The Working Capital Channel

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Abstract

The New Keynesian model augmented with the working capital channel predicts that a rise in the policy rate causes firms that use more working capital to increase their prices more and that the pass-through of policy rate changes to prices is gradual because of price rigidity. Using firm-level data, I show that a one percentage unit increase in the policy rate leads to a one percent increase in the firm's price via the working capital channel and that the pass-through takes about 4 months, consistent with standard assumptions in DSGE models.

Keywords: working capital, price setting, monetary policy, pass-through

JEL Codes: E31, E37, E52, L11

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1 Introduction

The price puzzle, which is the increase in prices after a positive monetary policy shock, remains a key feature of the time-series data[1]. The most widely-used explanation for the price puzzle is the working capital channel (Hanson, 2004; Barth and Ramey, 2001; Christiano, Eichenbaum and Evans, 2005). The working capital channel posits that a higher nominal interest rate increases firms' marginal costs because the interest rate scales the total amount of money that firms need to allocate in order to pre-fund their factors of production before sales are realized and payments for their products are received.

The suggestion from the time-series literature to use the working capital channel to explain the price puzzle has been taken seriously by central bankers. Prominent DSGE models such as COMPASS (Bank of England, Burgess (2013)) and Maja (Swedish Central Bank, Corbo (2020)) include a working capital channel. These DSGE models build on the seminal work of Christiano, Eichenbaum and Evans (2005) who show that switching off the working capital channel results in their models' loss of ability to reproduce the price puzzle. Following the lead of Christiano, Eichenbaum and Evans (2005), it is typically assumed that the firm pre-funds the *entirety* of its wage bill *one quarter ahead*. There is currently no micro foundation for these specific assumptions in prominent central bank models. In addition, there is no micro data evidence on the working capital channel that supports the claim that a working capital channel exists and, if it does, that it has the required strength to solve the price puzzle. Specifically, the effect of a monetary policy *shock* on prices via the working capital channel has not been examined at the firm level.

[1]It reduces to a lesser "residual price puzzle" when researchers follow the suggestions by Sims (1992) or Bernanke, Boivin and Eliasz (2005) and include commodity prices or a small number of factors as indicators for future inflation (Hanson, 2004).

The main contribution of this paper is that it brings micro evidence on the working capital channel as it is used in standard VAR and DSGE models. Second, it provides micro foundations for calibrating the working capital channel in standard DSGE models. Third, it identifies the total effect of policy rate changes on prices via the working capital channel as opposed to the effect of monetary policy shocks. Bernanke et al. (2005) point out that the VAR approach focuses only on the effects of unanticipated changes in monetary policy, not the effects of the arguably more important systematic monetary policy response. Variation across firms allows this study to replace the strong identifying assumption of a VAR model with a more favorable one that can identify the total effect of interest rate changes on prices via the working capital channel.

Using a theoretical framework based on the New Keynesian model, I derive a structural equation that can be estimated using firm-level data. In particular, I modify a basic New Keynesian model to accommodate firms with heterogeneous working capital holdings. The model predicts that an increase in the policy rate leads to an increase in firms' prices, and that firms with a higher level of working capital holdings increase their prices more. Furthermore, the pass-through of policy rate changes to prices is gradual because of price rigidity. In addition, the model predicts that anticipated and unanticipated interest rate changes have different effects on producer prices. Unanticipated interest rate changes should generate a larger pass-through than anticipated interest rate changes in the months following the interest rate change. The reason is that firms may already have started to adjust to the anticipated interest rate change before the monetary policy announcement occurs. It is important to note that, according to the theory, not only monetary policy shocks affect prices. Both anticipated and unanticipated interest rate changes have effects on producer prices and estimating only one effect would yield an incomplete assessment of the role of the working capital channel.

These model predictions are tested using micro data on Swedish firms. To identify the causal effect of monetary policy on producer prices via the working capital channel, I use a unique firm-level panel dataset containing detailed information on firm characteristics and firm-level monthly price indices. The dataset includes balance sheets and price data for 2,151 Swedish firms for the period 1997-2016. Working capital is defined as the sum of receivables and inventories net of payables and pre-payments from customers[2].

The pass-through of a change in the policy rate via the working capital channel is identified using the shift-share approach. In particular, panel regressions compare the responses of producer prices to policy rate changes of firms that have a large working capital to sales ratio to firms that have a small working capital to sales ratio. The idea is that firms which have larger working capital requirements should increase their prices more in response to an increase in the interest rate because it increases their marginal costs more. To eliminate the confounding responses of working capital holdings to changes in demand, I use the time-average working capital holdings at the firm-level so that the effect of policy rate changes on prices is identified from time-invariant variation in working capital across firms.

The baseline specification estimates the effects of monetary policy shocks and anticipated interest rate changes on firm-level prices via the working capital channel. The expected part of a policy rate change is calculated as the actual change in the repo rate minus the shock component. The identifying assumption I make in the panel regression is that firms' differential price responses are due to differences in their working capital holdings and not due to some omitted variable which is correlated with the change

[2]This definition follows convention by Barth and Ramey (2001) and Gaiotti and Secchi (2006).

in the interest rate and affects firms with higher working capital holdings more. To ensure identification, monetary policy shocks are estimated as high-frequency shocks à la Kuttner (2001) and the regression includes multi-dimensional fixed effects as well as numerous firm-level control variables to rule out confounding variation caused by firm-specific time-varying demand and cost shocks.

As robustness checks, two alternative measures of unanticipated interest rate changes are constructed. The first series consists of forecasting regression errors that are derived from a Taylor-type forecasting rule. Second, an identified monetary policy innovation series from the Riksbank's Ramses II DSGE model is used. I repeat the panel regressions with these alternative measures of anticipated and unanticipated interest rate changes.

For the baseline specification, I find that unanticipated interest rate changes have larger effects on prices than anticipated policy rate changes and the average effect of an interest rate change on prices via the working capital channel is significant and economically non-negligible. The average effect of the unanticipated and the anticipated interest rate changes shows that a one percentage unit increase in the repo rate increases the firm's price by one percent via the working capital channel 4 months after the policy rate change for a firm whose working capital requirement equals its sales. The robustness checks also confirm the coefficient of one. This means that a firm with the average working capital to sales ratio of 0.2 will increase its price by approximately 0.1 percent upon a one percentage unit increase in the repo rate after 3 months and 0.2 percent after 6 months. In addition, the results show that the effect is gradual and stabilizes around one. The gradual price increase supports the claim that prices are sticky and there is a substantial delay in firms' price responses[3].

[3]Since most trade credit and bank credit lines are documented to be flexible and short term (Sufi, 2009; Chodorow-Reich, Darmouni, Luck and Plosser, 2022), the sluggish price response is indicative of price stickiness rather than bank lending rate stickiness.

The micro data show that the average firm's working capital holdings amount to 20 percent of its sales. This value is roughly consistent with a model where firms pay their input costs a quarter before they receive payments (Christiano et al., 2005; Corbo, 2020). Thus, the micro data supports the working capital channel as it is used in standard macro models. In addition, the estimated price response indicates a 4-5 months adjustment process of prices which is consistent with a Calvo parameter of price stickiness around 0.6-0.75. This value is also in line with the baseline estimates of Christiano, Eichenbaum and Evans (2005) and Corbo (2020).

The results presented in this paper complement Barth and Ramey's (2001) pioneering work, which provides indirect evidence of the working capital channel by estimating the transmission of monetary policy shocks to wages and producer prices using an industry-level VAR framework. The present study brings direct firm-level evidence about the mechanism and it identifies the effects of anticipated and unanticipated interest rate changes as well as the total effect of a policy rate change on firms' prices via the working capital channel. This paper is most closely related to the study of Gaiotti and Secchi (2006) who use firm-level balance sheet data on Italian firms' working capital requirements and price data to identify the pass-through of bank lending rate changes to prices via a working capital channel. I corroborate the finding of Gaiotti and Secchi (2006) in that the working capital channel is important for firms' price setting behavior. However, the present study is different from that of Gaiotti and Secchi (2006). It focuses on the working capital channel as it is used in standard DSGE models, by using aggregate monetary policy shocks and repo rate changes in the estimation, whereas Gaiotti and Secchi (2006) use firm-specific bank lending rate changes. Gilchrist and Zakrajšek (2012) show that changes in corporate bond credit spreads and policy rates propagate through the economy in different ways. In this paper, the focus is on the effect of aggregate policy rate changes and not on changes in specific bank lending rates that may arise for other reasons.

Importantly, I do not analyze the general equilibrium effects of monetary policy in this study. Monetary policy affects prices via both supply and demand. This paper investigates the direct supply-side transmission mechanism and quantifies the average producer price increase after an increase in the policy rate, conditional on changes in demand. Changes in demand are captured by time-product fixed effects and other control variables. Therefore, I use the term "via the working capital channel", indicating that the price effect of a policy rate change in this paper should be understood as a partial effect, conditional on demand. While this study cannot say, for example, whether the working capital channel can explain the "missing disinflation puzzle" during a recession, it sheds light on the supply-side mechanism and it measures the average effect of monetary policy on prices via the working capital channel.

The paper is structured as follows. Section 2 describes the related literature. Section 3 explains the theoretical framework. Section 4 outlines the method and data used for the empirical analysis. Section 5 presents the baseline results as well as the results of extensions. Section 6 concludes the paper.

2 Related Literature

The working capital channel is widely used in central bank DSGE models (see e.g. Burgess (2013); Adolfson et al. (2013); Corbo (2020)) because aggregate data seems to support its role. Chowdhury, Hoffmann and Schabert (2006) estimate a New Keynesian Phillips curve augmented with a cost channel term for Canada, France, Germany, Italy, Japan, the UK, and the US; and find a significant interest rate elasticity. Ravenna and

Walsh (2006) estimate an augmented Phillips curve and build a New Keynesian model where a cost-push shock can arise endogenously through the cost channel. They find that the cost channel is present and it has significant implications for optimal monetary policy. More recently, Tillmann (2008) confirms the importance of the cost channel for inflation dynamics in the US, the UK, and the aggregate Euro area within a framework with a forward-looking Phillips curve. In addition, Tillmann (2009) examines the time-varying role of the cost channel in the US and finds that it was more important in the pre-Volcker period than during the Volcker-Greenspan era.

Barth and Ramey (2001) use an industry-level VAR model to test the strength of the working capital channel relative to the demand channel. They do not include a specific variable for working capital in their VAR specification, rather they assume that the reason why producer prices increase after a tightening in monetary policy is because of the cost and the demand channels. They show that in response to a positive shock to the Federal funds rate output falls and prices rise relative to wages which is evidence that the cost channel is more powerful than the demand channel. The only empirical study that uses firm-level data to examine the working capital channel is that of Gaiotti and Secchi (2006). In their data, the mean ratio of working capital to annual operating cost is 0.33 and their coefficient estimates range between 0.3 and 1, showing that a one percent rise in the annualized *bank lending rate* induces an increase in prices between 0.1 and 0.3 percent for a firm with the average working capital to operating cost ratio.

3 Theoretical framework

This section describes the working capital channel as it is implemented in the New Keynesian model of Christiano, Eichenbaum and Evans (2005). I use the model to show that a raise in the policy rate increases firms' prices via the working capital channel. In addition, I describe how anticipated and unanticipated changes in the interest rate affect firm-level price inflation via the working capital channel. A core feature of the model is the presence of staggered price changes à la Calvo.

The starting point is the firm's optimal price setting equation in the standard New Keynesian model

$$p^*_{i,t} = \mu + (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_{i,t}[\widetilde{mc}^n_{i,t+k|t}], \tag{1}$$

where $\widetilde{mc}^n$ is the firm's nominal marginal cost in logs. The micro foundations of equation (1) are presented in Appendix A.1.

I assume that the firm pre-funds its wage bill W_t, so its nominal marginal cost is

$$\widetilde{MC}^n_{i,t} = \frac{(1+i_t)^{\delta_i} W_t}{(\partial Y_t/\partial N_t)} = \frac{(1+i_t)^{\delta_i} W_t}{A_t} \tag{2}$$

Equation (2) says that the firm's marginal cost is a function of the aggregate interest rate i. This cost channel establishes a direct supply-side transmission mechanism of monetary policy. The parameter δ_i captures intra-period compound interest payments spent on pre-funding wages. δ_i has subscript i because it may differ between firms.[4] δ_i represents the firm-specific time delay between paying for inputs and receiving payments for the output. The longer the firm has to wait to get paid, the higher is δ_i. This formulation of the working capital channel explicitly accounts for

[4]Christiano et al. (2005) assume $\delta_i = 1$ for all firms in a quarterly model.

firm-level differences in the time lag between payments for inputs and the receipt of payments for output sold.

The definition in (2) can be used to express the log marginal cost as a linear function of firm-specific interest payments and the marginal input cost such that

$$\widetilde{mc}^n_{i,t} = \delta_i R_t + mc^n_t, \tag{3}$$

where $R_t \equiv ln(1 + i_t)$ and $mc^n_t = ln(W_t/A_t)$ is the log nominal marginal input cost, exclusive of financing costs, which is common to all firms.

Inserting expression (3) into the firm's price setting equation yields

$$p^*_{i,t} = \mu + (1 - \theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_{i,t}[\delta_i R_{t+k|t} + mc^n_{i,t+k|t}]. \tag{4}$$

Equation (4) shows that the pass-through from R_t to producer prices depends on δ_i, the firm's working capital requirement. In particular, the pass-through is larger for firms with higher working capital requirements. The intuition is that firms which must wait longer to get paid have more outstanding receipts and face higher interest expenses so that interest rates affect them to a larger extent.

3.1 Anticipated and unanticipated interest rate changes

To analyze the effect of anticipated and unanticipated interest rate changes, I consider a large group of firms with price stickiness (θ) and a specific value of pre-funding requirement (δ). For this group, price inflation can be written as

$$\pi_t \equiv p_t - p_{t-1} = (1 - \theta)(p^*_t - p_{t-1}), \tag{5}$$

where p_t^* is given by equation (1). Note that p_{t-1} can be expressed as the joint probability that the firms were able to change the price in $t-1$ and that they had not changed the price for τ periods

$$p_{t-1} = (1-\theta)\sum_{\tau=0}^{\infty}\theta^{\tau}p_{t-1-\tau}^{*}. \tag{6}$$

Using the expression for p_t^* in equation (1), the definition of the marginal cost in (3) and the definition of the price in the previous period in (6), it is possible to write (5) as

$$\begin{aligned}\pi_t = (1-\theta)(1-\theta\beta)\Bigg[&E_t\sum_{k=0}^{\infty}(\theta\beta)^k(\delta R_{t+k}+mc_{t+k}^n)\\ &-(1-\theta)\sum_{\tau=0}^{\infty}\theta^{\tau}E_{t-1-\tau}\sum_{k=0}^{\infty}(\theta\beta)^k(\delta R_{t-1-\tau+k}+mc_{t-1-\tau+k}^n)\Bigg].\end{aligned} \tag{7}$$

Now, let us consider the effect of ΔR_t^U, a fully unanticipated change in the interest rate. A fully unanticipated interest rate change means that, ceteris paribus, the firm has not changed any of its prices before period t as a response to an interest rate change in t, so the effect on the second term within the square brackets is zero. Thus, the price change resulting from an unanticipated change in the interest rate is

$$\frac{\Delta\pi_t}{\Delta R_t^U} = (1-\theta)(1-\theta\beta)\,\delta\,\left[E_t\sum_{k=0}^{\infty}(\theta\beta)^k\frac{\Delta R_{t+k}}{\Delta R_t^U}\right]. \tag{8}$$

The effect increases with δ and also with the persistence of the shock to the interest rate.

Next, let us consider a partly anticipated interest rate change. A partly anticipated interest rate change means that the firm has already incorporated a fraction of the anticipated interest rate change into its period t

price so

$$\frac{\Delta \pi_t}{\Delta R_t^A} = (1-\theta)(1-\theta\beta)\,\delta\left[E_t\sum_{k=0}^{\infty}(\theta\beta)^k\frac{\Delta R_{t+k}}{\Delta R_t^A}\right. \tag{9}$$
$$\left. - (1-\theta)\sum_{\tau=0}^{\infty}\theta^{\tau}E_{t-1-\tau}\sum_{k=0}^{\infty}(\theta\beta)^k\frac{\Delta R_{t-1-\tau+k}}{\Delta R_t^A}\right],$$

with perfect foresight $\Delta R_t^A = E_{t-1-\tau}\Delta R_t^A$.

By comparing equations (8) and (9), we see that the effect of a purely unanticipated interest rate change is larger than the effect of a partly anticipated interest rate change:

$$\frac{\Delta \pi_t}{\Delta R_t^U} > \frac{\Delta \pi_t}{\Delta R_t^A}.$$

3.2 Predictions of the model with and without price stickiness

Price rigidity affects the pass-through of marginal costs to prices and the extent to which firms incorporate anticipated and unanticipated interest rate changes into their prices. The flexible price model has clear predictions for the effects of anticipated and unanticipated interest rate changes. In the flexible price model, $\theta = 0$ which means that firms are free to set their optimal price every period, so ceteris paribus, prices change in proportion to the pre-funding requirement

$$\frac{\Delta \pi_t}{\Delta R_t} = \delta.$$

This holds independently of whether the change in the interest rate is anticipated or not.

It is important to note that price stickiness interacts with both anticipated and unanticipated interest rate changes and it determines the size of the response in equations (8) and (9). If price stickiness is high, then the probability of changing the price, $(1-\theta)$, is low so $\Delta\pi_t/\Delta R_t^U$ will be lower. Even if the change is unanticipated, price stickiness leads to a short-run pass-through that is less than one to one.

To investigate the numerical predictions of the model under different assumptions about price stickiness, I assume that changes in the interest rate and the marginal cost follow random walks

$$\Delta R_t = \epsilon_t \ ; \quad \epsilon_t \sim N(0, \sigma_\epsilon),$$
$$\Delta mc_t^n = v_t \ ; \quad v_t \sim N(0, \sigma_v),$$

so that the optimal reset price follows a random walk $p_t^* = p_{t-1}^* + \delta\Delta R_t + \Delta mc_t^n$. Using equation (5), the price response after an innovation to R_t can be written as

$$p_t - p_{t-1} = (1-\theta)(p_{t-1}^* - p_{t-1} + \delta\epsilon_t). \tag{10}$$

Considering longer price setting horizons and a single unexpected and permanent shock this can be generalized to

$$p_{t+k} - p_{t-1} = (1-\theta^{k+1})(p_{t-1}^* - p_{t-1}) + (1-\theta^{k+1})\delta\epsilon_t. \tag{11}$$

The derivation is shown in appendix A.2. Price stickiness, θ, pins down how fast prices adjust and the working capital share δ determines the new price level.

Figure 1 depicts this relation with $\theta = 0.4, 0.5, 0.6$ and with assuming $\delta = 1$. A higher θ denotes a higher probability for the firm to keep its price unchanged and $\delta = 1$ means that all input costs are pre-funded within a period. With higher levels of price stickiness (higher θ), we see a slower adjustment to the new price level of one upon a unitary shock in ϵ_t.

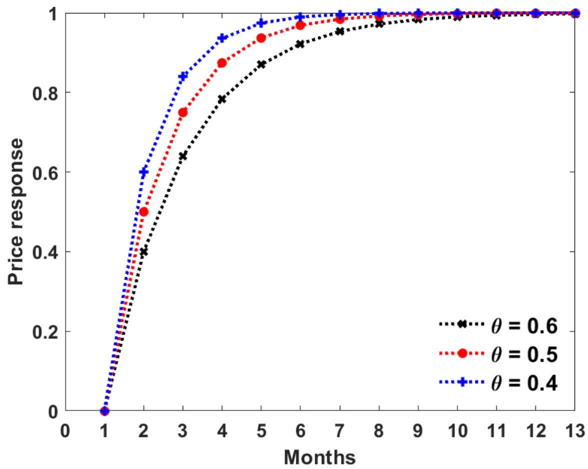


Figure 1: The effect of a permanent interest rate shock on the price with $\delta = 1$.

4 Estimation

In the baseline specification, I test the theoretical implication that anticipated and unanticipated changes in the policy rate both have effects on producer prices; and that unanticipated have larger short-run price effects. The idea behind identification is that the effects of anticipated and unanticipated policy rate changes on the price changes of firms that have large working capital holdings relative to sales can be compared with the price response of firms that have little working capital holdings relative to sales. Effectively, the price response of firms that wait longer to receive payments can be compared with the price response of firms that wait a shorter time. I estimate k Jordà-style (Jordà, 2005) regressions at the firm-product level for $k \in [0, 12]$ horizons and I consider a specification where the repo rate changes are divided into anticipated and unanticipated interest rate changes:

$$
\begin{aligned}
p_{i,j,t+k} - p_{i,j,t-1} &= \beta_{1,k}\left(\frac{\overline{W_i}}{S_i} \times \Delta R_t^A\right) + \beta_{2,k}\left(\frac{\overline{W_i}}{S_i} \times \Delta R_t^U\right) \\
&\quad + \alpha_{i,j,k} + \gamma_{i,j,k,t} + \xi_{1,k}(\overline{S_i} \times \Delta R_t) \\
&\quad + \sum_{s}^{S} \xi_{s,k}\left(\frac{\overline{W_i}}{S_i} \times D_s\right) + \epsilon_{k,i,t},
\end{aligned} \tag{12}
$$

where the firm has index i and it produces a 2-digit product j. Subscript t refers to the months between 1997m1-2016m12; and s denotes the months of the financial crisis between 2008m10-2009m6. $p_{i,j,t+k} - p_{i,j,t-1}$ is the log change in the firm-product-specific Home Market Price Index (HMPI) from a month before to k months ahead. $\frac{\overline{W_i}}{S_i}$ is the time-average working capital to sales ratio of firm i. $W_{t,i}$ is the firm's working capital, defined as the sum of inventories and receivables net of payables and prepayments from customers[5]. ΔR_t^A are anticipated and ΔR_t^U unanticipated changes in the interest rate at time t. ΔR_t^U is measured by high-frequency shocks which are often seen as exogenous monetary policy shocks. Anticipated interest rate changes are calculated as $\Delta R_t^A = \Delta R_t - \Delta R_t^U$. $\beta_{1,k}$ ($\beta_{2,k}$) measure the transmission of anticipated (unanticipated) interest rate changes to prices via the working capital channel. More specifically, the coefficients $\beta_{1,k}$ ($\beta_{2,k}$) measure the percentage price response to a one percentage unit anticipated (unanticipated) interest rate change for a firm whose working capital requirement equals its sales.

The control variables include $\gamma_{i,j,k,t}$, the time-product fixed effects which represent time-product-level factors such as variation in demand and input costs that affect prices. Firm-product-level fixed effects $\alpha_{i,j}$ control

[5]Note that this measure of working capital includes all of the firm's working capital requirement if unfinished goods are reported in inventories. If goods in process are not included in inventories, then this measure of working capital is lower than the complete value would be.

for time-invariant unobserved heterogeneity, for example the size, market power or location of the firm. Further control variables include the interaction term $\bar{S}_i \times R_t$, where $\bar{S}_i$ is the firm's time-average net sales. $\bar{S}_i \times R_t$ is a shift-share control variable which addresses the concern that larger firms may be more cyclical, have more or less working capital and respond to shocks differently than smaller firms. The regression also includes dummies D_s for the months of the financial crisis (2008m10-2009m6) interacted with the time-invariant working capital to sales ratio. These shift-share control variables take account of extreme fluctuations during the financial crisis. To take care of potential autocorrelation in the error term, the results are presented with Driscoll and Kraay standard errors.

As robustness checks, two additional measures of unexpected monetary policy shocks are constructed. The first are a series of forecasting regression errors from an OLS regression that resembles the Taylor-rule and the second are innovations from the Riksbank's DSGE model. Including the same control variables as in the baseline specification as well as interacting policy rate changes with further variables, e.g. debt-to-assets ratio, control for firm-level time-varying confounding channels so that the effects of anticipated and unanticipated changes can be identified even when monetary policy shocks and expected policy rate changes may not be believed to be exogenous.

To investigate the price effect of an actual repo rate change I estimate k regressions at the firm-product level for $k \in [0, 12]$ horizons according to

(13)

$$p_{i,j,t+k} - p_{i,j,t-1} = \alpha_{i,j,k} + \beta_k \left(\frac{\overline{W_i}}{S_i} \times \Delta R_t \right) + \gamma_{i,j,k,t} + \delta_k (\overline{S_i} \times \Delta R_t) + \sum_{s}^{S} \xi_{k,s} \left(\frac{\overline{W_i}}{S_i} \times D_s \right) + \epsilon_{k,i,j,t}$$

In this specification, I use simple repo rate changes, ΔR_t, and apply the same controls as in the baseline regression.

4.1 Identification

Identification is based on the shift-share approach. Borusyak, Hull and Jaravel (2018) argue that a sufficient identifying condition in the shift-share framework is to assume the exogeneity of shocks when multiple uncorrelated shocks are available. The identifying assumption that Borusyak et al. (2018) propose is that shocks should not be correlated with latent factors that impact the higher exposure firms to a higher degree *given the control variables*. In regressions (12) and (13) , the shares are given by firms' working capital holdings relative to sales, so the requirement for identification is that interest rate changes are not correlated with, for example, a demand shock that affects firms with higher working capital holdings to a larger or smaller extent. The main identification concern is that time-varying firm-specific demand changes may generate a correlation between price changes, interest rate changes and the working capital channel which is not causal. Since policy rate changes are related to the cycle, this could be the case if, for example, large firms are more cyclical, more responsive to demand shocks and have more or less working capital. I list the three main identification threats below and discuss how I address them in light of Borusyak et al.'s (2018) criteria.

Potential omitted variables Including time-product fixed effects as controls in regressions (12) and (13) take account of for two-digit product-time specific variation in costs and in demand. Firm fixed effects control for time-invariant unobserved heterogeneity at the firm level. Given fixed effects, the estimated coefficients measure the effect through the working capital channel as long as other latent factors such as changes in demand

and costs affect all firms in the same way, and they do not lead to a differential price response across firms with high and low working capital holdings.

The main concern is that firm and product-time fixed effects do not absorb time-varying firm-specific confounding factors that may correlate with the working capital channel. An important confounding variable may be the size of the firm. To control for this, I include the interaction term between the firm's time-average net sales and the change of the repo rate as a shift-share control variable in the baseline regression. I run additional robustness checks with multiple control variables such as the size of the firm and proxies for potential alternative financial and cost channels. These are discussed and reported in Appendix A.10.

Another concern may be that future interest rate changes within the k periods affect price changes and increase the estimated price effect of the initial periods' interest rate change. An example of this is if a price change between $t-1$ and $t+1$ is not only caused by the interest rate change at t but also by the concurrent interest rate change at $t+1$. Since high-frequency shocks are interpreted as exogenous and uncorrelated monetary policy shocks, the results using high-frequency shocks should present a compelling baseline argument where this is supposedly not a threat. To further address this potential bias for anticipated changes, Table 18 in Appendix A.10 includes repo rate changes for each of the k interim periods as controls.

Simultaneity problem One criterion for an unbiased estimation is the conditional quasi-random assignment of shocks. A concern in this respect is that monetary policy shocks and anticipated interest rate changes vary endogenously with exposures. Barth and Ramey (2001) argue that firms should decrease their inventories and receivables in response to a monetary contraction. In particular, aggregate inventories and receivables should rise relative to sales in response to a monetary contraction in the short run, for example, if a monetary contraction also works through demand. To remove the endogenous response of firms' working capital requirements to demand and cost shocks, I use the firm-average working capital to sales ratio in the main specification. Using this time-invariant ratio removes the cyclical, endogenous response of working capital to changes in the economy, while it preserves the ranking of firms with respect to the average intensity of working capital use. The time-average represents business-as-usual behavior and provides the cross-sectional variation in exposure to interest rate changes that is used for identification.

Reverse causality Reverse causality refers to the scenario when the central bank follows the Taylor-rule and increases the repo rate in response to higher prices. To ensure that there is no feedback between prices and interest rates, I include time-product fixed effects and compare firms with different working capital exposure shares.

4.2 Data

In order to study the working capital channel, I focus on firms in the manufacturing industry and I merge three datasets: firm-level monthly domestic price indices of a sample firms that produce in Sweden (1992m1-2017m12), the annual balance sheets of Swedish firms (1985-2017), and monthly interest rate shocks with corresponding anticipated changes that are constructed for the period 1997m1-2017m12. All datasets are obtained from Statistic Sweden (SCB, 2018). The years between 1992-1996 are excluded because Sweden underwent large economic transformations during these years[6] and Sweden's low inflation regime began in 1997. The merged dataset consists

[6]The economic changes include the banking crises and recession of 1992, the introduction of the floating interest rate in 1992 and interest rate targeting in 1993 as well as joining the European Union in 1994.

of a series of monthly price indices, monthly interest rate changes, monthly monetary policy shocks and annual balance sheet items for 2,151 Swedish firms for the period 1997m1-2016m12.

The final dataset excludes observations below the bottom one percentile and the top 99th percentile of the log price change distribution. This is due to the fact that extreme price changes are not plausible and they are likely to represent reporting mistakes by the firms. The final dataset includes only firms with a positive amount of inventories and receivables in order to remove missing values that may have been recorded as zeroes. I focus on firms in the manufacturing sector. Appendix A.3 shows the distribution of firms and observations across the 15 sub-industries within the manufacturing sector that constitute the focus of this study.

Table 1 shows the summary statistics of the working capital to sales ratio, sales, receivables, inventories, payables and advance payments from customers. The mean of the annual working capital to sales ratio is 0.2; and most firms receive very little prepayments from customers. The average values of receivables (169 mSEK) and payables (1643 mSEK) are similar in magnitude, indicating that firms do not only receive but also give trade credit.

Table 1: Summary Statistics

	Mean	SD	Min	Max
Working capital to sales ratio	0.20	0.8	-9.83	45
Receivables (mSEK)	169	1002	0.001	52833
Inventories (mSEK)	198	648	0	11136
Payables (mSEK)	163	810	0	40960
Prepayments (mSEK)	23	227	0	6373
Sales (mSEK)	1730	6826	0	130529
Avg no of employees	465	1293	0	20492
Value added (mSEK)	414	1636	-15603	39205
Total tangible assets (mSEK)	343	1166	-0.006	20837
Total current assets (mSEK)	764	3120	-434	65122
Liabilities (mSEK)	1744	10017	0.54	292523
Observations	157770			

Working capital The average working capital to sales ratio is 0.2, which means that firms on average have an equivalent of 2.5-month of sales in the form of inventories and receivables net of prepayments and payables. This implies that the average firm experiences a 2.5-month delay between producing the good and getting paid for it. If all firms had one-month delay in payments, this ratio would be 1/12, if the payment was delayed by two months it would be 2/12 and so on. The fact that firms seem to pay their input costs a quarter before they receive payments confirms the model of Christiano et al. (2005); Adolfson et al. (2013); Corbo (2020) who assume that the entirety of the representative firm's wage bill is pre-funded a quarter in advance.

In comparison, the industry-level study of Barth and Ramey (2001) report a larger stock of receivables and inventories, equivalent to 11 months of final sales in the manufacturing industry. One reason why their measure of working capital is higher is that their variable does not include prepayments from customers[7]. It is also likely that their industry-level data is constructed from a different selection of firms. Using data on Italian firms, Gaiotti and Secchi (2006) report that the average working capital to annual operating cost is 0.33, suggesting that four months of firms' operating costs are tied down as working capital. Gaiotti and Secchi's (2006) statistic is more comparable to and more in line with the average working capital to sales ratio of Swedish firms.

The working capital to sales ratio displays a large cross-sectional variation also within a sector. Figure 2 shows the distribution of firms' working capital to sales ratio in the manufacturing industry as a whole.

The variation in sales, receivables, inventories and payables over time is

[7]Considering the sales-weighted average of the working capital to sales ratio across firms in Sweden that have at least one employee, the average value is 0.12 in the whole economy and 0.17 in the manufacturing sector. Aggregation to the industry level, therefore, do not seem to explain the difference between the average working capital requirements between Sweden and the US.

depicted in Figures 4a and 4b. The variation in inventories is mostly driven by cyclical changes in demand, so sales and inventories show a high level of synchronised co-movement. Receivables and payables can be understood as trade credit given and received by firms.

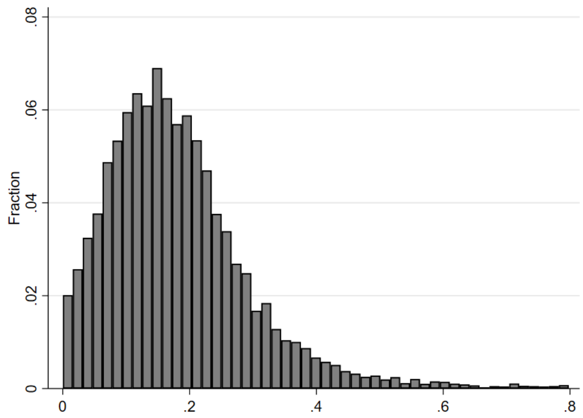
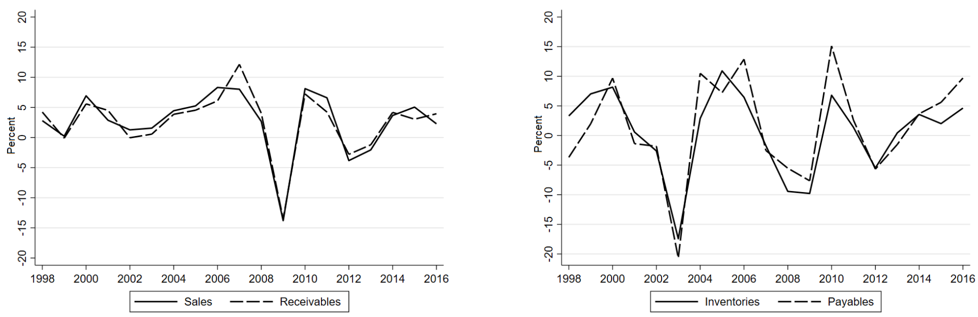


Figure 2

Figure 3: Variation in the working capital to sales ratio. *Note*: the tails of the histograms are cropped at 0.8. The figure shows the distribution of firms' working capital to sales ratio in the manufacturing industry as a whole.



(a) Avg. annual percentage changes in sales and receivables

(b) Avg. annual percentage changes in inventories and payables

Figure 4

Net trade credit fluctuates for a number of reasons. Firms may extend trade credit to help credit constrained downstream firms overcome financing impediments and as a substitute for bank credit during periods of monetary tightening and financial crises[8]. It is also a way for suppliers to engage in a form of price discrimination by giving favored clients longer terms (Wilner, 2000; Fisman and Raturi, 2004; Van Horen, 2007; Giannetti, Burkart and Ellingsen, 2011). Therefore, trade credit varies in response to changes in the firm's costs, credit conditions and its buyers' credit conditions.

Examining observed firm characteristics can help us evaluate whether there are underlying factors which are correlated with firms' working capital holdings and which may cause interest rate changes to affect firms with high and low working capital holdings differently. The risk that a confounding channel exists is larger if underlying characteristics are strongly correlated with the firm's choice of working capital holdings. Figure 5 plots the average value of total production, total liabilities, number of employees, and the value added of firms across the distribution of the working capital to sales ratio.

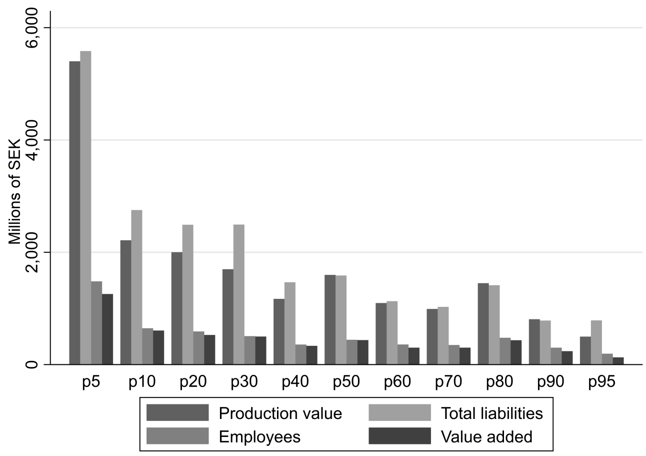


Figure 5: The bars depict the average production value, total liabilities and value added in millions of SEK and the average number of workers employed by firms across groups of firms. p5 indicates firms with the lowest percentiles of working capital to sales ratios.

[8]See, for example, Demirguc-Kunt and Maksimovic (2001); McMillan and Woodruff (1999); Marotta (2001), Choi and Kim (2005); Love, Preve and Sarria-Allende (2007) and Burkart and Ellingsen (2004).

Figure 5 shows that between the 10th and 90th percentiles of the working capital distribution the firm's size (e.g. employees) shows less systematic correlation with the working capital to sales ratio. However, very large firms seem to hold a relatively smaller share of working capital. The regressions account for this size effect by including an interaction term between the firm's time-average sales and interest rate changes.

Firm-level price indices and price changes The complete monthly price index dataset includes five firm-specific price index series. These indices are the Domestic (Home) Market Price Index (HMPI), Export Price Index (EXPI), Import Price Index (IMPI), Producer Price Index (PPI), and a price index for domestic supply (ITPI). The analysis in this paper uses the HMPI price index series in order to focus on production for the domestic market; and to abstain from price changes that are due to exchange rate fluctuations[9].

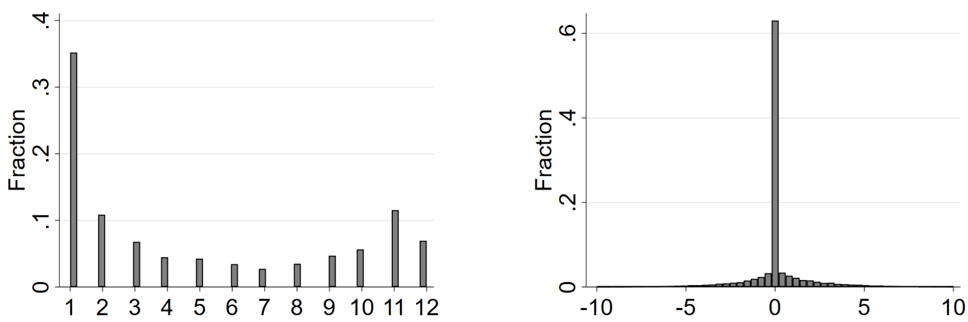
According to Statistics Sweden, SCB (2022), the price index data is constructed from a survey of firm-level prices[10]. The observations considered in this paper are at the firm-2-digit-product level due to data access limitations. The HMPI price index at the firm-2-digit HS product level

[9]Statistics Sweden converts foreign prices to SEK and, therefore, exchange rate fluctuations are part of the EXPI and the PPI index series. The EXPI and the PPI series are likely to be a more noisy measure of prices because Statistics Sweden uses monthly average exchange rates to convert prices reported in foreign currencies.

[10]The sample of price-reporting firms is drawn from the population of firms with a turnover larger than SEK 10 million. The true population of prices consists of producer prices of transactions, or product offerings, made in a year by Swedish firms. A product offering is the combination of an enterprise and a product to be priced for sales during the year. Prices on around 6000 product offerings are collected on a monthly basis. The sample of prices covers over 43 percent of all transactions in terms of value in SEK (SCB, 2022). Product offerings with large transaction values are always included in the sample, whereas smaller product offerings are drawn stratum by stratum, where a stratum include one or more 5-digit product groups. The product groups are defined according to the Harmonized System (HS). The observations on product offerings across strata are drawn so that the sample of product prices is representative of the product prices posted by firms in each 5-digit HS group, i.e. the probabilistic draw is weighted by the value of products sold in the 5-digit HS group (SCB, 2022).

is an arithmetically weighted average of the specific firm's price ratios for it's surveyed products. The price ratios are defined as $p_{t,i,s}/p_{b,i,s}$, where $p_{t,i,s}$ is the price of firm i's product s in period t and $p_{b,i,s}$ is the price of firm i's product s in the base period. If a firm has just one item in at the 2-digit HS level, then the index is equal to an individual price ratio (SCB, 2022). A full list of the two-digit product groups is published by UN (2016). The dataset includes multiple HMPI observations for firms that produce in different 2-digit product groups. In the data, 85 % of the 2,151 firms produce in one product group and 11 % produce in two product groups. The remaining 4 % of firms produce in three to six product groups. The HMPI index series is quality adjusted by the Swedish Statistics Agency; and therefore, it should exclude price changes that result from a change in quality (SCB, 2018).

Figure 6a shows the distribution of the average number of non-zero price changes across all firms. On average, firms change prices 4.6 times a year; which gives a 2-3 month average price duration. The bunching at the two ends indicate that many firms either change prices very often (almost every month) or very seldom (once a year). The HMPI distribution plotted in Figure 6b shows that the price change distribution has a spike at zero, indicating nominal price rigidities.



(a) HMPI percentage changes

(b) Avg. number of price changes per year

Figure 6

Anticipated and unanticipated interest rate changes The anticipated interest rate change are calculated as the difference between the repo rate change and the unanticipated component such that

$$\Delta R_t^A = \Delta R_t - \Delta R_t^U, \tag{14}$$

where ΔR_t^A is the anticipated component and ΔR_t^U is the unanticipated component of the repo rate change. I construct three measures of unanticipated interest rate changes. The high-frequency shocks are used in the baseline regression while the forecasting regression errors and the monetary policy shocks from the Ramses II DSGE model are used as robustness checks.

High-frequency shocks are based on the expectations of professional forecasters who follow central bank announcements and closely monitor interest rate movements. They are assumed to be orthogonal to other processes in the economy and, therefore, they are often interpreted as exogenous monetary policy shocks (Kuttner, 2001).

The estimation of these high-frequency shocks closely follows the procedure outlined in Iversen and Tysklind (2017) who adapt Kuttner's (2001) method to Sweden. Iversen and Tysklind (2017) estimate unexpected repo rate changes using the Swedish overnight indexed swap (OIS) rate with one month maturity, Stina1M. The details of the estimation are presented in Appendix A.6. The Stina1M rate is only available from 2002m9 so the time-series dimension in the estimation when using this shock is restricted to 2002m9-2016m12.

The high-frequency shocks are used in the preferred specification because identifying the effect of monetary policy shocks on prices is most convincing when the shocks themselves are arguably orthogonal to other economic processes and identification relies on the least strong identifying assumptions. However, the other shock series may better represent surprises to firms who likely do not share the forecast specialists' sophisticated expectations. The difficulty in estimating the relative impact of unanticipated interest rate changes on prices is that we do not know how firms form expectations. For example, if we assume that the firm's expectations are completely static and the firm's best forecast of future interest rates is the prevailing current rate, then changes in the repo rate will be surprises to firms.

When constructing the second set of unanticipated interest rate changes, I estimate unanticipated interest rate changes using a simple forecasting regression based on the Taylor-rule. I call these estimated unanticipated interest rate changes forecasting regression errors. Forecasting regression errors are constructed for a one-month, 4-months and 6-months forecast horizons. More specifically, the forecasting regression errors are the residuals from the regression

$$i_t = \beta_1 \Delta GDP_{t-k,t-k-3} + \beta_2 i_{t-k} + \beta_3 \Pi_{t-k,t-k-3} + \epsilon_t, \tag{15}$$

where $k = [1, 4, 6]$ and t are months. The regression coefficients and the details of the estimation are presented in Appendix A.4. Figure 7 shows that as information becomes less precise, the size of the forecasting regression error increases.

In the Calvo world, assigning forecasting regression errors from one specific forecast horizon to all firms implicitly assumes that a specific probability of price change is relevant for all firms in the economy. For example, a 4-month forecast horizon presumes that firms on average change prices three times a year, implying that the economy-wide probability of keeping the price unchanged is 2/3.

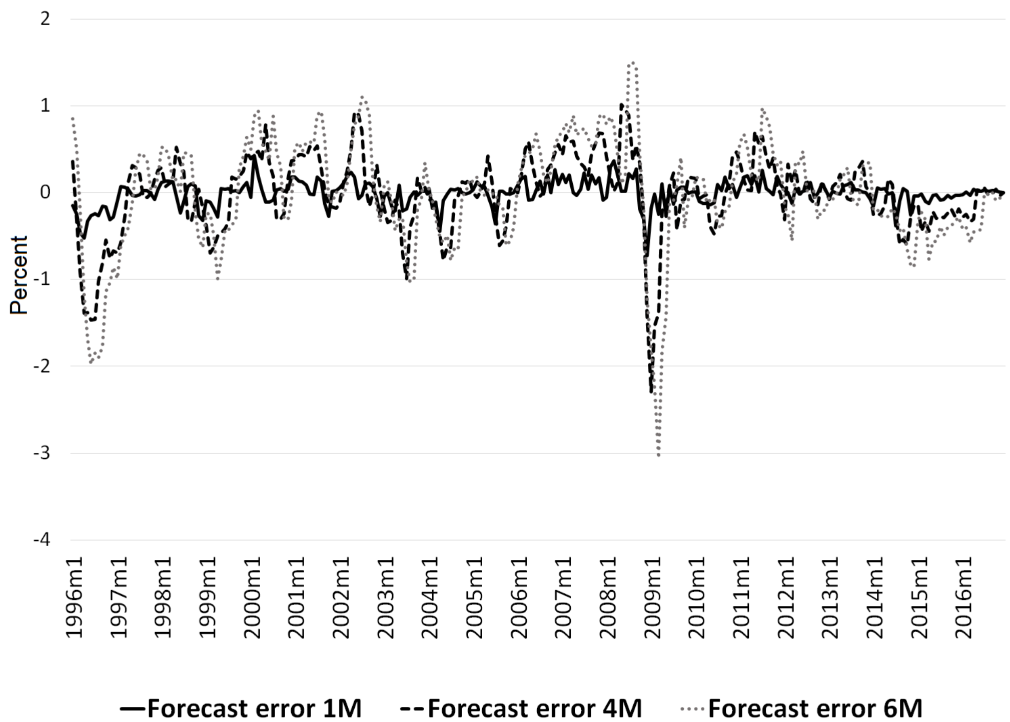


Figure 7: Firms' forecasting regression errors (1997m1-2016m12) based on information 1 month, 4 months and 6 months ago.

Figure 8 depicts the high-frequency shocks and the forecasting regression errors from a one-month forecast horizon. It shows a strong correlation between forecasting regression errors and high-frequency shocks when looking at negative changes, but little correlation between them when we examine positive changes. Apparently, the financial market is able to predict most increases.

The third measure of exogenous monetary policy shocks consists of policy rate innovations from Ramses II, the DSGE model of the Riksbank. Appendix A.5 presents the details of how Ramses II shocks are estimated. The shortcoming of using Ramses II shocks is that they are quarterly in frequency so these shocks can only be used with quarterly price changes in the regression, i.e. $p(t+3+k) - p(t-1)$ where $k = [3, 6, 9]$.

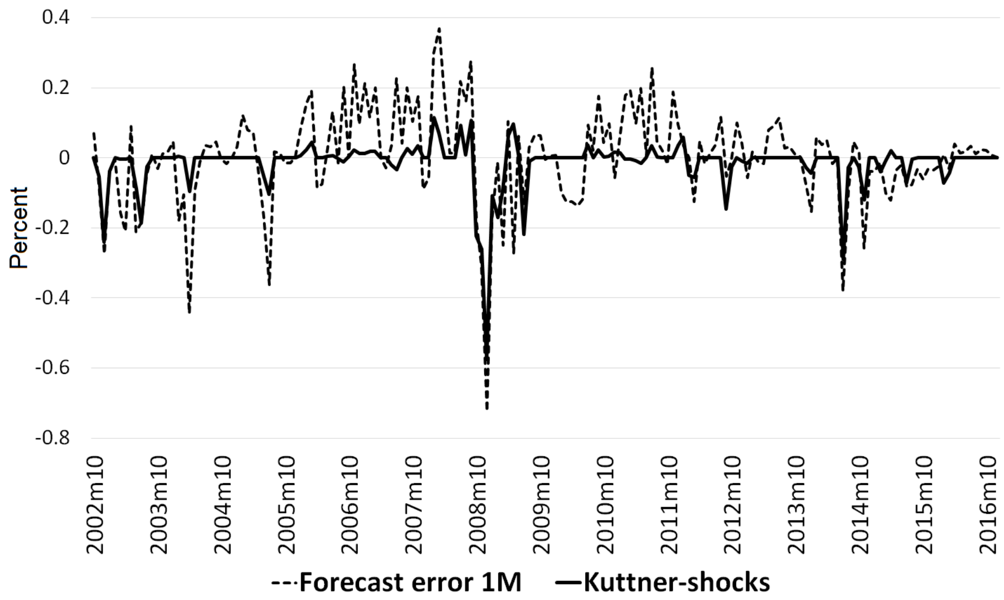


Figure 8: High-frequency shocks based on Stina1M rates and the firm's forecast error based on information available one month ago.

The summary statistics in Table 2 show that as expectations become more sophisticated the unanticipated interest rate changes become smaller. An average forecasting regression error based on the last quarter's information (i.e. Forecast error 4M) is around 0.3 percentage units, the average quarterly Ramses innovation is around 0.2 percentage units and the average high-frequency shock is only around 0.03 percentage units.

Table 2: Summary statistics for the different measures of unanticipated interest rate and repo rate changes

	Mean | dR |	SD	Min	Max	Period
Forecast error 6M	0.43	0.58	-3.06	1.50	1997m1-2016m12
Forecast error 4M	0.30	0.42	-2.29	1.01	1997m1-2016m12
Forecast error 1M	0.09	0.13	-0.72	0.43	1997m1-2016m12
Ramses Shocks	0.20	0.25	-0.73	0.69	1997q1-2016q4
Stina1M-shocks	0.03	0.07	-0.58	0.12	2002m10-2016m12
Repo change	0.08	0.15	-1.11	0.36	1997m1-2016m12

Notes: The mean value refers to the simple average of the absolute values of the unanticipated interest rate and repo rate changes.

5 Results

In the baseline results, I divide repo rate changes into anticipated and unanticipated components and measure unanticipated interest rate changes by high-frequency shocks. Figure 9 and Table 3 show the results.

The first column in the top part of Table 6 shows that unanticipated and anticipated repo rate change has little or no concurrent economic or statistically significant effect on prices. This result may be due to the timing of events, for example, if firms have already adjusted their prices earlier in the month before the change occured. A high-frequency shock of one percentage unit leads to a 0.6 (1.03) percent increase in the price of a firm with average working capital holdings over a 4 (9) month price setting horizon.

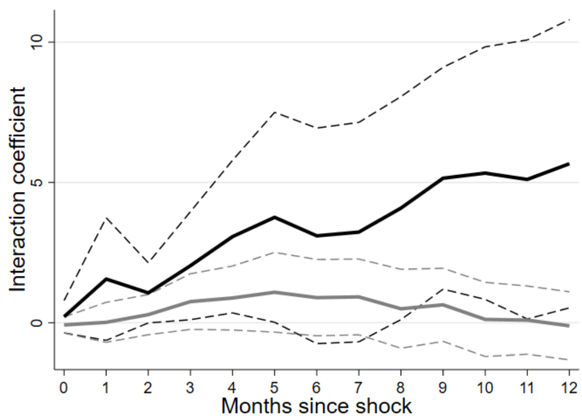


Figure 9: The transmission of high-frequency shocks and anticipated interest rate changes via the working capital channel. The solid black (gray) line depicts the interaction coefficient on the high-frequency shocks (anticipated interest rate changes) and the dashed lines depict the 5 percent confidence intervals.

This effect may seem large, however, the average mistake in forecasting repo rate changes professional forecasters make is small. An average high-frequency shock of 0.03 percentage unit leads to a 0.09 (0.15) percent increase in the price set by a firm with a working capital to sales ratio of one over a 4 (9) months price setting horizon. The corresponding anticipated component, had there been a one percentage unit increase in the repo rate, is 0.97 which leads to a 0.86 (0.62) percent increase in the price.

Table 3: The transmission of interest rate changes using Stina1M based high-frequency shocks

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × dR^U	0.217	1.558	1.066^+	2.034^*	3.071^*
	(0.295)	(1.114)	(0.547)	(0.982)	(1.387)
avg.W/S × dR^A	-0.0783	0.0164	0.290	0.754	0.883
	(0.147)	(0.363)	(0.365)	(0.506)	(0.582)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	124865	122363	119844	117348	114870
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S × dR^U	3.759^+	3.098	3.231	4.087^*	5.151^*
	(1.909)	(1.960)	(1.995)	(2.027)	(2.017)
avg.W/S × dR^A	1.088	0.896	0.922	0.499	0.640
	(0.725)	(0.694)	(0.689)	(0.718)	(0.664)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	112382	109890	107390	104888	102387
	p(t+10)-p(t-1)	p(t+11)-p(t-1)	p(t+12)-p(t-1)	p(t+13)-p(t-1)	p(t+14)-p(t-1)
avg.W/S × dR^U	3.759^+	3.098	3.231	4.087^*	5.151^*
	(1.909)	(1.960)	(1.995)	(2.027)	(2.017)
avg.W/S × dR^A	1.088	0.896	0.922	0.499	0.640
	(0.725)	(0.694)	(0.689)	(0.718)	(0.664)
avg. S # dR	x	x	x		
Firm FE	x	x	x		
Time-Product FE	x	x	x		
FC dummies	x	x	x		
Observations	112382	109890	107390	104888	102387

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

The total price change is then given by the weighted average of the two coefficients, where the weights are the shares of anticipated and unanticipated components. Taking the weighted sum of the effects confirms that the price increase after a percentage unit increase in the interest rate is around one (i.e. 0.12 plus 0.96) for a firm with a working capital ratio of one after approximately month 4. The weighted average price effect of a repo rate change via the working capital channel increases gradually and stabilizes around one after 4 months. This means that a firm whose working capital equals its sales would raise its price by one percent if the interest rate increased by one percentage unit.

In the next section, two additional measures of shocks are used as robustness checks. The alternative specifications should show a sluggish price response and a weighted average price effect which approaches one approximately 4 months after the policy rate change. Furthermore, the effect of the unanticipated component is expected to be larger or equal to that of the anticipated component.

5.1 Forecasting regression errors

Table 4 reports the price effect of unanticipated and anticipated interest rate changes when they are measured by forecasting regressions. These errors are based on simple expectations; and therefore it could be argued that they represent an average firm's expectations better. Table 4 consists of three parts. Each part uses forecasting regression errors derived from different forecast horizons: looking 1, 4 and 6 months ahead. Specification 1 matches all firms with forecasting regression errors based on information available to firms in the previous month. Specification 2 (3) assigns the forecasting regression errors based on information available to firms 4 (6) months ago to all firms.

Table 4: The transmission of anticipated and unanticipated interest rate changes via the working capital channel - simple firm forecasts

Specification 1 - errors from 1 month forecast horizon					
	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S#Error1m	-0.0467	0.331+	0.483*	0.898*	1.091*
	(0.116)	(0.187)	(0.221)	(0.410)	(0.491)
avg.W/S#Exp1m	-0.209	-0.0373	0.0645	0.858	1.189*
	(0.157)	(0.235)	(0.369)	(0.553)	(0.539)
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S#Error1m	1.273*	0.990	1.046	0.938	1.173
	(0.647)	(0.642)	(0.781)	(0.974)	(1.230)
avg.W/S#Exp1m	1.613*	1.346+	1.580+	1.448+	1.147
	(0.698)	(0.737)	(0.845)	(0.788)	(0.746)
Specification 2 - errors from 4 months forecast horizon					
	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S#Error4m	-0.0760	0.300+	0.433*	0.875*	1.078*
	(0.113)	(0.165)	(0.170)	(0.366)	(0.445)
avg.W/S#Exp4m	-0.107	0.311	0.412**	0.829**	1.026*
	(0.151)	(0.205)	(0.154)	(0.311)	(0.433)
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S#Error4m	1.293*	0.983+	1.040+	0.926	1.180
	(0.613)	(0.542)	(0.618)	(0.753)	(1.011)
avg.W/S#Exp4m	1.274+	0.887*	0.904*	0.781	1.201
	(0.660)	(0.446)	(0.407)	(0.500)	(0.749)
Specification 2 - errors from 6 months forecast horizon					
	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S#Error6m	-0.0745	0.302*	0.462**	0.912*	1.119*
	(0.107)	(0.154)	(0.179)	(0.389)	(0.461)
avg.W/S#Exp6m	-0.0940	0.314*	0.495**	0.944*	1.154*
	(0.122)	(0.144)	(0.153)	(0.398)	(0.499)
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S#Error6m	1.331*	1.037+	1.087+	0.972	1.204
	(0.625)	(0.540)	(0.602)	(0.721)	(0.976)
avg.W/S#Exp6m	1.387*	1.066*	1.072*	0.945+	1.254+
	(0.692)	(0.487)	(0.446)	(0.506)	(0.751)

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6. The tables with all coefficients can be found in Appendix A.8.

The coefficients on anticipated and unanticipated interest rate changes are similar in magnitude across all specifications of Table 4, which imply that anticipated and unanticipated interest rate changes are equally important for firms' price setting behavior under the assumption that firms use simple forecasting rules to predict interest rate changes. The coefficients show a gradual price adjustment and a sluggish response. An average forecasting regression error based information in the last quarter is 0.3. This value implies that prices should increase by 0.32 percentage unit due to unanticipated interest rate changes and around 0.83 percentage unit due to anticipated interest rate changes after a total repo rate change of one percentage unit if the firm's working capital to sales ratio is one. This result corroborates a weighted average effect that is around one after 4 months. For the firm with an average working capital to sales ratio of 0.2 these coefficients imply a 0.17 and a 0.16 percentage unit increase 4 months after the anticipated and the unanticipated changes respectively.

As an extension to the forecasting regression errors that are common to all firms, I implement a alternative specification with firm-specific forecasting errors based on somewhat more sophisticated expectations. In particular, I assume that firms know their own average price duration so that firm-specific forecasting regression errors can be matched to each firm based on how often the firm resets its price in a year. The corresponding result table is presented in Appendix A.9. It shows similar coefficients to those presented in Table 4, which corroborates that the pass-through to prices from expected and unexpected interest rate changes is equally important if we assume that the firms' expectations are simple or only slightly more sophisticated.

5.2 Ramses shocks

Table 5 report the average price response to quarterly Ramses II monetary policy shocks and anticipated policy rate changes via the working capital channel. The assumption is that innovations from the Ramses II model are based on more sophisticated expectations than the forecasting regression errors. These expectations are similar to those of central bankers. Note that the price changes are quarterly, with the first price change of $p(t+3)-p(t-1)$. Using the Ramses II policy innovations in place of the high-frequency shocks corroborates that unanticipated interest rate changes have larger short-run price effects than anticipated changes via the working capital channel. This specification also confirms a sluggish price response. The implied weighted average price increase is somewhat smaller, around 0.4 percentage units after 6 months and 0.6 percentage units after one year.

Table 5: The transmission of interest rate changes using Ramses II shocks

	p(t+3)-p(t-1)	p(t+6)-p(t-1)	p(t+9)-p(t-1)	p(t+12)-p(t-1)
avg.W/S $\times$ dR^U	0.344*	1.140***	1.510***	1.814***
	(0.148)	(0.262)	(0.320)	(0.506)
avg.W/S $\times$ dR^A	0.0270	0.185	0.291*	0.290*
	(0.0969)	(0.162)	(0.132)	(0.133)
avg. S # dR	x	x	x	x
Firm FE	x	x	x	x
Time-Product FE	x	x	x	x
FC dummies	x	x	x	x
Observations	45345	41501	39186	37107

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayment. S is sales. The control variables are the interaction of average sales and the change in the repo rate from $t-1$ to t, time-product fixed effects, and the financial crises dummies for the quarters of the financial crises 2008q4, 2009q1 and 2009q2.

5.3 Actual repo rate changes

In this section, I investigate the effect of actual repo rate changes on prices via the working capital channel in order to check if the total price effect is consistent with the previous weighted average estimates. Here, no distinction is made between anticipated and unanticipated interest rate changes. Figure 10 and Table 6 show the results.

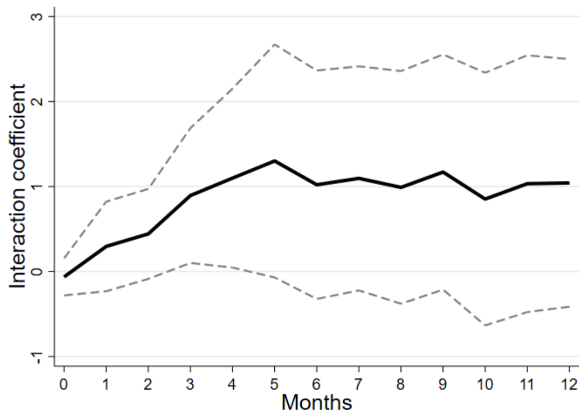


Figure 10: The transmission of repo rate changes via the working capital channel. The solid line depicts the interaction coefficient in Table 6 and the dashed lines depict the 95% confidence interval.

Table 6: The transmission of repo rate changes via the working capital channel

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × dR	-0.0631	0.295	0.443	0.894*	1.099*
	(0.111)	(0.269)	(0.270)	(0.405)	(0.537)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	154072	151337	148591	145852	143131
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S × dR	1.301+	1.021	1.096	0.990	1.170+
	(0.699)	(0.686)	(0.673)	(0.698)	(0.706)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	140397	137657	134909	132160	129410
	p(t+10)-p(t-1)	p(t+11)-p(t-1)	p(t+12)-p(t-1)		
avg.W/S × dR	0.852	1.033	1.043		
	(0.758)	(0.771)	(0.743)		
avg. S # dR	x	x	x		
Firm FE	x	x	x		
Time-Product FE	x	x	x		
FC dummies	x	x	x		
Observations	126281	123970	121860		

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6. The tables with all coefficients can be found in Appendix A.7.

In line with the baseline results, the first column in the top part of Table 6 shows that repo rate changes have no concurrent effects on prices via the working capital channel. There is a sluggish response so that the effect increases gradually and stabilizes around one after 4 months. This means that the firm with a working capital to sales ratio of one raises its price by one percent 4 months after the interest rate increases by one percentage unit.

The average firm with a working capital to sales ratio of 0.2 increases its prices by approximately 0.1 (0.2) percent upon a one percentage unit increase in the repo rate over the 3 (6 to 12) month horizons. The firm at the 10th percentile of the working capital to sales distribution increases its price by 0.03 (0.06) percent at the 3 (6 to 12) month horizon, whereas a firm at the 90th percentile increases its price by 0.35 (0.8) percent at the 3 (6 to 12) month horizon.

These results can also be used to calibrate price stickiness. Figure 11 compares the estimated coefficients and the theoretical model's predictions under three parameterization of price stickiness $\theta = [0.6, 0.5, 0.4]$.

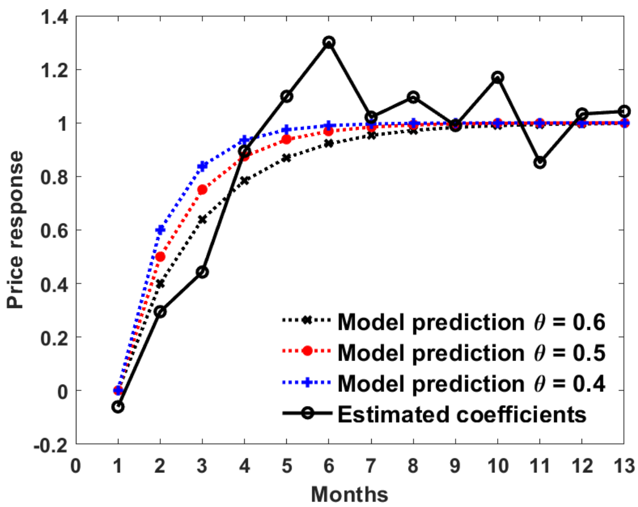


Figure 11: Predicted response from the model and the estimated coefficients.

The dotted lines show that the model predicts a coefficient of one after approximately 4 months if the interest rate change is unexpected and it is expected to last for some time. In line with the model, the estimated coefficients hover around 1 after approximately month 4. The fit of the model's short-run prediction with the estimated response is the best with a higher θ. This is consistent with the baseline calibration of price stickiness in Christiano, Eichenbaum and Evans (2005) and Corbo (2020) who assume 0.6 and 0.75, respectively.

5.3.1 Further robustness checks

Three additional robustness checks using the actual repo rate regressions are implemented in Appendix A.10. One examines the possibility that interest rate changes lead to price changes via observable firm-characteristics that may be correlated with the firm's working capital holdings. The second addresses the worry that the coefficient on the price effect of the repo rate change at time t may be biased due to the potential serial correlation of repo rate changes when multiple interest rate changes take place within a longer price setting horizon. The third specification investigates whether including only non-zero price changes in the dependent variable yield similar coefficients to the baseline results. Effectively, the last specification with only non-zero price changes investigates whether the data supports the Calvo-assumption that firms are randomly selected to change their prices. The sluggish price response and a pass-through of one after 4-5 months seems to be a robust finding in these alternative specifications.

6 Conclusion

This paper analyzes the transmission of policy rate changes to producer prices via the working capital channel. The New Keynesian model with

Calvo-type price stickiness predicts that prices should eventually rise by one percent after a one percentage unit increase in the policy rate if firms pay all their input costs one year before they receive payments. It also predicts that a monetary policy shock should lead to a gradual adjustment of prices because only a fraction of firms can change their prices in each period following a shock. Furthermore, unexpected monetary policy shocks should have larger short-run price effects than expected policy rate changes since anticipated changes may have already been incorporated in the prices before the policy rate change takes place. These predictions are tested using micro data on Swedish manufacturing firms.

Three measures of monetary policy shocks and actual repo rate changes are used in a shift-share framework to examine the pass-through of policy rate changes to producer prices via the working capital channel. In the main specification, unanticipated interest rate changes are measured by high-frequency shocks, which are, on average, very small because professional forecasters make only small mistakes when forecasting policy rate changes. Even though the estimated coefficient on the unanticipated change is 2-3 times larger than it is on the anticipated interest rate change, an average high-frequency shock of a modest 0.03 percentage unit leads to a 0.09 (0.15) percent increase in the price set by a firm with a working capital to sales ratio of one over a 4 (9) months price setting horizon. The corresponding anticipated component is 0.97 which leads to a 0.86 (0.62) percent increase in the price. The total price change is around one for a firm with a working capital to sales ratio of one percent after approximately 4 months.

The estimated price effect of actual repo rate changes corroborates the findings in the baseline specification. A one percentage unit increase in the repo rate increases producer prices by one percent for the firm with a working capital to sales ratio of one after 4 months. This result confirms the sluggish and gradual price response as well as the theoretical prediction that the transmission should be one-to-one after some time. In addtion, the results from a number of robustness checks are also consistent with the gradual pass-through and the coefficient of one.

The findings presented in this paper shows that the average amount of working capital that firms keep is roughly equivalent to a quarter of sales. It implies that firms pay all their input costs a quarter before they receive payments, which is a standard assumption in quarterly quantitative monetary models. For example, Christiano, Eichenbaum and Evans (2005) and Corbo (2020) assume that the entirety of the representative firm's wage bill is pre-funded a quarter in advance. Comparing the empirical estimates with the theoretical impulse responses suggest that it is reasonable to assign a value of 0.6-0.75 to the parameter of price stickiness in the Calvo model. A value between 0.6-0.75 is consistent with the baseline estimation of Christiano, Eichenbaum and Evans (2005) and Corbo (2020).

Future research may quantify the implications of heterogeneity in firms' working capital holdings for the aggregate price response and for distributional changes. Measuring the effect of a monetary policy shock within a New Keynesian DSGE model where firms are heterogeneous with respect to their working capital holdings could decipher whether the pass-through via the working capital channel has important general equilibrium indications.

A Appendix

A.1 The firm's price setting equation

I assume that the firm uses labor to produce a differentiated good $i \in [0,1]$

$$Y_{i,t} = A_t N_{i,t}, \tag{16}$$

where $Y_{i,t}$ is the firm-specific output, A_t is the economy wide technology and $N_{i,t}$ is the amount of labor the firm uses to produce good i. In every period, a set of firms in the economy cannot change their posted prices, so the firm's objective is to maximize profits, taking into account that prices are sticky. The firm's maximization problem can be written as

$$max_{P^*_{i,t}} \sum_{k=0}^{\infty} \theta^k E_t \Big\{ Q_{t,t+k} \Big(\frac{1}{P_{t+k}} \Big) \big(P^*_{i,t} Y_{i,t+k|t} - TC^n_{i,t+k|t}(Y_{i,t+k|t}) \big) \Big\} \tag{17}$$

subject to the sequence of firm-specific demand constraints

$$Y_{i,t+k|t} = \Big(\frac{P^*_{i,t}}{P_{t+k}} \Big)^{-\epsilon} C_{i,t+k}. \tag{18}$$

Equation (17) states that the firm chooses the optimal price $P^*_{i,t}$ to maximize the current market value of its profits. The firm takes into consideration the households' discount factor ($Q_{t,t+k}$) and the fact that the price remains effective for k periods with probability θ^k. Equation (18) states that the demand for output in period $t+k$ for a firm that sets its price in period t is determined by the ratio of the optimal reset price, the price level in $t+k$, and consumption ($C_{i,t+k}$). The first-order condition is

$$\sum_{k=0}^{\infty} \theta^k E_t \Big\{ Q_{t,t+k} Y_{i,t+k|t} \Big[(\epsilon - 1) - \epsilon \frac{MC^n_{i,t+k|t}}{P^*_{i,t}} \Big] \Big\} = 0. \tag{19}$$

If I let $\Pi^*_{i,t} \equiv P^*_{i,t}/P_{i,t-1}$, $\Pi_{t+k,t} \equiv P^*_{t+k}/P_t$, $MC^r_{i,t} = MC^n_{i,t}/P_t$, denote $\frac{\epsilon}{\epsilon-1} \equiv \mathcal{M}$ and divide by P_{t-1}, then equation (19) can be rearranged in the following way

$$\sum_{k=0}^{\infty} \theta^k E_t \Big\{ Q_{t,t+k} Y_{i,t+k|t} \Big[\Pi^*_{i,t} - \mathcal{M} MC^r_{i,t+k|t} \Pi_{t+k,t} \Big] \Big\} = 0 \tag{20}$$

The optimal price setting condition is log-linearized around the firm-specific perfect foresight zero inflation steady state where $Q_{t,t+k} = \beta^k$ and $\frac{P^*_{i,t}}{P_{t+k}} = \frac{P_{i,t}}{P_{t+k}} = 1$. Log-linearization of the firm's optimal price setting condition yields

(21)

$$\bar{\Pi}_i \frac{ln\Pi^*_{i,t} - ln\bar{\Pi}_i}{1-\beta\theta} - \sum_{k=0}^{\infty} (\theta\beta)^k E_t \Big\{ \mathcal{M} \bar{MC}^r_i \Big[lnMC^r_i - \bar{MC}^r_i + ln\Pi_{t+k,t-1} - 0 \Big] \Big\} = 0.$$

Note that in steady state $\overline{\Pi}_i = \mathcal{M}\overline{MC^r_i}$. I define $ln\Pi^*_{i,t} \equiv \pi^*_{i,t}$ to be the firm-specific optimal inflation rate, $ln\Pi_{t+k,t} \equiv \pi_{t+k,t}$ and $lnMC^r_{i,t} \equiv mc^r_{i,t}$ to get

(22)

$$p^*_{i,t} - p_{i,t-1} - \bar{\pi}_i = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t \Big\{ mc^n_{i,t+k|t} - p_{t+k} - \bar{mc}^n_i + p_{t+k} - p_{i,t-1} \Big\}.$$

Using the steady-state condition that $\bar{\pi}_i = ln\mathcal{M} + \bar{mc}^r_i$, it is possible to simplify (22) as

$$p^*_{i,t} = \mu + (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t[mc^n_{i,t+k|t}], \tag{23}$$

where $mc^n_{i,t+k|t}$ is the log nominal marginal cost and $\mu \equiv ln\mathcal{M} = ln\Big(\frac{\epsilon}{\epsilon-1}\Big)$ is the desired steady state markup. Equation (23) shows that the firm's optimal reset price is a function of the desired markup and the weighted average of current and expected nominal marginal costs with the weights being proportional to the probability of the price remaining effective at each horizon (θ^k).

A.2 Price response to a one time unexpected, permanent shock

With a common δ, aggregate inflation can be written as

$$p_t = \theta p_{t-1} + (1-\theta)p_t^*$$

Combining this equation with the assumption that optimal reset prices follow a random walk $p_t^* = p_{t-1}^* + \delta\epsilon_t$, the price response after an innovation to R_t can be written as

$$p_t - p_{t-1} = (1-\theta)(p_{t-1}^* - p_{t-1} + \delta\epsilon_t).$$

The price response over a one period longer horizon and with no new shock, i.e. $\epsilon_{t+1} = 0$, can be written as

$$\begin{aligned}
p_{t+1} - p_{t-1} &= \theta p_t + (1-\theta)p_{t+1}^* - p_{t-1} \\
&= \theta^2 p_{t-1} + (1-\theta)\theta p_t^* + (1-\theta)p_t^* - p_{t-1} \\
&= (\theta^2 - 1)p_{t-1} + (1+\theta^2)p_t^* \\
&= (1-\theta^2)(p_t^* - p_{t-1}) \\
&= (1-\theta^2)(p_{t-1}^* - p_{t-1} + \delta\epsilon_t).
\end{aligned}$$

Generalizing to k periods yields

$$p_{t+k} - p_{t-1} = (1-\theta^{k+1})(p_{t-1}^* - p_{t-1} + \delta\epsilon_t). \qquad (24)$$

A.3 Industry decomposition

Table 7: Number of observations and firms within the manufacturing industry by sector

	Observations	Percent	Firms	Percent
Food Production	27.001	15.70	264	11.91
Beverages	1.366	0.79	13	0.59
Tobacco products	455	0.26	5	0.23
Textiles	2.54	1.48	44	1.98
Clothing	1.045	0.61	14	0.63
Leather, leather and leather goods	735	0.43	8	0.36
Wood and articles of wood, cork, rattan	11.629	6.76	188	8.48
Paper and paper goods manufacturing	11.074	6.44	104	4.69
Graphic production and recordings	2.333	1.36	55	2.48
Coal products and refined petroleum	828	0.48	12	0.54
Chemicals and chemical products	10.181	5.92	103	4.65
Pharmaceuticals	1.119	0.65	16	0.72
Rubber and plastic products	8.988	5.22	121	5.46
Other non-metallic mineral products	8.872	5.16	89	4.01
Steel and metal production	10.451	6.08	93	4.19
Metal products, exc. machinery, equip.	19.822	11.52	339	15.29
Computers, electronics and optics	5.933	3.45	100	4.51
Electrical equipment	4.774	2.78	77	3.47
Other machinery	18.101	10.52	244	11.01
Motor vehicles, trailers	11.097	6.45	121	5.46
Other means of transport	2.45	1.42	31	1.40
Furniture	4.868	2.83	65	2.93
Other manufacturing	3.1	1.80	53	2.39
Repair and installation of machinery	3.265	1.90	58	2.62
Total	172.027	100.00	2.217	100.00

A.4 Forecasting regression errors

I estimate the monthly forecast error using quarterly GDP from SCB (2019) and quarterly CPI from OECD (2019). I define changes in GDP and inflation as

$$\Delta GDP_{t-k,t-k-3} = \frac{GDP_{t-k}}{GDP_{t-k-3}} - 1, \tag{25}$$

$$\Delta \Pi_{t-k,t-k-3} = \frac{CPI_{t-k}}{CPI_{t-k-3}} - 1, \tag{26}$$

where t is months. I use the Newey-West variance estimator with three lags to take care of autocorrelation and possible heteroskedasticity of the error term. The results of the regression are presented in Table 8.

Table 8: Results from firms' forecast using information available 1, 4 or 6 months ago

	1 month reporate forecast	4 months reporate forecast	6 months reporate forecast
dGDP	7.926**	27.01**	34.73***
	(2.661)	(8.145)	(10.07)
reporate lag	0.992***	0.940***	0.891***
	(0.00860)	(0.0351)	(0.0503)
dCPI	4.059**	13.69*	13.69
	(1.498)	(6.137)	(7.901)
Adj. R-squared	0.99	0.95	0.90
Observations	281	278	276

Standard errors in parentheses. Stars * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

A.5 RamsesII monetary policy shocks

The Ramses II monetary policy innovations are estimated quarterly between 1995q2-2016q4 using the Taylor rule in equation (27)

$$(27)\quad \begin{aligned} ln\left(\frac{R_t}{R}\right) &= \rho ln\left(\frac{R_{t-1}}{R}\right) + (1-\rho)\left[ln\left(\frac{\bar{\pi}_t^c}{\bar{\pi}^c}\right) + r_\pi ln\left(\frac{\pi_{t-1}^c}{\bar{\pi}^c}\right)\right. \\ &\left. + r_y ln\left(\frac{h_{t-1}}{h}\right)\right] + r_{\Delta\pi}\Delta ln\left(\frac{\pi_{t-1}^c}{\pi^c}\right) + r_{\Delta y}\Delta ln\left(\frac{h_t^c}{h}\right) + \epsilon_{i,t}, \end{aligned}$$

where $\bar{\pi}_t^c$ is the inflation target shock and h_t are hours worked instead of output as a measure of the utilization of resources. This monetary policy rule prescribes how the interest rate responds to inflation and hours worked. I consider $\epsilon_{i,t}$ to be a shock to monetary policy which is uncorrelated with other economic activity. For example, the monetary policy shock may represent a preference change at the central bank because a new member with a different opinion joined the board.

A.6 Estimation of the high-frequency shocks

To construct high-frequency shocks, I closely follow the procedure by Iversen and Tysklind (2017). Iversen and Tysklind (2017) adapt Kuttner' (2001) method to Sweden. I use daily Stina swaps closing data to estimate the shocks. These overnight swaps have the STIBOR T/N interest rate as the basis for the floating leg and are therefore called STINA swaps (Stockholm Tomnext Interbank Average) swaps. STINA Swaps are short-term interest-rate swaps, denominated in Swedish kronor, with a maturity of up to and including one year. I use the Stina swap that refers to a one-month contract because one-week contracts may be too short to capture the days of the announcement and the consequent repo rate change. The unexpected change in the repo rate is calculated using the following formula

$$\Delta repo_t^{unexpected} \approx \frac{[t_t^{STINA} - t_{t-1}^{STINA}(\tau_1 + \tau_2) - \Delta repo_t]}{\tau_2 - 1}, \tag{28}$$

where t represents the announcement or publication date of the new repo rate, τ_1 is the number of days the contract has run before the implementation of the new repo rate and τ_2 is the number of remaining days of the contract's maturity after the implementation of the new repo rate.

To construct monthly shocks, I follow Gertler and Karadi (2015) and calculate a monthly average of the cumulated daily shock that is cumulated over the full sample over all d days. First, I sum shocks over the full sample:

$$shock_d^{cumulated} = \sum_{s=1}^{d} shock_d. \tag{29}$$

Then, I make monthly averages

$$ma_t = \frac{\sum_{d=d_t^1}^{d_t^T} shock_d^{cumulated}}{d_t^T}, \tag{30}$$

where T is the number of trading days in month t. Finally, I take the difference in monthly averages to get monthly monetary policy shocks

$$Z_t = ma_t - ma_{t-1} \tag{31}$$

Z_t captures the unexpected change in the average policy rate between two subsequent months. A similar aggregation using the formula with quarters yields quarterly high-frequency shocks.

A.7 Result tables: repo changes

Table 9: The transmission of repo rate changes via the working capital channel

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × dR	-0.0631	0.295	0.443	0.894*	1.099*
	(0.111)	(0.269)	(0.270)	(0.405)	(0.537)
avg. S × dR	8.69e-13	-7.78e-12	-2.40e-11	-4.02e-11*	-4.98e-11*
	(3.32e-12)	(1.13e-11)	(1.86e-11)	(1.92e-11)	(2.13e-11)
Observations	154072	151337	148591	145852	143131
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S × dR	1.301+	1.021	1.096	0.990	1.170+
	(0.699)	(0.686)	(0.673)	(0.698)	(0.706)
avg. S × dR	-4.84e-11*	-5.03e-11+	-5.96e-11**	-6.60e-11**	-6.68e-11*
	(2.36e-11)	(2.60e-11)	(2.24e-11)	(2.30e-11)	(2.62e-11)
Observations	140397	137657	134909	132160	129410
	p(t+10)-p(t-1)	p(t+11)-p(t-1)	p(t+12)-p(t-1)		
avg.W/S × dR	0.852	1.033	1.043		
	(0.758)	(0.771)	(0.743)		
avg. S × dR	-7.25e-11*	-6.54e-11*	-6.37e-11*		
	(2.82e-11)	(3.09e-11)	(3.20e-11)		
Observations	126281	123970	121860		

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

A.8 Result tables: forecast errors

Table 10: Forecast error based on information available 1 month ago

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S#error1m	-0.0467	0.331+	0.483*	0.898*	1.091*
	(0.116)	(0.187)	(0.221)	(0.410)	(0.491)
avg.W/S#ExpdR1m	-0.209	-0.0373	0.0645	0.858	1.189*
	(0.157)	(0.235)	(0.369)	(0.553)	(0.539)
avg. S # dR	8.62e-13	-7.80e-12	-2.40e-11	-4.02e-11	-4.98e-11
	(3.30e-12)	(1.01e-11)	(2.39e-11)	(3.04e-11)	(3.29e-11)
avg(W/S)*2008m10	0.0800	0.330	1.478**	2.271***	2.599***
	(0.193)	(0.386)	(0.544)	(0.657)	(0.716)
avg(W/S)*2008m11	0.0580	1.372**	2.086***	2.800***	2.714***
	(0.239)	(0.463)	(0.594)	(0.728)	(0.604)
avg(W/S)*2008m12	0.530+	1.688**	2.069**	2.501***	2.816**
	(0.296)	(0.542)	(0.702)	(0.752)	(0.867)
avg(W/S)*2009m1	0.0326	0.598	-0.0794	0.400	1.783*
	(0.392)	(0.379)	(0.474)	(0.579)	(0.880)
avg(W/S)*2009m2	0.382+	-0.275	-0.117	0.973	0.958
	(0.201)	(0.502)	(0.633)	(0.902)	(1.161)
avg(W/S)*2009m3	-0.418	-0.138	0.997	1.511	0.979
	(0.370)	(0.507)	(0.845)	(1.038)	(0.746)
avg(W/S)*2009m4	-0.0912	0.580	0.488	0.327	-1.560*
	(0.393)	(0.667)	(0.932)	(0.663)	(0.763)
avg(W/S)*2009m5	0.600+	0.567	0.494	-1.298*	0.388
	(0.328)	(0.642)	(0.319)	(0.662)	(0.712)
avg(W/S)*2009m6	-0.137	-0.561	-2.514**	-0.769	-1.255+
	(0.353)	(0.381)	(0.949)	(0.617)	(0.701)
Constant	0.105***	0.221***	0.328***	0.441***	0.558***
	(0.00153)	(0.00253)	(0.00275)	(0.00363)	(0.00438)
Observations	154072	151337	148591	145852	143131

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 11: Forecast error based on information available 1 month ago

	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S# error1m	1.273*	0.990	1.046	0.938	1.173
	(0.647)	(0.642)	(0.781)	(0.974)	(1.230)
avg.W/S#ExpdR1m	1.613*	1.346+	1.580+	1.448+	1.147
	(0.698)	(0.737)	(0.845)	(0.788)	(0.746)
avg. S # dR	-4.84e-11	-5.03e-11	-5.96e-11*	-6.59e-11*	-6.68e-11*
	(3.09e-11)	(3.29e-11)	(2.95e-11)	(3.18e-11)	(3.26e-11)
avg(W/S)*2008m10	2.371***	2.285***	2.756**	2.771**	2.350*
	(0.520)	(0.655)	(0.846)	(0.950)	(0.913)
avg(W/S)*2008m11	2.927***	3.142***	3.350***	2.814**	1.662*
	(0.738)	(0.874)	(0.989)	(0.912)	(0.822)
avg(W/S)*2008m12	3.523***	3.284**	3.012*	1.843+	2.750+
	(1.042)	(1.221)	(1.184)	(1.014)	(1.651)
avg(W/S)*2009m1	1.874	1.129	-1.325*	0.915	0.314
	(1.255)	(0.968)	(0.596)	(1.534)	(1.571)
avg(W/S)*2009m2	0.736	-1.330*	0.384	-0.234	-0.363
	(0.850)	(0.662)	(1.217)	(1.070)	(1.062)
avg(W/S)*2009m3	-1.038	0.944	0.509	0.268	-0.246
	(0.740)	(1.016)	(0.813)	(0.837)	(0.987)
avg(W/S)*2009m4	0.136	-0.419	-0.348	-0.570	-0.872
	(1.021)	(0.959)	(0.908)	(0.877)	(0.830)
avg(W/S)*2009m5	-0.0745	-0.208	-0.531	-0.475	-0.314
	(0.655)	(0.642)	(0.693)	(0.628)	(0.732)
avg(W/S)*2009m6	-1.285+	-1.487+	-1.445+	-1.360	-1.575
	(0.680)	(0.788)	(0.858)	(0.841)	(1.128)
Constant	0.674***	0.779***	0.889***	0.997***	1.102***
	(0.00504)	(0.00561)	(0.00647)	(0.00714)	(0.00666)
Observations	140397	137657	134909	132160	129410

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 12: Forecast error based on information available 4 month ago

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S # error 4m	-0.0760	0.300+	0.433*	0.875*	1.078*
	(0.113)	(0.165)	(0.170)	(0.366)	(0.445)
avg.W/S # ExpdR4m	-0.107	0.311	0.412**	0.829**	1.026*
	(0.151)	(0.205)	(0.154)	(0.311)	(0.433)
avg. S # dR	8.67e-13	-7.78e-12	-2.40e-11	-4.02e-11	-4.98e-11
	(3.30e-12)	(1.01e-11)	(2.39e-11)	(3.04e-11)	(3.29e-11)
avg(W/S)*2008m10	0.0750	0.352	1.489**	2.254***	2.573***
	(0.206)	(0.416)	(0.558)	(0.662)	(0.694)
avg(W/S)*2008m11	0.0941	1.495**	2.209***	2.791***	2.656***
	(0.260)	(0.487)	(0.596)	(0.654)	(0.583)
avg(W/S)*2008m12	0.574+	1.787***	2.183**	2.514***	2.790**
	(0.307)	(0.521)	(0.675)	(0.730)	(0.899)
avg(W/S)*2009m1	0.126	0.695+	0.0793	0.478	1.826+
	(0.381)	(0.410)	(0.529)	(0.773)	(1.061)
avg(W/S)*2009m2	0.463*	-0.160	0.0438	1.026	0.969
	(0.215)	(0.569)	(0.762)	(1.075)	(1.377)
avg(W/S)*2009m3	-0.350	-0.0287	1.140	1.549	0.976
	(0.400)	(0.585)	(0.949)	(1.176)	(0.923)
avg(W/S)*2009m4	-0.0248	0.706	0.642	0.355	-1.579*
	(0.431)	(0.727)	(1.017)	(0.733)	(0.636)
avg(W/S)*2009m5	0.596+	0.576	0.497	-1.307+	0.374
	(0.331)	(0.648)	(0.309)	(0.676)	(0.699)
avg(W/S)*2009m6	-0.134	-0.543	-2.497**	-0.773	-1.266+
	(0.360)	(0.383)	(0.949)	(0.618)	(0.699)
Constant	0.105***	0.222***	0.330***	0.441***	0.558***
	(0.00102)	(0.00179)	(0.00231)	(0.00342)	(0.00434)
Observations	154072	151337	148591	145852	143131

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 13: Forecast error based on information available 4 month ago

	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S # error 4m	1.293*	0.983+	1.040+	0.926	1.180
	(0.613)	(0.542)	(0.618)	(0.753)	(1.011)
avg.W/S # ExpdR4m	1.274+	0.887*	0.904*	0.781	1.201
	(0.660)	(0.446)	(0.407)	(0.500)	(0.749)
avg. S # dR	-4.84e-11	-5.03e-11	-5.96e-11*	-6.60e-11*	-6.68e-11*
	(3.09e-11)	(3.29e-11)	(2.95e-11)	(3.18e-11)	(3.26e-11)
avg(W/S)*2008m10	2.346***	2.229***	2.676***	2.688**	2.360**
	(0.505)	(0.614)	(0.780)	(0.880)	(0.838)
avg(W/S)*2008m11	2.806***	2.980***	3.112**	2.579**	1.681*
	(0.762)	(0.881)	(1.003)	(0.949)	(0.795)
avg(W/S)*2008m12	3.427**	3.189*	2.871*	1.709	2.757
	(1.104)	(1.310)	(1.287)	(1.062)	(1.834)
avg(W/S)*2009m1	1.794	1.156	-1.296	0.965	0.292
	(1.535)	(1.366)	(0.994)	(2.119)	(2.173)
avg(W/S)*2009m2	0.635	-1.369*	0.319	-0.283	-0.372
	(1.116)	(0.658)	(1.603)	(1.443)	(1.482)
avg(W/S)*2009m3	-1.137+	0.884	0.415	0.187	-0.249
	(0.610)	(1.290)	(1.050)	(1.169)	(1.290)
avg(W/S)*2009m4	0.0212	-0.516	-0.495	-0.706	-0.869
	(1.163)	(1.043)	(1.023)	(0.962)	(0.891)
avg(W/S)*2009m5	-0.0866	-0.237	-0.571	-0.517	-0.309
	(0.652)	(0.628)	(0.679)	(0.621)	(0.712)
avg(W/S)*2009m6	-1.304+	-1.517+	-1.489+	-1.404+	-1.571
	(0.676)	(0.784)	(0.854)	(0.830)	(1.118)
Constant	0.673***	0.777***	0.886***	0.994***	1.102***
	(0.00536)	(0.00553)	(0.00584)	(0.00609)	(0.00632)
Observations	140397	137657	134909	132160	129410

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 14: Forecast error based on information available 6 month ago

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S # error 6m	-0.0745	0.302*	0.462**	0.912*	1.119*
	(0.107)	(0.154)	(0.179)	(0.389)	(0.461)
avg.W/S # ExpdR6m	-0.0940	0.314*	0.495**	0.944*	1.154*
	(0.122)	(0.144)	(0.153)	(0.398)	(0.499)
avg. S # dR	8.69e-13	-7.78e-12	-2.40e-11	-4.02e-11	-4.98e-11
	(3.30e-12)	(1.01e-11)	(2.39e-11)	(3.04e-11)	(3.29e-11)
avg(W/S)*2008m10	0.0816	0.351	1.507**	2.282***	2.604***
	(0.196)	(0.393)	(0.544)	(0.645)	(0.696)
avg(W/S)*2008m11	0.0926	1.500**	2.248***	2.840***	2.711***
	(0.255)	(0.474)	(0.576)	(0.652)	(0.599)
avg(W/S)*2008m12	0.564+	1.793***	2.198***	2.527***	2.804**
	(0.310)	(0.530)	(0.664)	(0.719)	(0.888)
avg(W/S)*2009m1	0.101	0.700+	0.0180	0.382	1.717+
	(0.368)	(0.363)	(0.464)	(0.689)	(0.995)
avg(W/S)*2009m2	0.442*	-0.153	0.0174	0.978	0.914
	(0.210)	(0.548)	(0.713)	(1.009)	(1.301)
avg(W/S)*2009m3	-0.354	-0.0308	1.107	1.502	0.922
	(0.394)	(0.590)	(0.940)	(1.169)	(0.918)
avg(W/S)*2009m4	-0.00882	0.694	0.594	0.300	-1.641**
	(0.436)	(0.751)	(1.069)	(0.814)	(0.635)
avg(W/S)*2009m5	0.616+	0.566	0.481	-1.318*	0.362
	(0.333)	(0.655)	(0.353)	(0.603)	(0.776)
avg(W/S)*2009m6	-0.127	-0.546	-2.499**	-0.772	-1.265+
	(0.357)	(0.379)	(0.929)	(0.627)	(0.690)
Constant	0.105***	0.222***	0.330***	0.442***	0.558***
	(0.00103)	(0.00191)	(0.00228)	(0.00339)	(0.00429)
Observations	154072	151337	148591	145852	143131

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 15: Forecast error based on information available 6 month ago

	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S # error 6m	1.331*	1.037+	1.087+	0.972	1.204
	(0.625)	(0.540)	(0.602)	(0.721)	(0.976)
avg.W/S # ExpdR6m	1.387*	1.066*	1.072*	0.945+	1.254+
	(0.692)	(0.487)	(0.446)	(0.506)	(0.751)
avg. S # dR	-4.84e-11	-5.03e-11	-5.96e-11*	-6.60e-11*	-6.68e-11*
	(3.09e-11)	(3.29e-11)	(2.95e-11)	(3.18e-11)	(3.26e-11)
avg(W/S)*2008m10	2.369***	2.275***	2.726***	2.739**	2.367**
	(0.510)	(0.634)	(0.814)	(0.918)	(0.873)
avg(W/S)*2008m11	2.861***	3.050***	3.165**	2.628**	1.716*
	(0.773)	(0.857)	(0.968)	(0.898)	(0.784)
avg(W/S)*2008m12	3.449**	3.196*	2.858*	1.694+	2.786
	(1.083)	(1.252)	(1.199)	(0.986)	(1.712)
avg(W/S)*2009m1	1.710	0.989	-1.476+	0.785	0.276
	(1.435)	(1.227)	(0.828)	(1.955)	(1.994)
avg(W/S)*2009m2	0.603	-1.461*	0.206	-0.400	-0.365
	(1.006)	(0.603)	(1.455)	(1.296)	(1.317)
avg(W/S)*2009m3	-1.188*	0.810	0.350	0.127	-0.269
	(0.603)	(1.286)	(1.048)	(1.176)	(1.293)
avg(W/S)*2009m4	-0.0579	-0.583	-0.517	-0.714	-0.927
	(1.297)	(1.166)	(1.170)	(1.104)	(1.017)
avg(W/S)*2009m5	-0.119	-0.235	-0.532	-0.467	-0.344
	(0.690)	(0.709)	(0.757)	(0.665)	(0.801)
avg(W/S)*2009m6	-1.310+	-1.509*	-1.468+	-1.380+	-1.581
	(0.668)	(0.765)	(0.818)	(0.805)	(1.085)
Constant	0.674***	0.778***	0.887***	0.995***	1.102***
	(0.00521)	(0.00534)	(0.00551)	(0.00569)	(0.00588)
Observations	140397	137657	134909	132160	129410

Notes: Driscoll and Kraay standard errors by firm are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. The same control variables are used in each regression. These are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

A.9 Result tables: forecast errors

In the micro data, it is possible to account for firm-level differences in the average price duration and match each firm with the forecasting regression errors that are most relevant for the individual firm. The monthly data allow for the construction of 12 forecast horizons that span one month, two months, three months and so on up to 12 months, according to $k = [1, ..., 12]$ in regression (15). Then, it is possible to assign each firm to one of the 12 groups based on the firm's average price duration so that firms can be matched with the anticipated and unanticipated interest rate changes that correspond to the firm's effective forecast horizon. In this way, firms with a longer (shorter) average price duration will face larger (smaller) forecasting regression errors. For example, a firm which sets new prices every month may also forecast interest rates monthly and make a mistake in predicting the policy rate change one month ahead.

As an extension to the forecasting regression errors that are common to all firms, I implement a alternative specification with firm-specific forecasting errors based on the assumption that firms know their own average price duration so that firm-specific forecasting regression errors can be matched to each firm based on the firm's average price duration. In addition to this, I also set the forecasting regression errors to zero on days when the central bank did not make an announcement. Letting forecasting errors to be zero on non-announcement days is consistent with a scenario in which firms listen to central bank announcements and they know exactly which days the policy rate will be changed. Using these firm-specific anticipated and unanticipated interest rate changes yield similar coefficients to those in Table 16 where the forecasting regression errors are assumed to be common across all firms. The corresponding result tables are presented in Table A.9.

Table 16: The transmission of anticipated and unanticipated interest rate changes via the working capital channel - moderately sophisticated firm forecasts

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S # ErrorR	-0.0953	0.239	0.371+	0.858*	1.049*
	(0.102)	(0.167)	(0.210)	(0.413)	(0.477)
avg.W/S # ExpR	-0.00101	0.399*	0.572**	0.958*	1.188**
	(0.111)	(0.165)	(0.206)	(0.373)	(0.444)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	154072	151337	148591	145852	143131
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S # ErrorR	1.262*	0.912	0.964	0.887	0.980
	(0.635)	(0.607)	(0.729)	(0.878)	(1.143)
avg.W/S # ExpR	1.369*	1.208*	1.320+	1.168	1.471
	(0.603)	(0.597)	(0.704)	(0.873)	(1.120)
avg. S # dR	x	x	x	x	x
Firm FE	x	x	x	x	x
Time-Product FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	140397	137657	134909	132160	129410

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6. The tables with all coefficients can be found in Appendix A.8.

A.10 Further robustness checks

Firm-level control variables Table 17 includes firm-level annual control variables in the repo change regressions. Controlling for firm-level observables aims to address the concern that firms' underlying characteristics may correlate with firms' working capital holdings and generate alternative channels for the pass-through of interest rate changes to prices. As a robustness check regarding the size of the firm, I interact the firm's time-varying market share with repo rate changes and include it as a control variable. To check for alternative financial channels, an interaction term between interest rate changes and the firm's time-varying cash to assets ratio and debt to assets ratio are also included as control variables. To account for the price responses that stem from another cost channel that correlate with the firm's working capital holdings, I include the firm's time-varying total variable cost to sales ratio interacted with repo rate changes as a control variable.

The main worry is that firms that are larger or have easier access to debt and cash may also have more working capital and therefore interest rates affect them via other channels rather than through pre-funding input costs. Specifically, the observable characteristics I include are the firm's time-varying total variable cost to sales ratio (tvctosales), 5-digit industry market share (mshare), cash to asset ratio (cashtoasset) and debt to asset ratio (debttoasset). The regressions with firm-level control variables yield estimates of the coefficients of interest that are similar in magnitude to the baseline results in table 6.

Table 17: Firm-level control variables added to the repo change regressions, only 3-month and 6-month horizons are reported.

	p(t+3)-p(t-1)	p(t+6)-p(t-1)	p(t+3)-p(t-1)	p(t+6)-p(t-1)
avg.W/S × dR	1.170*	1.542*	1.177*	1.551*
	(0.477)	(0.769)	(0.477)	(0.769)
avg. S × dR	-4.10e-11*	-4.73e-11+	-4.16e-11**	-4.81e-11+
	(1.59e-11)	(2.57e-11)	(1.57e-11)	(2.55e-11)
tvctosales × dR	5003.3**	4664.3	4990.7*	4679.4
	(1907.5)	(2852.6)	(1946.6)	(2900.9)
mshare × dR	0.355	-0.0322	0.365	-0.00776
	(0.820)	(0.844)	(0.815)	(0.836)
cashtoasset × dR			0.307	0.874
			(0.571)	(1.150)
debttoasset × dR			0.168+	0.252**
			(0.0856)	(0.0929)
Observations	120990	113508	120990	113508

Notes: Columns (1) and (2) refer to price changes 3 months ahead and columns (3) and (4) report the coefficients for price changes 6 months ahead. The difference between the first two and the last two columns is the number of firm-level annual control variables. Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels $p < 0.05$; $p < 0.01$ $p < 0.001$; t are months. W is working capital, defined as receivables and inventories; and S is sales. Additional control variables are the interaction of average sales and the change in the repo rate from $t-1$ to t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Controlling for interim interest rate changes Another concern may be that a price change between $t-1$ and $t+1$ is not only caused by the interest rate change at t but also by the concurrent interest rate change at $t+1$. For example, this would be the case if interest rate changes were serially correlated. To address this issue, the regressions in Table 18 include intra-horizon repo rate changes as control variables. Table 18 shows that the coefficients are only slightly reduced as compared to those in Table 6.

Table 18: The transmission of repo rate changes to prices via the working capital channel

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × dR_t	-0.0631	0.323*	0.432*	0.550*	0.865*
	(0.102)	(0.136)	(0.209)	(0.274)	(0.420)
avg. S × dR_t	8.69e-13	-2.11e-12	-5.78e-12	-8.92e-12	-1.06e-11
	(3.30e-12)	(5.52e-12)	(8.29e-12)	(1.08e-11)	(1.25e-11)
avg.W/S × dR_{t+1}		-0.0984	0.434+	0.524**	0.551+
		(0.111)	(0.262)	(0.201)	(0.323)
avg.W/S × dR_{t+2}			-0.463**	-0.101	-0.0719
			(0.174)	(0.160)	(0.188)
avg.W/S × dR_{t+3}				-0.575*	-0.142
				(0.268)	(0.259)
avg.W/S × dR_{t+4}					-0.793*
					(0.311)
Firm FE	x	x	x	x	x
Time-Industry FE	x	x	x	x	x
FC dummies	x	x	x	x	x
Observations	154072	148984	144244	139784	135531

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-product fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Considering only non-zero price changes As a last exercise, the sample of price changes is reduced to only include non-zero price changes. Under the Calvo assumption, firms are randomly selected to change their prices. Given random assignment, this regression is expected confirm the theoretical prediction of a pass-through of one after some months. However, table 19 shows a larger effect of repo changes via the working capital channel using the reduced sample. Excluding zero price changes increases the coefficients by approximately one relative to the baseline regression, e.g. from 1 to 1.9 and from 1.3 to 2.3 at the four and five month horizon, respectively. Similarly, the Stina monetary policy shocks and expected interest rate changes also have a larger effect in this sample. Table 20 shows that the coefficients double in most horizons. The pattern across these regressions suggest that firms who change their prices may not be randomly selected from the population of firms. This selection may bias the estimated coefficients upward.

Table 19: The transmission of repo rate changes via the working capital channel, only non-zero price changes

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × dR	-0.0508	0.771	0.862	1.563^{+}	1.896*
	(0.271)	(0.627)	(0.634)	(0.799)	(0.930)
avg. S × dR	2.23e-12	-5.93e-12	-2.91e-12	-7.54e-12	-1.53e-11
	(7.66e-12)	(1.75e-11)	(2.24e-11)	(2.14e-11)	(2.33e-11)
Observations	38373	38373	38373	38373	38373
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S × dR	2.249*	1.672	1.522	1.839	2.601*
	(1.085)	(1.054)	(1.063)	(1.168)	(1.192)
avg. S × dR	-1.91e-11	-1.93e-11	-4.38e-11	-3.30e-11	-2.57e-11
	(2.86e-11)	(3.70e-11)	(2.79e-11)	(2.86e-11)	(2.88e-11)
Observations	38373	38373	38373	38373	38373

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

Table 20: The transmission of the high-frequency shocks and expected repo changes via the working capital channel, only non-zero price changes

	p(t)-p(t-1)	p(t+1)-p(t-1)	p(t+2)-p(t-1)	p(t+3)-p(t-1)	p(t+4)-p(t-1)
avg.W/S × Stina shock	0.813	4.464^{+}	3.319*	5.184*	6.889**
	(0.772)	(2.549)	(1.523)	(2.304)	(2.520)
avg.W/S × Stina exp	-0.210	-0.169	0.292	0.680	0.599
	(0.316)	(0.831)	(0.752)	(0.868)	(1.000)
avg. S × dR	3.73e-13	-9.57e-12	-8.73e-12	-1.33e-11	-2.13e-11
	(7.78e-12)	(1.76e-11)	(2.20e-11)	(2.12e-11)	(2.30e-11)
Observations	36956	36956	36956	36956	36956
	p(t+5)-p(t-1)	p(t+6)-p(t-1)	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)
avg.W/S × Stina shock	7.742*	7.234*	6.558*	9.017*	10.75**
	(3.236)	(3.265)	(3.166)	(3.499)	(3.985)
avg.W/S × Stina exp	0.825	0.167	0.206	-0.137	0.363
	(1.201)	(1.197)	(1.235)	(1.404)	(1.414)
avg. S × dR	-2.67e-11	-2.81e-11	-5.30e-11^{+}	-4.17e-11	-3.54e-11
	(2.82e-11)	(3.68e-11)	(2.72e-11)	(2.82e-11)	(2.78e-11)
Observations	36956	36956	36956	36956	36956

Notes: Driscoll and Kraay standard errors with four lags are in parenthesis; significance levels + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; t are months. W is working capital, defined as receivables and inventories net of payables and prepayments. S is sales. The same control variables are used in each regression. These control variables are the interaction of sales and the repo rate change between $t-1$ and t, firm and time-industry fixed effects, and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

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