be guaranteed by deposits. Therefore, d must be considered as an aggregate including both sight deposits and cash. ϵ_t^α is a Gaussian white noise disturbance.

Apart from their necessity in a share of consumption purchases, bank-deposited funds yield a gross return R^d. Any change in the amount of d gives rise to quadratic adjustment costs. The representative household maximises its lifetime utility subject to the above constraints by determining an infinite series of optimal levels of $\{c_t, n_t, b_t, d_t\}$.

3.2 Monopolistically Competitive Intermediate Goods-Producing Firms

The continuum of intermediate goods producers is indexed by $i \in [0, 1]$. Hiring homogeneous labour $n(i)$ from the representative household, firm i produces a differentiated intermediate good $y(i)$, using a common constant returns to scale technology. Selling output in an imperfectly competitive market, intermediate goods producers earn a positive monopolistic profit.

The accumulation of productive physical capital, and therefore all investment decisions, is in the hands of the firm. The capital accumulation equation takes the usual deterministic form, $k_t(i) = (1 - \delta)k_{t-1}(i) + i_t(i)$, where $i_t(i)$ is gross investment into capital undertaken by firm i in period t. Production is described by the Cobb-Douglas function $y_t(i) = e^{\theta_t}k_{t-1}(i)^\gamma n_t(i)^{1-\gamma}$, where $\theta_t = \rho_\theta \theta_{t-1} + \epsilon_t^\theta$ is a persistent disturbance to total factor productivity, with ϵ_t^θ white noise. Note that the period t capital stock of a firm, which consists of the depreciated k_{t-1} and recently undertaken investment, will not be

productive before the beginning of period $t+1$.

Intermediate goods producers rely on bank loans to finance their current costs up front. In real terms, firm i must borrow an amount

$$\frac{L_t(i)}{P_t} = \frac{W_t}{P_t} n_t(i) + \frac{Q_t}{P_t} i_t(i). \tag{3}$$

For simplicity, I fix the typically pro-cyclical market price of capital $\frac{Q_t}{P_t} = q_t$ to unity in my model. Final consumption and investment goods are identical, and so are their prices. This largely switches off the "financial accelerator" in the sense of Bernanke et al. (1996). Still, the value of collateral, the demand for monitoring effort, and the EFP remain subject to changes in a firm's stock of physical capital and expected profits - two generally pro-cyclical quantities likely to amplify impulse responses. Note that this assumption is not a requirement for solving the model. A market price for capital can be derived by adding a representative capital goods producer who transforms the depreciated old capital stock and final output into new productive capital in a costly investment process.[4]

In equilibrium, default on debt obligations is not an option for firms. The screening activities of commercial banks exclude any would-be borrowers from the loan market right from the start. This avoids cases of bankruptcy among intermediate-goods producers.[5] All firms are owned by the representative household and do not accumulate own funds, apart from the stock of productive capital. At the end of each period, monopolistic profits g are therefore distributed to the household. The risk-neutral manager of firm i chooses optimal values of $\{n_t(i), P_t(i), k_t(i)\}$ to maximise

$$E_t \sum_{v=0}^{\infty} \beta^v \lambda_{t+v} g_{t+v}(i), \tag{4}$$

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[4]Another version of the model which includes this extension, replicates the "financial accelerator" phenomenon of Bernanke and Gertler (1995) and Bernanke et al. (1999), without, however, influencing the conclusions drawn from the introduction of monopolistically competitive banks. I therefore omit it in the present paper.

[5]This short cut is adopted from Goodfriend and McCallum (2007) who refer to Kocherlakota (1996).

where real current firm profits are given by

$$
\begin{aligned}
g_t(i) =& \frac{P_t(i)}{P_t} y_t(i) - \frac{R_{t-1}^l (w_{t-1}(i) n_{t-1}(i) + i_{t-1}(i))}{\pi_t} \\
& - \frac{\phi_p}{2} \left(\frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right)^2 y_t(i) - \frac{\phi_k}{2} \left(\frac{k_t(i)}{k_{t-1}(i)} - 1 \right)^2 k_{t-1}(i),
\end{aligned}
\tag{5}
$$

subject to satisfying demand for intermediate good i by the final goods producer:

$$
e^{\theta_t} k_{t-1}(i)^\gamma n_t(i)^{1-\gamma} \geq \left(\frac{P_t(i)}{P_t} \right)^{-\mu} y_t = y_t(i).
\tag{6}
$$

In the instantaneous profit function, R^l is the per period gross loan rate demanded by banks. I assume that monopolistically competitive firms face quadratic adjustment costs when resetting their prices[6] and when adjusting the stock of physical capital. Note that the presence of capital adjustment costs implies a value of installed productive capital to the firm that may well lie above q which has been normalised to unity. As intuition suggests, both price and capital adjustment cost are zero in the stationary equilibrium.

3.3 The Representative Final Goods-Producing Firm

The final goods producer operates in a perfectly competitive market, purchasing $y(i)$ units of the intermediate good i at the price $P(i)$ and assembling these inputs in the usual Dixit-Stiglitz way to produce the final good

$$
y_t = \left(\int_0^1 y_t(i)^{\frac{\mu-1}{\mu}} di \right)^{\frac{\mu}{\mu-1}},
\tag{7}
$$

where μ is the elasticity of substitution between intermediate goods of different producers. The profit-maximising demand of the final goods producer for the intermediate good i is thus $y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\mu} y_t$, with an aggregate price index $P_t = \left(\int_0^1 P_t(i)^{1-\mu} di \right)^{\frac{1}{1-\mu}}$.

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[6]The deferred repayment of working capital loans overly complicates the computation of an expression for real marginal costs. I therefore preferred quadratic price adjustment costs according to Rotemberg (1982) to the more popular price stickiness à la Calvo (1983). Note that both approaches deliver equivalent optimal price-setting behaviour of monopolistically competitive goods producers, which has been proven e.g. by Roberts (1995).

3.4 Monopolistically Competitive Financial Intermediaries

Commercial banks, indexed by $j \in [0,1]$, provide slightly differentiated products of financial intermediation. They face a constant finite elasticity of substitution in the market for deposits and loans, respectively. In line with Gerali et al. (2008, 2009), I assume that bank clients demand a Dixit-Stiglitz composite of the above differentiated contracts. Formally, this means that the representative household must divide its deposit holdings across the entire continuum of banks. Similarly, firms must sign loan contracts with every single bank j in order to borrow one unit of external funds. This approach lacks realistic micro-foundations, but it incorporates all the features necessary for analysing the impact of bank competition on the pass-through of monetary policy.[7] The responsiveness of a bank's share in the composite deposit and loan contract to the corresponding interest rate depends inversely on the parameters η_d and η_l. When resetting their interest rates, banks face Rotemberg (1982) adjustment costs. Similar to the case of a price-setting firm, the latter should be considered as "menu costs". In particular, they include any resource costs related to communicating the new interest rates to clients.

Bank j produces loans according to the CRS function

$$l_t(j) = F(g_t + qk_t)^\sigma (e^{\chi_t} s_t(j))^{1-\sigma}, \tag{8}$$

where monitoring effort s_t, supplied by the representative household, is the only costly input factor. I assume that all banks are of comparable size and have an identical number of clients. The latter are distributed randomly across financial institutions. As a consequence, the monitoring required to provide a line of credit $l(j)$ depends inversely on the economy-wide collateral.[8]

On the one hand, this collateral consists of current period profits which are only distributed to the household, if the firm honours its debt. On the other hand, the bank can seize the borrower's capital stock in the event of default which is excluded in this model.

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[7]Approaches with a richer economic content are taken e.g. by Andrés and Arce (2008). They use a version of Salop's (1979) circular city to model imperfect competition in the loan market, where borrowers suffer a utility cost when travelling to a bank. Aliaga-Díaz and Oliveiro (2007) introduce switching costs à la Klemperer (1995) as a source of market power. These costs lead to a bank client "lock-in" effect.

[8]While an influence of firm-specific collateral on the cost of external funding seems more realistic, I made this modelling choice to avoid feedback from the loan interest rate into a firm's optimal investment and production decisions. In the symmetric equilibrium, the assumption of economy-wide collateral is entirely unproblematic.

Since k is installed in the firm, only a constant fraction $q < 1$ is considered actually collectible by the bank.[9] $\chi_t = \rho_\chi \chi_{t-1} + \epsilon_t^\chi$ is an auto-correlated innovation to monitoring technology, in the following referred to as *external finance premium shock* or *EFP shock*, with ϵ_t^χ i.i.d. normal.

In addition, bank j provides deposits to the household. The associated costs $\frac{\omega_t d_t(j)}{m_t(j)}$ rise with the amount of d and fall in the bank's reserves of central bank money. Banks expand their reserves $m_t(j)$ by engaging in an open market operation. They issue a risk-free bond b which is bought by the monetary authority in exchange for high-powered money. The mean-reverting marginal cost $\omega_t = \rho_\omega \omega_{t-1} + (1 - \rho_\omega)\omega + \epsilon_t^\omega$ is not bank-specific. It fluctuates around a long-run average value of ω, disturbed by a white noise shock ϵ_t^ω, later on referred to as the *inside money premium shock* or *IMP shock*.

Private banks have access to the open or interbank market, where they can borrow at the risk-free rate R. They will thus not agree to pay a return on sight deposits above the risk-free rate, corrected for the cost of deposit provision. The difference between R_t and R_t^d is a liquidity premium. I call it the *inside money premium (IMP)*, in what follows. The risk-neutral manager of bank j sets $\{d_t(j), s_t(j), b_t(j), m_t(j), R_t^d(j), R_t^l(j)\}$ to maximise

$$E_t \sum_{v=0}^{\infty} \beta^v \lambda_{t+v} g_{t+v}^f(j), \tag{9}$$

where instantaneous profits are

$$
\begin{aligned}
g_t^f(j) = &\, d_t(j) + b_t(j) + \frac{m_{t-1}(j)}{\pi_t} + \frac{l_{t-1}(j) R_{t-1}^l(j)}{\pi_t} \\
& - \frac{d_{t-1}(j) R_{t-1}^d(j)}{\pi_t} - \frac{b_{t-1}(j) R_{t-1}(j)}{\pi_t} - l_t(j) - m_t(j) - w_t s_t(j) - \frac{\omega_t d_t(j)}{m_t(j)} \\
& - \frac{\phi_{R^d}}{2}\left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1\right)^2 d_t(j) - \frac{\phi_{R^l}}{2}\left(\frac{R_t^l(j)}{R_{t-1}^l(j)} - 1\right)^2 l_t(j),
\end{aligned}
\tag{10}
$$

subject to $d_t(j) \geq \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d} d_t$ and $l_t(j) \geq \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l} l_t$. As in Henzel et al. (2009), each bank faces a downward-sloping demand curve for loan contracts and an upward-sloping demand curve for deposit accounts. The above expressions derive from a cost-minimising

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[9]The real market price of the uninstalled physical capital would again be equal to 1, as it is identical in its characteristics to the final output good.

borrowing behaviour of intermediate goods producers and from the DIA-constrained utility maximisation of the representative household, respectively.

3.5 The Monetary Authority

I do not model a government or any kind of fiscal policy in this paper. Yet, I introduce an authority exercising monetary policy. Its highly stylised balance sheet only contains high-powered money m on the liabilities side and bank bonds b on the asset side. Every period, the monetary authority conducts open market operations to provide commercial banks with their desired amount of central bank money in exchange for risk-free bank bonds. Since its assets b yield a return, while its liability m doesn't, the central bank retains a positive seignorage profit from open market operations:

$$g_t^{cb} = m_t + \frac{b_{t-1}R_{t-1}}{\pi_t} - b_t - \frac{m_{t-1}}{\pi_t}. \tag{11}$$

To avoid that these proceeds are lost to the economy, I assume that they are transferred to the representative household as an additional source of non-labour income.

Monetary policy follows a simple version of the standard Taylor (1993) rule:

$$R_t = (1 - \rho)(\beta^{-1} + \varphi_\pi(\pi_t - 1)) + \rho R_{t-1} + \epsilon_t^R. \tag{12}$$

The risk-free gross nominal interest rate adjusts to offset any deviations of current inflation from its target value.[10] In a stationary environment, it is reasonable to assume that the central bank targets strict price stability, i.e. a zero inflation rate. The rule also incorporates interest rate inertia, capturing a strong aversion to fluctuations in the policy instrument $(0 < \rho < 1)$.

The Taylor principle for stability is fulfilled, if the central bank raises the real interest rate in response to an inflationary shock. This holds when $\varphi_\pi > 1$. The white noise shock ϵ_t^R cannot be controlled by the monetary authority. It prevents an exact pursuit of the policy rule.

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[10]Alternative Taylor rules, e.g. embedding a reaction to the so-called output gap, do not change neither qualitative nor quantitative results significantly, as long as empirically reasonable values for the monetary policy parameters are chosen.

4 Intertemporal Optimisation of Agents

4.1 Household Utility Maximisation

The first order conditions (FOCs), resulting from the representative household's optimisation problem, with respect to its choice variables are:

$$\frac{1}{c_t} = \lambda_t + \xi_t \alpha_t \tag{13}$$

$$\phi = \lambda_t w_t \tag{14}$$

$$\lambda_t = \beta E_t \lambda_{t+1} \frac{R_t}{\pi_{t+1}} \tag{15}$$

$$\left(1 + \phi_d \left(\frac{d_t}{d_{t-1}} - 1\right)\right) \lambda_t = \beta E_t \lambda_{t+1} \left[\phi_d \left(\frac{d_{t+1}}{d_t} - 1\right) \frac{d_{t+1}}{d_t} - \frac{\phi_d}{2} \left(\frac{d_{t+1}}{d_t} - 1\right)^2\right]$$

$$+ \beta E_t \lambda_{t+1} \frac{R_t^d}{\pi_{t+1}} + \xi_t. \tag{16}$$

Together with the DIA constraint, these 4 equations determine optimal household behaviour.

4.2 Profit Maximisation of Intermediate Goods Producers

The corresponding FOCs of the monopolistically competitive firms are:

$$\beta E_t \frac{\lambda_{t+1}}{\pi_{t+1}} R_t^l w_t = (1 - \gamma) \Xi_t(i) \frac{y_t(i)}{n_t(i)} \tag{17}$$

$$(1 - \mu)\lambda_t + \mu \Xi_t(i) + \mu \lambda_t \frac{\phi_p}{2} \left(\frac{\pi_t}{\pi} - 1\right)^2 =$$

$$\lambda_t \phi_p \left(\frac{\pi_t}{\pi} - 1\right) \frac{\pi_t}{\pi} - \beta E_t \lambda_{t+1} \phi_p \left(\frac{\pi_{t+1}}{\pi} - 1\right) \frac{\pi_{t+1}}{\pi} \frac{y_{t+1}}{y_t} \tag{18}$$

$$\beta^2 E_t \lambda_{t+2} \frac{R_{t+1}^l (1 - \delta)}{\pi_{t+2}} + \beta \gamma E_t \Xi_{t+1}(i) \frac{y_{t+1}}{k_t(i)} = -\beta E_t \lambda_{t+1} \phi_k \left(\frac{k_{t+1}(i)}{k_t(i)} - 1\right) \frac{k_{t+1}(i)}{k_t(i)}$$

$$+ \beta E_t \lambda_{t+1} \frac{\phi_k}{2} \left(\frac{k_{t+1}(i)}{k_t(i)} - 1\right)^2 - \beta E_t \lambda_{t+1} \frac{R_t^l}{\pi_{t+1}} + \lambda_t \phi_k \left(\frac{k_t(i)}{k_{t-1}(i)} - 1\right). \tag{19}$$

These conditions are completed by the capital accumulation equation and the Cobb-Douglas production function.

4.3 Profit Maximisation of Financial Intermediaries

The optimal behaviour of private banks is prescribed by the following equations:

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t^d(j)}{\pi_{t+1}} + \frac{\omega_t}{m_t(j)} - 1 = \frac{\lambda_t^1(j)}{\lambda_t} - \frac{\phi_{R^d}}{2} \left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1 \right)^2 \tag{20}$$

$$1 = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}} \tag{21}$$

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t^l(j)}{\pi_{t+1}} + \frac{\lambda_t^2(j)}{\lambda_t} - 1 = \frac{w_t s_t(j)}{(1-\sigma)l_t(j)} + \frac{\phi_{R^l}}{2} \left(\frac{R_t^l(j)}{R_{t-1}^l(j)} - 1 \right)^2 \tag{22}$$

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} = 1 - \frac{\omega_t d_t(j)}{m_t(j)^2}. \tag{23}$$

By combining (20) and (21), we receive an expression for the *inside money premium*, i.e. the spread between the risk-free interest rate and the return on deposits at bank j.

$$IMP_t: \qquad E_t \frac{\beta}{\pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} (R_t - R_t^d(j)) = \frac{\omega_t}{m_t(j)} - \frac{\lambda_t^1(j)}{\lambda_t} + \frac{\phi_{R^d}}{2} \left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1 \right)^2$$

This interest differential is determined by the marginal cost of deposit provision (the first term on the right hand side), the marginal cost in terms of household utility of a loss of clients who dissolve their accounts at the bank (the second term on the right hand side) and quadratic interest rate adjustment costs (the third term on the right hand side). Equivalently, we may substitute from (21) into the first-order condition w.r.t. monitoring (22) to obtain an expression for the *external finance premium*. It quantifies the opportunity cost of firms when relying on bank loans, i.e. external funds.

$$EFP_t: \qquad E_t \frac{\beta}{\pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} (R_t^l(j) - R_t) = \frac{w_t s_t(j)}{(1-\sigma)l_t(j)} - \frac{\lambda_t^2(j)}{\lambda_t} + \frac{\phi_{R^l}}{2} \left(\frac{R_t^l(j)}{R_{t-1}^l(j)} - 1 \right)^2$$

The meaning of the right hand side terms is corresponding: The marginal cost of an additional unit of monitoring effort, the change in utility terms of a gain or loss in loan market share, and the quadratic costs of adjusting the loan interest rate. I finally merge the FOCs w.r.t. m (23) and b to derive an explicit demand for central bank money:

$$E_t \frac{\beta}{\pi_{t+1}} \frac{\lambda_{t+1}}{\lambda_t} (R_t - 1) = \frac{\omega_t d_t(j)}{m_t(j)^2} \qquad \Leftrightarrow \qquad m_t(j) = \sqrt{\frac{\omega_t d_t(j)}{\beta(R_t - 1)E_t(\frac{1}{\pi_{t+1}})}}$$

In open market operations, commercial banks have no influence on the policy rate. Neither do they face adjustment costs. The difference between the risk-free interest rate and the return on high-powered money is thus determined by the marginal product of m in deposit provision. More intuitively, bank j demands reserves until the r.h.s. equals the net monetary policy rate

These optimality conditions are completed by the loan production function and the firm's credit requirement. I thus assume that demand for loans is satisfied in equilibrium.

In similar form, the above expressions also arise in a framework with fully competitive banks. Monopolistic competition among private banks adds two new decision variables. Deposit and loan interest rates are set in the face of adjustment costs and of a proportional loss of clients. Accordingly, the optimal values of R_t^d and R_t^l, respectively, must fulfil the following first-order conditions:

$$\lambda_t \eta_d \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d - 1} \frac{d_t}{R_t^d} - \beta E_t \lambda_{t+1}(1 + \eta_d) \frac{d_t}{\pi_{t+1}} \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d} - \lambda_t \eta_d \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d - 1} \frac{\omega_t d_t}{m_t(j) R_t^d}$$

$$- \lambda_t \phi_{R^d} \left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1\right) \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d} \frac{d_t}{R_{t-1}^d(j)} + \beta E_t \lambda_{t+1} \phi_{R^d} \left(\frac{R_{t+1}^d(j)}{R_t^d(j)} - 1\right) \left(\frac{R_{t+1}^d(j)}{R_{t+1}^d}\right)^{\eta_d} \frac{R_{t+1}^d(j)}{R_t^d(j)^2} d_{t+1}$$

$$- \lambda_t \eta_d \frac{\phi_{R^d}}{2} \left(\frac{R_t^d(j)}{R_{t-1}^d(j)} - 1\right)^2 \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d - 1} \frac{d_t}{R_t^d} - \lambda_t^1 \eta_d \left(\frac{R_t^d(j)}{R_t^d}\right)^{\eta_d - 1} = 0 \qquad (24)$$

$$\beta E_t \lambda_{t+1}(1 - \eta_l) \frac{l_t}{\pi_{t+1}} \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l} + \lambda_t \eta_l \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l - 1} \frac{l_t}{R_t^l}$$

$$- \lambda_t \phi_{R^l} \left(\frac{R_t^l(j)}{R_{t-1}^l(j)}\right) \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l} \frac{l_t}{R_{t-1}^l(j)} + \beta E_t \lambda_{t+1} \phi_{R^l} \left(\frac{R_{t+1}^l(j)}{R_t^l(j)} - 1\right) \left(\frac{R_{t+1}^l(j)}{R_{t+1}^l}\right)^{-\eta_l} \frac{R_{t+1}^l(j)}{R_t^l(j)^2} l_{t+1}$$

$$+ \lambda_t \eta_l \frac{\phi_{R^l}}{2} \left(\frac{R_t^l(j)}{R_{t-1}^l(j)} - 1\right)^2 \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l - 1} \frac{l_t}{R_t^l} + \lambda_t^2 \eta_l \left(\frac{R_t^l(j)}{R_t^l}\right)^{-\eta_l - 1} \frac{l_t}{R_t^l} = 0 \qquad (25)$$

It is straightforward to simplify these equations, dividing by the marginal utility of household consumption, λ_t, and by the economy-wide average levels of sight deposits, d_t, and loan contracts, l_t, as well as multiplying them by R_t^d and R_t^l, respectively.

4.4 The Symmetric Equilibrium

The competitive equilibrium is an infinite sequence of the endogenous model variables, where all economic agents optimise, the central bank follows its Taylor rule, and goods as well as financial contract markets clear.

I assume that the representative household holds zero bonds in equilibrium and accumulates financial wealth only in terms of bank deposits. Apart from that, the equilibrium conditions of the household and the monetary authority basically replicate their FOCs. The same is true for the monopolistically competitive firms and banks.

Although the latter two agents profit from quantifiable market power which allows each firm i to set its price and each bank j to set its interest rates independently, I assume symmetric behaviour in the following. Facing the same economic state and only aggregate innovations[11] , their factor demand and price-setting decisions will be identical in equilibrium. Under the above symmetry assumptions, I receive a system of 23 equations contained in Appendix A.

5 Calibration and Steady-State Analysis

From the equations in Appendix A, it is straightforward to derive the stationary equilibrium. I assume that no random shocks occur in the steady state, so that $\epsilon_t^R = 0$ and the exogenous variables α_t, θ_t, χ_t, ω_t adopt their long-run trend values α, θ, χ, ω. These are partially equal to zero. Due to the nonlinear nature of the model, a closed form analytical solution is not available. Instead, it is solved numerically by means of the Gauss-Newton method using MATLAB routines. As far as possible, I calibrate the parameter set according to the existing literature. When it comes to banking-related parameters, prior sources of information are rare. The calibration is thus geared to generate empirically relevant steady-state values of the key financial variables - especially bank interest rates and spreads.

5.1 Choice of Parameter Values

The household discount factor β is set to a quarterly value of 0.9951 to match the average inflation-adjusted Effective Federal Funds Rate between 1985 and 2009. This

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[11]Remember that the model does not incorporate idiosyncratic shocks to any of the economic agents.

corresponds to a real annual policy rate of just below 2%. With a weight of leisure $\phi = 2.14$ in the utility function, the representative household spends one third of its total time endowment working in either firms or banks. On average, the household must secure 80% of consumption by bank deposits ($\alpha = 0.8$).

I set the income share of capital in goods production γ to a standard value of 0.35. Productive capital depreciates with a quarterly rate δ of 2.5%. A price elasticity of intermediate good demand $\mu = 6$ implies a steady-state monopolistic mark-up of 20% over marginal costs.

Collateral is relatively more efficient in loan production than in goods production. The higher a borrower's guarantee, the less informational effort must be invested by banks to provide a given amount of credit and to ensure its repayment. Without collateral, no loans can be produced, at all. Similar to Goodfriend and McCallum (2007), I set σ, the contribution of collateral in the loan production function, equal to 0.6.

Installed physical capital is considered recoverable and marketable only to an extent q of 21%. A constant TFP in loan production $F = 6$ completes the set of loan-related parameters. They are calibrated to the average value of the US Prime Lending Rate between 1985 and 2009.

The long-run equilibrium value of the deposit interest rate is highly sensitive to the marginal administration cost. To obtain reasonable steady-state differentials, ω is kept very low.[12]

I finally calibrate the interest-rate elasticity of deposit and loan demand, η_d and η_l. For these parameters which are not yet well-established in the New Keynesian literature, the sole source of reference is Gerali et al. (2008, 2009). Setting $\eta_d = 500$ and $\eta_l = 400$, I implicitly assume that in a world with both heterogeneous firms and banks, the financial contracts provided by different banks can be substituted much easier than the consumption or investment goods of different firms. As a consequence, firms enjoy more market power than banks. They demand thus a bigger mark-up over marginal costs. The proper value of these last parameters is the most obvious source of vagueness in my calibration. I do not claim to set a benchmark, here, at all.

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[12]Increasing the parameter ω easily leads to a negative real interest rate paid on household deposit. Although this is imaginable when considering nominal interest rates on checking or overnight deposit accounts and correcting for inflation, I choose a calibration with positive steady-state real return on all financial assets.

5.2 The Stationary Equilibrium

As announced in the introduction to this chapter, the model is now solved numerically. Under the above parameterisation, I obtain the steady-state values listed in table 1. Several intuitive results follow directly. With a value of 2.42, the annual capital-output ratio is low but in an acceptable range. A consumption-to-GDP ratio c/y of 0.757 and an investment-to-GDP ratio i/y of 0.242 indicate that household consumption and firm investment absorb the lion's share of output, but not all. 0.1% of GDP is spent on the administration of deposits. These costs are sunk and not redistributed to bank employees in the form of wages or to the owners of deposits as interest payment. Remember that this is not the case in loan production, where only monitoring is costly. While monitoring reduces bank profits and thus the dividend distributable to households, it simultaneously raises the salary of the latter. Both banks and firms earn a positive monopolistic rent in the steady state.

The stationary equilibrium has been computed for quarterly data at zero inflation. The interest factors R, R^d, and R^l imply thus an annual real rate on risk-free bonds (the policy rate), sight deposits, and loans of about 1.96%, 0.8%, and 4.6%. This corresponds to a steady-state annual *IMP* of 1.16% and a steady-state annual *EFP* of 2.64%.

What I label *premium* is indeed the consequence of two special features of this model. On the one hand, there is an intermediation cost in both the deposit and the loan market that is passed on to clients. Private banks demand an interest rate above the risk-free rate on working capital loans and pay an interest rate below R on deposit accounts. On the other hand, imperfect competition among banks allows them to expand these interest differentials. The monopolistic mark-ups or mark-downs in R^d and R^l, respectively, generate positive steady-state profits.

Steady-State Values *(benchmark calibration)*								
y	c	i	k	n	s	R	R^d	R^l
1.1252	0.8515	0.2724	10.8959	0.3314	0.0020	1.0049	1.0020	1.0115
w	d	m	l	g	g^f	π	IMP	EFP
1.8274	0.6812	0.2637	0.8779	0.2372	0.0024	1.0000	0.0029	0.0066

Table 1: Steady-state results for a benchmark parameter calibration

5.3 Comparative Statics

The steady-state values presented in table 1 primarily serve as a guideline for an adequate calibration and lack illustrative power without further study. The question is thus nearby, how long-run economic activity in this model depends on the extent of competition among banks. For this purpose, I analyse the steady-state values of a few selected variables with respect to the interest rate sensitivities η_d and η_l.

Figure 1 illustrates the long-run relation between economic activity and competition in the market for deposits. Therein, I steadily increase the parameter of interest from 10, i.e. few competitors, to 1000, approximating perfect competition among the providers of deposits contracts. Obviously, output, investment and employment are negatively correlated with bank market power. The higher η_d, i.e. the less sensitive the demand for deposits of bank j to $R_t^d(j)$, the higher the mark-up demanded on top of marginal costs and the *IMP*.
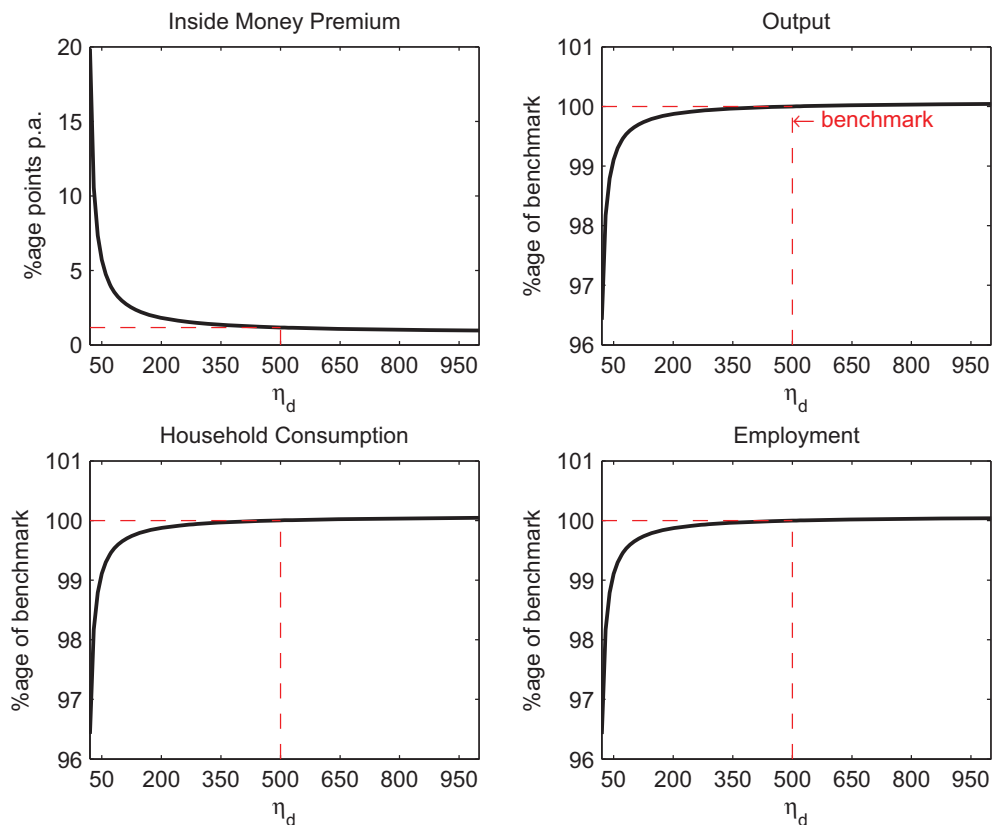

Figure 1: Imperfect competition on the deposit market for values of $\eta_d \in [10, 1000]$
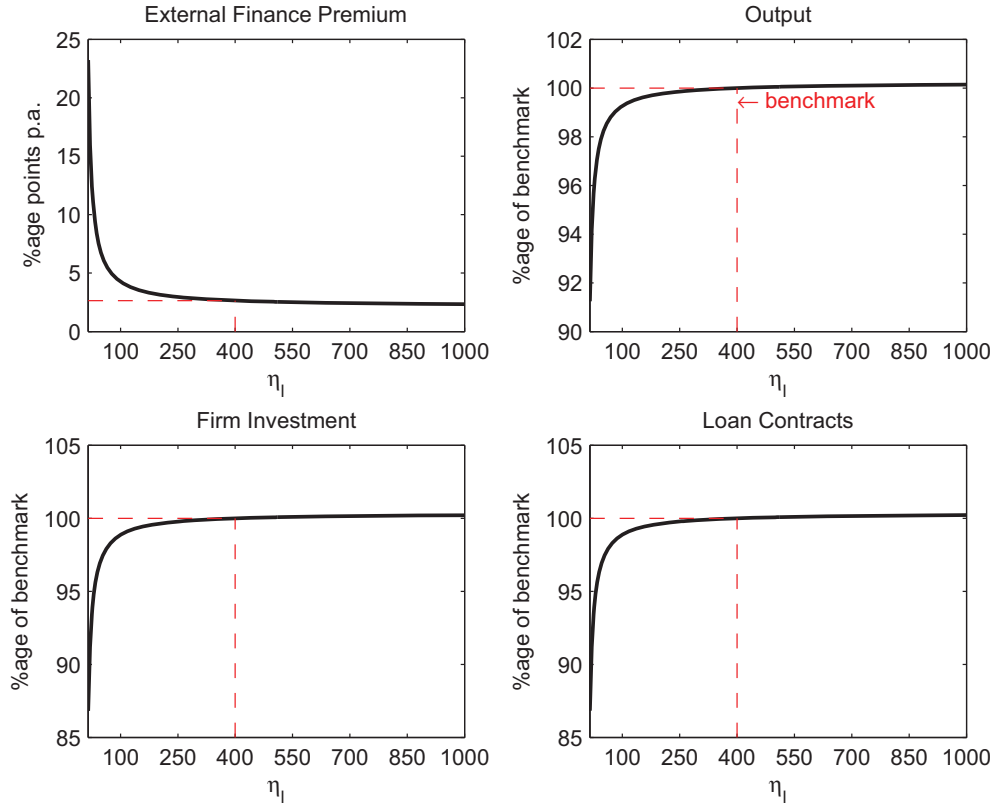
Figure 2: Imperfect competition in the market for loans, $\eta_l \in [10, 1000]$

In the case of extremely low competition, the spread between the policy and the bank rate climbs to a maximum of about 20 percentage points p.a.. The impact on economic activity is important. It leads to a contraction relative to the benchmark steady state of about 3.6% in each output, consumption, and employment. On the other hand, economic activity expands by less than 0.1% in the absence of market power. This implies that my benchmark calibration is not far from the case of perfect competition. Note that even then, the *IMP* does not drop to zero, because banks still face positive costs of deposit provision.

Accordingly, figure 2 illustrates the stationary levels of economic activity as a percentage of the benchmark case for different levels of competition in the market for loans. When I set η_l to 10, banks drive the *EFP* up to an annual value of more than 23 percentage points.[13] As a consequence, the steady state of output contracts by 8.75% relative to

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[13]Some readers might doubt the empirical relevance of these interest differentials. However, lenders in poorly developed financial markets with low competition are capable of demanding much higher premiums, even in real terms.

its benchmark value. Investment into productive capital and the amount of loans even shrink by up to 13.2%. Again, the expansionary effect of an above-benchmark level of competition is comparatively small, reaching values of 0.14% for output, and 0.21% for investment and loans. Lower market power of lenders reduces the *external finance premium* by only 30 basis points p.a..

In line with the first finding by van Leuvensteijn et al. (2008), imperfect competition among financial intermediaries leads to increased spreads between bank rates and the policy rate.[14] By causing an under-provision of economic agents with liquidity and working capital loans, bank market power unambiguously harms long-run economic activity. In an environment with monopolised markets for financial services, the model predicts a drop in output, consumption, employment, and investment below their potential steady-state equilibrium values.

6 Dynamic Analysis

In the following sections, the model is solved by numerical simulation. I examine whether it is able to reproduce the empirically predicted impulse responses to standard exogenous shocks. Further, I analyse how the level of competition among corporate banks affects the transmission mechanism and thus the efficiency of monetary policy.

6.1 Remaining Parameters

When calibrating the model for the steady-state analysis, irrelevant parameters were left open. On the one hand, this concerns the entire set of adjustment cost coefficients. Since quadratic adjustment costs have the convenient trait of disappearing in the steady state, their calibration has been postponed until now. The estimates in the related literature for the capital adjustment cost coefficient ϕ_k range from 10 to 35, depending on the respective model specifications and data sample period. Following Ireland (2003) who receives a highly significant ϕ_k of 32.13 in a sticky price model for the post-1979 period, I pick a value of 35. I further set the coefficient of price rigidity ϕ_p to 100, a value in the mid range of Ireland's estimates. Adjusting deposits is assumed to be slightly less costly

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[14]The model fails to reproduce an inverse relation between loan market competition and the rate on deposits.

than adjusting a firm's capital stock, i.e. $\phi_d = 30$. Finally, there are two parameters left for which I cannot resort to any conclusive empirical evidence.[15] It seems acceptable to assume that it is equally costly for a bank to change its interest rate as it is for a firm to change its price. I therefore set both ϕ_{R^d} and ϕ_{R^l} to 100.

On the other hand, the Taylor rule must be specified numerically. It is characterised by an exclusive reaction to deviations from the zero target inflation rate and by interest-rate inertia. The central bank is averse to sudden jumps in the policy rate and places a weight $\rho = 0.75$ on R_{t-1}. To satisfy the Taylor principle, the central bank must raise the nominal interest rate by more than one percentage point for each percentage point increase in inflation. In line with Taylor's original proposal, I set φ_π to 1.5.[16]

Finally, I calibrate the autoregressive coefficients and standard deviations of the four shocks. Following Ireland (2003) and many others, I assume that these processes display a significant persistence, with $\rho_\alpha = 0.88$, $\rho_\theta = 0.95$, $\rho_\chi = 0.9$, and $\rho_\omega = 0.9$. For the associated standard deviations of the i.i.d. disturbances, I choose $\sigma_\alpha = 0.6$, $\sigma_\theta = 0.8$, $\sigma_\chi = 0.8$, and $\sigma_\omega = 0.18$ in percentage terms. These parameters imply that technology shocks in the banking and the goods-producing sector are similarly highly auto-correlated and of same average magnitude.

The standard deviation of monetary policy shocks σ_r is set to 25 basis points on a quarterly basis. This corresponds to an innovation in the policy rate of one percentage point per annum. Table 2 provides an overview of the entire set of benchmark parameter values.

6.2 Results

The dynamic system of equations is solved in DYNARE on MATLAB. The model contains 10 forward-looking endogenous variables, so-called *jump variables*. It must therefore possess an identical number of eigenvalues outside the unit circle to fulfil the Blanchard-Kahn conditions. As the solution algorithm requires linear equations, I loglinearise the

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[15]Gerali et al. (2008) calibrate the adjustment cost coefficients for bank interest rates to 375 for loans to firms, 500 for loans to households, and 1800 for deposits. In a more recent and extended version of the paper, Gerali et al. (2009) estimate part of their model parameters, receiving posterior mean values for the above coefficients of 14.1, 13.95 and 10.13, respectively, strongly opposing their reasoning when calibrating the same parameters.

[16]Note that a calibration with $\varphi_\pi \leq 1$ does not satisfy the stability conditions for applying the solution method proposed by Blanchard and Kahn (1980). In this case, the equilibrium becomes indeterminate.

model at the steady state. Appendix B contains the transformed system of equations. The simulation results are presented in two steps, beginning with the impulse responses of a selection of important variables to the model's exogenous shocks. The subsequent sensitivity analysis focuses on the importance of monopolistic competition among commercial banks for the transmission of monetary policy.

6.2.1 Impulse Responses in the Benchmark Model

This section provides a survey of the model's implications for the dynamic behaviour of key economic variables. The corresponding impulse response functions are displayed at the end of the paper.

Technology shock

Figure 5 maps the reaction of selected variables to a one-standard-deviation shock to the technology parameter θ. It generates the empirically found hump-shaped responses in output, consumption, and investment. Output takes two years before it peaks at 0.49 percent above its stationary equilibrium and starts to converge back. Restricted by deposits which are costly to adjust, consumption reacts equally slowly. It reaches a maximum percentage deviation from steady state of 0.47 after 2.5 years, only. Investment, on the contrary, responds much quicker and increases by more than 1.5 times this fraction. As in the data, it displays thus the highest variability of the three. Due to a strong rise in the real wage, employment in goods production falls on impact. Over time, additional physical capital is accumulated and the growth in labour productivity justifies the payment of a higher real wage.

The monetary authority responds to the slowdown in inflation by 0.093 percentage points, and mechanically relaxes its policy. At the end of the first year, the quarterly risk-free interest rate has fallen by 6.5 basis points. This corresponds to 0.26 percent on an annual basis.

The technology shock spills over to the banking sector, as well. The immediate rise in desired investment is financed through additional loans. Employment in the banking sector increases, accordingly. While the direction of the overall changes in R^d and R^l is predetermined by the policy rate, the effect of the exogenous shock is visible in the *IMP* and *EFP*. With decreasing marginal productivity of monitoring effort, the expansion of

loan production raises marginal costs. Thus, banks demand a higher premium on top of the risk-free rate.

Although more deposits are required, as consumption rises with economic activity, banks are able to provide them at a reduced cost. Their increased demand for high-powered money m is amplified by the expansionary monetary policy. Temporarily, the inside money premium falls by more than 1.3 basis points.

Monetary Policy shock

Next, I analyse a positive disturbance of 25 basis points to the Taylor rule, i.e. an unforeseen increase in the annual policy rate by one percentage point. On the real side of the economy, the standard qualitative effects are observed. A monetary tightening leads to a drop in GDP, consumption, and investment by 0.21, 0.09, and 0.81 percent relative to the steady state. Employment in both goods production and the banking falls significantly (see figure 6).

At this point, the popular non-backward-looking character of firms' optimal price setting is somewhat unfortunate. Since the current period's inflation rate π_t is not predetermined[17], part of the monetary policy shock is absorbed by an instantaneous deceleration of inflation. Yet, I would like to emphasise that the impact on the *real* interest rate is the same, whether it originates from an increase in the nominal interest rate or from reduced inflation.

Central bank measures are destined to influence the inflation rate or the level of activity in an economy. It is thus of major interest, how a monetary contraction affects the banking sector as the provider of *inside money* and working capital loans.

Obviously, bank interest rates increase by less than the policy rate. A slowdown in economic activity lowers the demand for financial intermediation. Although liquidity services d fade by 0.09 percent in line with consumption, the severe contraction in the supply of high-powered money increases the costs of deposit provision. As a consequence, banks demand a higher *IMP* and adjust the deposit interest rate imperfectly to the new policy rate. At the same time, the demand for loans l falls by a full percent relative to its steady-state. The loan interest rate differential *EFP* decreases by up to 3.65 basis

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[17]Note that even if π_t, the change in the price level between period $t-1$ and t is not predetermined, the previous period's price level P_{t-1} clearly is. Accordingly, the rate of inflation becomes a jump variable through changes in the current period price level.

points.

Deposit-in-Advance shock

The largest part of an increase in the minimum deposit requirement per unit of consumption is compensated by an immediate waiving of household consumption. In response to a rise in α, the latter falls by 0.52 percent relative to its stationary value. The adjustment of deposits is costly and satisfies the new constraint with a lag, only. The drop in consumption generates a deceleration of inflation, illustrated in figure 7. As a consequence, real labour costs rise and employment decreases by more than 0.6 percent of its steady state. The delayed increase in investment by barely 0.04 percent is not sufficient to prevent the downturn in GDP.

The central bank reacts to the slowdown of inflation by easing monetary policy. While the interest rate on loans follows R closely, the deposit rate falls by somewhat less. The demand for loans drops by 0.38 percent. Therefore, banks require less monitoring. These redundancies in the banking sector are amplified by the steady increase in firms' productive capital stock and thus collateral. As a result, the *EFP* remains below its steady state during convergence.

Similar to the case of a positive technology shock, the spread between R^d and the policy rate does not rise in response to a tightening of the DIA constraint. With high-powered money reserves increasing by 0.9 percent in the first and another 0.4 percent in the second and third quarter, commercial banks can even provide deposit accounts at a slightly reduced cost. They demand thus a lower *IMP*.

Inside-Money-Premium shock

The two remaining exogenous disturbances originate directly from the banking sector. They are expected to have minor influence on the real economy. The impulse responses of selected variables to an increase in ω, which makes the provision of deposits more costly, are depicted in figure 8. Commercial banks react by accumulating larger reserves of high-powered money. This limits the rise in costs and has a moderating effect on the *IMP*. Accordingly, the interest rate on deposit accounts decreases by a mere 0.015 basis points relative to the steady state.

Nevertheless, any fall in R^d corresponds to an increase in the liquidity cost of consumption. Households thus reduce their consumption expenditure and deposit holdings;

however, by an insignificant amount. This lower level implies a higher marginal utility of consumption and, from the loglinearised equation (B.2), a fall in the real wage w. Consequently, the simulation predicts a slight expansive effect on output, employment in goods production and banking, as well as inflation, while firms invest less. Following the Taylor rule, the monetary authority counteracts any inflation by raising the policy rate. Note that all deviations in the impulse responses of real variables are of the order 10^{-4} or minor.

External-Finance-Premium shock

Finally, I expose the model to a positive technology shock in bank monitoring of size σ_χ. As expected, increased efficiency in loan production makes part of the financial sector employees redundant - s falls by 0.79 percent. Still, credit contracts can be provided at a lower cost. This is passed on to clients as a reduction in the *EFP* by 0.38 basis points and a comparable drop in the quarterly loan interest rate R^l, illustrated in figure 9.

Goods producers benefit from this cheaper source of funds. They borrow additional working capital to expand employment and investment by up to 0.28 and 0.6 basis points, respectively. It is due to the increased labour demand that firm output grows by 0.19 basis points during the first year. The faster accumulation of capital affects production capacity with a lag, only.

With regard to the lower borrowing costs of firms, a rise in the productivity of monitoring is comparable to a positive supply shock. It generates a small immediate slowdown in inflation. The monetary authority follows its Taylor rule and lowers the policy rate by a maximum of $2 \cdot 10^{-4}$ percentage points, after one year. This suffices to ensure convergence. The deposit rate follows closely, diverging merely by a negligible fluctuation in the *IMP*.

The quantitative analysis of impulse responses suggests that the contribution of disturbances emerging from financial intermediation to the business cycle is of second order importance. The present model contains two such shocks – one impeding the provision of deposit accounts and one varying the efficiency in loan production. By influencing the spreads between the deposit rate and the risk-free interest rate, and between the loan interest rate and R, these shocks have an impact on agents' optimal decision making. Both affect output, consumption, investment, and the like through a *bank interest rate channel*.

6.2.2 Monetary Policy and Financial Intermediation

This paper's key question is whether and to what extent the pass-through from changes in the policy rate to the real economy depends on the degree of competition in the banking sector. In the light of recent central bank behaviour, the subsequent sensitivity analyses focus on the impulse responses of a selection of variables to an expansive monetary policy shock.

The Impact of Competition in the Market for Deposits

The novelty in my model with respect to the underlying work by Goodfriend and McCallum (2007) is the fact that commercial banks enjoy a quantifiable interest rate setting power.

In the following analysis, I set the interest elasticity of demand for deposit contracts provided by a certain bank, η_d, to 9, 500, and $1 \cdot 10^{12}$. These values characterise a situation with highly monopolistic banks, the benchmark case, and perfect competition in the market for deposits. All three are solved numerically, i.e. simulated for 2000 periods, in order to extract so-called policy and transmission functions as well as first and second order moments of the model's endogenous variables. A selection of the impulse responses for the first 20 periods succeeding an expansionary monetary policy shock is presented in figure 3. While an interest rate mark-down of 12.5% on deposits seems quite high, I choose this value to exhaust the potential relevance of η_d for the transmission mechanism.

As expected, the stock of high-powered money soars directly after the drop in the policy rate. However, the extent of this increase is insensitive to the parameter under consideration. I thus focus on the impulse responses of R^d and the corresponding interest differential. With perfect competition, any variation in the *IMP* is entirely due to fluctuations in the endogenous costs of deposit provision. For the benchmark calibration η_d=500, demand for bank deposits is still elastic enough to trace the previous case closely. If, however, the market for deposits displays an oligopolistic structure, so that agents profit from considerable interest rate setting power, the *IMP* drops in response to the expansive monetary shock. Private banks find it optimal to adjust their deposit rate with a lag and only by one quarter of the percentage point revision we observe in a perfectly competitive market.
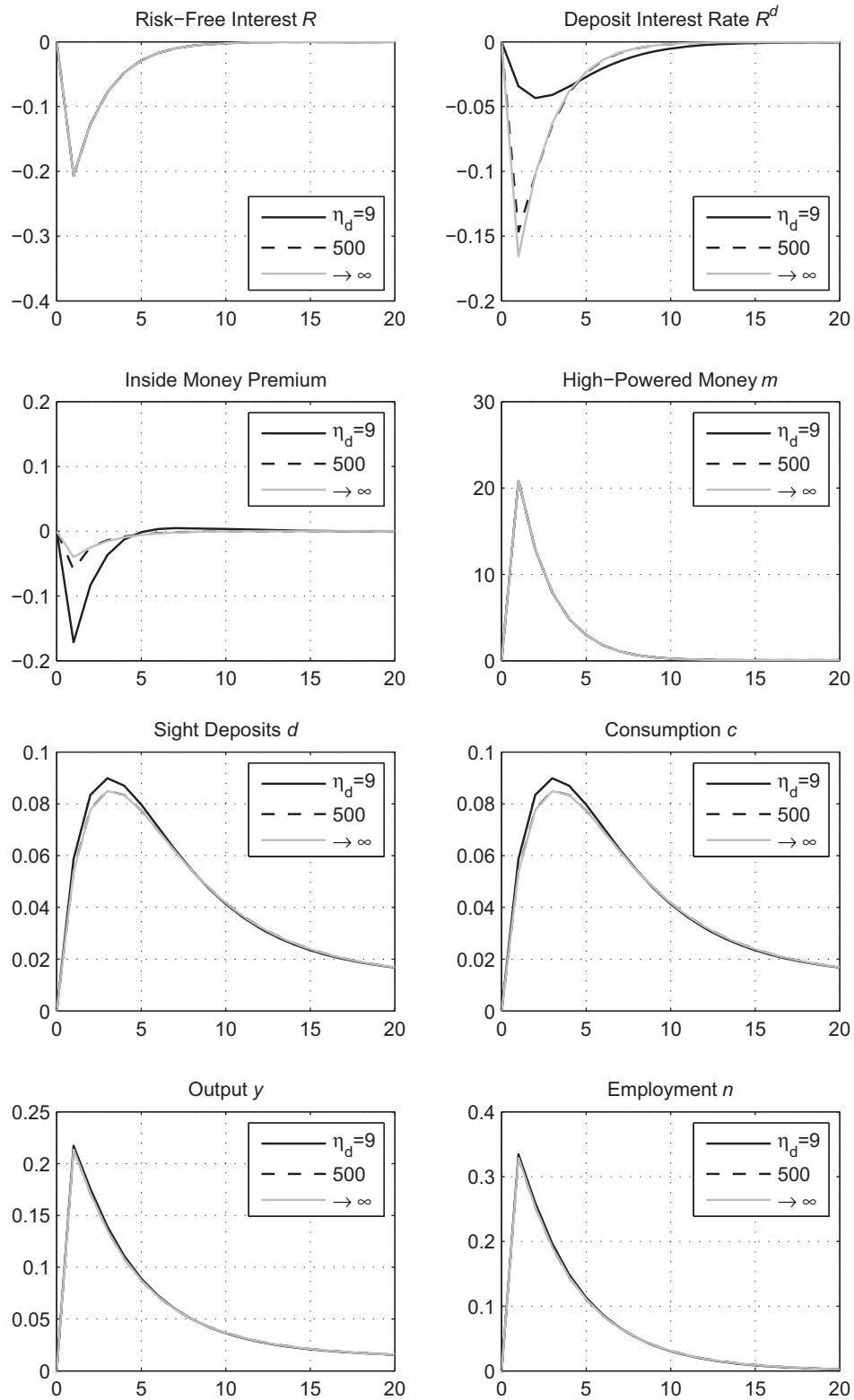
Figure 3: Impulse responses to a monetary policy innovation for $\eta_d = 9$, 500, and $1 \cdot 10^{12}$

Nevertheless, the effect on consumption and deposits is remarkable only in the first two years. The percentage deviation from steady state in the minimum competition scenario exceeds that in the perfect competition case by up to six percent. Incomplete pass-through from monetary policy to the bank interest rate leads to a stronger reduction in the opportunity cost of deposit-secured consumption – the *IMP*. It is thus optimal for the representative household to adjust consumption by more, ceteris paribus, the higher the market power of banks. The same is observable in the reactions of GDP and employment to an innovation in the policy rate. Yet, the effect is hard to recognise, even for a very low degree of interest-rate elasticity.

It seems to be optimal for commercial banks to exploit their interest rate setting power. While the adjustment of consumption is sensitive to η_d, the difference in output and employment is below one basis point and barely visible, unless impulse responses are magnified. Nevertheless, we can state that limited competition in the market for deposits amplifies the expansion of real economic activity after a surprise drop in the monetary policy rate.

Varying the Degree of Monopolistic Competition in the Loan Market

The final sensitivity analysis examines the role of monopolistic competition in the market for loans. Again, I choose three values for parameter η_l that characterise very low, benchmark, and – at least approximately – infinitely high substitutability between the credit contracts supplied by different banks. I therefore pick values of 9, 400, and $1 \cdot 10^{12}$. Surprisingly, the structural composition of the loan market has a much stronger influence on the economy's real side than that of the market for deposits. After an unanticipated monetary expansion, commercial banks naturally lower their loan rate. Yet, how closely they follow the policy rate, depends on two aspects: On the one hand, a falling real wage rate and a reduced need for monitoring effort – due to the drop in loan demand – lower the cost of loan production. On the other hand, monopolistically competitive banks consider market share effects and adjustment costs in their interest rate setting. By definition, the negative correlation between loan demand and the loan interest rate weakens with η_l. Imperfectly competitive banks exploit their interest rate setting power and accept a temporary surge in the *EFP* relative to the perfect competition scenario. If I set the interest sensitivity to an extremely low value, the model predicts a maximum

reduction in R^l by 4.6 basis points, opposed by nearly 20 basis points when $\eta_l \to \infty$. This corresponds to a percentage deviation from steady state four times as large. Even when the parameter takes its benchmark value, profit maximisation still invites banks to adjust their loan interest rate incompletely in response to a drop in R, allowing for a transitory increase in the *EFP*.

According to the model, endowing private banks with market power significantly attenuates the pass-through of monetary policy shocks. I already remarked that the role of competition in the loan market dwarfs the effect of competition among deposit providers. In absolute terms, the instantaneous impulse responses of output and employment for $\eta_l = 9$ and $\eta_l \to \infty$ differ by approximately 4.6 and 7 basis point; that of loans by up to 12 basis points. In line with the empirical evidence, investment into productive capital displays the highest interest sensitivity among the real variables. On impact, its deviations from the steady state reach from +0.66 to +0.85 percent – a difference of almost 30 percent.

The preceding sensitivity analysis unambiguously attests that monopolistic competition in the loan market can be a significant bottleneck for monetary policy. In this respect, the model matches the empirical evidence of van Leuvensteijn et al. (2008) who consider only loan market competition. The pass-through from policy and thus market rates to bank interest rates is weaker in less competitive markets. Banks as interest-rate makers cushion thus the deviation of real variables from steady state.

This result has an important implication in the light of the currently observed credit crunch. Although central banks worldwide pursued an expansive monetary policy of unprecedented determination[18], private banks failed to fully pass this reduction in the key interest rate on to borrowers. As a consequence, the shortage in loan supply, a major threat, especially to small and medium-sized firms which are unable to refinance themselves through the stock market, persists to this day. While it is not certain, to what extent the assessed imperfect pass-through reflects the risk considerations of intermediaries, delayed and incomplete adjustment of bank rates to the policy rate strongly indicates the existence of interest rate setting power.

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[18]Between October 2008 and May 2009, the European Central Bank has reduced the interest rate on main refinancing operations by 325 basis points from a level of 4.25% to currently 1.00%.
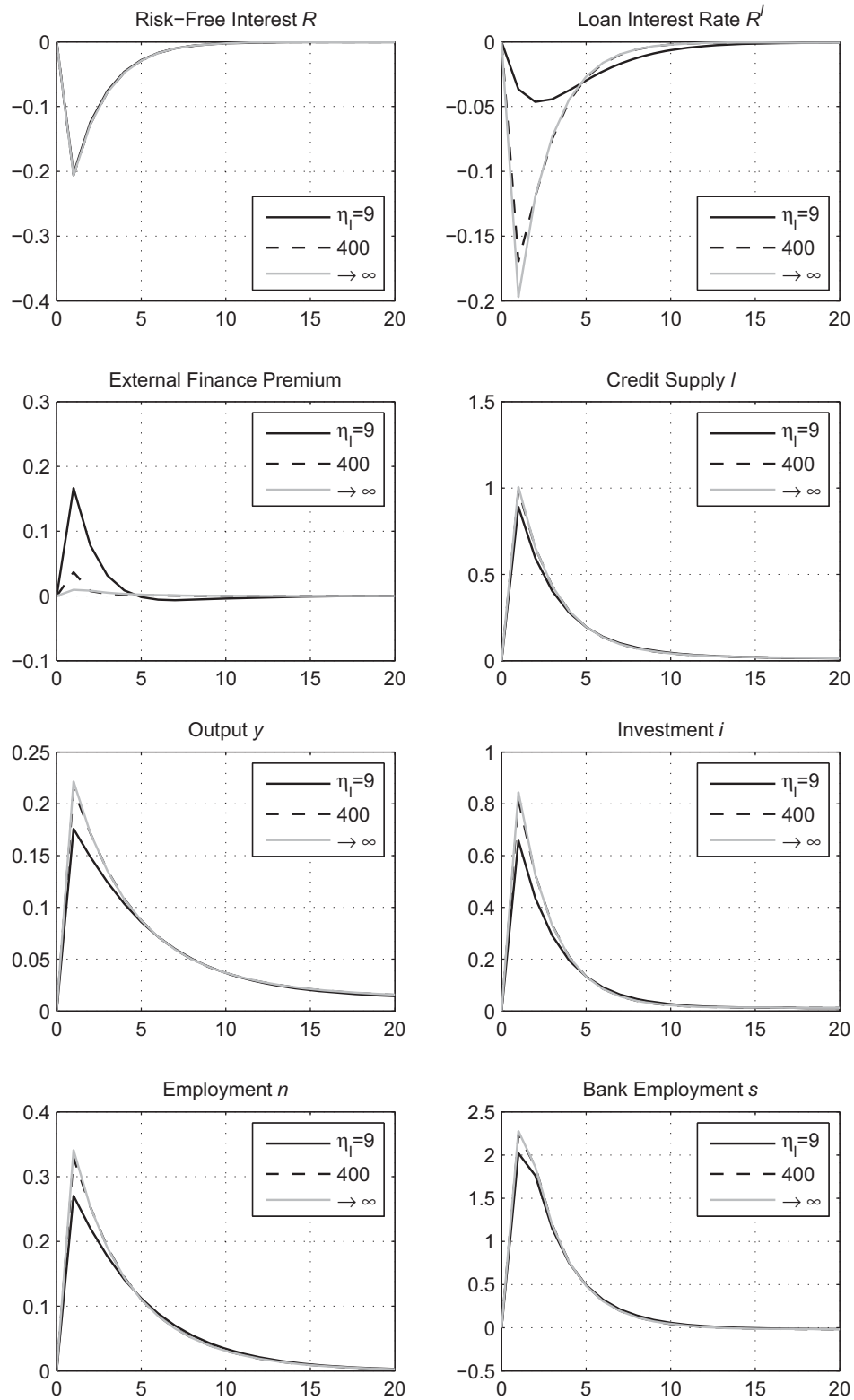
Figure 4: Impulse responses to a monetary policy shock for $\eta_l = 9$, 400, and $1 \cdot 10^{12}$

7 Conclusion

In the model presented here, private agents rely on two types of financial services. These deposits and loans are provided by commercial banks. The costs of financial intermediation determine most of the spread between the risk-free refinancing rate and bank rates, the so-called *inside money* and *external finance premium*, respectively. More importantly, the services of different banks substitute imperfectly against each other. Monopolistic competition in deposit and loan markets implies that banks enjoy an interest rate setting power through their influence on the *IMP* and *EFP*.

The results suggest that innovations inherent to the banking sector are relatively unimportant in comparison to the three standard shocks. Yet, my framework is not flexible enough to simulate a severe financial crisis like the present credit crunch, which might change theoretical predictions. This seems an interesting direction for further model extensions.

The concluding sensitivity analysis compares the impulse responses of selected variables to an unforeseen monetary expansion. It evaluates the importance of competition in bank product markets for the pass-through of monetary policy. Imperfect competition among the providers of deposits acts as a financial accelerator, in this model. By contrast, credit contract heterogeneity absorbs part of the effect of monetary policy shocks.

While the degree of competition in the deposit market has merely marginal influence, the interest sensitivity of loan demand not only dominates the former, but is clearly quantitatively important for the behaviour of economic agents.

Appendix A. The Symmetric Equilibrium

The symmetric equilibrium is an infinite time series of the 23 endogenous variables y, c, i, k, n, s, w, g, g^f, R, R^d, R^l, m, d, l, π, g^{cb}, b, λ, ξ, Ξ, λ^1, and λ^2 given the exogenous shock processes α, θ, ω, and χ, that solves the following system of 23 equilibrium conditions:

$$\frac{1}{c_t} = \lambda_t + \xi_t \alpha_t \tag{A.1}$$

$$\phi = \lambda_t w_t \tag{A.2}$$

$$\lambda_t = \beta E_t \lambda_{t+1} \frac{R_t}{\pi_{t+1}} \tag{A.3}$$

$$\beta E_t \lambda_{t+1} \frac{R_t^d}{\pi_{t+1}} + \xi_t$$
$$= \left(1 + \phi_d \left(\frac{d_t}{d_{t-1}} - 1\right)\right) \lambda_t + \beta E_t \lambda_{t+1} \left[\phi_d \left(\frac{d_{t+1}^2}{d_t^2} - \frac{d_{t+1}}{d_t}\right) - \frac{\phi_d}{2}\left(\frac{d_{t+1}}{d_t} - 1\right)^2\right] \tag{A.4}$$

$$\alpha_t c_t = d_t \tag{A.5}$$

$$k_t = (1 - \delta)k_{t-1} + i_t \tag{A.6}$$

$$y_t = e^{\theta_t} k_{t-1}^{\gamma} n_t^{1-\gamma} \tag{A.7}$$

$$\beta E_t \frac{\lambda_{t+1}}{\pi_{t+1}} R_t^l w_t n_t = (1 - \gamma)\Xi_t y_t \tag{A.8}$$

$$(1 - \mu)\lambda_t + \mu\Xi_t + \mu\lambda_t \frac{\phi_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 = \lambda_t \phi_p \left(\frac{\pi_t^2}{\pi^2} - \frac{\pi_{t+1}}{\pi}\right)\frac{y_{t+1}}{y_t} \tag{A.9}$$

$$\beta^2 E_t \frac{\lambda_{t+2}}{\pi_{t+2}}(1 - \delta)R_{t+1}^l - \beta E_t \frac{\lambda_{t+1}}{\pi_{t+1}}R_t^l + \beta\gamma E_t \Xi_{t+1}\frac{y_{t+1}}{k_t}$$
$$= \lambda_t \phi_k \left(\frac{k_t}{k_{t-1}} - 1\right) - \beta E_t \lambda_{t+1} \phi_k \left(\frac{k_{t+1}^2}{k_t^2} - \frac{k_{t+1}}{k_t}\right) + \beta E_t \lambda_{t+1} \frac{\phi_k}{2}\left(\frac{k_{t+1}}{k_t} - 1\right)^2 \tag{A.10}$$

$$g_t = y_t - \frac{R_{t-1}^l(w_{t-1}n_{t-1} + i_{t-1})}{\pi_t} - \frac{\phi_p}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 - \frac{\phi_k}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} \tag{A.11}$$

$$R_t = (1 - \rho)(\beta^{-1} + \varphi_\pi(\pi_t - 1)) + \rho R_{t-1} + \epsilon_t^R \tag{A.12}$$

$$g_t^{cb} = m_t + \frac{b_{t-1}R_{t-1}}{\pi_t} - b_t - \frac{m_{t-1}}{\pi_t} \tag{A.13}$$

$$m_t = b_t \tag{A.14}$$

$$g_t^f = d_t + b_t + \frac{m_{t-1}}{\pi_t} + \frac{l_{t-1}R_{t-1}^l}{\pi_t} - \frac{d_{t-1}R_{t-1}^d}{\pi_t}$$
$$- l_t - m_t - w_t s_t - \frac{\omega_t d_t}{m_t} - \frac{\phi_{R^d}}{2}\left(\frac{R_t^d}{R_{t-1}^d} - 1\right)^2 d_t - \frac{\phi_{R^l}}{2}\left(\frac{R_t^l}{R_{t-1}^l} - 1\right)^2 l_t \tag{A.15}$$

$$E_t \frac{\beta}{\pi_{t+1}}\frac{\lambda_{t+1}}{\lambda_t}(R_t - R_t^d) = \frac{\omega_t}{m_t} - \frac{\lambda_t^l}{\lambda_t} + \frac{\phi_{R^d}}{2}\left(\frac{R_t^d}{R_{t-1}^d} - 1\right)^2 \tag{A.16}$$

$$E_t \frac{\beta}{\pi_{t+1}}\frac{\lambda_{t+1}}{\lambda_t}(R_t^l - R_t) = \frac{w_t s_t}{(1-\sigma)l_t} - \frac{\lambda_t^2}{\lambda_t} + \frac{\phi_{R^d}}{2}\left(\frac{R_t^l}{R_{t-1}^l} - 1\right)^2 \tag{A.17}$$

$$E_t \frac{\beta}{\pi_{t+1}}\frac{\lambda_{t+1}}{\lambda_t}(R_t - 1) = \frac{\omega_t d_t}{m_t^2} \tag{A.18}$$

$$\eta_d d_t - \beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1+\eta_d)\frac{d_t}{\pi_{t+1}}R_t^d - \eta_d \frac{\omega_t d_t}{m_t} + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\phi_{R^d}\left(\frac{R_{t+1}^{d2}}{R_t^{d2}} - \frac{R_{t+1}^d}{R_t^d}\right)d_{t+1}$$
$$= \phi_{R^d}\left(\frac{R_t^{d2}}{R_{t-1}^{d2}} - \frac{R_t^d}{R_{t-1}^d}\right)d_t + \eta_d \frac{\phi_{R^d}}{2}\left(\frac{R_t^d}{R_{t-1}^d} - 1\right)^2 d_t + \frac{\lambda_t^l}{\lambda_t}\eta_d d_t \tag{A.19}$$

$$\eta_l l_t + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}(1-\eta_l)\frac{l_t}{\pi_{t+1}}R_t^l + \beta E_t \frac{\lambda_{t+1}}{\lambda_t}\phi_{R^l}\left(\frac{R_{t+1}^{l2}}{R_t^{l2}} - \frac{R_{t+1}^l}{R_t^l}\right)l_{t+1}$$
$$= \phi_{R^l}\left(\frac{R_t^{l2}}{R_{t-1}^{l2}} - \frac{R_t^l}{R_{t-1}^l}\right)l_t - \eta_l \frac{\phi_{R^l}}{2}\left(\frac{R_t^l}{R_{t-1}^l} - 1\right)^2 l_t - \frac{\lambda_t^2}{\lambda_t}\eta_l l_t \tag{A.20}$$

$$l_t = w_t n_t + i_t \tag{A.21}$$

$$l_t = F(g_t + q k_t)^\sigma (e^{\chi_t} s_t)^{1-\sigma} \tag{A.22}$$

$$c_t + d_t + \frac{\phi_d}{2}\left(\frac{d_t}{d_{t-1}} - 1\right)^2 d_{d-1} = w_t(n_t + s_t) + \frac{d_{t-1}R_{t-1}^d}{\pi_t} + g_t + g_t^f + g_t^{cb} \tag{A.23}$$

Appendix B. The Model in Loglinear Form

Below, $\hat{x}_t$ stands for the percentage deviation of variable x from its stationary equilibrium in period t. Note that the denotations of $\hat{R}_t$, $\hat{R}_t^d$, and $\hat{R}_t^l$ have a slightly different meaning: The interest rates on risk-free bonds, deposits, and loans enter the loglinear system in terms of absolute deviation from steady states measured in percentage or basis points, respectively.

$$0 = \left(\frac{1}{c}\right)\hat{c}_t + \lambda\hat{\lambda}_t + \xi\alpha\hat{\xi}_t + \alpha\xi\hat{\alpha}_t \tag{B.1}$$

$$0 = \hat{w}_t + \hat{\lambda}_t \tag{B.2}$$

$$0 = \hat{d}_t - \hat{c}_t - \hat{\alpha}_t \tag{B.3}$$

$$0 = \hat{k}_t - (1-\delta)\hat{k}_{t-1} - \delta\hat{i}_t \tag{B.4}$$

$$0 = \gamma\hat{k}_{t-1} + (1-\gamma)\hat{n}_t - \hat{y}_t + \hat{\theta}_t \tag{B.5}$$

$$0 = y\hat{y}_t - \frac{wn+i}{\pi}\hat{R}_{t-1}^l - \frac{R^l wn}{\pi}(\hat{w}_{t-1} + \hat{n}_{t-1}) - \frac{R^l i}{\pi}\hat{i}_{t-1} - \frac{R^l(wn+i)}{\pi}\hat{\pi}_t - g\hat{g}_t \tag{B.6}$$

$$0 = d\hat{d}_t + b\hat{b}_t + \frac{m}{\pi}(\hat{m}_{t-1} - \hat{\pi}_t) + \frac{l}{\pi}\hat{R}_{t-1}^l + \frac{lR^l}{\pi}(\hat{l}_{t-1} - \hat{\pi}_t) - \frac{d}{\pi}\hat{R}_{t-1}^d - \frac{dR^d}{\pi}(\hat{d}_{t-1} - \hat{\pi}_t)$$

$$\quad - \frac{b}{\pi}\hat{R}_{t-1} - \frac{bR}{\pi}(\hat{b}_{t-1} - \hat{\pi}_t) - l\hat{l}_t - m\hat{m}_t - ws(\hat{w}_t + \hat{s}_t) - \frac{\omega d}{m}(\hat{\omega}_t + \hat{d}_t - \hat{m}_t) - g^f\hat{g}_t^f \tag{B.7}$$

$$0 = -\hat{R}_t + \rho\hat{R}_{t-1} + (1-\rho)\varphi_\pi\pi\hat{\pi}_t + r_t \tag{B.8}$$

$$0 = \hat{m}_t - \hat{b}_t \tag{B.9}$$

$$0 = m\hat{m}_t + \frac{b}{\pi}\hat{R}_{t-1} + \frac{bR}{\pi}(\hat{b}_{t-1} - \hat{\pi}_t) - b\hat{b}_t - \frac{m}{\pi}(\hat{m}_{t-1} - \hat{\pi}_t) - g^{cb}\hat{g}_t^{cb} \tag{B.10}$$

$$0 = wn(\hat{w}_t + \hat{n}_t) + i\hat{i}_t - l\hat{l}_t \tag{B.11}$$

$$0 = \frac{\sigma qk}{g+qk}\hat{k}_t + (1-\sigma)\hat{s}_t - \hat{l}_t + \frac{\sigma g}{g+qk}\hat{g}_t + (1-\sigma)\hat{\chi}_t \tag{B.12}$$

$$0 = c\hat{c}_t + d\hat{d}_t - wn(\hat{w}_t + \hat{n}_t) - ws(\hat{w}_t + \hat{s}_t)$$

$$- \frac{d}{\pi}\hat{R}^d_{t-1} - \frac{R^d d}{\pi}(\hat{d}_{t-1} - \hat{\pi}_t) - g\hat{g}_t - g^f\hat{g}^f_t - g^{cb}\hat{g}^{cb}_t \tag{B.13}$$

$$0 = \beta\hat{R}_t - E_t\hat{\pi}_{t+1} + E_t\hat{\lambda}_{t+1} - \hat{\lambda} \tag{B.14}$$

$$0 = \beta\phi_d E_t\hat{d}_{t+1} - (1+\beta)\phi_d\hat{d}_t + \phi_d\hat{d}_{t-1} + \beta\frac{1}{\pi}\hat{R}^d_t - \beta\frac{R^d}{\pi}E_t\hat{\pi}_{t+1} + \beta\frac{R^d}{\pi}E_t\hat{\lambda}_{t+1} - \hat{\lambda}_t + \frac{\xi}{\lambda}\hat{\xi}_t \tag{B.15}$$

$$0 = (1-\mu)\hat{\lambda}_t + (\mu-1)\hat{\Xi}_t - \phi_p\hat{\pi}_t + \beta\phi_p E_t\hat{\pi}_{t+1} \tag{B.16}$$

$$0 = \hat{R}^l_t + E_t(\hat{\lambda}_{t+1} - \hat{\pi}_{t+1}) + \hat{w}_t + \hat{n}_t - \hat{\Xi}_t - \hat{y}_t \tag{B.17}$$

$$0 = \beta\phi_k E_t\hat{k}_{t+1} - \left[(1+\beta)\phi_k + \beta\gamma\frac{\Xi}{\lambda}\frac{y}{k}\right]\hat{k}_t + \phi_k\hat{k}_{t-1} + \beta^2\frac{1-\delta}{\pi}R^l E_t(\hat{\lambda}_{t+2} - \hat{\pi}_{t+2})$$

$$+ \beta\gamma\frac{\Xi}{\lambda}\frac{y}{k}E_t\hat{y}_{t+1} - \beta\frac{R^l}{\pi}E_t(\hat{\lambda}_{t+1} - \hat{\pi}_{t+1}) + \beta\gamma\frac{\Xi}{\lambda}\frac{y}{k}E_t\hat{\Xi}_{t+1} + \frac{\beta^2}{\pi}(1-\delta)\hat{R}^l_{t+1} - \frac{\beta}{\pi}\hat{R}^l_t \tag{B.18}$$

$$0 = \frac{\beta}{\pi}(\hat{R}_t - \hat{R}^d_t) - \frac{\beta}{\pi}(R - R^d)E_t(\hat{\pi}_{t+1} - \hat{\lambda}_{t+1} + \hat{\lambda}_t) - \frac{\omega}{m}(\hat{\omega}_t - \hat{m}_t) + \frac{\lambda^l}{\lambda}(\hat{\lambda}^l_t - \hat{\lambda}_t) \tag{B.19}$$

$$0 = \frac{\beta}{\pi}(\hat{R}^l_t - \hat{R}_t) - \frac{\beta}{\pi}(R^l - R)E_t(\hat{\pi}_{t+1} - \hat{\lambda}_{t+1} + \hat{\lambda}_t) - \frac{ws}{(1-\sigma)l}(\hat{w}_t + \hat{s}_t - \hat{l}_t) + \frac{\lambda^2}{\lambda}(\hat{\lambda}^2_t - \hat{\lambda}_t) \tag{B.20}$$

$$0 = \frac{\beta}{\pi}\hat{R}_t - \frac{\beta}{\pi}(R-1)E_t(\hat{\pi}_{t+1} - \hat{\lambda}_{t+1} + \hat{\lambda}_t) - \frac{\omega d}{m^2}(\hat{\omega}_t + \hat{d}_t - 2\hat{m}_t) \tag{B.21}$$

$$0 = \beta\frac{\phi_{R^d}}{R^d}E_t\hat{R}^d_{t+1} + \left[\eta_d\left(1 - \frac{\omega}{m}\right) - \frac{\beta}{\pi}(1+\eta_d)R^d\right]\hat{d}_t - \left[(1+\beta)\frac{\phi_{R^d}}{R^d} + \frac{\beta}{\pi}(1+\eta_d)\right]\hat{R}^d_t + \frac{\phi_{R^d}}{R^d}\hat{R}^d_{t-1}$$

$$+ \eta_d\frac{\omega}{m}(\hat{m}_t - \hat{\omega}_t) + \frac{\beta}{\pi}(1+\eta_d)R^d E_t(\hat{\pi}_{t+1} - \hat{\lambda}_{t+1} + \hat{\lambda}_t) - \eta_d\frac{\lambda^l}{\lambda}(\hat{\lambda}^l_t + \hat{d}_t - \hat{\lambda}_t) \tag{B.22}$$

$$0 = \beta\frac{\phi_{R^l}}{R^l}E_t\hat{R}^l_{t+1} + \left[\eta_l + \frac{\beta}{\pi}(1-\eta_l)R^l\right]\hat{l}_t + \left[\frac{\beta}{\pi}(1-\eta_l) - (1+\beta)\frac{\phi_{R^l}}{R^l}\right]\hat{R}^l_t$$

$$+ \frac{\phi_{R^l}}{R^l}\hat{R}^l_{t-1} - \frac{\beta}{\pi}(1-\eta_l)R^l E_t(\hat{\pi}_{t+1} - \hat{\lambda}_{t+1} + \hat{\lambda}_t) + \eta_l\frac{\lambda^2}{\lambda}(\hat{\lambda}^2_t + \hat{l}_t - \hat{\lambda}_t) \tag{B.23}$$

References

Aliaga-Díaz, R., Oliveiro, M. P., 2007. Macroeconomic Implications of Market Power in Banking, unpublished, available at `www.aeaweb.org/annual_mtg_papers/2008/2008_508.pdf`.

Andrés, J., Arce, O., 2008. Banking Competition, Housing Prices and Macroeconomic Stability. Banco de España Documentos de Trabajo 0830.

Bernanke, B. S., Gertler, M., 1989. Agency Costs, Net Worth, and Business Fluctuations. American Economic Review 79 (1), 14–31.

Bernanke, B. S., Gertler, M., 1995. Inside the Black Box: The Credit Channel of Monetary Policy Transmission. Journal of Economic Perspectives 9 (4), 27–48.

Bernanke, B. S., Gertler, M., Gilchrist, S., 1996. The Financial Accelerator and the Flight to Quality. The Review of Economics and Statistics 78 (1), 1–15.

Bernanke, B. S., Gertler, M., Gilchrist, S., 1999. The Financial Accelerator in a Quantitative Business Cycle Framework. In: Taylor, J. B., Woodford, M. (Eds.), Handbook of Macroeconomics, 1st Edition. Vol. 1. Elsevier, Ch. 21, pp. 1341–1393.

Blanchard, O. J., Kahn, C. M., 1980. The solution of linear difference models under rational expectations. Econometrica 48 (5), 1305–1311.

Calvo, G. A., 1983. Staggered prices in a utility-maximizing framework. Journal of Monetary Economics 12 (3), 383–398.

Carlstrom, C. T., Fuerst, T. S., 1997. Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis. American Economic Review 87 (5), 893–910.

Christiano, L. J., Eichenbaum, M., 1995. Liquidity Effects, Monetary Policy, and the Business Cycle. Journal of Money, Credit and Banking 27 (4), 1113–1136.

Gerali, A., Neri, S., Sessa, L., Signoretti, F. M., 2008. Credit and Banking in a DSGE Model, unpublished, available at `www.bankofengland.co.uk/publications/events/ccbs_wgem2008/paper_neri.pdf`.

Gerali, A., Neri, S., Sessa, L., Signoretti, F. M., 2009. Credit and Banking in a DSGE Model of the Euro Area, unpublished, available at `www.federalreserve.gov/events/conferences/fmmp2009/papers/Gerali-Neri-Sessa-Signoretti.pdf`.

Goodfriend, M., 2005. Narrow Money, Broad Money, and the Transmission Process of Monetary Policy. In: Faust, J., Orphanides, A., Reifschneider, D. (Eds.), Models and Monetary Policy: Research in the Tradition of Dale Henderson, Richard Porter, and Peter Tinsley. Board of Governors of the Federal Reserve System, pp. 276–303.

Goodfriend, M., King, R. G., 1997. The New Neoclassical Synthesis and the Role of Monetary Policy. In: Bernanke, B. S., Rotemberg, J. J. (Eds.), NBER Macroeconomics Annual 1997. MIT Press.

Goodfriend, M., McCallum, B. T., 2007. Banking and interest rates in monetary policy analysis: A quantitative exploration. Journal of Monetary Economics 54 (5), 1480–1507.

Henzel, S., Hülsewig, O., Mayer, E., Wollmershäuser, T., 2009. The price puzzle revisited: Can the cost channel explain a rise in inflation after a monetary policy shock? Journal of Macroeconomics 31 (2), 268–289.

Ireland, P. N., 2003. Endogenous money or sticky prices? Journal of Monetary Economics 50 (8), 1623–1648.

Ireland, P. N., 2004. Money's role in the Business Cycle. Journal of Money, Credit and Banking 36 (6), 969–983.

Klemperer, P., 1995. Competition when Consumers Have Switching Costs: An Overview with Applications to Industrial Organization, Macroeconomics, and International Trade. The Review of Economic Studies 62 (4), 515–539.

Kocherlakota, N., 1996. Implications of efficient risk sharing without commitment. The Review of Economic Studies 63 (4), 595–609.

Roberts, J. M., 1995. New Keynesian Economics and the Phillips Curve. Journal of Money, Credit and Banking 27 (4), 975–984.

Rotemberg, J. J., 1982. Sticky Prices in the United States. Journal of Political Economy 90 (6), 1187–1211.

Salop, S., 1979. Monopolistic Competition with Outside Goods. Bell Journal of Economics 10, 141–156.

Scharler, J., 2008. Do bank-based financial systems reduce macroeconomic volatility by smoothing interest rates? Journal of Macroeconomics 30 (3), 1207–1221.

Smets, F., Wouters, R., 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. Journal of the European Economic Association 1 (5), 1123–1175.

Smets, F., Wouters, R., 2005. Comparing Shocks and Frictions in US and Euro Area Business Cycles: A Bayesian DSGE Approach. Journal of Applied Econometrics 20 (2), 161–183.

Smets, F., Wouters, R., 2007. Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. American Economic Review 97 (3), 586–606.

Stark, J., April 2009. Krisenbewältigung: Markt versus staat. Speech delivered at Franz-Böhm-Kolleg, Siegen, 29 April 2009, `http://www.ecb.int/press/key/date/2009/html/sp090429_1.de.html`.

Stracca, L., 2007. Should we take inside money seriously? ECB Working Papers 841.

Taylor, J. B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Conference Series on Public Policy 39 (1), 195–214.

van Leuvensteijn, M., Sørensen, C. K., Bikker, J. A., van Rixtel, A. A. R. J. M., 2008. Impact of Bank Competition on the Interest Rate Pass-Through in the Euro Area. ECB Working Papers 885.

Woodford, M., 2003. Interest and Prices: Foundations of a Theory of Monetary Policy. Princeton University Press, Princeton, NJ.

Woodford, M., 2009. How Important is Money in the Conduct of Monetary Policy? Journal of Money, Credit and Banking forthcoming.

Completive Tables and Figures

Parameter Values *(benchmark calibration)*			
Coefficient	Value	Coefficient	Value
α	0.8	ϕ_d	30
β	0.9951	ϕ_{R^d}	100
γ	0.35	ϕ_{R^l}	100
δ	0.025	ρ	0.75
ϕ	2.141	ϕ_π	1.5
ω	0.0005	σ_r	0.25
σ	0.6	ρ_θ	0.95
F	6	σ_θ	0.80
q	0.21	ρ_α	0.88
μ	6	σ_α	0.60
η_d	500	ρ_ω	0.90
η_l	400	σ_ω	0.18
ϕ_k	35	ρ_χ	0.90
ϕ_p	100	σ_χ	0.80

Table 2: Benchmark calibration of all model parameters relevant for the economy's steady state and dynamic behaviour
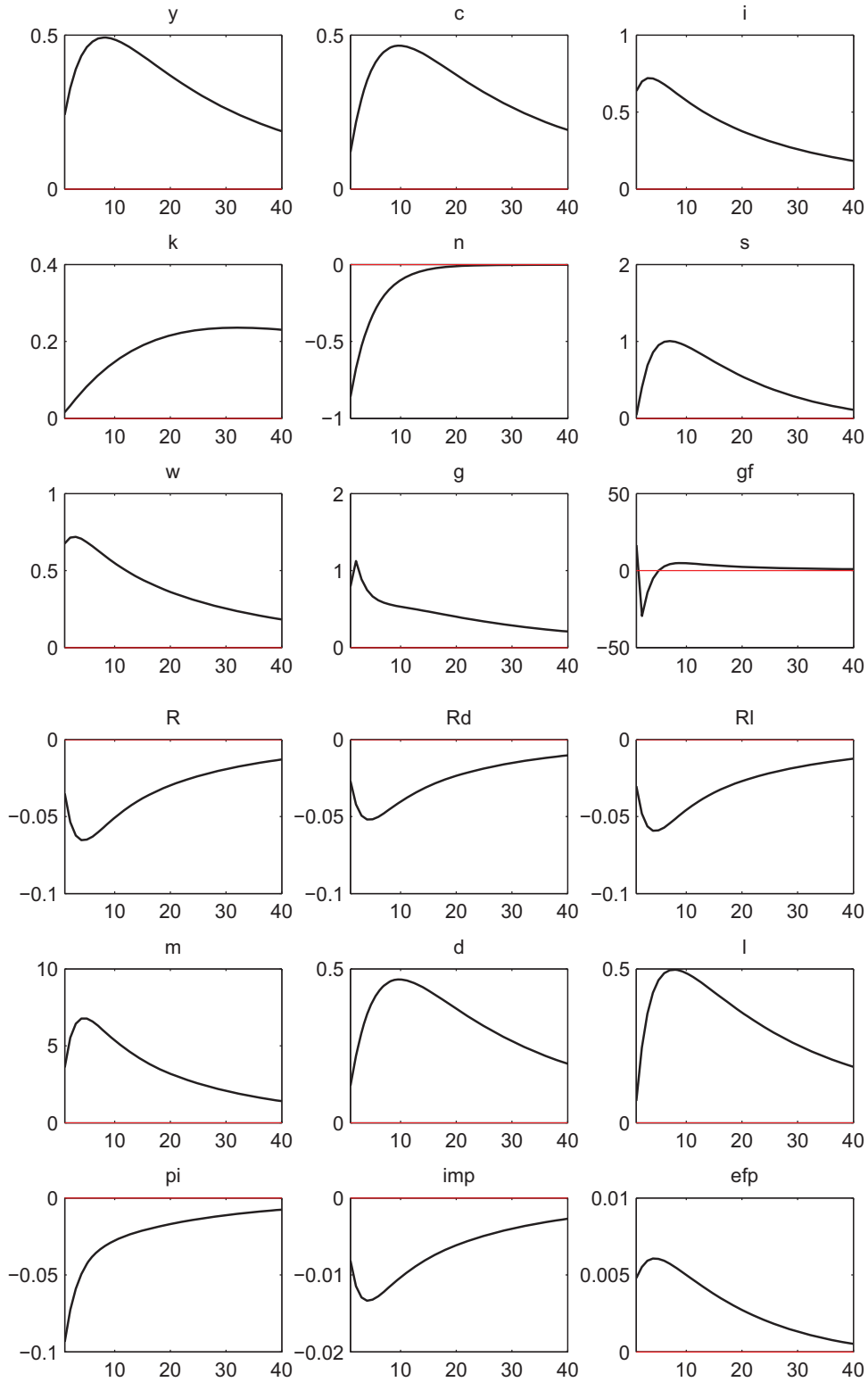
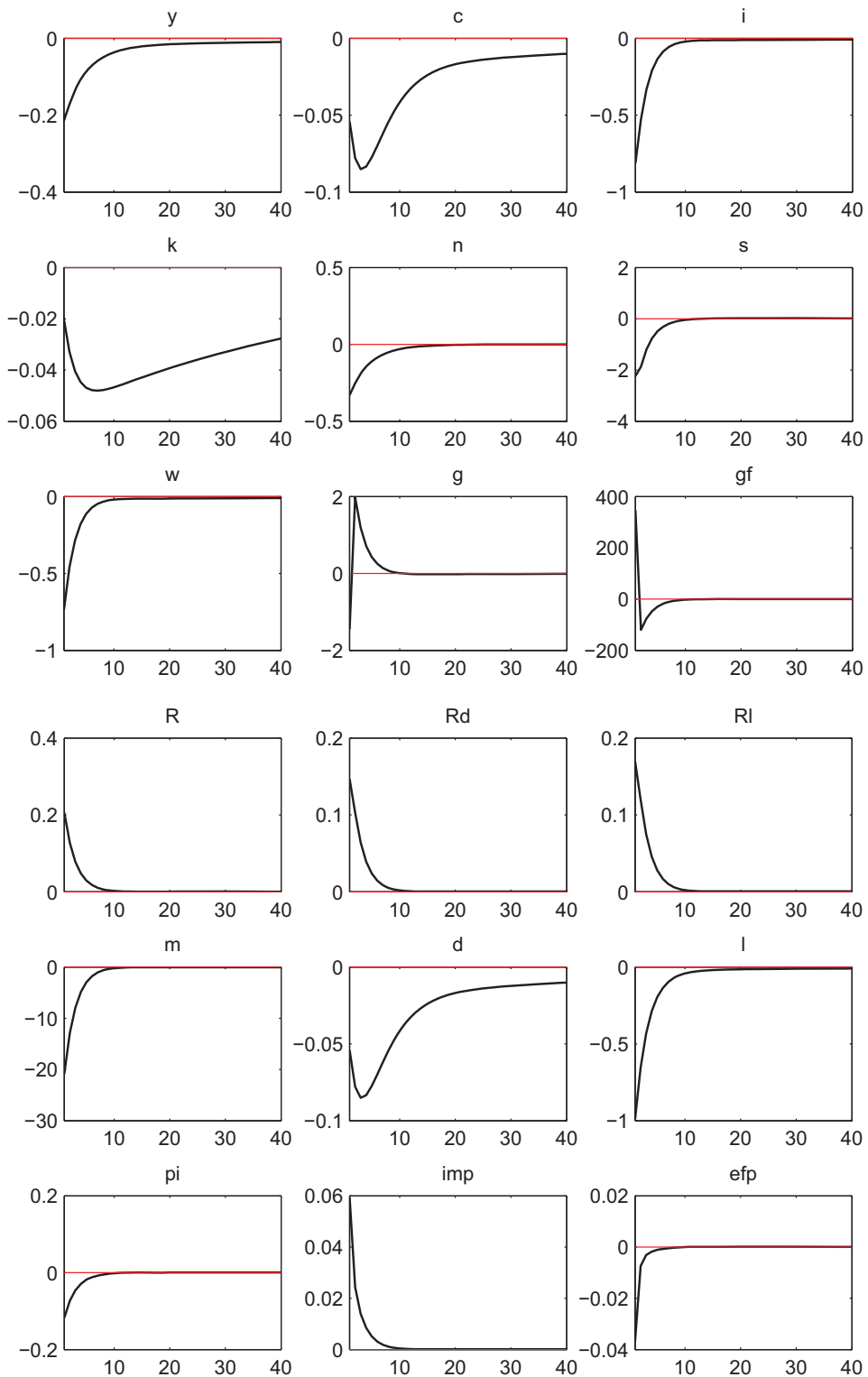**Figure 5:** Selected impulse responses to an orthogonalised technology shock ε_t^θ in goods production

Figure 6: Selected impulse responses to an isolated shock ε_t^r to the monetary policy rate
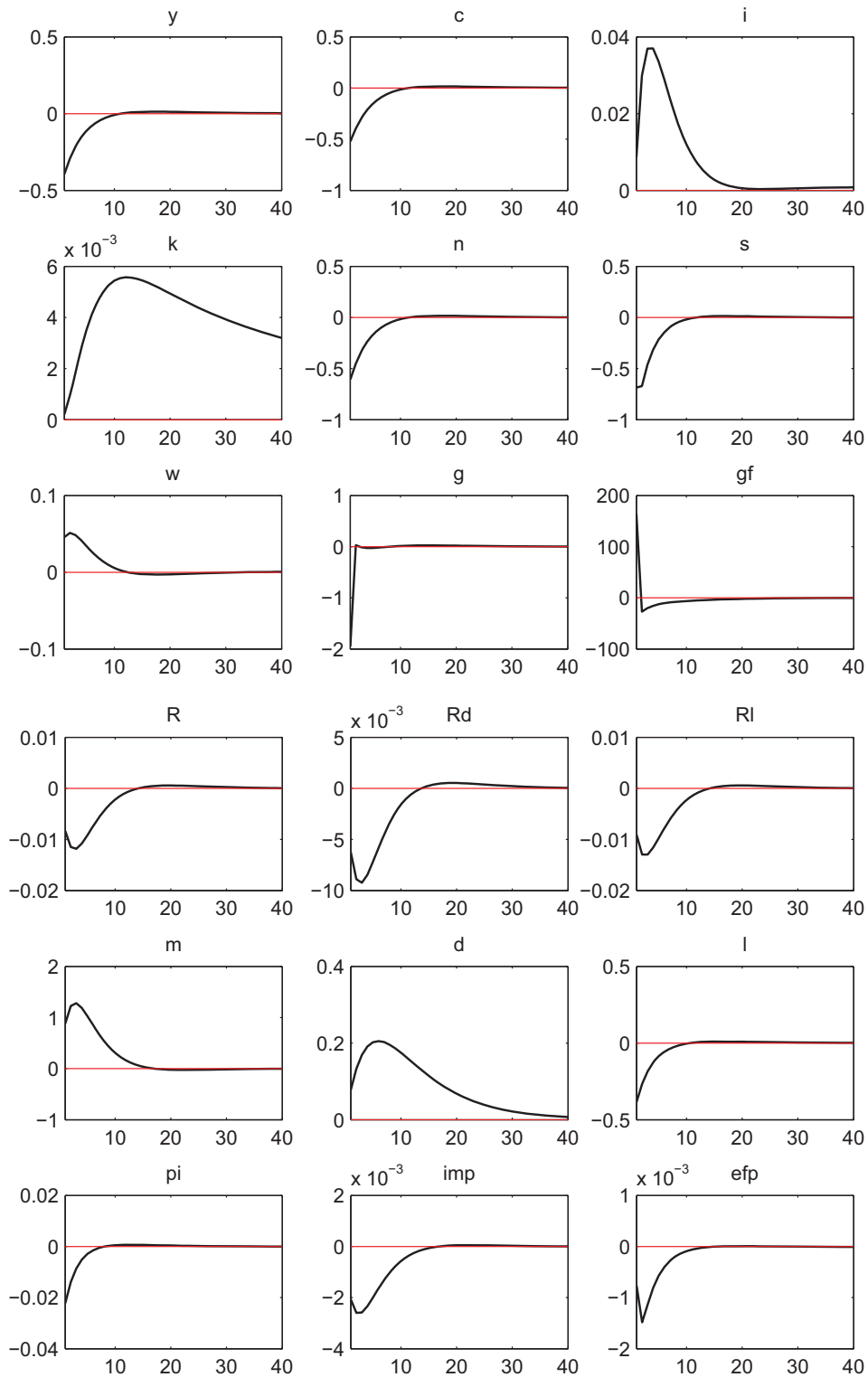
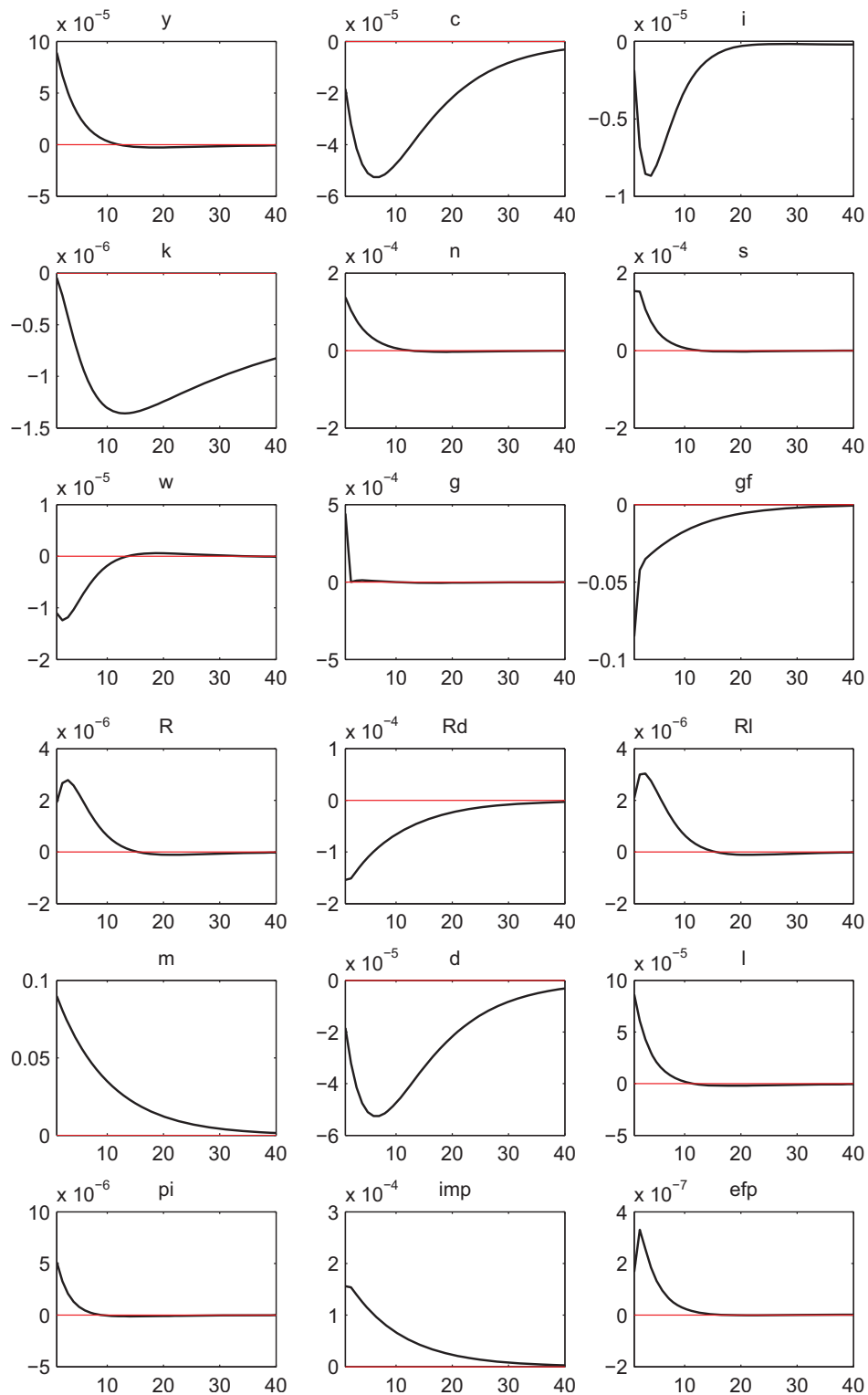**Figure 7:** Selected impulse responses to an orthogonalised Deposit-in-Advance disturbance ε_t^α

Figure 8: Selected impulse responses to an orthogonalised Inside Money Premium shock ε_t^ω

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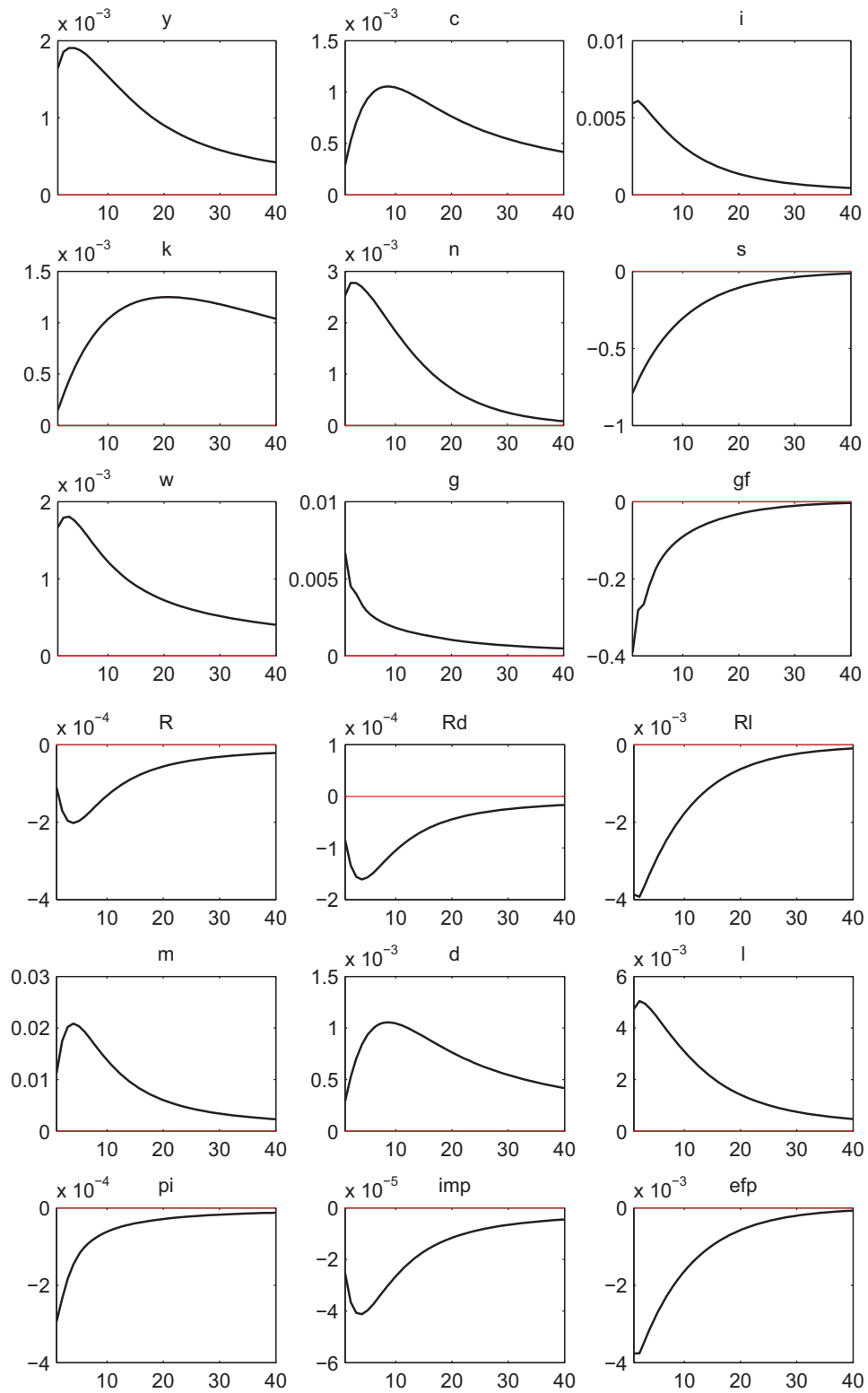
Figure 9: Selected impulse responses to an isolated shock ε_t^χ to the External Finance Premium