RESEARCH INSTITUTE OF INDUSTRIAL ECONOMICS

IFN Working Paper No. 1482, 2023

The Working Capital Channel

Melinda Suveg

Research Institute of Industrial Economics
P.O. Box 55665
SE-102 15 Stockholm, Sweden
info@ifn.se
www.ifn.se

The Working Capital Channel

Melinda Suveg [*]

November 15, 2023

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 is gradual because of price rigidity. Using a unique dataset on firm-product-level price indices, I show that a one percentage point monetary policy shock leads to a 6 percent increase in the firm's price and that the pass-through takes about 4 months. The pass-through in the microdata is 6 times larger than it is implemented in the supply-side block of standard New Keynesian DSGE models.

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

JEL Codes: E31, E37, E52, L11

[*]melinda.suveg@ifn.se, Research Institute of Industrial Economics, Grevgatan 34, Box 55665, 102 15 Stockholm, +46764271048. I would like to thank Nils Gottfries, Simon Gilchrist, Plamen Nenov, David Vestin, Teodora Borota Milicevic for their outstanding dedication to improve this paper. I would like to thank the seminar participants at Uppsala University, New York University, the Sveriges Riksbank and the 13th Nordic Summer Symposium in Macroeconomics for their helpful comments and suggestions. I acknowledge funding from the Marianne and Marcus Wallenberg Foundation (2020.0049) and I would also like to thank the Department of Economics at Uppsala University and the Jan Wallander and Tom Hedelius Foundation for their financial support.

1 Introduction

The price puzzle, characterized by a rise in prices following a positive monetary policy shock, remains a prominent feature of 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.

Even 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 variable costs one quarter ahead. There is currently no micro foundation for these specific assumptions in prominent central bank models. Specifically, the effect of a monetary policy shock on prices via the working capital channel has not been examined at the firm level, and we currently do not know how monetary policy shocks affect individual firms' prices via the working capital channel. The main contribution of the present paper is to fill this gap by providing firm-level evidence of the pass-through of monetary policy shocks to individual firms' prices and to document the variation in working capital requirements across firms and industries. In addition, the paper discusses the importance of the working capital channel in a standard general equilibrium New Keynesian model under

[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 assumption that the calibration of such model uses the microdata estimates found in this paper.

Using a theoretical framework based on the New Keynesian model, I derive a structural partial equilibrium equation that shows how monetary policy shocks affect producer prices via the working capital channel. In particular, the basic New Keynesian model is modified to accommodate firms with a specific share of working capital requirement. This assumption gives scope to calibrating the working capital channel to the share of working capital that the representative firm requires in the microdata. The model predicts that firms with a higher level of working capital holding increase their prices more after a monetary policy shock. The partial equilibrium model predicts that the pass-through of monetary policy shocks to prices should be one-to-one after some time via the working capital channel if firms pre-fund the entirety of their variable costs. The pass-through of policy rate changes to prices should be gradual because of price rigidity.

The predictions from the theoretical model are tested using unique survey data on monthly firm-product-level price indices between 2002-2017 and annual balance sheet information on Swedish firms. The dataset includes firm characteristics and firm-product-level price indices for around 2000 Swedish firms. Working capital is defined as the sum of receivables and inventories net of payables and pre-payments from customers. This definition follows the convention by Barth and Ramey (2001) and Gaiotti and Secchi (2006), but extends it by also deducting pre-payments from customers. In addition, I construct high-frequency monetary policy shocks and aggregate them to a monthly frequency using the method of Kuttner (2001) and Gertler and Karadi (2015).

The pass-through of a monetary policy shock via the working capital channel is then identified using the shift-share approach in Jordà-style local projection regressions (Jordà, 2005).

Conditional on controls, multiple orthogonal shocks identify the price effect of a monetary policy shock in a shift-share regression design following the methodological framework of Borusyak, Hull and Jaravel (2022). In particular, panel regressions compare the responses of producer prices to monetary policy shocks of firms that have a large working capital-to-sales ratio to firms that have a small working capital-to-sales ratio. Firms that 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 monetary policy shocks on prices is identified from the time-invariant variation in working capital across firms. The regressions include product group fixed effects as well as numerous firm-level control variables interacted with the monetary policy shocks (shift-share control variables) to rule out confounding variation caused by firm-specific time-varying financial, demand and cost shocks that may affect the higher working capital firms to a larger degree.

I find that a high-frequency shock of one percentage point leads to a 1.25 (1.37) percent increase in the price of a firm with the average working capital holdings (0.2) over a 4 (9) month price setting horizon. For a firm with a working capital-to-sales ratio of one, the estimates imply a price response between 6-7 percent after 4 months. A percentage point monetary policy shock, therefore, has an at least 6 times larger price effect via the working capital channel than what is predicted by the theory in the supply-side block of standard monetary models. In addition, the results show that the effect is gradual and stabilizes around one after 4 months. The gradual price increase supports the claim that prices are sticky and there is a substantial delay in firms' price responses.

Multiple robustness checks are implemented to address two main concerns. These concerns are potential pre-trends and other channels via confounding variables that may bias the estimates. To check for pre-trends, lagged price changes are included in the main specification as regressors. Potential confounding channels may be other financial mechanisms that correlate with or affect the working capital channel. These alternative financial mechanisms include, for example, the customer markets theory, in which more liquid firms find it optimal to drop their prices as a means of gaining market shares from their competitors (Gilchrist, Schoenle, Sim and Zakrajsek, 2017). In addition, Duca, Montero, Riggi and Zizza (2018) show that firms that face financial frictions and also have stable customer relations may find it optimal to keep their prices high in the face of decreasing demand. These theories indicate that high working capital firms may have incentives to increase, or decrease, their prices for reasons other than the working capital channel, for example due to the liquidity channel or financial constraints. For this to be the case, the firms' working capital ratio would have to be correlated with their debt and cash holdings. I show that on average there is no clear correlation between the firms' working capital, short-term debt and cash holdings, and I also include these financial variables interacted with monetary policy shocks as shift-share control variables to rule out any confounding via these potential alternative financial channels.

The findings in this paper are most important for DSGE models used by monetary authorities. The New Keynesian model prescribes that firms that operate within the New Keynesian model framework pre-fund the totality of their variable costs every quarter; and that the pass-through from monetary policy shocks to producer prices in the supply side of the model is one-to-one after some time. The findings in this paper indicate that firms on average have 20 percent of annual sales tied down in working capital, which can be interpreted as 2 months of pre-funding requirement or a 66 percent working capital share in a quarterly model. In addition, the price pass-through via the working capital channel is much stronger in the microdata than it is accounted for by the standard calibration in the New Keynesian model. The pass-through of a percentage point monetary shock to producer prices via the working capital channel is 6 percent after 4 months and the effect levels off between 6-7 percent after 5 months. These estimates indicate that the working capital channel should have a multiplier which can account for the larger supply side effects of monetary policy measured in the microdata.

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 monetary policy shocks 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 form of cost channel. 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.

In addition, Renkin and Zuellig (2022) investigate the pass-through between bank lending rates and prices to estimate the price effects of credit supply shocks. Examining changes in monetary policy shocks, vis-à-vis bank lending rates, is an important contribution of this study because the price effects of changes in the bank lending rate and the repo rate are different. This difference is highlighted by Gilchrist and Zakrajšek (2012) who show that changes in corporate bond credit spreads and policy rates propagate through the economy in different ways. In addition, bank lending rates reflect idiosyncratic differences across firms which can endogenously change due to reasons other than changes in monetary policy and therefore capture individual developments between firms and banks. 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. Similarly, the use of high-frequency shocks helps identify the price effect of aggregate monetary policy shocks, but this exercise does not provide a framework to conclude about the relation between prices and bank lending rates, which is the focus of Gaiotti and Secchi (2006) and Renkin and Zuellig (2022).

This paper makes conclusions about the general equilibrium effects of monetary policy. Monetary policy affects prices via both supply and demand. The present study 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 fixed effects and other control variables. Therefore, I use the term ”via the working capital channel” to indicate 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 documents the strength of the supply-side mechanism and helps calibrate the parameters which govern the supply-side price pass-through in a general equilibrium model.

The paper is structured as follows. Section 2 explains the theoretical framework. Section 3 outlines the method and Section 4 describes the data used for the empirical analysis. The data section reviews important statistics about the firms’ working capital shares and distributions as well as their underlying observed characteristics. Section 5 presents and discusses the main results. Section 6 shows the results of robustness checks and section 7 examines heterogeneity in the price pass-through via the working capital channel based on financial and size differences across firms. Section 8 concludes the paper.

2 A modified New Keynesian model for benchmark

This section describes the working capital channel as it appears in the standard New Keynesian model with one modification. Christiano, Eichenbaum and Evans (2005) assume that the representative firm pre-funds its variable cost every quarter and waits a quarter to get paid for its goods produced and sold. The core difference to the formulation in Christiano et al. (2005) is the introduction of the parameter δ which explicitly assigns the firms' pre-funding duration, that is how long firms on average have to wait to get paid. Assuming for example $\delta = 1/3$ and following the interpretation of Christiano et al. (2005) in their quarterly model means that firms pre-fund their input cost every month and, thus, wait a month to get paid for their variable input costs. An alternative interpretation of δ is that it represents the share of variable inputs that are pre-funded within a quarter.

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

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

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

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

where it is assumed that the firm pre-funds its variable input cost W_t and pays interest $(1+i_t)$ for some firm-specific duration δ_i. Equation (2) says that the firm's marginal cost is a function of the aggregate interest rate i to a firm-specific degree of exposure δ_i. 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. 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 firm-level differences in the time lag between payments for inputs and the receipt of payments for output sold.

Taking logs allows us to interpret δ_i as the fraction of variable cost that is pre-funded by the firm

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

Equation (3) describes the log marginal cost of the firm as a linear function of firm-specific interest payments $R_t \equiv ln(1 + i_t)$ and the log marginal input cost where $mc^n_t = ln(W_t/A_t)$, exclusive of financing costs, which for simplicity is common to all firms ex ante any disturbances.

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. The firm's working capital requirement δ_i in equation (4) can be thought of as *either* the firm's pre-funding time *or* the share of pre-funded inputs. The firms working capital requirement determines the direct supply-side pass-through from interest rate changes to prices. It is larger for firms with a higher working capital requirement. Firms that must wait longer to get paid are affected by interest rate changes to a larger extent because they face higher interest expenses.

Note that in the standard New Keynesian model, the means of obtaining the financing to pre-fund variable costs is not explicitly defined. Potential microfoundations may include financing via bank loans, trade credit or equity. The formulation above is kept simple for two reasons. First, to stay close to the working capital channel as it is used in central bank models. Second, to make the point that changes in the policy rate affect producer prices irrespective of the means of financing because the risk free rate underlies all financing activities. More sophisticated assumptions about the micro foundations of financing channels may be made to answer alternative questions about the types of financing that affect the pass-through for a given level of working capital requirement. The objective of this study, however, is to measure the direct effect of a monetary policy shock on producer prices for the firm with the average working capital requirement, analogous to current central bank models; and by varying firms' working capital requirement to shed light on heterogeneity in the working capital channel itself.

To analyze the producer price effect of interest rate changes, I consider the economy with price stickiness θ and the average value for the pre-funding requirement δ. Price inflation can be written as

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

Using that p_t^* is given by equation (1), the price change resulting from a shock to the policy rate ΔR_t^{shock} is therefore

$$\frac{\Delta \pi_t}{\Delta R_t^{shock}} = (1-\theta)(1-\theta\beta)\ \delta \left[E_t \sum_{k=0}^{\infty} (\theta\beta)^k \frac{\Delta R_{t+k}}{\Delta R_t^{shock}} \right]. \tag{6}$$

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

2.1 Model predictions with varying price stickiness

Price rigidity affects the pass-through of marginal costs to prices via the working capital channel. The flexible price model has clear predictions for the effect of monetary policy shocks. In the flexible price model, $\theta = 0$ which means that firms are free to set their optimal price every period. Ceteris paribus, prices change in proportion to the pre-funding requirement

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

When price stickiness is present, the pass-through via the working capital channel is pinned down by the price stickiness parameter and the process for R_t. If price stickiness θ is high, then the probability of changing the price, $(1 - \theta)$, is low so that $\Delta\pi_t / \Delta R_t^{Shock}$ will be lower. A higher level of price stickiness leads to a lower supply-side pass-through for a given level of working capital requirement in the economy.

To simulate the working capital channel with alternative calibrations for the price stickiness parameters, 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

$$p_t - p_{t-1} = (1 - \theta)(p_{t-1}^* - p_{t-1} + \delta \epsilon_t). \tag{7}$$

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

$$(8) \qquad p_{t+k} - p_{t-1} = (1 - \theta^{k+1})(p^*_{t-1} - p_{t-1}) + (1 - \theta^{k+1})\delta\epsilon_t.$$

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 variable 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.

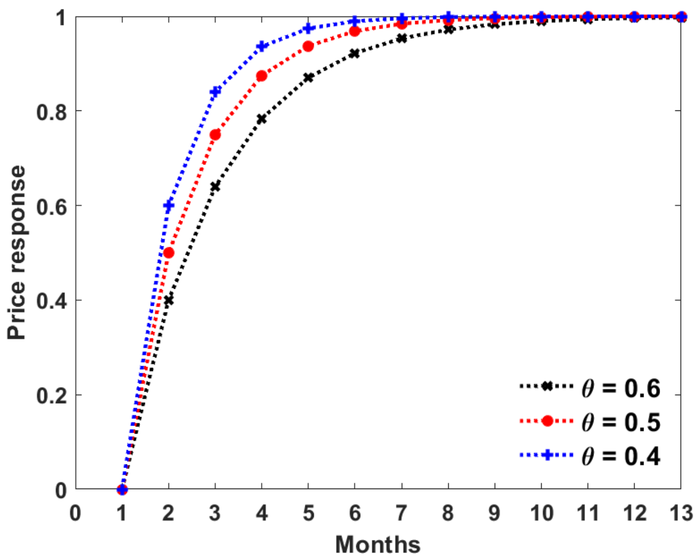


Figure 1: The effect of a permanent interest rate shock on the price with $\delta = 1$.

3 Estimation and Identification

This section outlines the method to measure the price effect of a monetary policy shock via the working capital channel using microdata on prices and firm balance sheets. In particular, the empirical strategy targets to identify the theoretical prediction formalized in equation (6) and test whether a micro foundation for the price puzzle can be found in the firm-product level data. Adopting an identification strategy that follows the shift-share approach of Borusyak, Hull and Jaravel (2022) allows for the estimation of unbiased coefficients by leveraging the heterogeneous exposure of firms to a series of random shocks. The exposure shares in the present empirical set-up are firms working capital shares and the shifters are high-frequency monetary policy shocks. The average price effect via the working capital channel is identified by comparing the price changes of firms with high and low working capital holdings relative to sales after a series of uncorrelated and exogenous monetary policy shocks. I estimate k Jordà-style (Jordà, 2005) regressions at the firm-product level for $k \in [0, 12]$ price setting horizons to investigate the pass-through and its duration

$$\begin{aligned} p_{i,j,t+k} - p_{i,j,t-1} = {} & \beta_{1,k} \left(\frac{\overline{W_i}}{S_i} \times \Delta R_t^{Shock} \right) + \beta_{2,k} \left(\frac{\overline{W_i}}{S_i} \right) + \beta_{3,k} \left(\Delta R_t^{Shock} \right) \\ & + \gamma_{j,k} + \xi_{1,k} (\overline{S_i} \times \Delta R_t^{Shock}) + \sum_s^S \xi_{s,k} \left(\frac{\overline{W_i}}{S_i} \times D_s \right) + \epsilon_{k,i,t}, \end{aligned} \tag{9}$$

where the firm has index i and it produces a 2-digit product j. Subscript t refers to the months between 2002m10-2017m12; and s denotes the months of the large fluctuations during the financial crisis in Sweden 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. This definition is a more complete measure of the working capital variable used in the pioneering study of Barth and Ramey (2001) by deducting payables and prepayments. 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 monetary policy shocks on prices is identified from the time-invariant variation in working capital across firms.

ΔR_t^{Shock} are the estimated high-frequency monetary policy shocks aggregated to a monthly frequency t. Monetary policy shocks are high-frequency shocks that are calculated following Fransson and Tysklind (2016) and Iversen and Tysklind (2017) and aggregated following Gertler and Karadi (2015). $\beta_{1,k}$ measures the transmission of monetary policy shocks to prices via the working capital channel. More specifically, the coefficients $\beta_{1,k}$ identifies the percentage price response to a one percentage point monetary policy shock for a firm whose working capital requirement equals its sales.

The control variables include the main effect of working capital $\frac{\overline{W_i}}{S_i}$, the main effect of a monetary policy shock, and $\gamma_{j,k}$ product fixed effects that account for product-level factors such as variation in demand and input costs for specific products that affect prices. Further shift-share control variables include the interaction term $\bar{S}_i \times R_t$, where $\bar{S}_i$ is the firm's time-average net sales. $\bar{S}_i \times R_t^{Shock}$ 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. To take care of potential autocorrelation in the error term, the results are presented with standard errors clustered at the firm level. As a robustness check, standard errors are clustered at the firm-month level.

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, where bank rates, such as the underlying Stibor bank lending rate were very volatile and jumped in response to multiple events in the same period when central bank announcements took place. The concern during the crisis is that the large unanticipated policy rate hikes may be correlated with large surprises in demand which may, in turn, downward bias the results. The main specification excludes the months of the financial crisis in order to implement the cleanest specification to estimate the working capital channel by using the data points where monetary policy shocks are more likely to be uncorrelated with other events and shocks. The rationale for this precaution is that the high-frequency shocks are very large and negative during these months and may be viewed as outliers in the series. To corroborate this reasoning, the estimated coefficients in and outside of the crisis are presented as a robustness exercise.

There are two main concerns for identification. One is that of parallel price trends and whether the high working capital firms set higher prices than low working capital firms for reasons other than their high working capital holdings. A robustness check includes past price changes as control variables to check for parallel trends in the shift-share framework.

The other concern for identification is the potential correlation between the firm's working capital holding and its financial status. An example of this would be if high working capital firms were less cash-constrained and they would strategically lower their prices when their cash-constrained competitors increase them (Gilchrist, Schoenle, Sim and Zakrajsek, 2017). This would introduce a negative bias in estimating $\beta_{1,k}$ due to the correlation between the firms' working capital and cash holdings. To take account of financial channels that may be correlated with the firms' responses to monetary policy shocks via the working capital channel, a robustness check includes shift-share control variables in the form of interaction terms between monetary policy shocks and the firm's time-average total variable-cost-to-sales ratio, short-term debt-to-sales ratio, and cash-to-sales ratio. In addition, a series of heterogeneity checks are implemented to elicit whether the estimated working capital pass-through coefficient varies across firms with high and low cash holdings, short-term debt and variable cost ratios.

4 Data

To study the working capital channel, I merge three datasets: firm-product-level monthly domestic price indices of a sample of firms that produce in Sweden (1992-2017), the annual balance sheets of all Swedish firms, and monthly high-frequency shocks available between 2002m10-2017m12. The microdatasets on firms are obtained from Statistics Sweden (SCB, 2018) and the Stina overnight swap rates used to construct the high-frequency shocks are downloaded from Refinitiv.

The merged dataset consists of a series of monthly firm-product level price indices, monthly monetary policy shocks and annual firm-level balance sheet items for 1,926 Swedish firms for the period 2002m10-2017m12. To remove outliers in the variables of interest, the final dataset excludes the top and bottom one percentile in log price changes and the average working capital-to-sales ratio. Extreme price changes and extreme values of working capital are likely to represent reporting mistakes by firms.

Table 1 shows the summary statistics of the firms' average working capital-to-sales ratio, average sales, percentage price changes at 12 horizons and the high-frequency shocks.

Working capital The average working capital-to-sales ratio is around 0.17, which means that firms on average have an equivalent of 2 month of sales in the form of inventories and receivables net of prepayments and payables. This implies that the average firm experiences a 2-month delay between producing the good and getting paid for it. If all firms had a 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 working capital-to-sales ratio can also be interpreted as the firm's sales share of working capital. This interpretation is useful for empirical work since it can be compared with the sales share of cash holdings, debt, variable costs and other firm characteristics.

Table 1: Summary statistics of the main variables

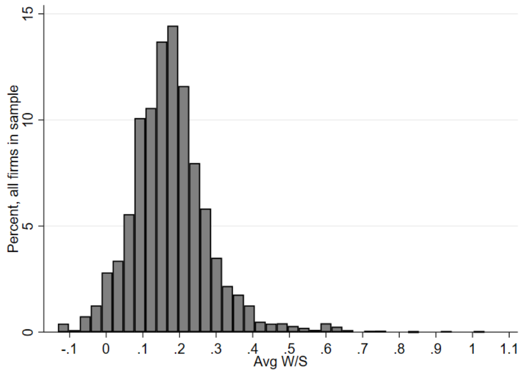
	mean	sd	min	max
avg. W/S	0.17	0.11	-0.13	1.03
avg. S	1.33	4.44	0.00	61.96
p(t)-p(t-1)	0.11	1.81	-44.83	45.33
p(t+1)-p(t-1)	0.24	2.15	-14.98	16.21
p(t+2)-p(t-1)	0.36	2.43	-12.76	14.67
p(t+3)-p(t-1)	0.48	2.65	-11.83	14.19
p(t+4)-p(t-1)	0.60	2.83	-11.04	13.86
p(t+5)-p(t-1)	0.72	2.98	-10.66	13.58
p(t+6)-p(t-1)	0.84	3.13	-10.27	13.44
p(t+7)-p(t-1)	0.96	3.27	-9.98	13.35
p(t+8)-p(t-1)	1.09	3.40	-9.88	13.24
p(t+9)-p(t-1)	1.20	3.51	-9.62	13.08
p(t+10)-p(t-1)	1.32	3.62	-9.41	12.94
p(t+11)-p(t-1)	1.44	3.74	-9.10	12.94
p(t+12)-p(t-1)	1.55	3.89	-8.80	12.97
HF shock	-0.01	0.07	-0.58	0.12

The fact that firms on average seem to pay their input costs 2 months before they receive payments suggests that the working capital channel is assumed to be slightly larger in the model of Christiano et al. (2005); Adolfson et al. (2013); Corbo (2020) who assume that the entirety of the representative firm's variable cost is pre-funded a quarter in advance. In comparison, the industry-level study of Barth and Ramey (2001) reports 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[2]. It is also likely that their industry-level data is constructed from a selection of larger firms in specific industries. Using data on Italian firms, Gaiotti and Secchi (2006) report that the average working capital to annual operating cost ratio is 0.33, suggesting that four months of firms' operating costs are tied down as working capital. Gaiotti and Secchi's (2006)

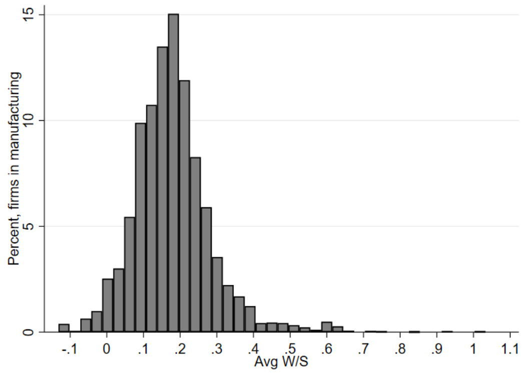
[2]Using the balance sheet data which contains information on all Swedish firms and considering the sales-weighted average of the working capital-to-sales ratio across firms in Sweden that have at least one employee, the average value is 0.12 in the whole economy and 0.17 in the manufacturing sector. Aggregation to the industry level, therefore, does not seem to explain the difference between the average working capital requirements between Sweden and the US.

statistic is more comparable to the average working capital-to-sales ratio of Swedish firms.

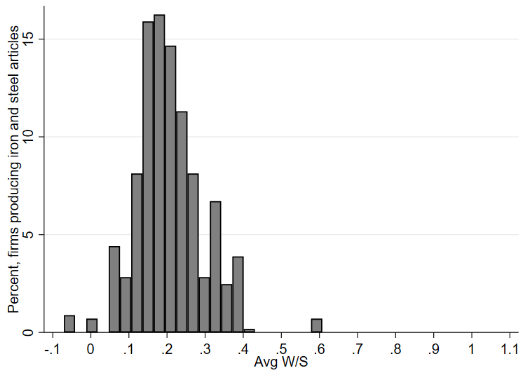
The working capital-to-sales ratio displays a large cross-sectional variation across firms in the economy as well as within industries. Figures 2a and 2b show the distribution of firms' average working capital-to-sales ratio in the sample and in the manufacturing sector, respectively. Given that 1,726 firms in the sample are producers of goods in the manufacturing sector, the working capital distribution looks very similar for all firms in the sample and the manufacturing sector with a range between -0.13 and 1.03. Most firms have a working capital share of sales between 0.1-0.3 and only a few percent of firms have values above 0.4.



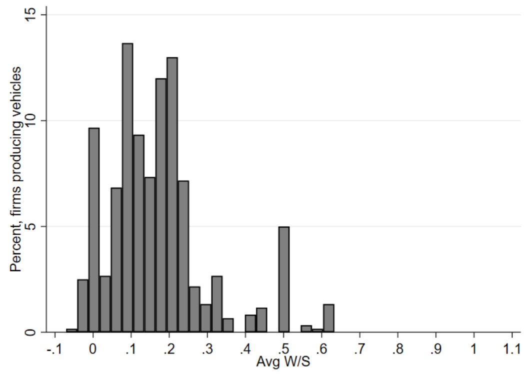
(a) Avg W/S, all firms in sample



(b) Avg W/S, firms in manufacturing



(c) Avg W/S, firms producing iron and steel



(d) Avg W/S, firms producing vehicles

Figure 2: Distribution of the average working capital-to-sales ratio.

Figures 2c and 2d show the variation within the 2-digit product group of iron and steel articles and vehicles. These are large industries in Sweden, populated by many firms. Figures in 2 overall highlight that there is large variation in firms' working capital requirements both across and within industries. The largest mass of firms who produce iron and steel articles seems to hold 10-20 percent of sales in working capital, whereas vehicle producers have a more even distribution, with the working capital shares mostly below 25 percent.

Figure 3 shows the average working capital-to-sales ratios across some example industries that produce different products. Firms in the milling industry have one of the largest average working capital shares (0.4), whereas firms producing apparel and accessories have one of the lowest (0.1)

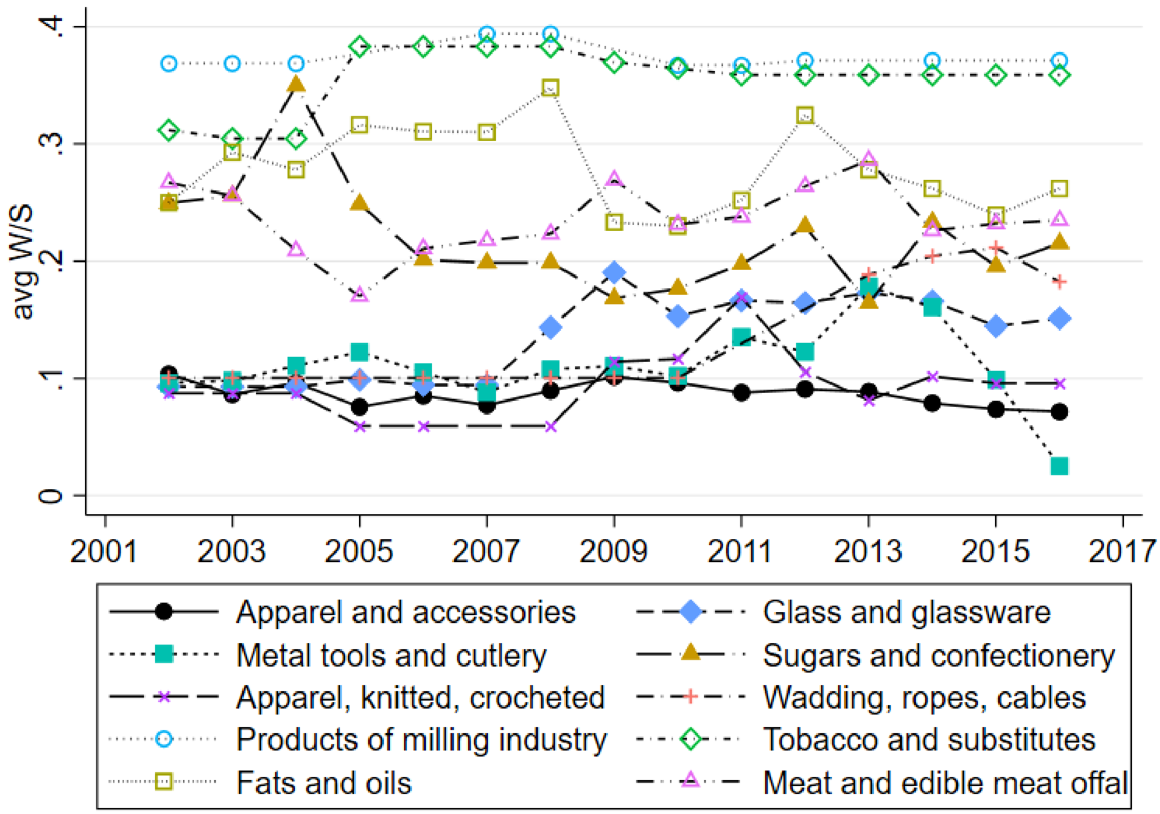
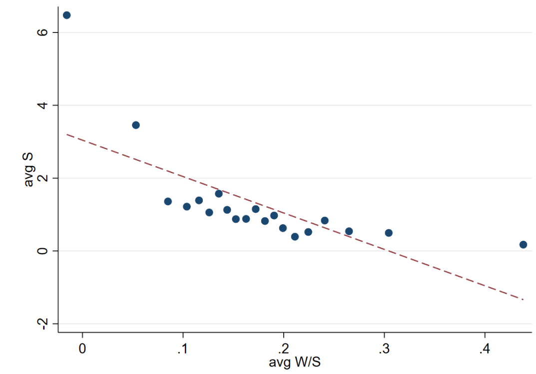


Figure 3: The average working capital-to-sales ratios across firms producing 2-digit (HS2) products.

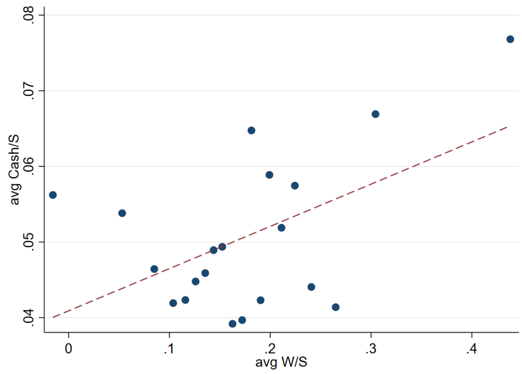
Working capital and other firm characteristics The identification strategy and the identifying assumption based on Borusyak et al. (2022) prescribes that shocks should not be correlated with latent factors that impact the higher exposure firms to a higher degree given the control variables, which are often interaction terms in the form of shift-share control variables. In the main regression specification in equation (9), the shares are the firms' average working capital holdings relative to sales, and thus the requirement for identification is that monetary policy shocks that affect firms with higher working capital holdings to a larger extent are not correlated with, for example, financial shocks that affect the high working capital firms more. The main identification concern is that time-varying firm-specific financial shocks may generate a correlation between price changes, monetary policy shocks and the working capital channel which is not causal. This could be the case if, for example, monetary policy shocks affect prices via other financial channels that are correlated with the firm's share of working capital such as the sales share of cash holdings, debt and input costs. It may also appear as a confounding if there is a correlation between sales shares of working capital, cash holdings, debt and input costs due to the size of the firm.

Examining observed firm characteristics in Figure 4 can help us evaluate whether there are underlying factors which may be correlated with firms' working capital holdings. If so, including these factors in a robustness exercise as shift-share control variables can rule out potential confounding.

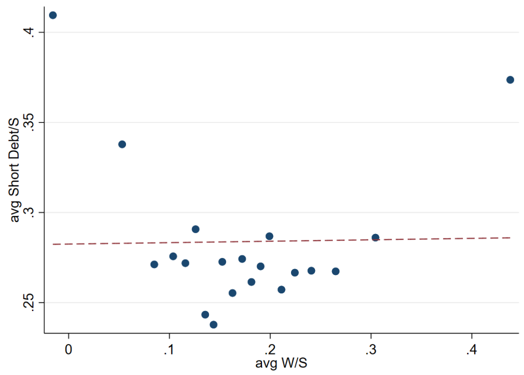
Figure 4a shows the correlation between average sales and the average working capital-to-sales ratio. Firms with a very low working capital-to-sales ratio, below 0.08, seems to have much higher average sales (4-6 vs 1 billion SEK), implying that large firms may have a relatively smaller working capital channel whilst also practicing price-setting strategies that differ from other firms. This negative correlation in the left tale of the working capital-to-sales distribution is the reason why the main specification includes average sales as a shift-share control variable. The interaction term between average sales and monetary policy shocks accounts for the possibility that monetary policy shocks may affect larger firms' prices in other ways.



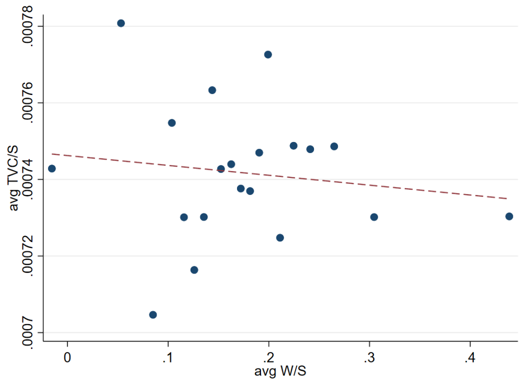
(a) Avg. sales and avg. W/S



(b) Avg. cash-to-sales and avg. W/S



(c) Avg. short-term debt-to-S and avg. W/S



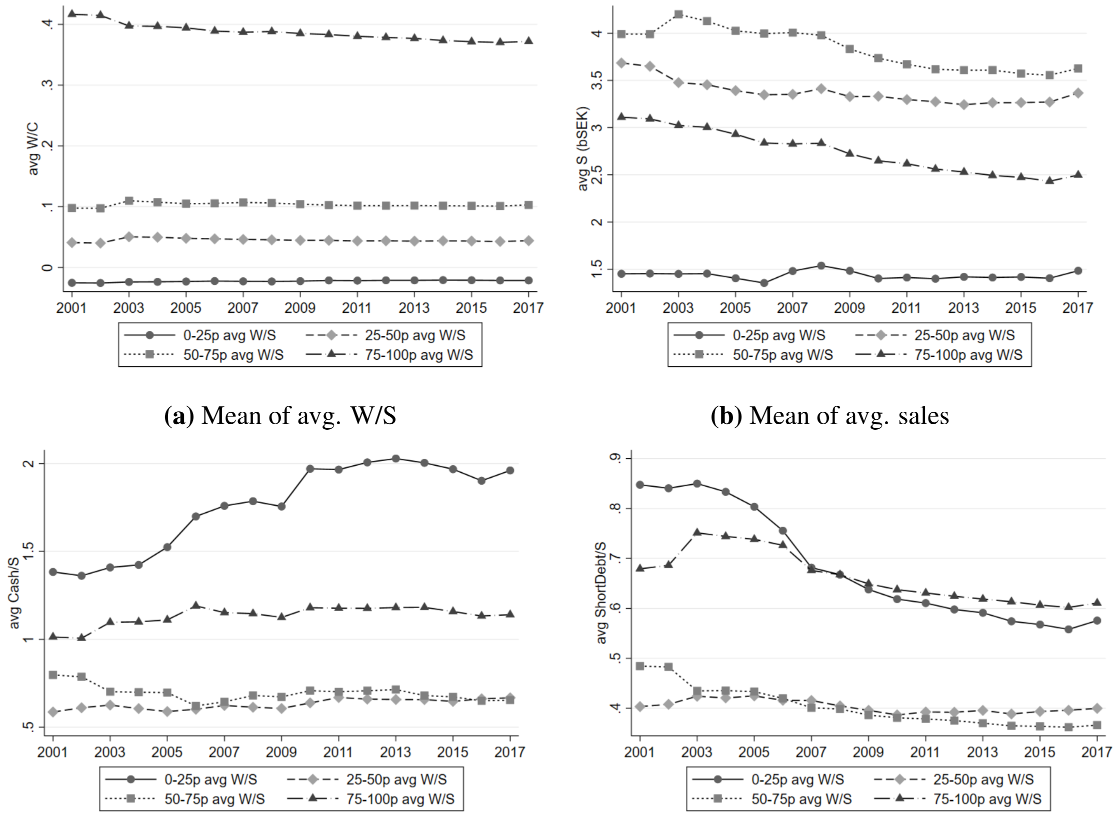
(d) Avg. total variable cost-to-S and avg. W/S

Figure 4: Binscatter of firms time-average average sales and sales ratios of cash holdings, short-term debt and total variable cost on the y axis and the average working capital-to-sales ratio on the x axis. Average sales in 4a are in billions of SEK.

Figures 4b-4d show the correlation between firms' average cash-to-sales, short-term debt-to-sales and total variable cost-to-sales ratios along the working capital share distribution. Only cash holdings demonstrate a slight positive correlation for firms with the highest cash ratios. Since the range of cash holding varies between 4-8 percent, even the largest cash ratios of 7-8 percent are not far from the mean. Despite that no clear correlations appear when eyeballing the data, these variables are included as shift-share control variables in the robustness exercise to assess potential confounding and whether alternative financial mechanisms are more important than the working capital channel.

Figure 5 provides an overview of the average working capital-to-sales ratio and firm characteristics across quartiles of the average working capital-to-sales ratio including all firms in

Sweden, not only for the firms that are in the price sample. Figure 5a shows that in the Swedish economy, the quartile with the lowest working capital ratios have an average negative ratio just below zero, whereas the firms with the largest working capital-to-sales shares hold 40 percent of their sales as working capital. Most firms in the middle two quartiles have just above 0 and around 10 percent of sales tied down as working capital. This figure suggests that the working capital shares (mean 0.17) in a sample of firms with price information is representative of the economy average working capital shares.



(a) Mean of avg. W/S

(b) Mean of avg. sales

(c) Mean of avg. cash to sales

(d) Mean of avg. short-term debt to S

Figure 5: Time trend of avg. W/S, sales, cash to sales and short-term debt to sales across quartiles of avg. W/S.

Figure 5b does not corroborate the negative correlation between working capital shares and sales to the same degree as it appears in the sample of firms. In the full population, firms that are in the second and third quartile of the working capital shares distribution have the largest sales on average, and firms with the lowest sales seem to also have the lowest working capital shares. This is likely a reflection of the sampling method of Statistics Sweden who select firms to measure and represent industry and aggregate price dynamics and thus selects larger firms on average.

Cash holdings-to-sales ratios do not seem to show a positive correlation with working capital in the population data since Figure 5c depicts that the firms with the largest average cash ratios (1.5-2) are those that have the smallest working capital ratios and firms that have the largest working capital shares have lower cash ratios around one. Short-term debt-to-sales ratios in the population of firms in Figure 5d behave in a similar manner. Firms in the highest and lowest quartiles of the working capital to sales distribution have the largest short-term debt shares around 0.7. In addition, both cash and debt ratios have similar means for firms in the middle two quartiles of the working capital to sales distribution. The depicted relations, therefore, do not support the worry that the main specification, which excludes additional financial control variables, would be biased due to confounding.

Firm-product-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.

The price index data is constructed from a survey of firm-level prices[3]. The observations

[3]The sample of price-reporting firms is drawn from the population of firms with a turnover larger than SEK 10 million (SCB, 2022). 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 sale 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 includes 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

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 is an arithmetically weighted average of the specific firm's price ratios for its 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 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 the UN (2016). The dataset includes multiple HMPI observations for firms that produce in different 2-digit product groups. In the data, 85 % of the 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).

Price changes are defined as log changes in the index. They are multiplied by 100 so that a one percent change appears as one. The summary statistics in Table 1 show that the monthly price changes range between -45 and 45 percent. At longer horizons they range between -10 and 13 percent. The standard deviation of price changes becomes larger at a longer price setting horizon and the average price change becomes increasingly skewed towards more positive price changes.

High-frequency monetary policy shocks In constructing the high-frequency shocks, I follow the procedure by Fransson and Tysklind (2016) and Iversen and Tysklind (2017) who adapt Kuttner's (2001) method to Sweden. I use end-of-day Stina (Stockholm Tomorrow Next Inrabank Average) swaps data, available from 2002, to estimate the shocks. These overnight swaps have the Stibor T/N interest rate as the basis for the floating leg, which in turn is the repo rate

group, i.e. the probabilistic draw is weighted by the value of products sold in the 5-digit HS group (SCB, 2022).

plus a fixed risk premium of 10 basis points. Please note that the shocks are defined daily due to the lack of access to intra-day data for this study. 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 rate 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 Riksbank's monetary policy announcements take place at 9:30 a.m. and I observe changes in the closing Stina rates. The unexpected change in the repo rate is calculated using the following formula

$$\Delta repo_t^{shock} \approx \frac{[t_t^{STINA} - t_{t-1}^{STINA}(\tau_1 + \tau_2) - \Delta repo_t]}{\tau_2 - 1}, \tag{10}$$

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.

The method developed by Gertler and Karadi (2015) is used to calculate a monthly average of the cumulated daily shock which is cumulated over the full sample over all d days. First, a sum of the shocks over the full sample is taken

$$shock_d^{cumulated} = \sum_{s=1}^{d} shock_d. \tag{11}$$

Then, monthly averages are constructed

$$ma_t = \frac{\sum_{d=d_t^1}^{d_t^T} shock_d^{cumulated}}{d_t^T}, \tag{12}$$

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

$$Z_t = ma_t - ma_{t-1}, \tag{13}$$

where Z_t captures the unexpected change in the average policy rate between two subsequent months.

The time-series variation in the high-frequency shocks and repo changes are depicted in Figure 6. Financial market participants are less likely to be surprised by positive changes in the repo rate. For example, shocks are very small during the interest rate hikes in the period between 2006-2008 and 2011-2012. On the other hand, shocks are negative when there is a decrease in the repo rate, indicating that the change in the repo rate seems to be smaller than what financial markets forecast. For example in 2009m12 the HF shock was -.58 whereas the repo rate dropped by -1.1 percentage points. With a back-of-the-envelope calculation, these negative statistics imply a -1.7 change in the Stina rate.

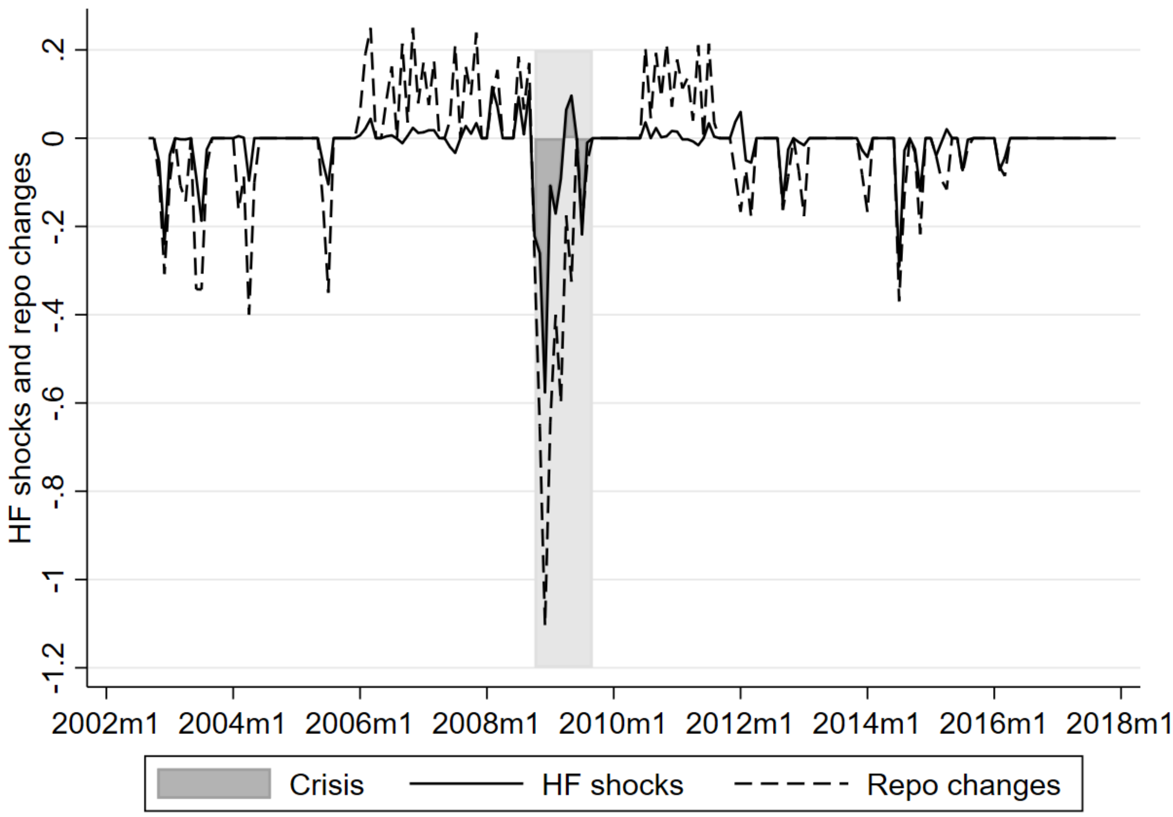


Figure 6: The estimated series of monthly high-frequency shocks and the actual repo rate changes 2002-2017

The summary statistics for the shocks and repo rate changes in Table 2 show that the standard deviation of shocks (0.07) is half of that of the actual repo rate changes (0.16) between a narrow range of -0.58-0.12. A one percentage unit shock may, therefore, show very large outcomes and an average shock of 0.03 percent will have more moderate effects. The Durbin-Watson (DW) statistic of serial correlation is 2 for the HF shocks, implying no serial correlation, whereas actual repo rate changes are positively correlated. The mean of the HF shocks, which is close to zero (-0.01), and the DW statistic of 2 are in line with the popular interpretation that the HF shocks may be viewed as as-good-as random or i.i.d.

Table 2: Summary statistics and autocorrelation of the monetary shocks.

Summary statistics				
	mean	sd	min	max
HF shock	-0.01	0.07	-0.58	0.12
$\lvert$HF shock$\rvert$	0.03	0.07	0.00	0.58
ΔR	-0.03	0.16	-1.11	0.25

Durbin-Watson statistic of serial correlation	
$HFShock = \beta_1 HFShock_{-1} + \epsilon$	2.03
$\Delta R = \beta_1 \Delta R_{-1} + \epsilon$	2.21

5 Results and discussion

The main results, corresponding to the regression specification in equation (9) are presented in Figure 7 and Table 3. A one percentage point monetary policy shock leads to a close to 7 percent price increase after 5 months for a firm whose working capital equals its sales. An average monetary policy shock of 0.03 percentage point increases prices by 0.21 percent via the working capital channel for a firm whose working capital equals its sales.

For the average firm with a 20 percent working capital share, an average monetary policy shock of 0.03 percent yields a 0.04 percent price increase via the working capital channel. The largest positive monetary policy shock of 0.12 percentage point yields a 0.17 percent increase in prices of the firm with an average working capital requirement.

In terms of industry variation, firms in the milling industry with one of the largest average working capital shares of 0.4, this effect is 0.08 percent. Firms producing apparel and accessories, with a working capital share of only 0.1, the pass-through via the working capital channel is 0.002.

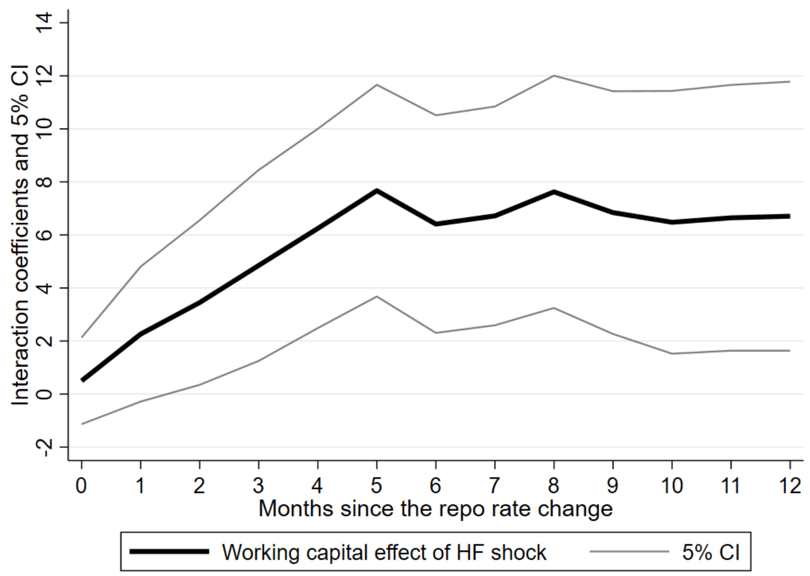


Figure 7: The price effect of a monetary policy shock via the working capital channel.

Table 3: The price effect of a monetary policy shock 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)	p(t+5)-p(t-1)	p(t+6)-p(t-1)
avg W/S×HF shock	0.500	2.263^{+}	3.453*	4.853**	6.246**	7.671***	6.411**
	(0.833)	(1.299)	(1.583)	(1.837)	(1.916)	(2.036)	(2.093)
avg W/S	0.0591	0.170*	0.287**	0.336*	0.444**	0.546**	0.661**
	(0.0437)	(0.0725)	(0.105)	(0.136)	(0.172)	(0.207)	(0.241)
HF shock	0.286^{+}	0.0898	0.271	0.343	0.232	0.515	0.511
	(0.156)	(0.268)	(0.346)	(0.405)	(0.409)	(0.423)	(0.416)
avg S×HF shock	-0.00162	-0.0000213	0.00637	-0.00265	-0.00720	-0.0316	-0.0478
	(0.0145)	(0.0192)	(0.0304)	(0.0383)	(0.0394)	(0.0452)	(0.0481)
Observations	100579	100579	100579	100579	100579	100579	100579
	p(t+7)-p(t-1)	p(t+8)-p(t-1)	p(t+9)-p(t-1)	p(t+10)-p(t-1)	p(t+11)-p(t-1)	p(t+12)-p(t-1)	
avg W/S×HF shock	6.720**	7.626***	6.845**	6.479*	6.648**	6.709**	
	(2.104)	(2.234)	(2.335)	(2.528)	(2.556)	(2.588)	
avg W/S	0.729**	0.766*	0.783*	0.798*	0.805*	0.846*	
	(0.274)	(0.307)	(0.338)	(0.372)	(0.402)	(0.426)	
HF shock	0.793^{+}	0.793^{+}	1.042*	1.382**	1.609***	1.879***	
	(0.431)	(0.437)	(0.449)	(0.473)	(0.481)	(0.497)	
avg S×HF shock	-0.0531	-0.0192	-0.00633	-0.00198	0.00430	-0.00268	
	(0.0621)	(0.0637)	(0.0756)	(0.0673)	(0.0632)	(0.0590)	
Observations	100579	100579	100579	100579	100579	100579	
HS2 product FEs	x	x	x	x	x	x	x
Crisis dummies × Avg W/S	x	x	x	x	x	x	x
Clustered SE (firm)	x	x	x	x	x	x	x

Notes: Standard errors, clustered at the firm level, 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 HF shock and the financial crises dummies for the months of the financial crises between 2008m10-2009m6. Regression specification in equation (9).

Discussion in partial equilibrium The partial equilibrium regression estimates can be contrasted with the theoretical predictions in section 2.1. The theory predicts that after some adjustment time there should be a one-to-one pass-through between monetary policy shocks and prices if the working capital share of firms is one, i.e. if firms borrow their entire variable costs one period in advance. The speed of the price adjustment is pinned down by price stickiness.

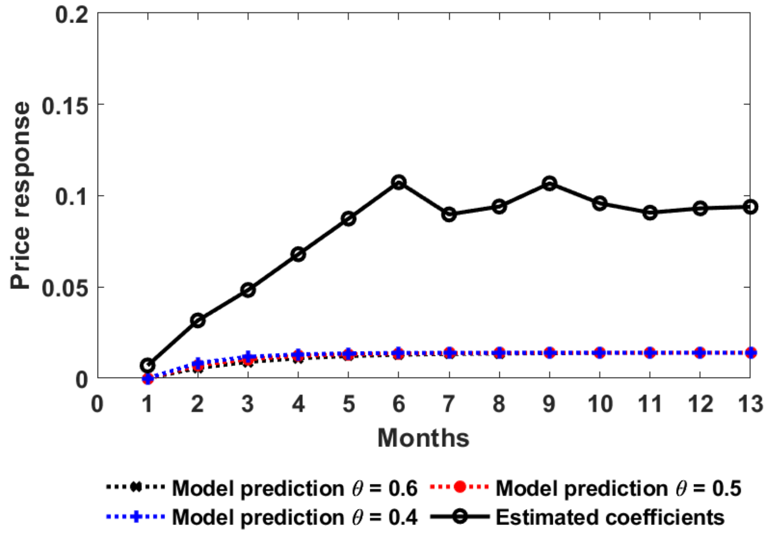


Figure 8: The short-run partial equilibrium price effect of a standard deviation monetary policy shock via the working capital channel. The average working capital share is $\delta = 0.2$.

The estimates reveal that a one percentage point monetary policy shock has a much larger price effect via the working capital channel for a firm with a working capital to sales ratio of one. Namely, prices rise 6 percent after 4 months and level off around 6-7 percent after 5 months via the working capital channel, absent other processes in the economy. The estimated effect is at least 6 times larger relative to the partial equilibrium model predictions.

Figure 8 shows that a standard deviation monetary policy shock of 0.07 percentage point yields an 0.1 percent increase in the price of the representative firms with the average working capital share of 0.2 some time after the shock. In contrast, the model predicts a response much closer to zero.

Discussion in general equilibrium The summary statistic for the working capital share distribution reveals that firms wait around 2 months to get paid, which sets the parameter δ to be 0.66 in a quarterly model. In addition, the coefficient estimates imply that the working capital channel should have a multiplier that is 6 times larger than it currently appears in standard central bank models. Introducing a multiplier $\lambda = 6$ and $\delta = 0.66$ in the model of Christiano, Eichenbaum and Evans (2005) modifies the marginal cost by

$$s_t = \alpha r^k + (1 - \alpha)\ \lambda\ \delta\ (W_t + R_t). \tag{14}$$

Simulating the price response within their general equilibrium model with these modifications yields the impulse responses in Figure 9.

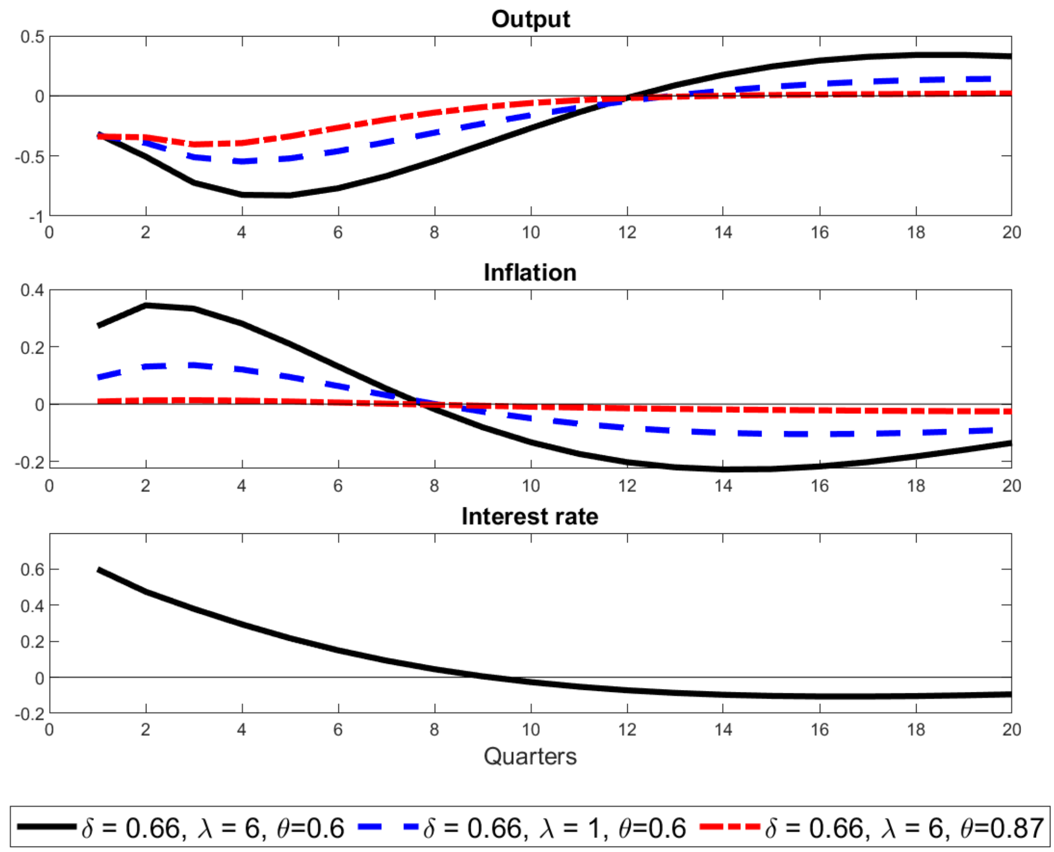


Figure 9: Simulating the working capital channel with pass-through multiplier $\lambda = 6$ and working capital share $\delta = 0.66$ in the general equilibrium model of Christiano, Eichenbaum and Evans (2005).

The calibration with price stickiness $\theta = 0.6$ as in Christiano, Eichenbaum and Evans (2005) is depicted by the blue dashed line. The solid line represents the response that would occur if the working capital pass-through to producer prices was in line with the empirical estimates found in the microdata. The figure shows that both output and inflation produce a much larger hump-shaped response with the empirically consistent working capital channel than what the model produces under the standard calibration. The simulated results imply that prices move strongly in the opposite direction to the intentions of the monetary authority in the short run, and they also drop more in the long run. The cycle in the price response, as well as in the output response, is more pronounced.

The red line depicts that the working capital channel is highly sensitive to the assumed level of price stickiness. Increasing θ from 0.6 to 0.87 almost entirely eliminates the price puzzle and the price response via the working capital channel. The output response through other general equilibrium channels persists even when price stickiness is high.

6 Robustness: parallel trends and financial characteristics

Three sets of robustness checks are implemented in this section. The first investigates whether the parallel trends assumption holds by including past price changes as controls. The second examines whether the estimated coefficient is sensitive to conditioning on observed financial characteristics of the firm. The third tests the sensitivity of the results to the choice of clustering of the standard errors. Table 4 shows an overview of the robustness checks for the 4-month price setting horizon and Figure 10 shows the estimated coefficients for all horizons including the control variables addressing the financial state of the firm.

Column (1) in Table 4 shows the main specification corresponding to equation (9). Implementing two-way clustering of the standard errors in column (2) does not affect the statistical significance of the estimated coefficients.

To account for potential differences in the price trends of high and low working capital firms regression (3) conditions on past price changes. The estimated coefficient increases from 6.2 to 8.5 percent which may indicate a downward bias stemming from the difference in the price trajectories between high and low working capital firms.

Regression (4) includes the interaction term between the firm's average working capital share and the past HF shock. The coefficient is only slightly reduced from 6.2 to 5.5 percent which provides another piece of evidence in favor of viewing the HF shocks as independent over time. To be conservative, columns (5)-(7) retain the control with the lagged HF shock and add shift-share control variables for the firm's observable financial characteristics, such as its average cash-to-sales, short-term debt-to-sales and total variable cost-to-sales ratios. The working capital pass-through coefficient does not change (5.3-5.5).

Table 4: The price effect of a monetary policy shock via the working capital channel

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)	p(t+4)-p(t-1)
avg W/S×HF shock	6.246**	6.246***	8.533***	5.426**	5.486**	5.389**	5.255**		
	(1.916)	(1.498)	(1.915)	(1.873)	(1.879)	(1.890)	(1.889)		
avg W/S	0.444**	0.444***	0.565**	0.486**	0.485**	0.485**	0.485**		0.428*
	(0.172)	(0.0925)	(0.203)	(0.176)	(0.176)	(0.176)	(0.176)		(0.176)
HF shock	0.232	0.232	0.0575	0.215	0.212	0.227	0.857^{+}	0.435	0.630
	(0.409)	(0.299)	(0.405)	(0.402)	(0.403)	(0.405)	(0.474)	(0.317)	(0.463)
avg S×HF shock	-0.00720	-0.00720	-0.0278	-0.0272	-0.0272	-0.0282	-0.0294		-0.0285
	(0.0394)	(0.0324)	(0.0419)	(0.0400)	(0.0400)	(0.0400)	(0.0400)		(0.0401)
avg TVC/S×HF shock					-1.425***	12.08***	-798.6**		-799.6**
					(0.0360)	(1.520)	(301.9)		(300.1)
avg Cash/S×HF shock						-0.00117***	0.0692**		0.0693**
						(0.000131)	(0.0262)		(0.0261)
avg ShortDebt/S×HF shock							-0.000686**		-0.000687**
							(0.000255)		(0.000254)
avg W/S× lag HF shock				5.408***	5.411***	5.412***	5.415***		1.824**
				(0.867)	(0.867)	(0.867)	(0.868)		(0.707)
p(t-1)-p(t-2)			-0.320***						
			(0.0110)						
p(t-2)-p(t-3)			-0.178***						
			(0.00905)						
p(t-3)-p(t-4)			-0.109***						
			(0.00859)						
lag W/S								0.237*	
								(0.0930)	
lag W/S×HF shock								5.027***	
								(1.235)	
lag sales×HF shock								-7.98e-12	
								(2.65e-11)	
crisis=0×avg. W/S×HF shock									6.798***
									(1.877)
crisis=1×avg. W/S×HF shock									-8.486***
									(2.224)
crisis=1									-0.172*
									(0.0784)
Observations	100579	100579	87914	95160	95106	95106	95106	98208	95106
HS2 product FEs	x	x	x	x	x	x	x	x	x
Crisis dummies × Avg W/S	x	x	x	x	x	x	x	x	
Clustered SE (firm)	x		x	x	x	x	x	x	x
Clustered SE (firm×month)			x						

Notes: Standard errors, clustered at the firm level, 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 HF shock and the financial crises dummies for the months of the financial crises between 2008m10-2009m6. Regression specification in equation (9).

Column (8) uses the firm's working capital-to-sales ratio from the year before the price changes are measured. This may be a less robust specification because the past working capital requirement of the firm can be correlated with its current working capital requirement, which, in turn, may be driven by aggregate trends in demand and supply. Despite a more likely estimation bias via supply and demand shocks, the coefficient estimate remains around 5 percent.

Specification (9) tests whether the estimated coefficient differs during and outside of the crisis period. The coefficient during non-crisis times is 6.8 percent whereas during the crisis it is -8.5 percent. Considering that there are large negative outliers in the shock series during the crisis, these large shocks may be correlated with other large shifts in the economy. It is, therefore, unclear whether the large negative coefficient represents an unbiased estimate or simply a spurious correlation. For example, Barth and Ramey (2001) claim that a strong negative correlation may be detected if firms with large inventories find it optimal to decrease their prices during crisis times with the purpose of getting rid of their inventory costs and improving cash flows. This would create a spurious correlation between large negative monetary policy shocks and the price setting of firms with higher average working capital holdings. It is nevertheless interesting to observe that firms with higher working capital shares seem to decrease their prices during a recession, but it is not supportive of the causal claim that the ”working capital is flipped” during crises.

The coefficient estimates over 12 horizons using the main specification and specification (7) in Table 4 are depicted in Figure 10. The comparison is an attempt to highlight that cash holding, short-term debt and total variable cost ratios seem to represent independent channels to that of the working capital channel because the working capital pass-through estimates remain around 6 percent. The next section investigates whether there is heterogeneity in the working capital channel based on firms' financial characteristics. For example, if the liquidity channel (Gilchrist et al., 2017) is important, firms with high and low cash ratios would have a different working capital pass-through coefficients.

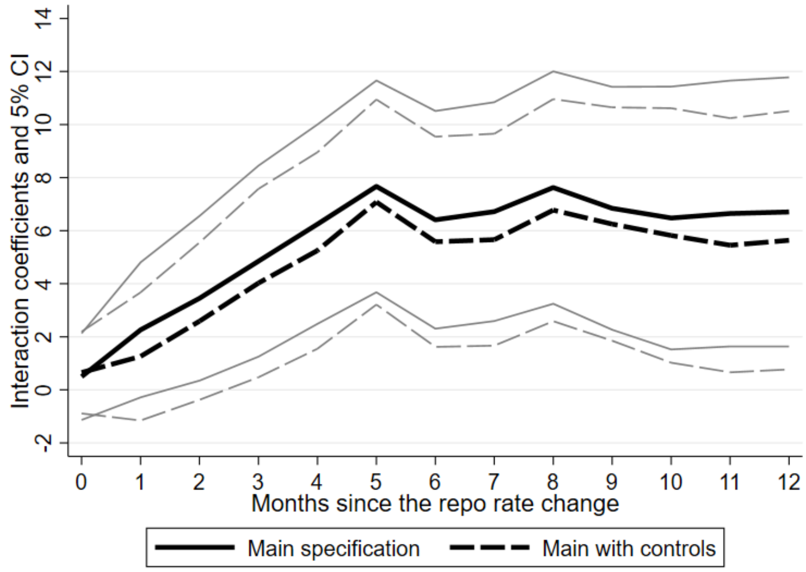


Figure 10: The solid curve shows the main specification corresponding to equation (9) and the dashed curve exhibits the main regression with additional shift-share control variables. The control variables include the interaction between the HF shock and the average cash-to-sales ratio, the average short-term debt-to-sales ratio, the average total variable cost-to-sales ratio, and the interaction between the average working capital-to-sales ratio and the lag HF shock from the month before (t-2). The corresponding table to the regression specification with controls is included in Appendix 6.

7 Heterogeneity: liquidity and financial channels

Table 5 shows four specifications that aim to elicit whether the working capital channel affects the firms in the economy in different ways depending on their financial characteristics. Dividing firms into two groups, those above and below the 50th percentile of their average cash, short-term debt and total variable cost ratio within the 2-digit product group, I designate firms into the ’high’ and ’low’ groups.

Table 5: The price effect of a monetary policy shock via the working capital channel

	(1) p(t+4)-p(t-1)	(2) p(t+4)-p(t-1)	(3) p(t+4)-p(t-1)	(4) p(t+4)-p(t-1)
low avg Cash/S×avg W/S×HF shock	6.763***			
	(2.041)			
high avg Cash/S×avg W/S×HF shock	5.208*			
	(2.262)			
avg Cash/S×HF shock	-0.000127***			
	(0.00000779)			
low avg ShortDebt/S×avg W/S×HF shock		6.702**		
		(2.053)		
high avg ShortDebt/S×avg W/S×HF shock		5.239*		
		(2.321)		
avg ShortDebt/S×HF shock		-0.000000887		
		(0.00000237)		
low TVC/S×avg W/S×HF shock			6.924***	
			(2.051)	
high TVC/S×avg W/S×HF shock			5.506*	
			(2.202)	
avg TVC/S×HF shock			-1.410***	
			(0.0388)	
low avg S×avg W/S×HF shock				6.617***
				(1.973)
high avg S×avg W/S×HF shock				4.816+
				(2.748)
avg S×HF shock	-0.00674	-0.00415	-0.00935	0.00133
	(0.0395)	(0.0393)	(0.0395)	(0.0399)
avg W/S	0.441*	0.442*	0.442*	0.443**
	(0.172)	(0.172)	(0.172)	(0.172)
HF shock	0.232	0.215	0.248	0.226
	(0.410)	(0.411)	(0.412)	(0.409)
Observations	100579	100579	100522	100579
HS2 product FEs	x	x	x	x
Crisis dummies × Avg W/S	x	x	x	x
Clustered SE (firm)	x	x	x	x

Notes: Standard errors, clustered at the firm level, 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 HF shock and the financial crises dummies for the months of the financial crises between 2008m10-2009m6.

While there is an economically significant difference between the high and low groups of firms in columns (1)-(3), all coefficient estimates for the high and low groups lie within the 5 percent confidence interval of the main estimates. What the regressions in columns (1)-(3) confirm with certainty is that the pass-through of the working capital channel seems to be a strong channel across all firms in the economy, and there are small differences between firms with higher cash holding, short term debt and total variable cost ratios relative to firms with low ratios.

Column (1) of Table 5 shows that firms that have relatively higher cash ratios seem to be less affected by the working capital channel and increase their prices by 1.5 percent less. This finding supports theories where firms with more access to liquid assets set prices differently, e.g. Gilchrist et al. (2017). Columns (2) and (3) depict a similar pattern where firms with higher short-term debt and total variable cost ratios seem to pass monetary policy shocks through to prices via the working capital channel to a lesser degree. This finding is puzzling and shows the opposite effect to the liquidity channel. Policy rate changes should affect firms that borrow more and have larger variable cost ratios to a higher degree, but the estimated coefficients indicate otherwise.

Column (4) investigates whether firm size, measured by the volume of average sales, impacts the working capital channel. Low-sales firms have a larger and more significant pass-through coefficient. These estimates may reflect the mechanical correlation in the data that some of the largest firms have the lowest working capital shares as depicted in Figure 4a.

8 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 quarter 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. The focus of this paper is to test these predictions using a unique firm-product-level price index and firm-level balance sheet data on Swedish firms.

High-frequency shocks are used in a shift-share framework to examine the pass-through of monetary policy shocks to producer prices via the working capital channel. In the main specification, a one percentage point high-frequency shock leads to a 6.3 (6.9) 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 price increase following the monetary policy shock levels off around 6-7 percent for a firm with a working capital-to-sales ratio of one after approximately 4 months. This is a much larger coefficient estimate than the model predictions from the partial equilibrium model. This result implies that the working capital channel seems to be about 6 times stronger than it is used in standard central bank models. If the general equilibrium model was to be calibrated using the micro estimates the short-run price puzzle would appear much larger and output and prices would demonstrate larger hump-shaped swings.

A Appendix

A.1 The firm's price setting equation

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

$$Y_{i,t} = A_t N_{i,t}, \tag{15}$$

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

$$max_{P^*_{i,t}} \sum_{k=0}^{\infty} \theta^k E_t \Big\{ Q_{t,t+k} \Big(\frac{1}{P_{t+k}} \Big) \big(P^*_{i,t} Y_{i,t+k|t} - TC^n_{i,t+k|t}(Y_{i,t+k|t}) \big) \Big\} \tag{16}$$

subject to the sequence of firm-specific demand constraints

$$Y_{i,t+k|t} = \Big(\frac{P^*_{i,t}}{P_{t+k}} \Big)^{-\epsilon} C_{i,t+k}. \tag{17}$$

Equation (16) 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 (17) 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

$$\sum_{k=0}^{\infty}\theta^k E_t\Big\{Q_{t,t+k}Y_{i,t+k|t}\Big[(\epsilon-1)-\epsilon\frac{MC^n_{i,t+k|t}}{P^*_{i,t}}\Big]\Big\}=0. \tag{18}$$

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 (18) can be rearranged in the following way

$$\sum_{k=0}^{\infty}\theta^k E_t\Big\{Q_{t,t+k}Y_{i,t+k|t}\Big[\Pi^*_{i,t}-\mathcal{M}MC^r_{i,t+k|t}\Pi_{t+k,t}\Big]\Big\}=0 \tag{19}$$

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

$$\bar{\Pi}_i\frac{ln\Pi^*_{i,t}-ln\bar{\Pi}_i}{1-\beta\theta}-\sum_{k=0}^{\infty}(\theta\beta)^k E_t\Big\{\mathcal{M}\bar{MC}^r_i\Big[lnMC^r_i-\bar{MC}^r_i+ln\Pi_{t+k,t-1}-0\Big]\Big\}=0. \tag{20}$$

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

$$p^*_{i,t}-p_{i,t-1}-\bar{\pi}_i=(1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t\Big\{mc^n_{i,t+k|t}-p_{t+k}-\bar{mc}^n_i+p_{t+k}-p_{i,t-1}\Big\}. \tag{21}$$

Using the steady-state condition that $\bar{\pi}_i=ln\mathcal{M}+\bar{mc}^r_i$, it is possible to simplify (21) as

$$p^*_{i,t}=\mu+(1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t[mc^n_{i,t+k|t}], \tag{22}$$

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 (22) 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

$$p_{t+k} - p_{t-1} = (1-\theta^{k+1})(p_{t-1}^* - p_{t-1} + \delta\epsilon_t). \tag{23}$$

A.3 Financial shift-share control variables

Table 6: The price effect of a monetary policy shock 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	0.0868*	0.204**	0.268*	0.331*	0.485**
	(0.0426)	(0.0736)	(0.105)	(0.139)	(0.176)
HF shock	-0.161	-0.0621	0.441	1.007*	0.857^{+}
	(0.279)	(0.356)	(0.349)	(0.482)	(0.474)
avg W/S×HF shock	0.655	1.262	2.591^{+}	4.028*	5.255**
	(0.787)	(1.232)	(1.513)	(1.812)	(1.889)
avg S×HF shock	-0.00443	-0.0185	-0.0213	-0.0234	-0.0294
	(0.0110)	(0.0207)	(0.0290)	(0.0373)	(0.0400)
avgtvctosales×HF shock	581.8^{+}	375.4	-164.9	-896.7**	-798.6**
	(342.2)	(334.1)	(141.4)	(343.9)	(301.9)
avgcashtosales×HF shock	-0.0506^{+}	-0.0327	0.0142	0.0778**	0.0692**
	(0.0297)	(0.0290)	(0.0123)	(0.0299)	(0.0262)
avgshdebttosales×HF shock	0.000491^{+}	0.000311	-0.000149	-0.000770**	-0.000686**
	(0.000289)	(0.000283)	(0.000120)	(0.000291)	(0.000255)
avg W/S×L.HF shock	-0.634	1.567*	3.021***	3.390***	5.415***
	(0.661)	(0.705)	(0.769)	(0.792)	(0.868)
Constant	0.100***	0.208***	0.327***	0.439***	0.539***
	(0.00857)	(0.0151)	(0.0219)	(0.0289)	(0.0364)
Observations	95106	95106	95106	95106	95106

	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	0.629**	0.753**	0.822**	0.843**	0.887*
	(0.213)	(0.247)	(0.281)	(0.313)	(0.346)
HF shock	0.679	0.583	1.056*	0.923^{+}	1.493**
	(0.444)	(0.450)	(0.459)	(0.471)	(0.525)
avg W/S×HF shock	7.081***	5.584**	5.662**	6.776**	6.251**
	(1.972)	(2.022)	(2.038)	(2.135)	(2.244)
avg S×HF shock	-0.0459	-0.0573	-0.0531	-0.0170	0.00409
	(0.0482)	(0.0504)	(0.0635)	(0.0662)	(0.0757)
avgtvctosales×HF shock	-319.3*	-293.2	-543.0***	-495.6**	-863.3**
	(124.5)	(188.7)	(143.2)	(166.3)	(317.3)
avgcashtosales×HF shock	0.0276*	0.0254	0.0470***	0.0429**	0.0749**
	(0.0108)	(0.0164)	(0.0124)	(0.0144)	(0.0276)
avgshdebttosales×HF shock	-0.000281**	-0.000257	-0.000469***	-0.000430**	-0.000744**
	(0.000105)	(0.000160)	(0.000121)	(0.000141)	(0.000268)
avg W/S×L.HF shock	3.609***	5.271***	5.960***	6.659***	7.586***
	(1.032)	(1.096)	(1.164)	(1.231)	(1.311)
Constant	0.637***	0.737***	0.853***	0.975***	1.089***
	(0.0439)	(0.0508)	(0.0577)	(0.0645)	(0.0714)
Observations	95106	95106	95106	95106	95106

	p(t+10)-p(t-1)	p(t+11)-p(t-1)	p(t+12)-p(t-1)
avg W/S	0.885*	0.936*	0.963*
	(0.379)	(0.405)	(0.432)
HF shock	1.597**	1.584**	1.421*
	(0.514)	(0.524)	(0.638)
avg W/S×HF shock	5.822*	5.453*	5.639*
	(2.448)	(2.444)	(2.484)
avg S×HF shock	0.0128	0.0121	0.00156
	(0.0679)	(0.0638)	(0.0607)
avgtvctosales×HF shock	-564.5**	-197.0	341.2
	(172.9)	(237.8)	(532.8)
avgcashtosales×HF shock	0.0490**	0.0171	-0.0296
	(0.0150)	(0.0206)	(0.0463)
avgshdebttosales×HF shock	-0.000492***	-0.000180	0.000273
	(0.000146)	(0.000201)	(0.000451)
avg W/S×L.HF shock	8.778***	10.08***	10.18***
	(1.332)	(1.373)	(1.438)
Constant	1.212***	1.322***	1.432***
	(0.0782)	(0.0835)	(0.0892)
Observations	95106	95106	95106

Notes: Standard errors, clustered at the firm level, 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

References

Adolfson, M., S. Laséen, L. Christiano, M. Trabandt, and K. Walentin, "Ramses II - Model Description," Technical Report, Sveriges Riksbank 2013.

Barth, III Marvin J. and Valerie A. Ramey, "The Cost Channel of Monetary Transmission," *NBER Macroeconomics Annual*, 2001, *16* (1), 184–240.

Bernanke, Ben S., Jean Boivin, and Piotr Eliasz, "Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach," *The Quarterly journal of economics*, 2005, *120* (1), 387–422.

Borusyak, Kirill, Peter Hull, and Xavier Jaravel, "Quasi-Experimental Shift-Share Research Designs," *The Review of economic studies*, 2022, *89* (1), 181–213.

Chodorow-Reich, Gabriel, Olivier Darmouni, Stephan Luck, and Matthew Plosser, "Bank liquidity provision across the firm size distribution," *Journal of financial economics*, 2022, *144* (3), 908–932.

Chowdhury, Ibrahim, Mathias Hoffmann, and Andreas Schabert, "Inflation dynamics and the cost channel of monetary transmission," *European Economic Review*, 2006, *50* (4), 995–1016.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 2005, *113* (1), 1–45.

Duca, Ioana A, José M Montero, Marianna Riggi, and Roberta Zizza, "I will survive. Pricing strategies of financially distressed firms.," *European Central Bank Working Paper Series*, June 2018, (2164).

Fransson, L. and O. Tysklind, "The effects of monetary policy on interest rates," *Sveriges Riksbank Economic Review*, 2016, *2016:1.*

Gaiotti, Eugenio and Alessandro Secchi, "Is There a Cost Channel of Monetary Policy Transmission? An Investigation into the Pricing Behavior of 2,000 Firms," *Journal of Money, Credit and Banking*, 2006, *38* (8), 2013–2037.

Gertler, Mark and Peter Karadi, "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 2015, *7* (1), 44–76.

Gilchrist, S., R. Schoenle, J. Sim, and E. Zakrajsek, "Inflation Dynamics during the Financial Crisis," *AMERICAN ECONOMIC REVIEW*, 2017, *107* (3), 785–823.

Gilchrist, Simon and Egon Zakrajšek, "Credit Spreads and Business Cycle Fluctuations," *The American Economic Review*, 2012, *102* (4), 1692–1720.

Hanson, Michael S., "The "price puzzle" reconsidered," *Journal of monetary economics*, 2004, *51* (7), 1385–1413.

Iversen, J. and O. Tysklind, "The effect of repo rate path changes on asset prices," Technical Report, Sveriges Riksbank 2017.

Konjunkturinstitutet, "Fördjupning i Konjunkturläget," Technical Report December 2009.

Kumar, Saten, Yuriy Gorodnichenko, and Olivier Coibion, "The Effect of Macroeconomic Uncertainty on Firm Decisions," Working Paper 30288, National Bureau of Economic Research July 2022.

Kuttner, Kenneth N., "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market," *Journal of Monetary Economics*, 2001, *47* (3), 523–544.

Lundgren, Gustaf, "Enkätbaserade inflationsförväntningar," Technical Report 7 May 2021.

OECD, "OECD Data: Inflation," Technical Report, OECD 2019.

Ravenna, Federico and Carl E. Walsh, "Optimal monetary policy with the cost channel," *Journal of Monetary Economics*, 2006, *53* (2), 199–216.

Renkin, T and G Zuellig, "Credit supply shocks and prices: Evidence from Danish firms," *Working Paper*, 2022.

Òscar Jordà, "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, March 2005, *95* (1), 161–182.

SCB, "Quality declaration: Producer and Import Price Index (PPI)," Technical Report, Statistics Sweden 2018.

_ , "Statistical database: GDP: expenditure approach (ESA2010) by type of use, seasonally adjusted. Quarter 1980K1 - 2018K3," Technical Report, Statistics Sweden 2019.

_ , "Production of the statistic: Producer and Import Price Index," Technical Report 2022.

Sims, Christopher A., "Interpreting the macroeconomic time series facts: The effects of monetary policy," *European economic review*, 1992, *36* (5), 975–1000.

Stephen, Fernandez-Corugedo Emilio Groth Charlotta Harrison Richard Monti Francesca Theodoridis Konstantinos Waldron Matt Burgess, "The Bank of England's forecastingplatform: COMPASS, MAPS, EASEand the suite of models," *Bank of England Working Paper Series*, May 2013, (471).

Sufi, Amir, "Bank Lines of Credit in Corporate Finance: An Empirical Analysis," *The Review of financial studies*, 2009, *22* (3), 1057–1088.

Tillmann, Peter, "Do interest rates drive inflation dynamics? An analysis of the cost channel of monetary transmission," *Journal of Economic Dynamics and Control*, 2008, *32* (9), 2723–2744.

_ , "The time-varying cost channel of monetary transmission," *Journal of International Money and Finance*, 2009, *28* (6), 941–953.

UN, "HS 2002 Classification by Section," Technical Report 2016.

Vesna, Strid-Ingvar Corbo, "MAJA: A two-region DSGEmodel for Sweden and its maintrading partners," Technical Report 2020.