Monetary Policy Transmission and the Cost Channel in Euro Area Industries

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Preliminary Version

Abstract

In empirical macroeconomics it is frequently observed that, in the short–run, prices tend to rise after a monetary contraction *(price puzzle)*. This observation cannot be explained by the interest rate channel which would induce a co–movement of prices and output. However, such a price puzzle can be explained if the central bank can directly influence marginal costs of firms *(cost channel)*. We set up a New Keynesian DSGE model which explains industry specific price responses after a monetary contraction by differences in firms' short–term financing requirements. Applying an SVAR to Euro area industry level data, we observe a heterogeneous output and price response. Following a monetary tightening, some industries clearly display rising prices while output declines. It turns out that this observation seems to come along with higher need for short–term financing requirements of industries.

JEL classifications: *Keywords*: Monetary Transmission; Cost Channel; Inflation Dynamics

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1 Introduction

The transmission of monetary impulses on output and prices has been subject of economists' research for a long time. In the majority of New Keynesian models, the effect of monetary policy is captured by the interest rate channel. Traditionally, in a framework with sticky prices, the central bank can influence the real side of the economy by changing real interest rates. Hence, monetary policy effects the economy via the demand side. However, in empirical studies we commonly find that, as a result of an unanticipated monetary contraction, output falls rather quickly whereas prices remain unchanged for several periods and sometimes even rise (Sims, 1992). In the literature this observation has become known as the *price puzzle*. Why should a decline in aggregate output following a monetary shock not lead firms to lower their prices at the same time? In particular, if we assume forward-looking behavior? To encounter this problem, a more recent approach stresses the supply side effects of monetary policy and argues in favor of an additional *cost channel*. Here, monetary policy has a direct impact on marginal cost of firms that have to rely on external funds[1]. The basic insight is that firms can pass on higher marginal costs to its customers by way of mark-up pricing. Ravenna and Walsh (2006), Chowdhury, Hoffmann, and Schabert (2006) and Tillmann (2006) show that in such a framework the interest rate which is set by the central bank directly influences inflation dynamics via a New Keynesian Phillips curve relationship. In an empirical approach Barth and Ramey (2000) find evidence for supply side effects such that in certain industry branches in the U.S. the price to wage ratio temporarily rises after a monetary contraction. This finding being consistent with a supply shock. Ravenna and Walsh (2006) argue that the existence of a cost channel would have important implications for the conduct of monetary policy because in the presence of a cost channel any shock gives rise to a trade off between stabilizing output and inflation. Moreover, these authors also provide empirical evidence for a cost channel in the U.S. by estimating interest rate augmented Phillips curves. Chowdhury, Hoffmann, and Schabert (2006) take a similar approach and support the presence of a supply side effect of monetary policy in addition to the traditional demand side effects in the G7 countries. By contrast, using Bayesian methods, Rabanal (2007) finds that a cost channel on an aggregate level is not supported by U.S. data. But he also concludes that looking at the industry level will give better insights because there may be washing out effects due to aggregation. On an industry level, Peersman

[1] A common assumption e.g. made by Christiano and Eichenbaum (1992) or Christiano, Eichenbaum, and Evans (2005) is that firms have to borrow working capital to finance production factors in advance to production.

and Smets (2005) investigate output effects of a monetary tightening in seven countries of the Euro area in a single equation Markov–Switching framework. They do not only find a considerable degree of industry heterogeneity as far as the average policy sensitivity is concerned, but they also state differences between expansions and recessions. According to Peersman and Smets (2005) these types of cross industry heterogeneity can be explained by industry specific demand and balance–sheet characteristics. Consequently, they interpret the findings in favor of a traditional interest rate channel and financial accelerator channels being in force and leading to differences in monetary policy effects. However, as they do not look at price effects, they are not able to investigate transmission via the cost channel. In another study, Dedola and Lippi (2005) also find considerable heterogeneity in the response of industrial production following a monetary policy shock in single country VARs for France, Germany, Italy, U.K. and U.S. They can also explain differences by industry specific characteristics but, again, do not consider price effects of monetary policy.

In section 2 we develop a New Keynesian Model which builds the framework for the interpretation of the empirically observed transmission mechanism of monetary policy. The sectors differ with respect to their dependence on external short–term financing. If a firm heavily relies on short–term financing, it is assumed to belong to a cost channel sector and the central bank can directly influence the firm's marginal cost. The remaining sector is affected by monetary policy only via the interest rate channel. Whether a monetary policy shock empirically mainly operates via the supply or the demand side of the economy can be identified from the reaction of both, prices and output. If, for instance, both measures co–move after a monetary tightening, the shock has shifted demand and can be interpreted as a demand shock. If the correlation between both measures is negative, then we interpret this as a shift of the supply curve.

In section 3 we take a look at the pricing behavior of Euro area industries following a monetary contraction. Taking a similar approach as Barth and Ramey (2000) we use a structural VAR to measure the effects of a monetary impulse. In a first step, we follow Peersman and Smets (2003) and present a baseline VAR model to evaluate the price dynamics on the level of the Euro area. In a second step we include the respective industries as block exogenous to the baseline specification so that industries can be influenced by monetary policy in the Euro area but not vice versa. This reflects the fact that the European Central Bank mainly reacts to aggregate developments on the area–wide level. The output and price dynamics following a monetary contraction are then obtained from impulse response analysis. In doing so, we are able to identify differences with respect to monetary policy transmission

on prices. In particular, we observe a rise of producer prices in industries that are commonly considered as "heavy".
Whether in an industry the demand side effect (i.e. the interest rate channel) or the cost channel dominates should depend on industry specific characteristics. Consequently, in section 4, we relate the observed output and price effects to financial key figures that measure the extent to which a sector depends on external short–term financing. We find that, indeed, some of the financial variables are systematically related to monetary policy effects. Finally, section 5 concludes.

2 The model

We employ a standard New Keynesian Model that comprises households, firms and financial intermediaries. Households obtain utility from consumption, leisure and cash holdings. Firms are partitioned into three categories that include final good producers, sector consumption good producers and intermediate good producers. The final good producers produce the aggregate final good that comprises two sector specific final consumption goods, which are provided by the sector consumption good producers. In each sector there is a continuum of intermediate good producer that each produce a differentiated type of good by using labor services. Intermediate good producers have some monopoly power over prices that a set in a staggered way as in Calvo (1983). We account for the cost channel of monetary policy by assuming that in one sector all intermediate good producer have to borrow to finance their wage bill before their get the revenue from selling their product. Loans are provided by financial intermediaries that charge a mark–up over the nominal rate set by the monetary authority.

2.1 Households

There is a continuum of households, indexed by $k \in (0, 1)$ that decide on consumption $C_{k,t}$, labor supply $N_{k,1}$, cash holdings $M_{k,t}$ and deposits $D_{k,t}$. Household k maximizes its expected life time utility:

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

where $\beta \in (0, 1)$ is a time invariant subjective discount factor where E_{t-1} denotes the expectation operator, conditional on the information set of the

household at time $t-1$.[2]
Utility at time t is given by

$$U_{k,t} = \frac{1}{1-\sigma}\left(C_{k,t} - hC_{t-1}\right)^{1-\sigma} - \frac{N_{k,t}^{1+\eta}}{1+\eta}. \tag{2}$$

.
The way the utility function is specified implies external habit formation with habit persistence of degree h. σ denotes the degree of relative risk aversion and η is the elasticity of marginal disutility of labor.
Households maximize their expected lifetime utility (1) by choosing optimal consumption subject to an intertemporal budget constraint:

$$P_t C_{k,t} + D_{k,t} \leq W_t N_{k,t} + \left(1 + r_{t-1}^D\right) D_{k,t-1} + \Pi_{k,t}. \tag{3}$$

where $D_{k,t}$ are deposits hold at banks at the gross deposit rate R_t^D, W_t is the nominal wage rate, and $\Pi_{k,t}$ are aggregate profits from the firms and banks that are distributed at the end of period t.
The relevant first–order conditions for optimal consumption and savings are given by:

$$E_{t-1}\lambda_{k,t} = \beta E_{t-1}\left[\lambda_{k,t+1}\frac{R_t^D P_t}{P_{t+1}}\right] \tag{4}$$

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

where the Lagrange multiplier on the intertemporal budget constraint $\lambda_{k,t}$ denotes household k'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.
We assume that households have access to state–contingent securities that insure them against variations in household–specific labor income. This ensures that, in equilibrium, households are homogenous with respect to consumption and deposit holdings (Christiano, Eichenbaum, and Evans, 2005).

2.2 Final consumption good producers

The final good producers combine sector specific goods into a consumption bundle by using a CES production technology where μ denotes the elastic-

[2]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.

ity of substitution between the two sector–specific goods. As there are *two distinct sectors* $i = 1, 2$ in the economy that provide two goods that are imperfect substitutes to the households, and the respective weights in the economy are ν_1 and ν_2, final good producers face the following optimization problem:

$$\texttt{max} \quad P_t Y_t - P_{1,t} Y_{1,t} - P_{2,t} Y_{2,t} \quad \texttt{s.t.} \quad Y_t = \left[\nu_1^{1/\mu} Y_{1,t}^{\frac{\mu-1}{\mu}} + \nu_2^{1/\mu} Y_{2,t}^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}. \tag{6}$$

The demand for $Y_{i,t}$ is thus

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\mu} Y_t \nu_i. \tag{7}$$

Under perfect competition ($P_t Y_t - P_{1,t} Y_{1,t} - P_{2,t} Y_{2,t} = 0$) the price level of the aggregate consumption good is

$$P_t = \left[P_{1,t}^{1-\mu} \nu_1 + P_{2,t}^{1-\mu} \nu_2 \right]^{\frac{1}{1-\mu}}. \tag{8}$$

2.3 Production of sector specific goods

Each distinct sector $i = 1, 2$ produces a differentiated (sector-specific) good $Y_{i,t}$ by combining *a continuum of intermediate* goods indexed by j. The sector final good firm in sector i employs a CES production technology and faces the following optimization problem:

$$\texttt{max} \quad P_{i,t} Y_{i,t} - \int_0^1 P_{i,t}(j) Y_{i,t}(j) dj \quad \texttt{s.t.} \quad Y_{i,t} \leq \left[\int_0^1 Y_{i,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{9}$$

where ϵ describes the elasticity of substitution between the intermediate goods $Y_{i,t}(j)$.
The demand for $Y_{i,t}(j)$ is thus

$$Y_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}} \right)^{-\epsilon} Y_{i,t}. \tag{10}$$

Under perfect competition the resulting price level for the sector specific good is

$$P_{i,t} = \left[\int_0^1 P_{i,t}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}. \tag{11}$$

2.4 Production of intermediate goods

In each sector i, 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:

$$Y_{i,t}(j) = A_t N_{i,t}(j), \tag{12}$$

where $N_{i,t}(j)$ is employment and A_t is an aggregate technology 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:

$$P_t^{1-\epsilon} = (1-\theta)(P_t^*)^{1-\epsilon} + \theta(P_{t-1})^{1-\epsilon}. \tag{13}$$

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 follow a simple rule of thumb:

$$P_t^* = (P_t^f)^{1-\omega}(P_t^b)^{\omega}. \tag{14}$$

We use the following pricing scheme for backward looking firms:

$$P_t^b = P_{t-1}^* \frac{P_{t-1}}{P_{t-2}}. \tag{15}$$

Sector 1: Cost channel firms For a forward–looking firm that is allowed to reset the price optimally maximizes the future discounted sum of profits:

$$\max \quad E_t \left[\sum_{\tau=0}^{\infty} \theta_1^{\tau} \Delta_{\tau,t+\tau} \Pi_{1,t+\tau}(j) \right] \quad \text{s.t.} \quad Y_{1,t}(j) \leq A_t N_{1,t}(j), \tag{16}$$

where A_t reflects productivity shocks and $N_{1,t}(j)$ is labor input. Here, firms take into account the probability of not being able to change prices in the future. Moreover, $\Delta_{\tau,t+\tau}$ is a term that captures the elasticity of intertemporal substitution because firms are owned entirely by households and is given by:

$$\Delta_{\tau,t+\tau} = \beta^{\tau} \frac{U_C(C_{t+\tau})}{U_C(C_t)}.$$

Profit can be written as

$$\Pi_{1,t+\tau}(j) = P_{1,t}^f(j) Y_{1,t+\tau}(j) - Q_{1,t+\tau}(j),$$

where $Q_{1,t+\tau}(j)$ is the cost function of the firms in sector 1 and $P^f_{1,t}(j)$ denotes the price set by the foreward–looking firm. In particular, $R^L_t = 1 + r^L_t$ enters the marginal cost term because sector 1 firms have to rely on short-term financing because they have to pay their production factors $W_t N_{1,t}(j)$ before the profits are realized.

$$Q_{1,t+\tau}(j) = R^L_{t+\tau} W_{t+\tau} N_{1,t+\tau}(j) \tag{17}$$

Since marginal costs are given by: $rmc_{1,t+\tau} = R^L_{t+\tau} \frac{W_{t+\tau}}{P_{t+\tau} A_{t+\tau}}$, the cost function can be expressed in terms of real marginal cost $rmc_{1,t+\tau}$. Thus, for the analysis we conduct later in chapter 3.2, we expect some industries to feature an additional cost channel of monetary transmission that acts like a supply shock. Intuitively, by way of higher policy rates, which translate into rising loan rates, a firm in sector 1 faces higher $rmc_{1,t}$. It will then raise prices because it has some market power. A new equilibrium will then also be characterized by lower production. On the whole, it may be possible that these effects outweigh the price effects induced by the interest rate channel (see also 1 and 2).

$$Q_{1,t+\tau}(j) = rmc_{1,t+\tau} Y_{1,t+\tau}(j) P_{t+\tau} \tag{18}$$

Sector 2: Non cost channel firms Firms in sector 2 are so-called non-cost-channel firms and produce with the same technology as sector 1:

$$Y_{2,t}(j) = A_t N_{2,t}(j). \tag{19}$$

However, these firms do not have to rely on short term loans. This gives rise to the following cost function:

$$Q_{2,t+\tau}(j) = W_{t+\tau} N_{2,t+\tau}(j) \tag{20}$$

This optimization problem leads to the optimal forward-looking price $P^f_{i,t}(j) = P^f_{i,t}$.

2.5 Banking sector

The banking sector provides short-term loans to firms in sector 1. It is merely an intermediary that charges a mark-up ψ_R over the nominal interest rate set by the central bank. Following Chowdhury, Hoffmann, and Schabert (2006) this can be stated in a linearized version:

$$\hat{R}^L_t = (1 + \psi_R) \hat{R}^D_t. \tag{21}$$

In the following a ˆ denotes variables in percentage deviations from steady–state in the linearized version of the model.

2.6 Monetary policy

Monetary policy is conducted via a simple contemporaneous Taylor-type rule that features interest rate smoothing of degree γ_1. γ_2 reflects the responsiveness to inflation and γ_3 measures the reaction of output deviations from steady–state. The unsystematic part of monetary policy - i.e. the monetary policy shock - is given by ζ_t.

$$\hat{R}_t^M = \gamma_1 \hat{R}_{t-1}^M + \gamma_2 \pi_t + \gamma_3 \hat{Y}_t + \zeta_t. \tag{22}$$

2.7 The linearized model

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, $\hat{X}_t = ln(X_t) - ln(\bar{X})$. Notice that aggregate demand is given by $Y_t = C_t$ and household demand is summarized by equation (23). It is assumed that $\hat{A}_t = 0$ and additionally that expectations are predetermined when the shock occurs. The model is summarized by the following equations:

$$
\begin{aligned}
\hat{Y}_t &= \frac{1}{1+h}E_{t-1}\hat{Y}_{t+1} + \frac{h}{1+h}\hat{Y}_{t-1} - \frac{1-h}{(1+h)\sigma}E_{t-1}\left(\hat{R}_t^M - \pi_{t+1}\right) && (23)\\
\pi_t &= \nu_1\pi_{1,t} + \nu_2\pi_{2,t} && (24)\\
\pi_{1,t} &= \frac{(1-\omega_1)(1-\theta_1)(1-\beta\theta_1)}{\theta_1+\omega_1[1-\theta_1(1-\beta)]}\left(\widehat{rmc}_{1,t} - \hat{X}_{1,t}\right) \\
&+ \frac{\beta\theta_1}{\theta_1+\omega_1[1-\theta_1(1-\beta)]}E_{t-1}\pi_{1,t+1} \\
&+ \frac{\omega_1}{\theta_1+\omega_1[1-\theta_1(1-\beta)]}\pi_{1,t-1} && (25)\\
\pi_{2,t} &= \frac{(1-\omega_2)(1-\theta_2)(1-\beta\theta_2)}{\theta_2+\omega_2[1-\theta_2(1-\beta)]}\left(\widehat{rmc}_{2,t} - \hat{X}_{2,t}\right) \\
&+ \frac{\beta\theta_2}{\theta_2+\omega_2[1-\theta_2(1-\beta)]}E_{t-1}\pi_{2,t+1} \\
&+ \frac{\omega_2}{\theta_2+\omega_2[1-\theta_2(1-\beta)]}\pi_{2,t-1} && (26)\\
\widehat{rmc}_{1,t} &= E_{t-1}\hat{R}_t^L + \frac{\sigma+(1-h)\eta}{1-h}E_{t-1}\hat{Y}_t - \frac{h\sigma}{1-h}\hat{Y}_{t-1} && (27)\\
\widehat{rmc}_{2,t} &= \frac{\sigma+(1-h)\eta}{1-h}E_{t-1}\hat{Y}_t - \frac{h\sigma}{1-h}\hat{Y}_{t-1} && (28)\\
\hat{X}_{1,t} &= \hat{X}_{1,t-1} + \pi_{1,t} - \pi_t && (29)\\
\hat{X}_{2,t} &= \hat{X}_{2,t-1} + \pi_{2,t} - \pi_t && (30)\\
\hat{R}_t^L &= (1+\psi_R)\hat{R}_t^M && (31)\\
\hat{R}_t^M &= \gamma_1\hat{R}_{t-1}^M + \gamma_2\pi_t + \gamma_3\hat{Y}_t + \zeta_t. && (32)
\end{aligned}
$$

Calibration of model parameters The calibrated values for the parameters of the model are given in table 1. They are chosen to mimic a quarterly model reasonably well and are also in the range commonly suggested by the empirical literature. The values describing the sectors imply that both sectors have equal size with respect to output. The central bank is assumed to put equal weight on inflation and output. Note, however, that the resulting dynamics of the model do not crucially depend on the chosen parameter values. In order to demonstrate the dynamics of the model, we simulate the linearized version with different calibrations of ψ_R.

Parameter		
h	0.90	habit formation
η	1.50	labor supply elasticity
σ	1.50	degree of risk aversion
θ_1	0.70	probability of keeping prices fixed in sector 1
ω_1	0.80	degree of price indexation in sector 1
θ_2	0.70	probability of keeping prices fixed in sector 2
ω_2	0.80	degree of price indexation in sector 2
β	0.99	discount factor
μ	1.00	elasticity of substitution between the two sectors
ν_1	0.50	share of intermediate good 1 in total basket
ν_2	0.50	share of intermediate good 2 in total basket
γ_1	0.60	interest rate smoothing parameter
γ_2	1.50	weight of the inflation rate in the Taylor Rule
γ_3	0.50	weight of the output gap in the Taylor Rule

Table 1: Calibration of parameters

Theoretical impulse response functions Calculating the rational expectations solution of the model and simulating the response to a monetary contraction gives the following figures 1 and 2.

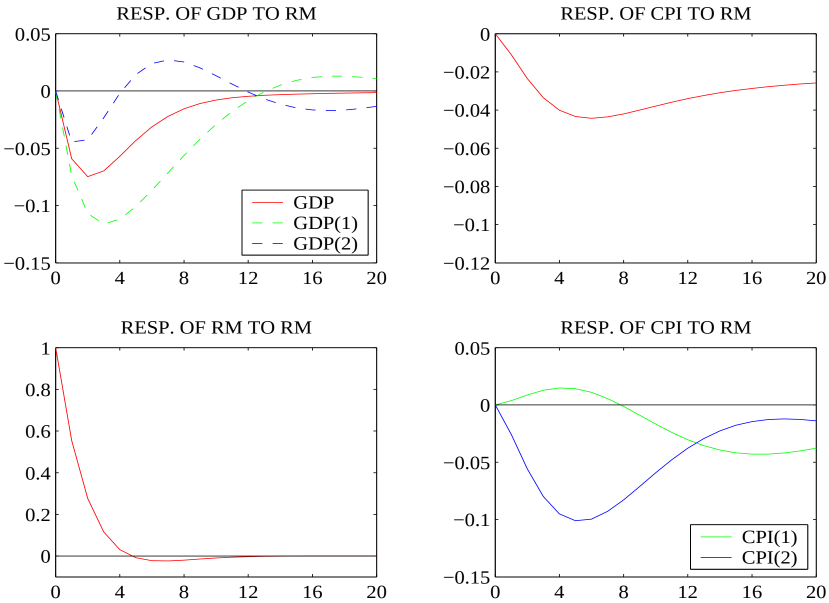

Figure 1: Theoretical Impulse Responses $\psi_R = 1$

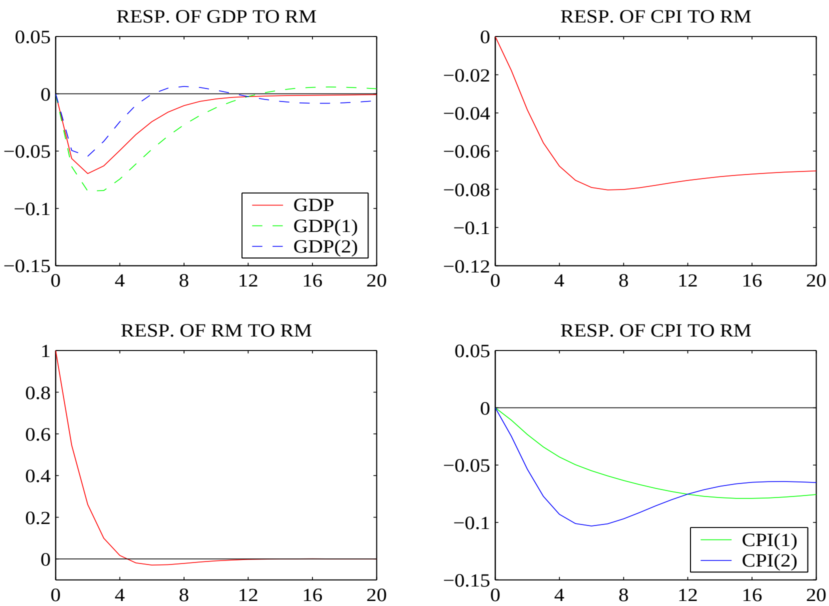

Figure 2: Theoretical Impulse Responses $\psi_R = 0$

Irrespective of the calibration of the parameter ψ_R, the model produces a negative output response on the aggregate level which is followed by a decline in aggregate prices. This is due to the fact that half of the firms are assumed to be non–cost–channel firms. As the interest rate channel operates in both industries, whereas the cost channel, however, takes effect only in industry 1, the reaction of industry 2 is more pronounced than the response of industry 1 because the initial rise of marginal cost due to a higher loan rate is partly offset by the decline in demand and, hence, marginal cost.
If we calibrate $\psi_R = 0$, meaning banks serve only as intermediaries and do not charge a mark–up, the classical interest rate channel dominates the cost-channel and prices in industry 1 will also fall. However, if there is a more than proportionate relationship ($\psi_R = 1$), a rise of the central bank rate induces higher marginal cost although there is a decline in demand. Thus, if firms have to rely on short–term capital to finance production (sector 1) and the cost channel (at least temporarily) dominates the traditional interest rate channel, the model can produce a temporary rise in prices after a monetary contraction in industry 1. Note, that the interest rate channel dominates after about 8 quarters, ultimately leading to a fall in producer prices. Thus, we would expect to find rising prices in cost channel industries during the first eight quarters after the monetary contraction. Moreover, also a mitigated price response can stem from a cost channel being in place. By contrast, non cost channel industries will experience an immediate fall in both, production and prices.

3 The effects of a monetary policy shock

In the following section we investigate the transmission of a monetary tightening into different sectors of the Euro area. The empirical investigation begins with the specification of a baseline VAR for the Euro area. In a next step, we estimate sector–specific responses by taking the baseline VAR as block–exogenous to the respective industry.

3.1 A baseline VAR for the Euro area

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

$$Y_t = C + \sum_{i=1}^{3} S_i + T + \sum_{p=1}^{3} A_p Y_{t-p} + \sum_{q=0}^{2} B_q X_{t-q} + \varepsilon_t, \qquad (33)$$

where Y_t is a vector of endogenous variables, X_t is a vector of exogenous variables, A_p and B_q are coefficient matrices. The vector of deterministic variables consists of the constant C, S_i which is a seasonal dummy variable and a deterministic trend T. Finally, ε_t is a vector of error terms. The vector Y_t comprises the variables:

$$Y_t = [GDP_t \quad HICP_t \quad WAGE_t \quad STR_t]',$$

where GDP_t stands for real output, $HICP_t$ for the price level measured as the harmonized index of consumer prices, STR_t is the policy rate of the central bank, which is approximated by a short–term money market rate, and $WAGE_t$ for the nominal wage rate. The vector X_t consists of a commodity price index. All variables are taken from the the *Area Wide Model* of Smets and Wouters (2002) provided by the Euro Area Business Cycle Network (EABCN).[3]

We refrain from differencing the data, but estimate the VAR in levels, to avoid the exclusion of long–run effects from the system. The sample period starts in the first quarter of 1990 and ends in the fourth quarter of 2005. All variables except for the interest rate are expressed in logs. Choosing a lag length of three ensures that the error terms dismiss signs of autocorrelation. Based on the VAR model (33), we generate impulse responses of the variables in Y_t to an (orthogonal) monetary policy shock. For the moment we identify the monetary policy shock by setting $Var(\varepsilon_t) = (A_0^{-1})(A_0^{-1})'$ and imposing a recursive ordering of variables.[4] The identifying assumption is such that an innovation in the money market rate affects the other endogenous variables in the system with a lag of one quarter. Figure 3 displays the impulse responses of the variables to a shock in the monetary policy rate of one standard deviation. The simulation horizon covers 20 quarters. The solid lines denote impulse responses. The dotted lines are approximate 95% error bands that are simulated using a bootstrap routine with 2000 replications[5].

As in Peersman and Smets (2003) and Smets and Wouters (2002), the results are such that the output level declines by degrees after a monetary policy shock, reaching a peak after six quarters, and returns to the baseline value subsequently. The harmonized consumer price level falls slowly, but persistently. Compared to the decline in output after about three quarters, the price adjustment is rather slow and the question arises whether this finding is still consistent with a predominant demand side effect of monetary policy. The wage rate declines after about six quarters and shows a rather persis-

[3]The dataset is available from http://www.eabcn.org/data/awm/index.htm.

[4]Here, A_0 is the coefficient matrix that describes the contemporaneous impact in the structural VAR we estimate.

[5]We calculate the error bands of the impulse response functions with the procedure introduced in Hall (1992)

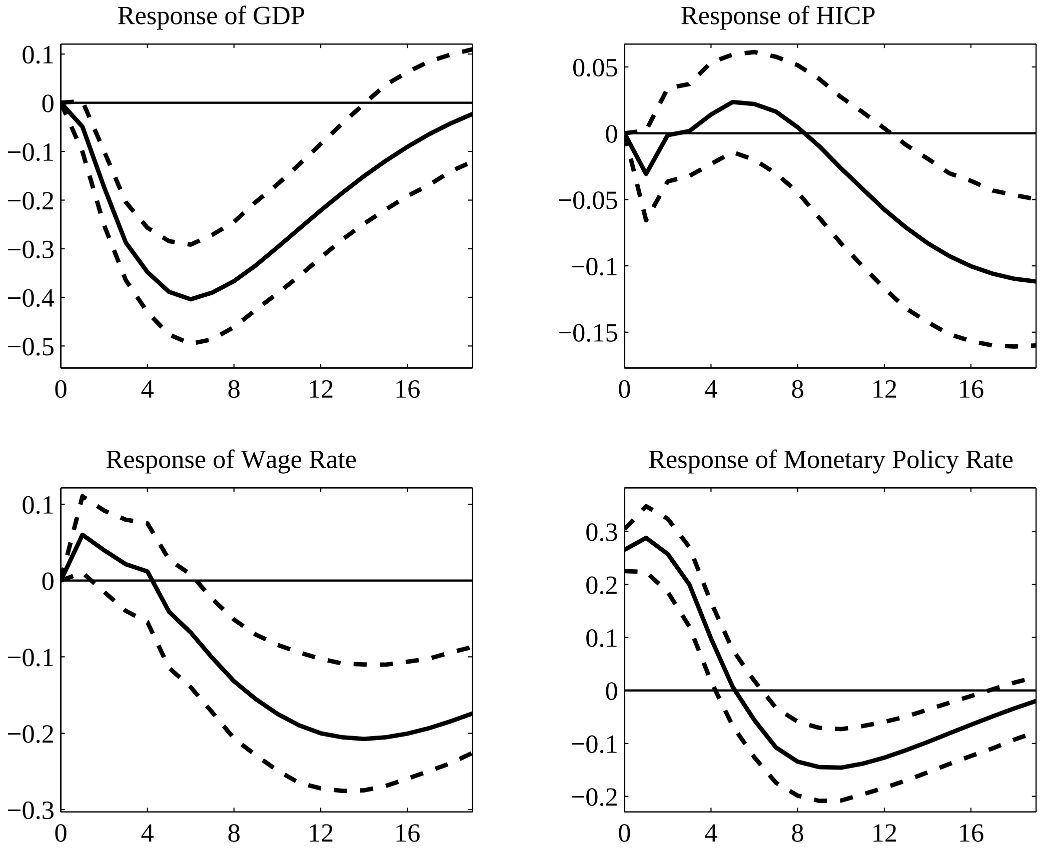

Figure 3: Monetary Policy Shock in a baseline VAR for the Euro zone

tent response. Following a monetary tightening, the policy rate of the central bank returns to the baseline value subsequently.

3.2 Testing for the cost channel

Following our model, the fact that firms that depend on external finance will experience changes in financing conditions when the policy rate of the central bank rises. For these firms a monetary policy shock is equal to a change in marginal cost. Firms would then react and lower supply and/or raise prices. If a cost channel is in place in a particular industry then, after a monetary policy shock in the Euro zone, prices and output show a negative correlation. In particular, as we expect the output to fall after a monetary policy shock, prices will rise temporarily. The estimated model consists of the (block–exogenous) baseline VAR from above (compare section 3.1) and an additional part which captures the reaction of the considered industry. The vector Y_t then consists of five variables:

$$Y_t = [GDP_t \quad HICP_t \quad WAGE_t \quad STR_t \quad IPI_{j,t}]'$$

respectively

$$Y_t = [GDP_t \quad HICP_t \quad WAGE_t \quad STR_t \quad PPI_{j,t}]'.$$

Where $IPI_{j,t}$ is the production index in industry j and $PPI_{j,t}$ is the corresponding producer price level. The other variables are defined as above. When we estimate the model with the block exogenous part, the matrix A_i has the general form:

$$A_i = \begin{bmatrix} a^i_{11} & a^i_{12} & a^i_{13} & a^i_{14} & 0 \\ a^i_{21} & a^i_{22} & a^i_{23} & a^i_{24} & 0 \\ a^i_{31} & a^i_{32} & a^i_{33} & a^i_{34} & 0 \\ a^i_{41} & a^i_{42} & a^i_{43} & a^i_{44} & 0 \\ a^i_{51} & a^i_{52} & a^i_{53} & a^i_{54} & a^i_{55} \end{bmatrix}. \qquad (34)$$

The system is then estimated using a SUR estimator with the appropriate restrictions on the coefficients.
We identify the monetary policy shock by setting $Var(\varepsilon_t) = (A_0^{-1})(A_0^{-1})'$ and imposing a recursive ordering of the variables we consider as block–exogenous. In contrast to Dedola and Lippi (2005), we restrict the contemporaneous impact of a monetary policy shock on industries to zero. Given that GDP and aggregate prices are assumed to react with a delay of one quarter, this seems a reasonable identifying assumption. This, of course, implies that also within the industries a monetary tightening takes time to come into effect. Moreover, shocks which only hit the industry also affect all other variables with a lag of one quarter. Thus, the shocks in the model are overidentified with the matrix A_0^{-1} having the following form:[6]

$$A_0^{-1} = \begin{bmatrix} \star & 0 & 0 & 0 & 0 \\ \star & \star & 0 & 0 & 0 \\ \star & \star & \star & 0 & 0 \\ \star & \star & \star & \star & 0 \\ 0 & 0 & 0 & 0 & \star \end{bmatrix}. \qquad (34)$$

To be able to distinguish the industry specific effects of a monetary policy shock, a number of industries ranging from NACE classifications C to E are

[6] A "⋆" denotes the parameters that are estimated using the scoring algorithm introduced in Amisano and Giannini (1997).

considered. Also note, that we control for commodity price movements in the baseline VAR.

3.3 Data description

First of all, we present in table 2 a summary of industry branches. To be precise, we investigate the transmission into industries defined by NACE 2003 classification on the 2–digit level using data provided by Eurostat. The last column reports relative weights of the respective industry measured by the average industrial production as percentage of total industrial production during the years 2000 to 2004. With almost 90%, the manufacturing sector accounts for the largest share by far. The energy sector and mining contribute about 8.5% respectively 1.5% to total production. Within manufacturing sector, the largest industries are motor vehicles, chemicals, machinery, food and fabricated metal, which make up for about 43% of total production. Thus, price movements in these industries should have the largest impact on the aggregate price level. The smallest industries in the Euro area are recycling, tobacco, leather, office machinery and clothing, which only contribute 4% to total production.

NACE 2003	Industry	IPI % EUR
CDE	Total industry excluding construction	
C	Mining and quarrying	1.57
D	Manufacturing	89.83
E	Electricity, gas and water supply	8.59
CA10	Mining of coal and lignite, extraction of peat	0.11
CA11	Extraction of crude petroleum and natural gas	0.51
CA12	Mining of uranium and thorium ores	0.00
CB13	Mining of metal ores	0.01
CB14	Other mining and quarrying	0.36
DA15	Food products and beverages	8.12
DA16	Tobacco products	0.61
DB17	Textiles	2.01
DB18	Wearing apparel; dressing and dyeing of fur	1.43
DC19	Tanning and dressing of leather; luggage and footwear	0.89
DD20	Wood and of products of wood and cork, except furniture	1.69
DE21	Pulp, paper products	2.38
DE22	Publishing, printing and reproduction of recorded media	3.54
DF23	Coke, refined petroleum products and nuclear fuel	5.00
DG24	Chemicals, chemical products and man-made fibres	9.34
DH25	Rubber and plastic products	3.46
DI26	Glass, ceramic and other non-metallic mineral products	3.23
DJ27	Basic metals	4.02
DJ28	Fabricated metal products except machinery and equipment	6.28
DK29	Machinery and equipment	8.26
DL30	Office machinery and computers	1.08
DL31	Electrical machinery and apparatus	3.74
DL32	Radio, television and communication equipment and apparatus	2.63
DL33	Medical, precision and optical instruments	1.84
DM34	Motor vehicles, trailers and semi-trailers	10.89
DM35	Other transport equipment	2.40
DN36	Furniture	2.43
DN37	Recycling	0.29
E40	Electricity, gas and water supply	7.96
E41	Collection, purification and distribution of water	0.63

Note: Numbers in the right column represent the average industrial production (2000-2004) as percentage of industry total excluding construction (CDE). Data on production is not available for Greece. For Ireland the industries CA10, CA11, DN23, DN36, E40 are not available. Therefore they are neglected when calculating total production of the Euro area.

Table 2: NACE Classification of Industries

3.4 Estimation results

In order to investigate production and price dynamics in these industries we proceed by showing the responses to a monetary contraction simulated by an unanticipated shock in the short–term rate which has the magnitude of one standard deviation as described in section 3.2. Figures 4 to 6 display on the left–hand side the response of industrial production denoted by IPI and to the right of IPI we present the related response of producer prices which is denoted by PPI. Error bands for the impulse response functions are again simulated by a bootstrap procedure with 2000 replications[7]. In the title of the respective graph we also give the NACE 2003 classification of the industry.

[7] We calculate the error bands with the procedure introduced by Hall (1992).

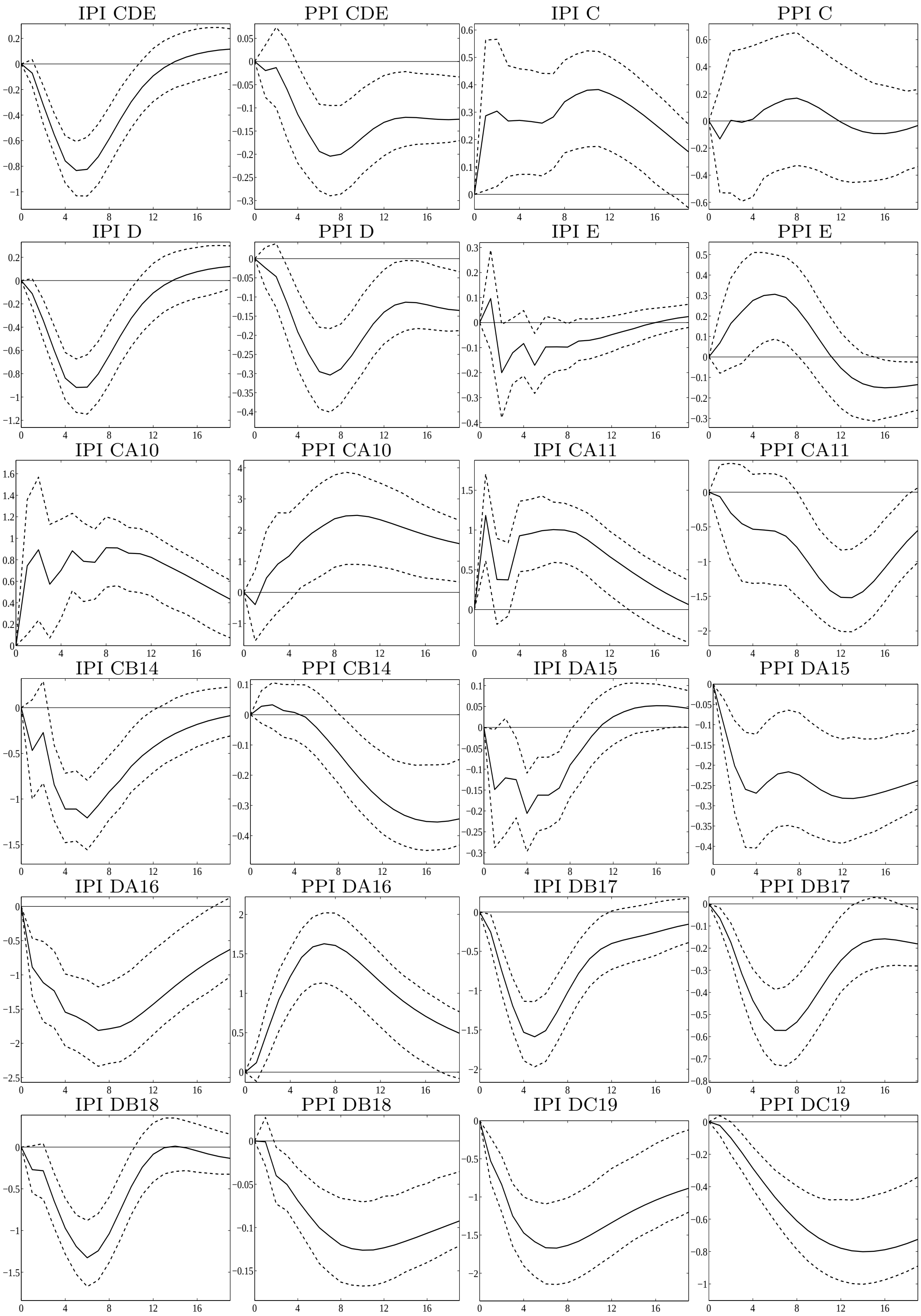

Figure 4: Monetary Policy Shock in Euro area Industries 1

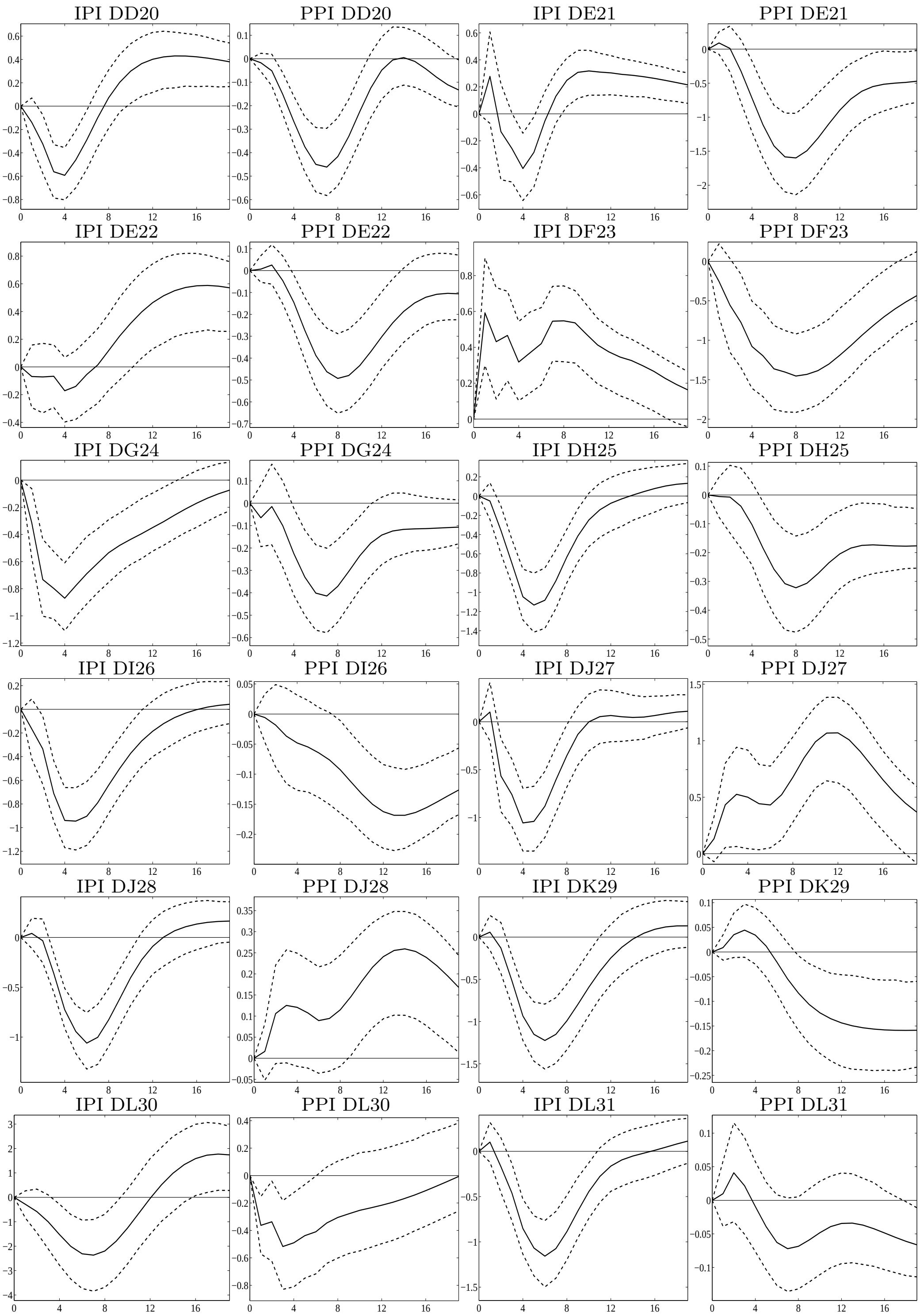

Figure 5: Monetary Policy Shock in Euro area Industries 2

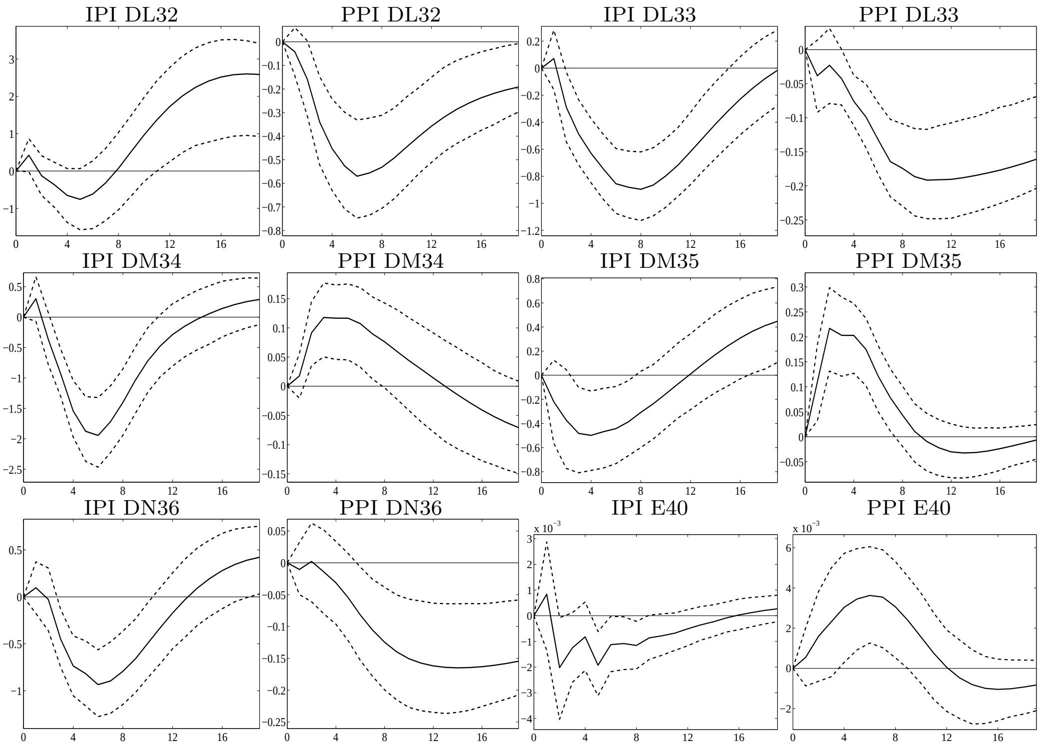

Figure 6: Monetary Policy Shock in Euro area Industries 3

We present a summary of the graphs in tables 3 and 4. Table 3 gives the output and price response to a monetary tightening in the respective industry after 4, 8, and 12 quarters, as well as the maximum elasticity measured within the simulation period.

Ind.	Euro area							
	4Q		8Q		12Q		Max	
	IPI	PPI	IPI	PPI	IPI	PPI	IPI	PPI
CDE	*-0.55*	*-0.06*	*-0.73*	*-0.20*	-0.18	*-0.15*	-0.83 [6]	-0.20 [8]
C	*0.27*	-0.01	*0.28*	0.16	*0.38*	0.04	0.38 [12]	0.1 [9]
D	*-0.60*	*-0.12*	*-0.80*	*-0.30*	-0.20	*-0.17*	-0.92 [6]	-0.30 [8]
E	-0.12	*0.22*	*-0.10*	*0.29*	-0.06	*0.01*	-0.20 [3]	0.31 [7]
CA10	*0.57*	0.91	*0.78*	*2.14*	*0.86*	*2.43*	0.91 [9]	2.47 [11]
CA11	*0.37*	-0.45	*1.01*	*-0.63*	*0.77*	*-1.415*	1.18 [2]	-1.52 [14]
CB14	*-0.85*	0.01	*-1.07*	*-0.08*	-0.53	*-0.25*	-1.21 [7]	-0.36 [18]
DA15	*-0.13*	*-0.26*	*-0.15*	*-0.22*	0.01	*-0.28*	-0.21 [5]	-0.28 [14]
DA16	*-1.23*	*0.92*	*-1.81*	*1.63*	*-1.56*	*1.28*	-1.81 [8]	1.63 [8]
DB17	*-1.19*	*-0.32*	*-1.28*	*-0.57*	-0.47	*-0.32*	-1.59 [6]	-0.57 [8]
DB18	*-0.65*	*-0.05*	*-1.24*	*-0.11*	-0.24	*-0.13*	-1.33 [7]	-0.13 [11]
DC19	*-1.25*	*-0.19*	*-1.67*	*-0.54*	*-1.42*	*-0.75*	-1.67 [8]	-0.80 [15]
DD20	*-0.56*	*-0.15*	-0.10	*-0.46*	*0.36*	-0.13	-0.59 [5]	-0.46 [8]
DE21	*-0.26*	*-0.32*	*0.13*	*-1.58*	*0.31*	*-1.10*	-0.41 [5]	-1.60 [9]
DE22	-0.07	*-0.05*	0.01	*-0.46*	*0.40*	*-0.37*	0.59 [18]	-0.49 [9]
DF23	*0.47*	*-0.78*	*0.55*	*-1.40*	*0.41*	*-1.30*	0.59 [2]	-1.45 [9]
DG24	*-0.80*	*-0.10*	*-0.61*	*-0.41*	*-0.39*	-0.18	-0.87 [5]	-0.41 [8]
DH25	*-0.70*	-0.04	*-0.88*	*-0.31*	-0.14	*-0.24*	-1.13 [6]	-0.32 [9]
DI26	*-0.71*	-0.04	*-0.79*	*-0.08*	-0.27	*-0.15*	-0.95 [6]	-0.17 [15]
DJ27	*-0.76*	*0.53*	*-0.61*	*0.52*	0.05	*1.07*	-1.06 [5]	1.07 [13]
DJ28	*-0.36*	0.13	*-1.00*	0.09	-0.22	*0.22*	-1.06 [7]	0.26 [15]
DK29	*-0.52*	0.04	*-1.15*	*-0.06*	-0.41	*-0.14*	-1.22 [7]	-0.16 [19]
DL30	*-1.00*	*-0.52*	*-2.37*	-0.35	-0.65	-0.24	-2.37 [8]	-0.52 [4]
DL31	*-0.46*	0.02	*-1.07*	-0.07	-0.28	-0.04	-1.16 [7]	-0.07 [8]
DL32	-0.37	*-0.34*	-0.32	*-0.56*	*1.37*	*-0.40*	2.60 [19]	-0.57 [7]
DL33	*-0.49*	*-0.04*	*-0.88*	*-0.16*	*-0.72*	*-0.19*	-0.90 [9]	-0.19 [11]
DM34	*-0.94*	*0.12*	*-1.72*	*0.09*	-0.48	0.03	-1.95 [7]	0.12 [4]
DM35	*-0.48*	*0.20*	-0.39	0.08	-0.07	-0.02	-0.50 [5]	0.22 [3]
DN36	*-0.45*	-0.01	*-0.90*	*-0.11*	-0.33	*-0.16*	-0.94 [7]	-0.17 [15]
E40	-0.13	*0.23*	*-0.11*	*0.36*	-0.07	0.07	-0.20 [3]	0.36 [7]

Note: Numbers refer to the mean of a sample of 2000 bootstrapped impulse response functions. Italics indicate a significant response. For the sectors CA12, CB13, DN37 and E41 data is not available. "Max" denotes the maximum response. In brackets we also give the quarter after a monetary policy shock in which the maximum response is observed.

Table 3: Elasticities after 4, 8 and 12 quarters and maximum elasticity

As is predicted by theory, we observe a negative reaction of output, in most of the two–digit industries. With the some notable exceptions (CA10, CA11, DF23) production declines rather quickly, i.e. after four quarters, following a monetary tightening. Apart from DE22, DL32 and E40, the decline is significant. With the course of time output recovers by degrees. This translates into more and more elasticities becoming insignificant after twelve quarters and reflects the fact that monetary policy can not have a permanent effect on output. In contrast to IPI, the response of the price level after the first four quarters varies considerably across industries. However, some patterns can be observed. First, prices in the mining industries tend to rise after a restrictive monetary policy shock. The same is observed for the industries in the lower part of table 3. According to Dedola and Lippi (2005) these are the "heavy" branches like metal, machinery, motor vehicles and transport equipment. However, the majority of branches is characterized by sinking prices. Note, that for many industries, a significant price response can be observed only after eight respectively twelve quarters. This is also reflected by the numbers in brackets which give the timing of the maximum response in quarters after the monetary shock. Here, it becomes clear that on average IPI reaction reaches the maximum several quarters before PPI. Thus, in the light of the fact that we observe an immediate response of production in the vast majority of branches, PPI seems to lag IPI a few quarters.

Table 4 depicts mean elasticities after 4, 8, 12 and 20 Quarters. Also here it becomes clear that there we observe rising prices either in the mining or in the "heavy" industries. Moreover, rising prices is an issue in the earlier periods Thus, our findings from above are again confirmed by the latter table which qualitatively shows the same picture as before. It can be quite conclusive to consider the main industry sectors (CDE, C, D, E) separately as three different patterns of monetary transmission emerge. Observing the average response of the manufacturing sector (D), it becomes clear that output and prices move into the same direction. As the manufacturing sector makes up the largest part of industrial production (CDE), transmission of an unanticipated monetary tightening here is quite similar although prices react somehow more inertial. A second pattern can be observed in the mining industry. Here, output initially rises and prices follow, although the reaction is not statistically significant. Finally, in the energy sector, declining production is accompanied by higher prices.

Industry	Euro area								
	4Q Mean		8Q Mean		12Q Mean		20Q Mean		
	IPI	PPI	IPI	PPI	IPI	PPI	IPI	PPI	CORR
CDE	-0.24	-0.02	-0.51	-0.10	-0.47	-0.12	-0.26	-0.12	0.40
C	0.22	-0.03	0.24	0.03	0.28	0.06	0.28	0.01	0.26
D	-0.26	-0.05	-0.57	-0.15	-0.52	-0.18	-0.29	-0.16	0.71
E	-0.06	0.11	-0.08	0.20	-0.08	0.18	-0.05	0.06	-0.71
CA10	0.55	0.24	0.67	0.97	0.74	1.46	0.70	1.64	0.49
CA11	0.48	-0.21	0.73	-0.39	0.79	-0.63	0.61	-0.83	-0.02
CB14	-0.40	0.02	-0.76	-0.01	-0.75	-0.07	-0.54	-0.18	-0.57
DA15	-0.10	-0.14	-0.13	-0.19	-0.10	-0.21	-0.04	-0.23	-0.21
DA16	-0.81	0.39	-1.24	0.93	-1.39	1.11	-1.23	0.98	-0.94
DB17	-0.55	-0.14	-1.01	-0.33	-0.91	-0.37	-0.66	-0.29	0.86
DB18	-0.30	-0.02	-0.74	-0.06	-0.70	-0.08	-0.45	-0.09	0.08
DC19	-0.65	-0.08	-1.13	-0.25	-1.26	-0.39	-1.19	-0.55	0.42
DD20	-0.26	-0.06	-0.31	-0.22	-0.13	-0.24	0.09	-0.17	0.46
DE21	-0.03	-0.06	-0.09	-0.63	0.04	-0.88	0.13	-0.77	-0.15
DE22	-0.05	-0.00	-0.07	-0.16	0.04	-0.26	0.25	-0.22	0.00
DF23	0.37	-0.40	0.39	-0.83	0.43	-1.02	0.37	-0.92	-0.61
DG24	-0.46	-0.05	-0.60	-0.19	-0.55	-0.22	-0.41	-0.18	0.53
DH25	-0.28	-0.01	-0.66	-0.11	-0.56	-0.17	-0.32	-0.17	0.20
DI26	-0.30	-0.02	-0.60	-0.04	-0.55	-0.07	-0.34	-0.10	-0.47
DJ27	-0.31	0.27	-0.60	0.37	-0.44	0.55	-0.23	0.62	0.27
DJ28	-0.09	0.06	-0.51	0.08	-0.51	0.11	-0.27	0.16	0.43
DK29	-0.15	0.02	-0.63	0.01	-0.65	-0.03	-0.39	-0.08	-0.46
DL30	-0.47	-0.30	-1.26	-0.36	-1.33	-0.33	-0.32	-0.25	0.79
DL31	-0.13	0.02	-0.59	-0.01	-0.58	-0.03	-0.35	-0.04	0.24
DL32	-0.02	-0.14	-0.30	-0.33	0.04	-0.38	0.96	-0.33	0.42
DL33	-0.18	-0.03	-0.48	-0.07	-0.59	-0.11	-0.47	-0.14	0.37
DM34	-0.25	0.06	-1.01	0.08	-0.98	0.07	-0.56	0.03	-0.88
DM35	-0.27	0.13	-0.36	0.14	-0.30	0.09	-0.08	0.05	-0.80
DN36	-0.10	-0.01	-0.47	-0.04	-0.50	-0.07	-0.23	-0.11	-0.30
E40	-0.06	0.11	-0.09	0.23	-0.09	0.22	-0.06	0.10	-0.76

Note: Numbers are calculated from the mean of 2000 bootstrapped impulse response functions. For the sectors CA12, CB13, DN37 and E41 data is not available. The right column "CORR" gives the correlation of IPI and PPI impulse response functions.

Table 4: Mean elasticities after 4, 8, 12 and 20 quarters

A more detailed view on the distinct sectors in manufacturing reveals considerable differences with respect to monetary transmission. In the tobacco producing industry (DA16) we clearly observe what has been called a *price–puzzle*. Although output declines the price response is positive. Here, one possible explanation might be misspecification because price dynamics are to a major extent driven by movements of tax rates and we do not control for changes in administered prices. So, the impulse–response functions mainly mirror the fact that the ECB reacts to a change in administered prices of tobacco and we are not able to identify a structural monetary policy shock in this branch. Another notable result can be found in the publishing and printing industry (DE22) as well as in the radio, television and communication equipment producing branch (DL32). Apart from the fact that both reactions are very similar, production rises after about ten quarters. However, prices fall quickly. From this finding, we conclude that the media sector is not very well described by the transmission channels that have been described so far. *One conjecture could be that low aggregate demand is accompanied by higher expenses in advertising and media of firms. But at the same time firms are not able to pay high prices.* Also in the coke and refined petroleum producing industries (DF23) a restrictive monetary impulse is followed by higher production and lower prices. Note, that the reaction is very similar to the associated mining industries (CA11). Turning to the "heavy" industries basic metal products (DJ27) and fabricated metal products, we find that production falls and this fall is accompanied by higher prices. As we do control for movements in commodity prices, this is a strong hint at a cost–channel being in place and dominating the traditional interest rate channel and the conclusion we can draw from this is, that, monetary policy shocks can indeed act as a supply shock in certain industries. Only little price response is found in the electrical machinery sector (DL31), although production declines significantly. As these sectors mainly produce durable goods where demand is driven by investment decisions, that, in turn depend on interest rates, this is quite astonishing. On the other hand, this is again a "heavy" sector. This would again be in line with an additional cost–channel of monetary transmission. The largest sector according to table 2 (motor vehicles producing industry (DM34)) and also other transport equipment (DM35) seems to feature a cost–channel effect of monetary policy as production declines considerably in the first place. But it is not followed by sinking prices as would be predicted by the interest rate channel. Thus, in these sectors supply–side effects seem to be the dominant transmission channel at least in the short term.

On the whole, transmission of monetary policy into the industry branches of the Euro area is quite heterogeneous. Moreover, we find that in some important industries prices seem to rise or respond sluggish after a monetary tightening. In the light of the model we have presented in section 2, we would argue that the cost–channel clearly dominates the interest rate channel in these branches – at least during the first quarters.

4 Financing of firms and the cost channel

From the reasoning of the theoretical model, the prevalence of either a traditional interest rate channel – possibly augmented by a financial accelerator channel – and a cost channel determines the price and output dynamics we observe in section 3.4. However, from a theoretical point of view, the relative strength of the channels varies with the dependence on short–term financing and the degree of interest rate sensitivity of demand in an industry. Therefore, we now follow Hayo and Uhlenbrock (2000) and investigate whether the various elasticities are systematically related to industry specific characteristics, thereby identifying some of the crucial variables that drive monetary transmission. In principal, the strength of the different transmission mechanisms can be explained by various potential candidates:

Interest rate channel According to the interest rate channel, firms that sell to customers who take into account the interest rate – like in the durable goods market – should experience more pressure on prices relative to other industry sectors. As a result, industry–specific pricing decisions should solely depend on demand characteristics. Consequently, Dedola and Lippi (2005) and Peersman and Smets (2005) find that industries producing durable goods experience a larger downturn in production after a monetary policy shock. Following the classical interest rate channel, we would expect prices to parallel output dynamics and fall markedly. Thus, price dynamics should be explained by the reaction of output to a monetary policy shock.

Balance–sheet channel (financial accelerator) In addition, Dedola and Lippi (2005) and Peersman and Smets (2005) state that the interest rate channel can be amplified by industry specific balance–sheet characteristics. In particular, small firms and those that have a large interest burden tend to face constraints with regard to their borrowing capacities and, hence, are more heavily affected by a monetary contraction leading to an even stronger downturn of aggregate demand (Bernanke and Gertler, 1989). But again, price dynamics after a monetary shock are only demand–side driven, i.e. they are explained solely by movements of production.

Cost channel From the model we have presented in section 2 it becomes clear that monetary policy can also act as a supply shock if it operates via a cost channel. Thereby, the need for short–term financing of production determines the relative strength of the cost channel in an industry. Thus, potential candidates that support the occurrence of a cost channel are those that are related to the need for short–term capital. Following Dedola and Lippi (2005), Peersman and Smets (2005) and Hayo and Uhlenbrock (2000) we use working capital (WOCA), the interest burden (IBUR), the short–term debt ratio (DEBT) and the short–term loan ratio (LOAN) as the financial key figures[8]. In particular, IBUR measures the extent to which profits are achieved by external finance, whereas WOCA is a proxy for the need to finance current assets which most commonly cannot be used as collateral. DEBT and LOAN are more general proxies for the amount of indebtedness of a sector. The data is taken from BACH database which has also been used by Peersman and Smets (2005) and which is provided by the European Commission[9]. Unfortunately, aggregate balance–sheet data for the Euro area is not available. Therefore, we proxy the aggregate by calculating the respective weighted average considering Germany, France, Italy and Spain[10]. This can be justified by the fact that these countries account for the largest part of the Euro area with a share of total value added in manufacturing of 80 %, the single contributions being 36% (Germany), 17% (France), 18%(Italy) and 9% (Spain)[11]. Moreover, we have to limit the following investigations to industries of the manufacturing sector. The remaining industries are food (DA15), textiles (DB17), wearing apparel (DB18), wood (DD20), paper (DE21), publishing and media (DE22), chemicals (DG24), rubber and plastic (DH25), glass (DI26), basic metals (DJ27), fabricated metals (DJ28), machinery (DK29), electrical machinery (DL31) and motor vehicles (DM34)[12]. Note that the sample still contains all different types of

[8]The key figures are defined as follows:
WOCA = current assets − short–term debt + short–term loans (as % of total assets),
IBUR = interest payments / gross operating profits,
DEBT = short–term debt / total debt,
LOAN = short–term loans / total debt.

[9]The dataset is available from http://ec.europa.eu/economy_finance/indicators/bachdatabase_en.htm.

[10]Due to the definition of the variables, WOCA is weighted by total assets in the industry of a country relative to the sum of assets in the industries of Germany, France, Italy and Spain. The same is done for DEBT and LOAN. As IBUR is a figure taken from the profit and loss account, the weight is calculated as the share of total turnover of a country's industry in the sum of total turnover of Germany, France, Italy and Spain.

[11]Note, that these are average values of the period 2000–2004

[12]This reduction of the sample is largely due to the fact that in BACH database the missing industries for Germany are not available.

industries.

4.1 Relating responses to short–term financing

Explaining IPI response In the following, IPI response is measured by the summary statistics given in table 3 and 4, which measure short–term effects as well as elasticities covering a longer period. However, we exclude the maximum elasticities from the following analysis because table 3 reveals that the timing of the peaks of IPI and PPI responses are quite different and we do not consider dynamic aspects here. Figures 7 to 8 in the appendix show correlograms of the elasticities and the financial key figures presented above. The first graph reveals that there is clearly a negative correlation of IPI response and IBUR. This result holds irrespective of the measure for the elasticity. Table 5 summarizes the results and reveals a significant correlation in the short run. As far as WOCA is concerned, the relationships are also negative but not very precise. The DEBT ratio again clearly displays a negative correlation which is significant in five cases. However, the LOAN ratio does not seem to be correlated with IPI elasticities. What is encouraging in this respect is, that most of the correlations have the expected sign. As the balance–sheet channel and the cost channel both operate into the same direction as far as output is concerned, we would expect larger (negative!) IPI elasticities to be accompanied by higher values for the financial key figures. Interestingly, IBUR seems to be associated with a higher immediate response, whereas DEBT has a higher coefficient for the elasticities measured after the 8th quarter following a monetary tightening. Hence, there seems to be some relationship in the sense that firms facing higher short–term financing requirements are more heavily exposed to a restrictive monetary policy shock in terms of output. However, from the output reaction we cannot distinguish whether the interest rate channel or the cost channel is the dominant mechanism.

Explaining PPI response As the results from the previous paragraph point into the expected direction, we now investigate, whether the price response is systematically related to the financial key variables. However, we do not expect a systematic response here, if both transmission channels indeed play a role. In fact, if we observed a negative correlation this would be some evidence in favor of the balance–sheet channel being the dominant mechanism, as then PPI dynamics can be explained solely by industrial output dynamics and therefore would simply parallel output. A positive correlation would be the outcome of a predominant cost channel because higher dependence on short–term financing would be associated with either a lower

X:	IBUR		WOCA		DEBT		LOAN	
	α	β	α	β	α	β	α	β
4Qmean	0.16	-1.39	-0.10	0.00	-0.24	0.01	-0.05	-1.17
8Qmean	0.16	-2.50	-0.30	-0.01	1.47	-2.65⋆	-0.38	-1.00
12Qmean	0.15	-2.20	-0.19	-0.01	2.05⋆	-3.33⋆	-0.36	-0.68
20Qmean	0.32	-2.05	0.01	-0.01	1.51⋆	-2.34⋆	-0.12	-0.85
4Q	0.34	-3.26⋆	-0.44	-0.01	0.04	-0.82	-0.31	-1.66
8Q	0.03	-2.76	-0.22	-0.02	4.49⋆	-6.92⋆	-0.67	-0.48
12Q	0.25	-1.32	0.05	-0.01	2.09⋆	-2.92⋆	-0.14	0.09

Note: Results from a regression $IPI = \alpha + \beta X$. A "⋆" indicates 10 % significance.

Table 5: Correlations of IPI

(negative) or even a larger positive price response. The results presented in table 6 and in the appendix in figures 9 and 10 are mixed. As far as IBUR is concerned, we observe a positive correlation, however not significant. WOCA, in fact, is not related to price response. Notably, the price response seems to be related to the DEBT ratio in a positive way, with the 8th quarter response being significant. This finding is pretty much in line with a cost channel, because a higher (positive) price response seem to be associated with higher DEBT. LOAN seems to suggest a slightly negative but insignificant relationship for shorter horizons. The response after 12 quarters is not related to LOAN. Combining the results, there seems to be lower (negative) or even a higher positive price response associated with higher values for the financial key figures. Thus, the price response does not seem to parallel IPI which can be taken as a hint that the interest rate channel – augmented by the balance–sheet channel – may not be the only driving force of PPI.

X:	IBUR		WOCA		DEBT		LOAN	
	α	β	α	β	α	β	α	β
4Qmean	-0.17	0.58	0.12	0.00	-0.22	0.29	0.09	-0.57
8Qmean	-0.24	0.50	-0.02	0.00	-1.45⋆	1.79⋆	0.02	-0.76
12Qmean	-0.41	1.00	-0.09	0.00	-1.79	2.19	-0.04	-0.57
20Qmean	-0.48	1.31	-0.08	0.00	-1.43	1.74	-0.06	-0.34
4Q	-0.30	0.95	0.18	-0.01	-0.87	1.11	0.15	-1.17
8Q	-0.41	0.54	-0.33	0.00	-3.31⋆	4.03⋆	-0.15	-0.65
12Q	-0.89	2.73	-0.11	0.00	-1.71	2.09	-0.13	0.03

Note: Results from a regression $PPI = \alpha + \beta X$. A "⋆" indicates 10 % significance.

Table 6: Correlations of PPI

Explaining the difference in the responses One way of summarizing the results of the previous paragraphs is to take the difference of both variables and see how it relates to the financial key variables. The reasoning behind this is that the existence of a cost channel will drive a wedge between the elasticities of IPI and PPI following a monetary shock. Therefore, we define the distance measure $\Delta = PPI - IPI$ for each summary measure we calculate in table 3 and 4. If we see a positive correlation, this is a hint that firms facing higher financial financing requirements are more likely to feature a price puzzle. Hence, the price puzzle would emerge from a cost channel of monetary policy. However, as a part of the price response is possibly explained by IPI dynamics induced by the interest rate channel – which implies simultaneity of IPI and PPI – we cannot distinguish both channels in this bivariate setting. But if the cost channel is in force, then PPI should not be negatively correlated with the financial key figures and behave different from IPI. Indeed, the results we present in the Appendix in figure 11 and 12 and summarize in table 7 are encouraging. Although WOCA and LOAN indicate a flat correlation, the remaining measures IBUR and DEBT clearly show a positive relation. Thus, higher financing requirements, indeed, are accompanied by a larger difference of IPI and PPI elasticities, irrespective of the elasticity measure taken. Interestingly, IBUR comes along with an increased difference after 4 quarters, whereas DEBT is significantly associated with the elasticity measures after 8 to 20 quarters.

X:	IBUR		WOCA		DEBT		LOAN	
	α	β	α	β	α	β	α	β
4Qmean	-0.33	1.98*	0.22	0.00	0.02	0.27	0.13	0.59
8Qmean	-0.40	2.99	0.27	0.01	-2.92*	4.44*	0.40	0.24
12Qmean	-0.56	3.20	0.10	0.01	-3.84*	5.52*	0.32	0.10
20Qmean	-0.80	3.36	-0.09	0.01	-2.94*	4.07*	0.06	0.52
4Q	-0.64	4.21*	0.62	0.00	-0.92	1.93	0.47	0.49
8Q	-0.44	3.29	-0.10	0.02	-7.80*	10.95*	0.52	-0.18
12Q	-1.14	4.05	-0.17	0.01	-3.79*	5.01*	0.01	-0.06

Note: Results from a regression $\Delta = \alpha + \beta X$. A "$\star$" indicates 10 % significance.

Table 7: Correlations of Δ

On the whole, IPI exhibits a stronger downturn if dependence on external short–term financing is high. This finding would be in line with both, a balance–sheet channel and a cost channel. For the PPI response we do not find a strong negative relationship in the bivariate setting which contrasts the view of a balance–sheet channel being the single transmission mechanism. However, the findings so far are encouraging and shed some light on mone-

tary transmission and the presence of the cost channel in single industries, as there seems to be a systematical relationship between industry specific characteristics – i.e. short–term financing requirements – and the prevalence of the respective transmission channel. Higher dependence leads to an amplified IPI elasticity while PPI response is mitigated.
The analysis presented in the previous paragraphs, of course, suffers from the fact that it relies solely on bivariate correlations. Furthermore, IPI and PPI are obviously highly endogenous which makes it impossible to disentangle a causal effect of a downturn of IPI on PPI in order to identify and control for the impact of the interest rate channel in conjunction with the balance–sheet channel.

5 Concluding remarks

According to traditional models of monetary transmission, a monetary tightening exerts its influence by lowering interest rate dependent demand, thereby exerting downward pressure on aggregate prices. Hence, the monetary policy shock operates like a demand shock. However, a frequent finding in empirical literature, that has become known as the price puzzle, is that prices rise following a restrictive monetary impulse. Following Christiano, Eichenbaum, and Evans (2005) or Rabanal (2007), we present a New Keynesian Model that allows for a sector that features a cost channel of monetary policy. In other words: monetary policy can act as a supply shock by way of directly exerting influence on firms' marginal cost. It can be shown that in some industries which require short–term financing for production, prices tend to rise after a monetary contraction for several quarters, because – in the short–run – the interest rate channel is dominated by the cost channel. As Rabanal (2007) points out, there may be washing out effects on the aggregate level as far as monetary transmission is concerned. Hence, we look at IPI and PPI dynamics following a monetary tightening on an industry level, thereby trying to identify sectors where a price puzzle can be observed.
In order to do so, we specify a baseline VAR model that captures the aggregate dynamics of GDP, HICP, wages and the policy rate in the Euro area. We observe that prices tend to react rather sluggish after a monetary contraction, even though wages react somehow quicker. Hence, our empirical analysis supports evidence on a moderate version of the price puzzle because prices do not rise significantly but fall eventually. The baseline VAR is then assumed to be block–exogenous to the respective industry dynamics. We identify a monetary policy shock by assuming that only the interest rate itself displays a contemporaneous reaction after a monetary policy shock.

Moreover, we avoid the important source of misspecification by controlling for commodity price movements. The analysis shows that there is considerable heterogeneity across industries first and foremost in PPI dynamics but also in IPI response. We find that some industries clearly display a price puzzle while others don't. In fact, many of the "heavy" industries feature a rise in prices after a monetary tightening. Furthermore, PPI reaction seems to lag IPI dynamics. To identify whether the cost channel is the driving force behind the price puzzle, we relate output and price elasticities to industry specific characteristics which capture the extent to which an industry depends on external short–term financing. In the first place, we find a negative relationship between IPI elasticity and the financial key figures, which is in line with our theoretical model. So far, we cannot tell if this relationship can be attributed to a balance–sheet channel or a cost channel. Secondly, the response of PPI does not seem to be negatively correlated with short–term financing requirements. The fact that PPI does not show the same correlations as IPI can be taken as a hint that PPI additionally is affected by a cost–channel. Moreover, our findings suggest that the strength of the cost channel changes with the extent to which firms have to rely on external short–term financing.

As BACH database only covers data for the single Euro area member countries, the sample is reduced quite dramatically. For further research, it will be advisable to work with a richer dataset that comprises more industries. This is needed to complete the inference using a multivariate regression approach and to infer the determinants of PPI dynamics apart from simple correlation analysis in order to control for the effects of the interest rate channel and the balance–sheet channel on prices.

Appendix

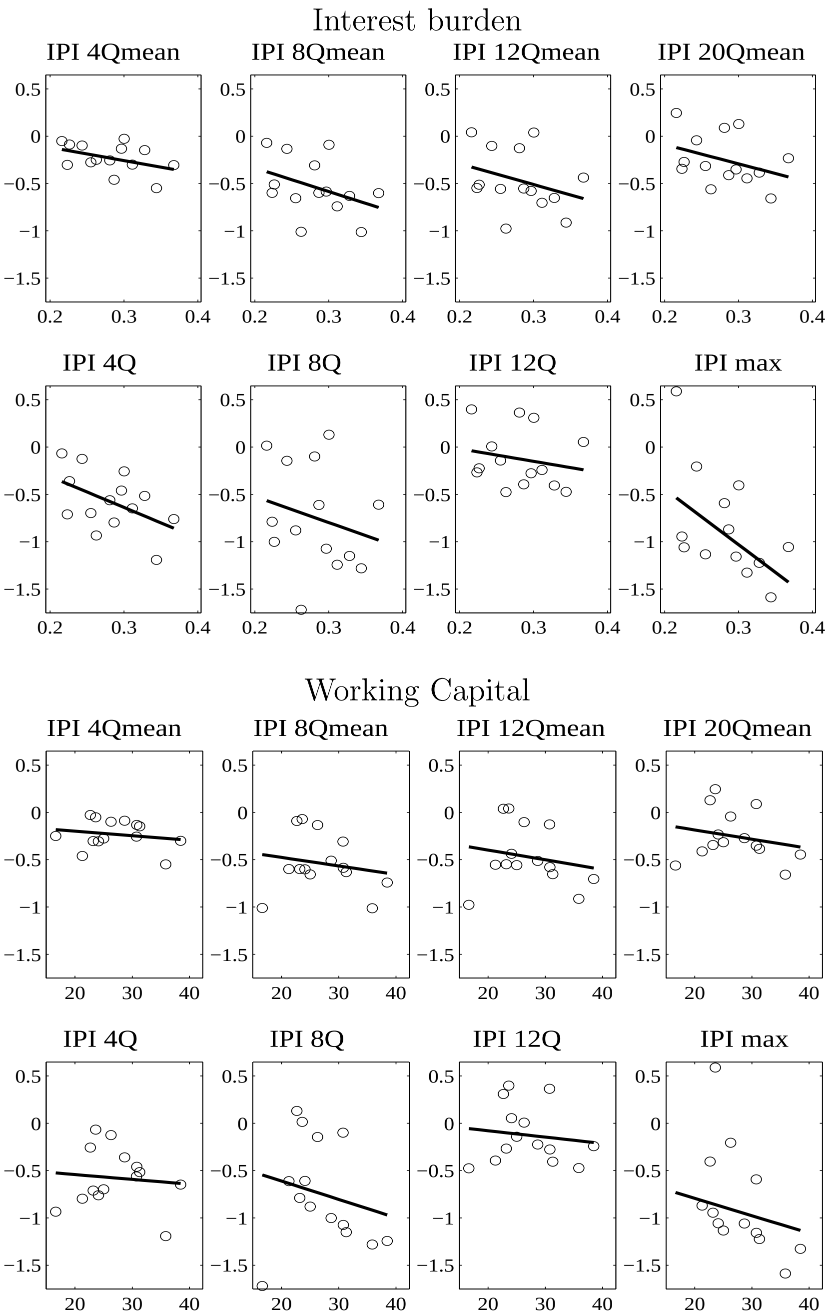

Figure 7: Correlation of IPI 1

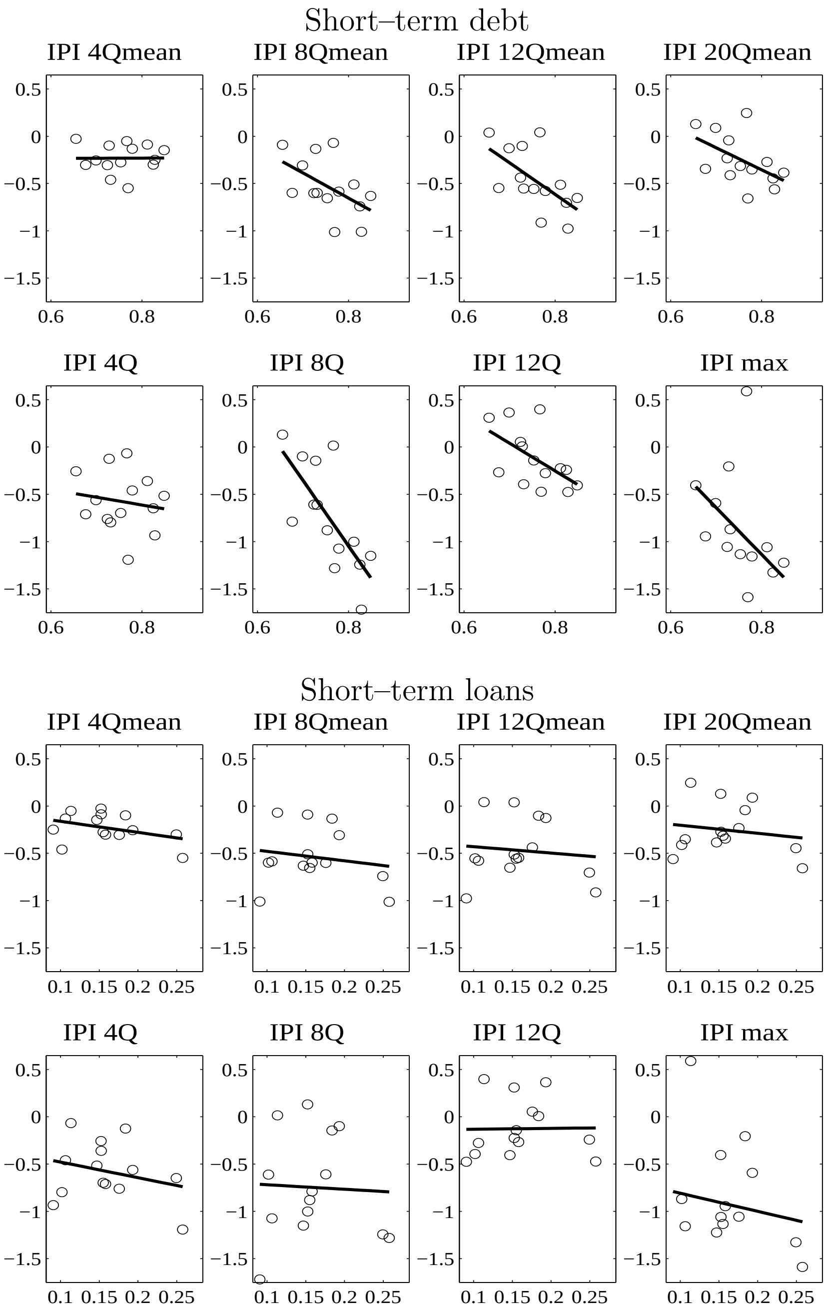

Figure 8: Correlation of IPI 2

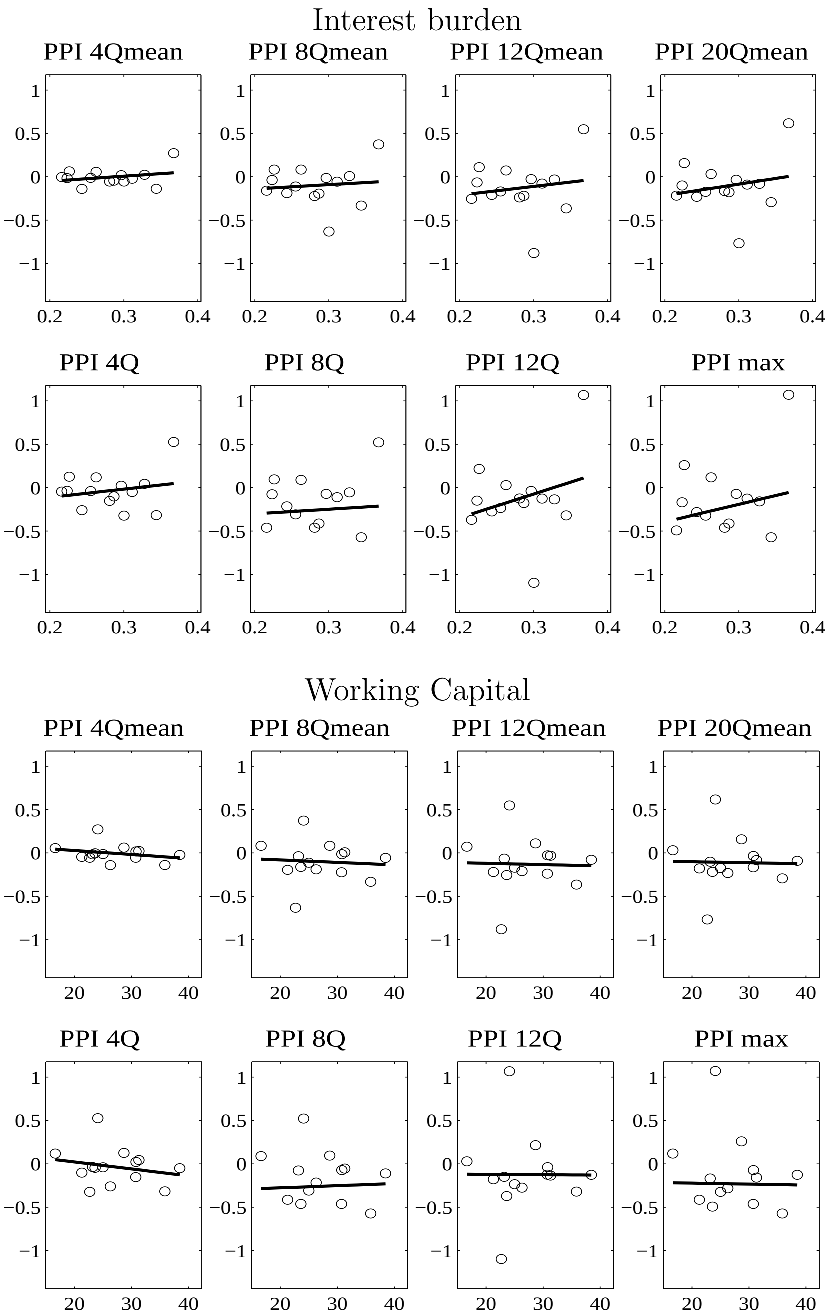

Figure 9: Correlation of PPI 1

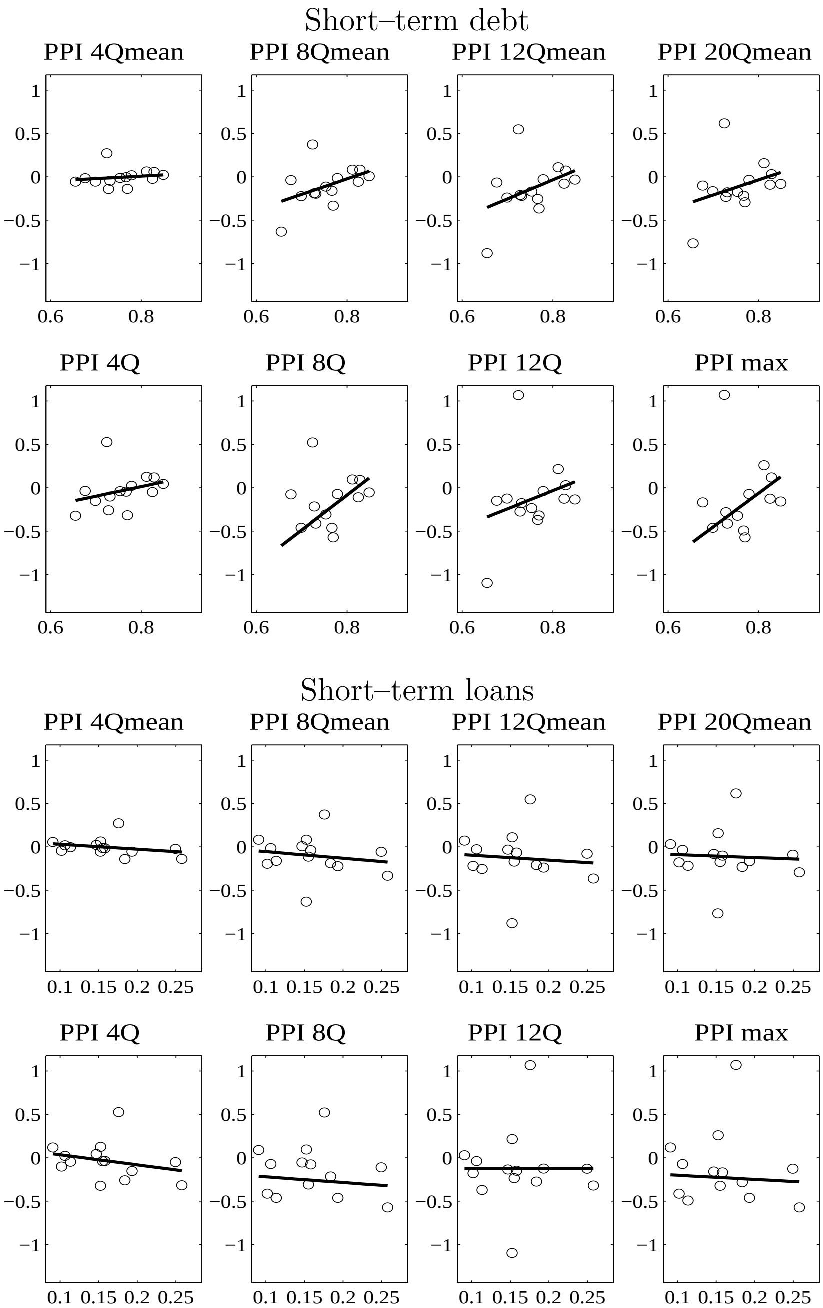

Figure 10: Correlation of PPI 2

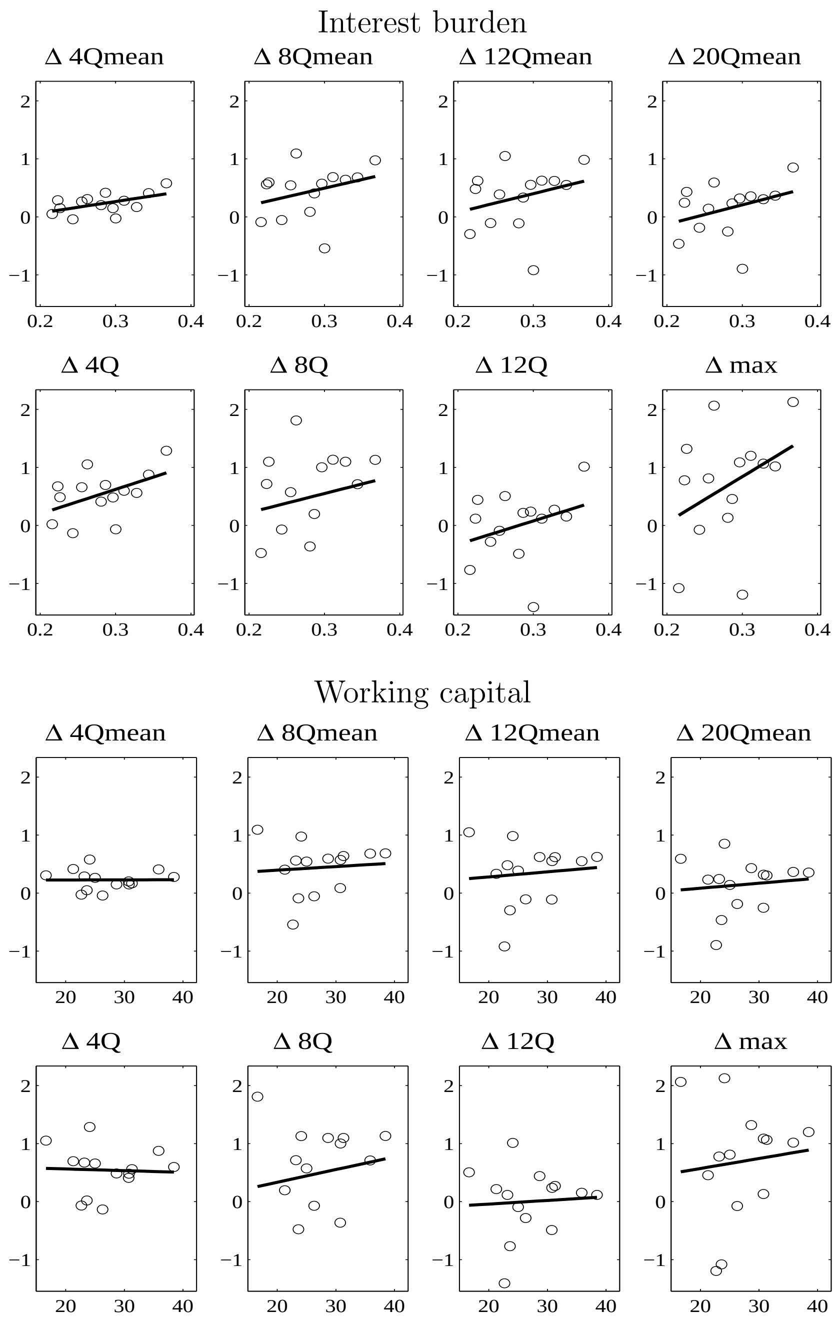

Figure 11: Correlation of Δ 1

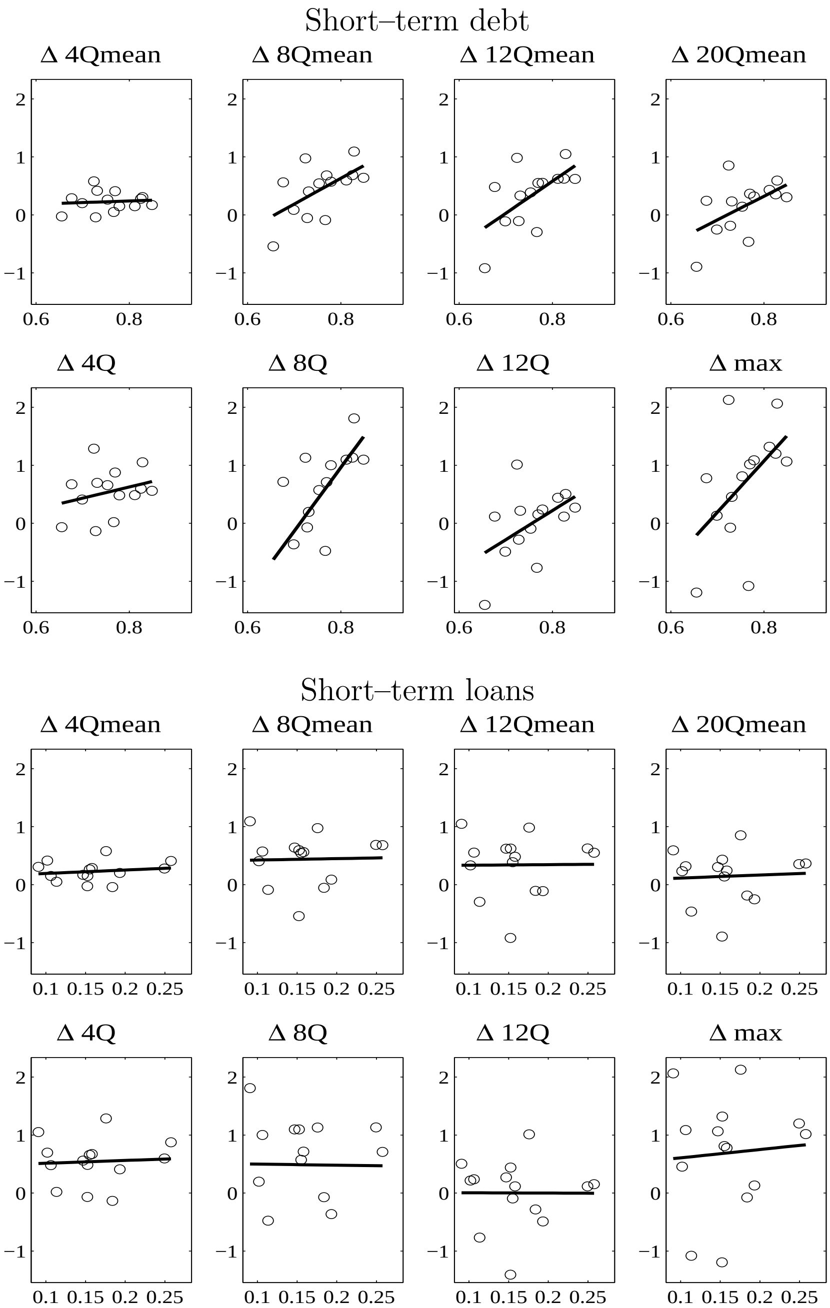

Figure 12: Correlation of Δ 2

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