Prices and Monetary Policy: The Role of Financial Constraints*

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Abstract

Firm heterogeneity in financial constraints is a quantitatively important driver of how monetary policy transmits to inflation. Using detailed microdata on Swedish public and private firms, and high-frequency monetary policy surprises around Riksbank announcements, we document that smaller, financially constrained firms adjust prices significantly less than larger firms in response to changes in monetary policy. This heterogeneous price response materially dampens the aggregate PPI inflation response to monetary policy. Models of customer markets and financial frictions can explain our findings: because the external finance premium rises after a monetary contraction, constrained firms cut prices less to preserve cash flows, sacrificing future market share. Additional evidence on heterogeneous sales, debt, marginal cost, and markup responses further supports this channel. We consider several alternative explanations, including differences in price adjustments, working capital, market share, and export share, but these cannot rationalize our main heterogeneity result.

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JEL: E31, E32, E52, G32, L11.

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1 Introduction

The recent global inflationary episode of 2021–2023 has renewed attention to the ability of monetary policy to control inflation. A thorough understanding of monetary transmission requires detailed micro-level empirical analysis, and a growing body of evidence has shed light on how individual firms respond to monetary policy changes, mainly focusing on heterogeneity due to financial constraints. Yet while the role of financial constraints has been studied extensively for the firm-level response of investment, employment, sales, and other outcomes, little is known about how they affect the price-setting of firms.[1] Using detailed microdata and high-frequency monetary policy surprises from Sweden, this paper provides the first systematic evidence on the role of financial constraints in shaping firm-level price responses to monetary policy shocks, and shows that this heterogeneity matters quantitatively for aggregate inflation dynamics.

We estimate the effects of monetary policy on firm-level prices following the monetary economics literature on high-frequency identification (e.g., Gürkaynak et al., 2005; Bauer and Swanson, 2023). The surprise component of Swedish monetary policy is measured as changes in short-term interest rates around Riksbank monetary policy announcements. To validate our Riksbank surprises and establish baseline results, we estimate their effects on financial asset prices using event studies as well as their dynamic effects on aggregate macroeconomic variables using Jordà (2005) local projections. Both exercises yield responses that are in line with the textbook prediction and standard empirical estimates: A surprise monetary policy tightening leads to an increase in interest rates across maturities, an appreciation of the Swedish currency, and a persistent and significant decline in aggregate demand and prices.

Our empirical analysis leverages the unique advantages of Swedish government statistics for the corporate sector. We construct a comprehensive product- and firm-level panel dataset, which combines the microdata underlying the Swedish Producer Price Index (PPI) with administrative data on financial statements from a large sample of public and private firms.

The price data are the product-level producer prices in the PPI, based on a representative sample of products within the manufacturing sector constructed by Statistics Sweden (SCB). The data cover the period from 2001 to 2023 and contain close to 340,000 month-product price observations from almost 4,400 unique products, produced by about 2,200 unique firms. We validate the micro-level price data by aggregating them into an inflation series that closely

[1] Existing papers have studied the role of financial constraints for the transmission of monetary policy to firm-level investment (e.g., Ottonello and Winberry, 2020; Cloyne et al., 2023; Jeenas, 2026), borrowing behavior, employment, sales and stock prices, among other outcome variables. Studies of the role of financial constraints for the price-setting of firms, such as Gilchrist et al. (2017) and Renkin and Züllig (2024), generally focus on financial shocks and the Great Financial Crisis.

tracks aggregate PPI inflation. The dynamic response of inflation to a monetary policy shock is negative and hump-shaped, with a trough at about the two-year horizon. The impulse responses from product-level panel regressions and aggregate PPI time series regressions are broadly similar in both magnitude and persistence.

A distinctive feature of the Swedish setting is the availability of administrative firm-level data from the credit bureau Upplysningscentralen and the Companies Registration Office. These data include financial statements and sales, and they uniquely identify firms, enabling precise matching with product prices. We merge the product-level price data with yearly firm-level financials to construct commonly-used measures of financial constraints: size, age, leverage, and liquidity. The firm-level data cover a large portion of the universe of Swedish firms, crucially including privately held firms, which substantially increases coverage relative to studies that rely on Compustat data on public firms. Private firms tend to be smaller, more reliant on bank financing, and more likely to face binding financial constraints, with important implications for their response to monetary policy.

Our main analysis provides cross-sectional evidence on the role of financial constraints in the transmission of monetary policy to prices. We estimate panel local projections for the response of product-level prices to monetary policy shocks, conditional on standard proxies for financial constraints. Our central result is that the price response to monetary policy depends on firm size: smaller firms exhibit a significantly more muted price decline, and this heterogeneity is both statistically and economically significant. In response to a 25 basis point tightening surprise, firms one standard deviation below average size lower their prices by roughly a quarter less than the average firm. Splitting the price observations into quartiles based on firm size, we find that the price responsiveness of firms in the top quartile is roughly twice as large as for firms in the bottom quartile. This muted response of constrained firms is striking given that financial frictions are known to *amplify* the firm-level investment response to monetary policy (Cloyne et al., 2023; Jeenas, 2026).

This firm-level heterogeneity is quantitatively relevant for aggregate inflation. Products sold by small firms constitute a non-negligible share of the aggregate PPI, and their prices respond about half as much to monetary policy. Two counterfactual scenarios show that if more firms responded like large, financially unconstrained firms, the aggregate PPI effects of changes in monetary policy would be 14–34% larger.

In addition to size, we also consider other common measures of financial constraints: age, leverage, and liquidity. We find no meaningful differences in the price response conditional on these other measures. These findings suggest that size is the best available proxy for financial constraints in our context, consistent with earlier literature on measurement of financial constraints (Gertler and Gilchrist, 1994; Oliner and Rudebusch, 1996; Hadlock and Pierce, 2010).

Our results survive a battery of robustness checks. In particular, they are robust to including more narrowly defined sector-by-time fixed effects, which absorb any industry-level differences in demand elasticity, cost pass-through, or exposure to sector-specific shocks. Under this more demanding specification, the size interaction remains large and significant while the estimated heterogeneities for age, leverage, and liquidity are essentially flat. Our findings are further robust to estimating a non-linear interaction between measures of financial constraints and monetary policy shocks, excluding the recent high inflation period by ending the sample in December 2020, and controlling for the interaction of monetary policy with various other firm-level characteristics like export share and market share.

The muted price response of smaller firms to monetary policy shocks is consistent with theoretical models of customer markets and financial frictions such as Gottfries (1991), Chevalier and Scharfstein (1996), and Gilchrist et al. (2017). In these models, the customer base for a given product is sticky—due to deep habits, adjustment costs, or search frictions—and therefore becomes an investment asset for the firm. By setting a lower price today, a firm can attract customers and increase future market shares and profits at the expense of lower profits today. Hence there is a trade-off between investing in the customer base and maintaining current cash flows. A monetary contraction implies lower demand and higher costs of finance, and both effects reduce current profits for a given price. Smaller, more constrained firms face a larger increase in the external finance premium (e.g., Gertler and Karadi, 2015; Anderson and Cesa-Bianchi, 2024), reducing their ability to invest in their customer base. As a consequence, we expect smaller firms to lower prices less and therefore to lose market share and future sales.

In support of this explanation, we provide several additional pieces of evidence. While smaller firms cut prices less after a tightening, their sales indeed fall by more than the sales of larger firms, consistent with a loss of customer base and market share. Small firms in our data also tend to have a higher share of bank debt, pledge more collateral, be closer to their borrowing constraints on credit lines, and have a higher default probability. Their debt also falls significantly more after a tightening, consistent with stronger effects of monetary policy on the external finance premium for smaller firms. When we combine the muted price response with the larger sales decline, we find that the sacrifice ratio for smaller firms is roughly five times that of larger firms, implying a significantly less favorable output-inflation trade-off for monetary policy.

We consider several alternative explanations related to other size-related firm characteristics. According to the working capital channel of Christiano and Eichenbaum (1992) and Christiano et al. (2015), differences in working capital can lead to heterogeneous effects of monetary policy across firms. If small firms rely more heavily on working capital financing, then this could explain their muted price response without any role for customer markets and financial frictions. We investigate this possibility empirically and find no evidence for the working capital channel in our data. In addition, we consider the role of firms' market share and export share. While these characteristics are positively correlated with firm size, the size heterogeneity in the price response remains essentially unchanged when we control for them, confirming that size captures financial constraints rather than other firm characteristics that matter for price setting.

A natural alternative is that smaller firms use less sophisticated pricing strategies, e.g., due to rational inattention or coarser price-setting policies. We find no support for this in our data. Small and large firms adjust prices with the same frequency and by similar magnitudes, and their group-specific impulse responses share the same dynamic shape, just with smaller magnitude for small firms. These patterns suggest that the heterogeneous price response to monetary policy is not a reflection of how often or by how much small and large firms typically adjust prices.

Direct evidence on the heterogeneous response of costs and margins further supports our interpretation based on customer markets and financial frictions. We document that the marginal costs of smaller firms respond more strongly to monetary policy than those of larger firms, while a cost-based explanation of our results would require the opposite. This finding implies that the weaker price response of small firms reflects differential markup adjustment: small firms compress markups less, or even raise them, in response to a monetary tightening. Following Renkin and Züllig (2024), we provide direct evidence using gross profit margins as a proxy for markups. After a monetary tightening, the gross margin of smaller firms rises substantially relative to that of larger firms. Constrained firms thus appear to preserve cash flows by maintaining markups rather than investing in their customer base.

Our paper makes two main contributions to the empirical literature in monetary economics. First, we show that financial frictions affect the transmission of monetary policy to prices. Previous studies, including Gilchrist et al. (2017) and Renkin and Züllig (2024), have documented that financially constrained firms set relatively higher prices than unconstrained firms following financial shocks, such as the credit crunch of the Great Financial Crisis. Our evidence demonstrates that this heterogeneity is not confined to episodes of financial stress but operates as part of standard monetary transmission.

Second, while previous studies have generally found that financial frictions *amplify* the firm-level investment response to monetary policy, we document the opposite for prices: financial frictions *dampen* the price response. This result implies that financial frictions impede the transmission of monetary policy to inflation, because the price response of constrained firms is significantly muted. Because they magnify the investment response but mute the inflation response, financial frictions also influence the monetary policy trade-off between price and output stabilization. As noted above, the sacrifice ratio for small firms is materially larger than that for large firms. Both the impediment to monetary policy effectiveness and the impact on the output-inflation trade-off are likely exacerbated during times of financial distress, when the external finance premium rises and financial frictions become more severe.[2]

Our paper is related to a large literature on the role of financial frictions in the transmission of monetary policy. A number of papers have shown that proxies for financial frictions at the firm level—including age (Cloyne et al., 2023), leverage (Ottonello and Winberry, 2020; Durante et al., 2022), debt structure (Jungherr et al., 2024), and liquidity (Jeenas, 2026)—are related to the strength of the firm-level investment response to monetary policy. These papers generally find that more constrained firms adjust their investments relatively *more* compared to less constrained firms in response to changes in monetary policy.[3] Other related work has studied the heterogeneous effects of monetary policy on borrowing behavior (Oliner and Rudebusch, 1996), employment (Bahaj et al., 2022), sales (Gertler and Gilchrist, 1994), and stock prices (Ippolito et al., 2018; Ozdagli, 2018; Ozdagli and Velikov, 2020; Gürkaynak et al., 2022). Aruoba and Drechsel (2024) document substantial heterogeneity in the price response to monetary policy across disaggregated U.S. consumer price categories and speculate that heterogeneous financial constraints may explain it. We extend this literature to the differential price response, documenting a more muted price response of constrained firms to monetary policy that is consistent with models of customer markets and financial frictions.[4] More generally, our results bear on the debate over whether firm size proxies for financial constraints (Crouzet and Mehrotra, 2020). The differential price, sales, and debt responses we document are jointly consistent with size capturing constraints rather than other firm characteristics.

As mentioned above, a closely related strand of the literature studies how financial frictions influence pricing behavior. The closest predecessor is Gilchrist et al. (2017), who study the response of pricing decisions by publicly listed U.S. firms to the credit crunch during the Great Financial Crisis (GFC). Their main finding is that high-liquidity firms lowered prices

[2]This channel is not present in conventional monetary models with financial frictions, e.g., Bernanke et al. (1999), where changes in the cost of external finance affect only investment.

[3]A notable exception is Ottonello and Winberry (2020), who find that the investment of financially constrained firms is less responsive to monetary policy. They argue that the difference between their results and, e.g., Jeenas (2026) is mainly driven by the fact that they consider within-firm changes in financial constraints over time, while Jeenas compares permanent differences across firms.

[4]Kim and Park (2024) find that firms with higher levels of short-term debt exhibit a stronger price response to a credit shock or change in monetary policy, in contrast with our results. Core et al. (2025) show that firms with a higher share of floating rate debt keep prices more elevated in response to the ECB's tightening over the period from 2021 to 2023.

in response to the credit shock, while low-liquidity firms actually raised theirs. Renkin and Züllig (2024) study the price-setting behavior of Danish manufacturing firms during the GFC. Using product-level price data merged with data on bank lending relationships, they show that firms that borrowed from banks that were more severely affected by the GFC experienced a relatively larger fall in loan supply and set relatively higher prices. Gilchrist et al. (2023) provide similar evidence for the euro area during the GFC.[5] Gilchrist and Zakrajšek (2016) show that financial frictions also influence the price-setting response to credit spread variation, using the size-age measure of financial constraints proposed by Hadlock and Pierce (2010). We complement their work by focusing specifically on the transmission of monetary policy, using exogenous high-frequency surprises and product-level price data covering private firms.

The rest of the paper is structured as follows. Section 2 describes the construction of our Riksbank monetary policy surprises and empirically evaluates the effect of the surprises on Swedish financial markets and macroeconomic variables. Section 3 describes our microdataset, presents our new estimates of the effects of Swedish monetary policy shocks on product-level producer prices, and documents our key result on the role of firm size in the heterogeneous price-setting response. Section 4 interprets our main results through a model of customer markets and financial frictions, provides direct evidence that firm size proxies for financial constraints in our sample, and tests the mechanism using firm-level sales, borrowing, marginal costs, and markups. Section 5 concludes.

2 Riksbank Policy Surprises and Aggregate Effects

In this section, we present a new measure of monetary policy surprises for Sweden based on rate changes around Riksbank policy announcements. We then use this measure to estimate the response of asset prices and macroeconomic aggregates to unexpected changes in the Riksbank's monetary policy.

2.1 Construction of Monetary Policy Surprises

Our analysis focuses on the Riksbank's monetary policy over the period from 2001 to 2023. During this period, the Riksbank has pursued a 2 percent inflation target and a flexible exchange rate regime. The Executive Board of the Riksbank meets at regular intervals to decide on monetary policy and announces its decision on the day after each meeting. The

[5] In contrast, Kim (2021) finds that U.S. consumer-goods producers hit by GFC bank shocks *lowered* prices through an inventory-liquidation channel.

decision includes a numerical value for the Riksbank policy rate, which serves as a target for rates on overnight interbank lending and directly impacts other short-term interest rates, including repo rates. In addition, the Riksbank provides information about the outlook for the Swedish economy and the future course of monetary policy. Until 2006, the announcements included a discussion of the economic outlook and inflation assessment, with qualitative language about the likely direction of the policy path. Since 2007, the Riksbank has published forecasts of the policy rate path, providing quantitative forward guidance. These are published in the Monetary Policy Report, currently released four times a year with the policy decision. The number of policy decisions has varied between five and nine per year during our sample period, and our sample contains a total of 149 Riksbank announcements.

Following common practice in monetary economics (Kuttner, 2001; Gürkaynak et al., 2005), we estimate exogenous variation in Swedish monetary policy using high-frequency changes in interest rates around the Riksbank's policy announcements. Such "monetary policy surprises" reflect new information about the current stance and future course of monetary policy. They can therefore be plausibly considered as predetermined with respect to current financial and economic conditions, enabling event-study analysis of financial market effects and impulse-response estimation of monetary transmission (Bauer and Swanson, 2023).

Our calculation uses daily changes in the closing prices of Forward Rate Agreement (FRA) contracts on monetary policy announcement dates. FRA contracts are tied to short-term interest rates and therefore reflect market-based expectations of future Riksbank policy rates.[6] We include FRA contracts with maturities of three, six, nine, and twelve months ahead (FRA1-FRA4). We then follow the common approach of taking the first principal component of individual rate changes to construct a univariate monetary policy surprise that summarizes both policy rate surprises and forward guidance news contained in the policy announcement (Nakamura and Steinsson, 2018; Bauer and Swanson, 2023; Acosta et al., 2025). The principal component is normalized so that a one-unit change corresponds to a 1 percentage point change in the FRA4 rate, i.e., the fourth quarterly FRA contract.

The standard deviation of the resulting surprise measure is 7.4 basis points. The surprises for individual announcements are shown in Figure A.1. Riksbank announcements caused sizable surprises in policy rate expectations, including during the period from October 2014 to May 2022, when the policy rate was near or below zero. Unlike in the U.S., the Riksbank moved the policy rate materially below zero, so the effective lower bound was less binding and Riksbank surprises remained informative throughout the sample.

Previous studies of Swedish monetary policy include Fransson and Tysklind (2016) and

[6] FRA contracts settle against three-month Stockholm Interbank Offered Rate (STIBOR), which closely tracks the policy rate.

Iversen and Tysklind (2017), who estimated the effects on asset prices, Laséen (2020) and Almerud et al. (2024), who estimated macroeconomic effects using VARs, and Amberg et al. (2022), who documented distributional income effects. These studies also relied on high-frequency changes in interest rates around Riksbank announcements, but generally used changes in STIBOR swap rates. The advantage of using FRA contracts is that they are available farther back in time, allowing us to start our sample in 2001, several years earlier than other studies.

2.2 Financial Market Effects

Using our new high-frequency Riksbank surprises, we carry out an event-study analysis of the effects of monetary policy on Swedish financial markets. This analysis mainly serves as an empirical validation of the newly constructed policy surprises. We estimate event-study regressions

$$\Delta y_t = \alpha + \beta \, mps_t + u_t, \tag{1}$$

where t indexes days with Riksbank announcements, Δy_t is the interest rate change or asset return on those days, and mps_t is the monetary policy surprise. We estimate equation (1) for changes in the three-month, two-year, and ten-year government bond yields, and the two- and five-year mortgage bond rates. In addition, we estimate the regression for log returns in the EUR/SEK and USD/SEK exchange rates, the KIX/SEK exchange rate (a trade-weighted exchange rate for a basket of 32 foreign currencies against the Swedish krona), and the OMXSPI and OMXS30 stock market indices.

Table 1 shows the results of these regressions, which estimate the financial market responses to a one-unit (100 bp) unexpected tightening of monetary policy. As evident from Panel (A), all interest rates exhibit a strong positive response, with highly significant coefficients between 0.50 and 0.91 and R^2 values in the range of 38–79%. Panel (B) shows that, in line with the standard theoretical prediction of the uncovered interest rate parity, this type of hawkish surprise leads to an appreciation of the SEK—as indicated by the negative coefficients—against the euro, the dollar, and the KIX currency basket of generally around 3 percent. All three response coefficients are significant at the 1-percent level. The R^2 values are lower compared to the interest rate regressions, ranging from 13% to 22%. These strong estimated responses of interest rates and exchange rates are similar to earlier results documented for Sweden (Fransson and Tysklind, 2016; Iversen and Tysklind, 2017).

Monetary policy shocks typically have negative effects on stock prices, due to their effects on risk-free discount rates, dividend expectations, and risk premia (Bernanke and Kuttner, 2005; Bauer et al., 2023). Panel (B) of Table 1 shows instead positive, marginally significant

Table 1: Financial Market Response to Monetary Policy Surprises

(A) Interest Rates					
	3m yield	2yr yield	10yr yield	2yr mrtg. rate	5yr mrtg. rate
Coeff.	0.63***	0.82***	0.50***	0.91***	0.73***
	(0.11)	(0.08)	(0.09)	(0.08)	(0.08)
R^2	0.46	0.75	0.38	0.79	0.68
(B) Exchange Rates and Stock Market Indices					
	EUR/SEK	USD/SEK	KIX/SEK	OMXSPI	OMXS30
Coeff.	-2.88***	-3.31***	-2.68***	3.68*	4.31*
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
R^2	0.22	0.13	0.21	0.04	0.05

Estimated coefficients β and regression R^2 from high-frequency event-study regressions $\Delta y_t = \alpha + \beta mps_t + u_t$, where Δy_t is the daily change in a given asset return, exchange rate, or interest rate on monetary policy announcement days and mps_t is the estimated monetary policy surprise. Exchange rates are expressed as units of SEK per unit of foreign currency (or currency basket), so a negative coefficient indicates SEK appreciation. Heteroskedasticity-robust (White) standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sample: 149 Riksbank announcement days from 2001:1 to 2023:12.

coefficients, and low R^2. These estimates are consistent with Iversen and Tysklind (2017), who also find a positive but statistically insignificant Swedish stock market response to Riksbank surprises.[7]

2.3 Macroeconomic Effects

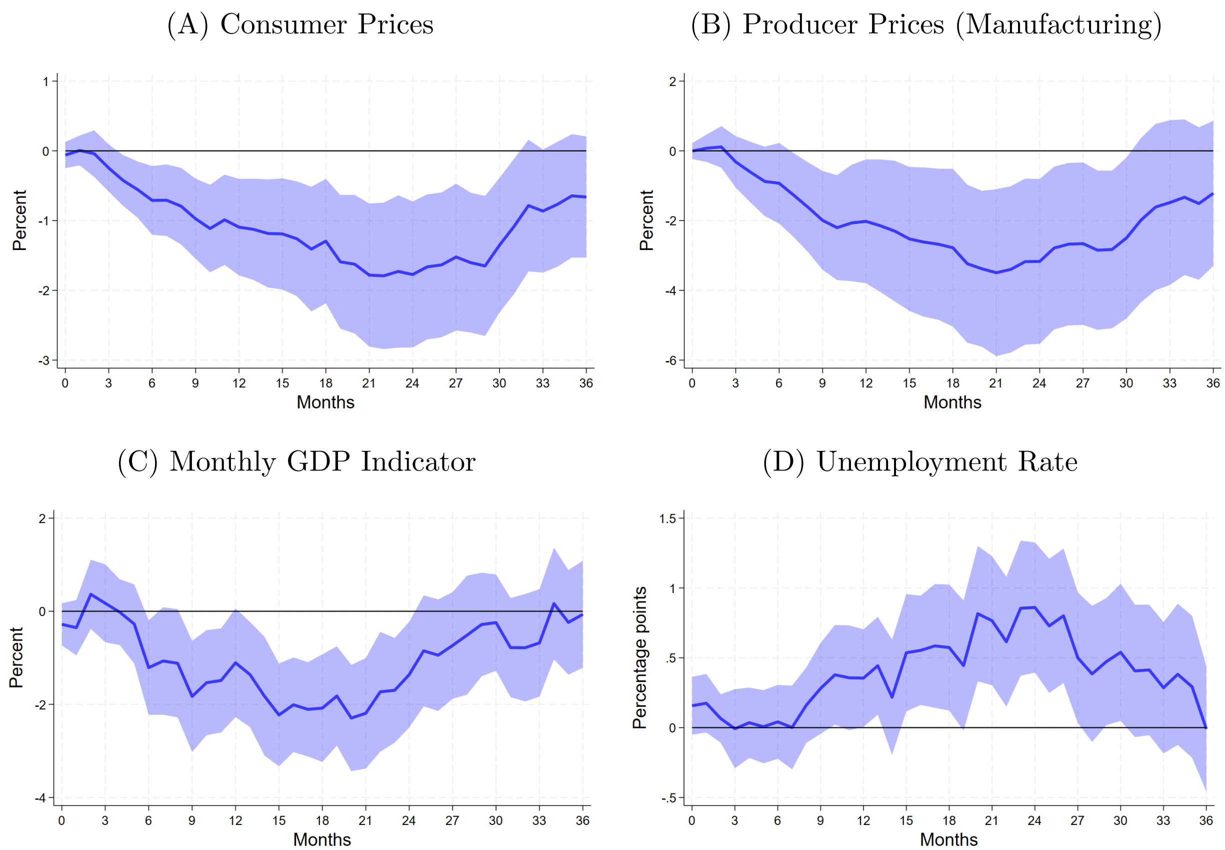
We now turn to the estimation of the effects of Swedish monetary policy shocks, proxied by high-frequency surprises, on macroeconomic variables. We start by converting the daily surprises into a monthly series by summing the surprises within each month and setting the months with no surprises to zero. We then estimate the Jordà (2005) local projections

$$\Delta_h Y_{t+h} = \alpha_h + \beta_h mps_t + \Gamma_h' X_{t-1} + u_{t+h}, \tag{2}$$

where $h = 0, ..., 36$ indexes the horizon of the impulse response function, $\Delta_h Y_{t+h} = Y_{t+h} - Y_{t-1}$ is the cumulative change, or "long difference", in the outcome variable Y_t. We estimate equation (2) for four different outcome variables: consumer prices with fixed interest rate (CPIF), producer prices in the manufacturing sector (PPI), SCB's monthly GDP indicator

[7] There are some institutional reasons to expect a different market response in Sweden than in the U.S.: The Swedish stock market is heavily influenced by large multinational corporations (Almerud et al., 2024). Riksbank policy surprises may have countervailing effects on stock returns in part due to exchange rate movements that affect the revenues of these multinationals.

Figure 1: Impulse Response Functions of Monthly Macro Variables



Solid lines report point estimates from the local projections in equation (2) to a 25 bp unexpected tightening of monetary policy. Shaded regions report 90% confidence bands based on heteroskedasticity-robust (White) standard errors. Sample: monthly data from 2001:1 to 2023:12.

(GDP), and the unemployment rate. We use log-levels for all variables other than the unemployment rate. Here mps_t denotes the monthly monetary policy surprise and X_{t-1} is a vector of controls, which includes 12 lags of the log of CPIF, GDP, Bloomberg commodity price index, the KIX/SEK exchange rate, and the OMXSPI stock market index. Given that our controls include extensive lags, we construct confidence intervals using heteroskedasticity-robust (White) standard errors (Montiel Olea and Plagborg-Møller, 2021).

Figure 1 shows the impulse response functions to a 25 bp contractionary monetary policy shock. Both consumer and producer prices decline substantially after such a shock. CPIF declines by about 1.8 percent and PPI by about 3.5 percent at the trough, which is reached after seven quarters. Output also declines, with a trough after about six quarters. Unemployment rises to a peak after two years. These estimated macroeconomic effects are statistically significant, as the impulse responses remain significantly different from zero for many periods. These results are qualitatively consistent, in terms of signs and hump shapes, with other impulse response estimates for Swedish monetary policy transmission by Laséen (2020), Almerud et al. (2024), and Coglianese et al. (2025).

Our estimated price responses are quantitatively larger than those from VAR-based studies of Swedish monetary policy.[8] We trace this difference to our more extensive set of controls: the local projections condition on 12 lags of five macroeconomic and financial variables. The controls serve two purposes. First, they absorb a substantial share of low-frequency price variation unrelated to monetary policy and thus improve the precision of the estimated effects. Second, they address endogeneity concerns arising from the predictability of high-frequency monetary policy surprises emphasized by Bauer and Swanson (2023), who document that such surprises can be correlated with macroeconomic and financial variables observed before policy announcements. This correlation, which can arise from various forces including incomplete information about the central bank's policy reaction function, creates an omitted variable bias that typically attenuates estimated policy effects toward zero. We find that our Riksbank surprises exhibit predictability patterns similar to those documented for U.S. surprises.[9] The variables that exhibit the strongest predictive power for the surprises, when added to the local projections, also yield the largest increase in the magnitude of the estimated effects, because they both predict the surprises and absorb substantial variation in the outcome variables.

In summary, our new high-frequency Riksbank surprises generate responses of interest rates and asset prices that are consistent with earlier results. Our LP estimates of the effects on macroeconomic variables are in line with textbook predictions and qualitatively similar to other estimates for Sweden, but they show larger magnitudes due to our more extensive controls, which account for the predictability of monetary policy surprises documented in the recent literature.

3 The Heterogeneous Response of Firm-Level Prices

Having constructed a new measure of Swedish monetary policy shocks and verified its empirical effect on aggregate variables, we now turn to the response of product-level prices and the role of firms' financial constraints.

[8] Almerud et al. (2024) estimate a CPIF trough decline of about 1 percent per 100 basis point tightening using a proxy VAR; Laséen (2020) and Coglianese et al. (2025) report broadly similar magnitudes. Our local projections imply a CPIF trough of about 7 percent per 100 basis points.

[9] Table A.1 in the appendix reports predictive regressions of our monetary policy surprises on lagged macroeconomic and financial variables. Lagged commodity prices and employment growth show the strongest correlations, with an overall R^2 of 0.16. Including these variables as controls in our local projections is an alternative to the orthogonalization approach recommended by Bauer and Swanson (2023) for addressing this concern. Both approaches yield qualitatively similar impulse responses.

3.1 Product- and Firm-Level Data

The dataset for our main analysis is constructed from detailed data on producer prices merged with firm-level administrative data. A key advantage of our data is its breadth: Our sample covers a large and representative set of manufacturing firms, including the many private firms that are absent from publicly traded samples.

For the price data, we use the microdata underlying the Swedish Producer Price Index (*Prisindex i producent- och importled, PPI*) maintained by SCB. The PPI data consist of monthly product-level prices for a representative sample of goods produced by Swedish firms.[10] We use the PPI data for goods produced by the manufacturing sector and sold on the domestic market.[11] Our focus on manufacturing goods is consistent with the PPI microdata literature (e.g., Nakamura and Steinsson, 2008; Gilchrist et al., 2017; Renkin and Züllig, 2024), and the restriction to domestic market prices ensures that we capture firms' pricing decisions without the confounding influence of exchange rate pass-through that dominates export price variation. As in other developed economies, manufacturing is a major part of the Swedish economy, accounting for 60 percent of goods production and 15 percent of GDP, on average, over the sample period.

Swedish firms, whether publicly traded or privately held, are generally required to report their financials to public agencies that maintain detailed records.[12] These data are maintained by the credit bureau Upplysningscentralen (UC), from which we obtain a comprehensive dataset of firm financials, including balance sheet data and income statements for both public and private Swedish firms. We merge these yearly firm-level financial data with the monthly product-level price data from the PPI, as well as the firms' registration year obtained from the Swedish Companies Registration Office (*Bolagsverket*).

A notable advantage of the Swedish firm data is that firms are uniquely identified by a firm ID, allowing us to accurately match price data to firm financials. Related analyses using price data for U.S. firms, by contrast, typically rely on fuzzy matching algorithms based on firm names (e.g., Gilchrist et al., 2017).

We measure financial constraints with four different commonly used proxies: size, age,

[10]Sampled firms are asked to report the average transaction price of a representative product they sell within a narrowly defined product code, given by the 8-digit Combined Nomenclature (CN) classification, and are required by law to respond. An example of an 8-digit CN code is 40114000 "New pneumatic tyres, of rubber, of a kind used for motorcycles."

[11]The Swedish PPI covers goods in several sectors (manufacturing, mining, energy, water supply), but manufacturing accounts for approximately 80 percent of the domestic market index by weight. Services are tracked in a separate quarterly index (the Services Producer Price Index) and are not part of the monthly PPI microdata.

[12]More specifically, this reporting requirement applies to "limited companies" (aktiebolag), the dominant corporate form in Sweden, which encompasses both publicly and privately held firms. Other companies, such as partnerships or sole proprietorships, have lighter reporting requirements.

leverage, and liquidity. Following the usual definitions (see, e.g., Cloyne et al., 2023), we define size as the log of total assets, age as the number of years since the creation (registration) of the firm, leverage as the sum of short- and long-term debt over total assets, and liquidity as the sum of cash and short-term investments over total assets.

Other controls are constructed following standard methods; for example, sales growth is the yearly change in log total nominal sales. We apply several standard filters to reduce the noise in our data.[13]

Our final dataset consists of 4,397 unique products produced by 2,195 unique firms. While this may seem like a small subset of the roughly 50k Swedish manufacturing firms, it is based on representative sampling of products, and it is notably larger than the firm samples used in related studies.[14]

Appendix B reports various summary statistics of the resulting panel dataset. Table B.1 shows summary statistics for the monthly price changes and the yearly firm characteristics. Table B.2 compares the mean values of the firm characteristics of the firms in our final dataset with those of the universe of Swedish firms. These values show that the average firm in our sample is larger, faster-growing, and older, and holds less liquid assets, than the average Swedish firm. Since the composition of our sample is tilted toward larger firms, our subsequent results may understate the size heterogeneity in firm-level price responses to monetary policy.

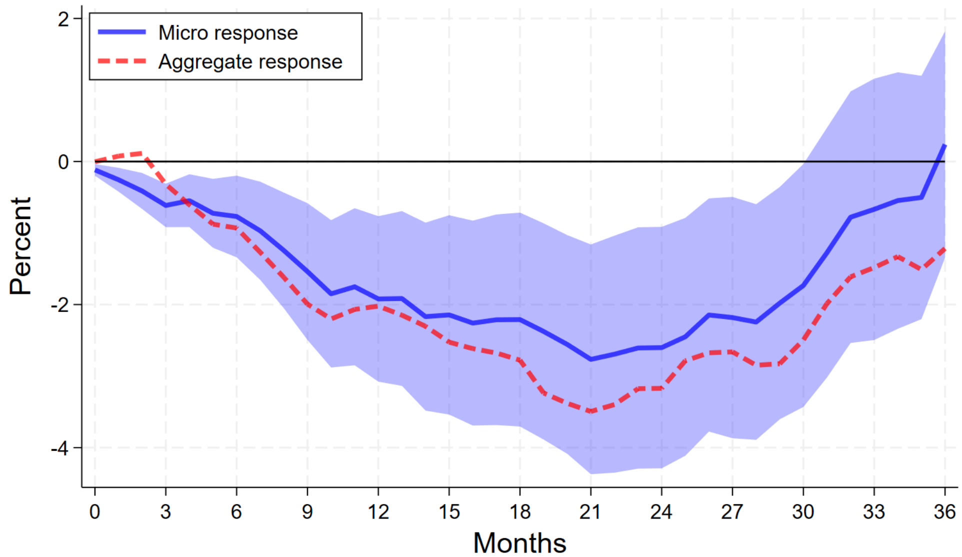
3.2 Comparison with Aggregate Inflation Series

Before investigating the heterogeneous price response across firms conditional on financial constraints, we validate our price data to ensure that it is representative of economy-wide price trends. First, we compare an aggregate inflation measure with average inflation rates based on our microdata. Figure B.1 plots the year-on-year inflation rates for the aggregate manufacturing PPI alongside two year-on-year inflation series constructed from product-level prices. The unweighted series is constructed as the simple arithmetic average of product-level inflation rates; the weighted series uses the same method as the aggregate PPI, following Statistics Sweden (2023). Both the weighted and unweighted series follow the official PPI

[13] We start by removing a few observations with non-positive total assets or total sales. To match the length of the impulse responses, we also remove products that are observed for less than 36 months. We winsorize the cumulative log price changes, size, age, leverage, and liquidity at the 1 percent level to remove outliers. For sales growth, we remove observations with an absolute value above 100 percent.

[14] In total, the UC data contain 837,504 unique firms during the sample period, of which 50,333 are manufacturing firms. The PPI data contain 3,156 unique firms. After merging the datasets and applying the sample restrictions, the final sample consists of 2,195 unique firms. For comparison, Gilchrist et al. (2017) match 584 U.S. corporations with the PPI database, and Renkin and Züllig (2024) link 213 Danish firms to the PPI survey.

Figure 2: Impulse Response Functions of Producer Prices



The blue solid line reports the point estimate of the average product-level price response from the panel local projection in equation (3) to a 25 bp unexpected tightening of monetary policy. The shaded region reports 90% confidence bands clustered two-way at the firm and time levels. The red dashed line shows the response of aggregate producer prices estimated using equation (2). Sample: monthly data from 2001:1 to 2023:12.

inflation series closely, with correlations of 0.99 and 0.94, respectively.

Our second validation compares the aggregate inflation response to monetary policy shocks (from Section 2.3) with the average product-level price response based on panel regressions. We estimate the panel data local projections

$$\Delta_h ln(P_{i,t+h}) = \alpha_{i,h} + \alpha_{m,h} + \beta_h mps_t + \Gamma'_{1,h} X_{t-1} + \Gamma'_{2,h} Z_{j,t-1} + u_{i,t+h}, \tag{3}$$

where $\Delta_h ln(P_{i,t+h}) = ln(P_{i,t+h}) - ln(P_{i,t-1})$ is the cumulative change in the log price of product i, $\alpha_{i,h}$ are product i fixed effects that control for time-invariant differences in price setting across products, $\alpha_{m,h}$ are monthly dummies that control for seasonal variation in price setting, X_{t-1} is the same vector of aggregate controls used in equation (2), and $Z_{j,t-1}$ is a vector of firm-level controls, including previous year's size, sales growth, leverage and liquidity of producing firm j. For this local projection, and for all subsequent ones that do not include time fixed effects, we calculate standard errors using two-way clustering at both the firm and time levels (Petersen, 2009; Cameron et al., 2011). For specifications that include time fixed effects, we cluster only at the firm level, since the time fixed effects absorb common period shocks (Petersen, 2009).

Figure 2 shows the impulse response function of average product-level producer prices to a

25 bp unexpected tightening of monetary policy. The pattern and magnitude of the subsequent price decline are broadly similar to the aggregate PPI response, which we reproduce from Figure 1. Prices fall significantly, reaching a trough of -2.8 percent after 21 months before reverting, and the dynamic response exhibits the same hump shape as for the aggregate estimates.

Our results confirm that the microdata are representative of aggregate price dynamics, and that estimates of unweighted price responses across firms are informative about the inflation response in the manufacturing sector. Having validated the price data, we now turn to the main heterogeneity analysis to understand the role of financial constraints.

3.3 Heterogeneity: Linear Interaction Effects

Our key question about firm-level monetary transmission is whether the response of prices to changes in monetary policy depends on firms' financial positions. To answer it, we interact monetary policy shocks with measures of financial constraints in the panel data local projections

$$\Delta_h ln(P_{i,t+h}) = \alpha_{i,h} + \alpha_{t,h} + \beta_h(mps_t \times FC_{j,t-1}) + \Gamma'_h Z_{j,t-1} + u_{i,t+h}, \tag{4}$$

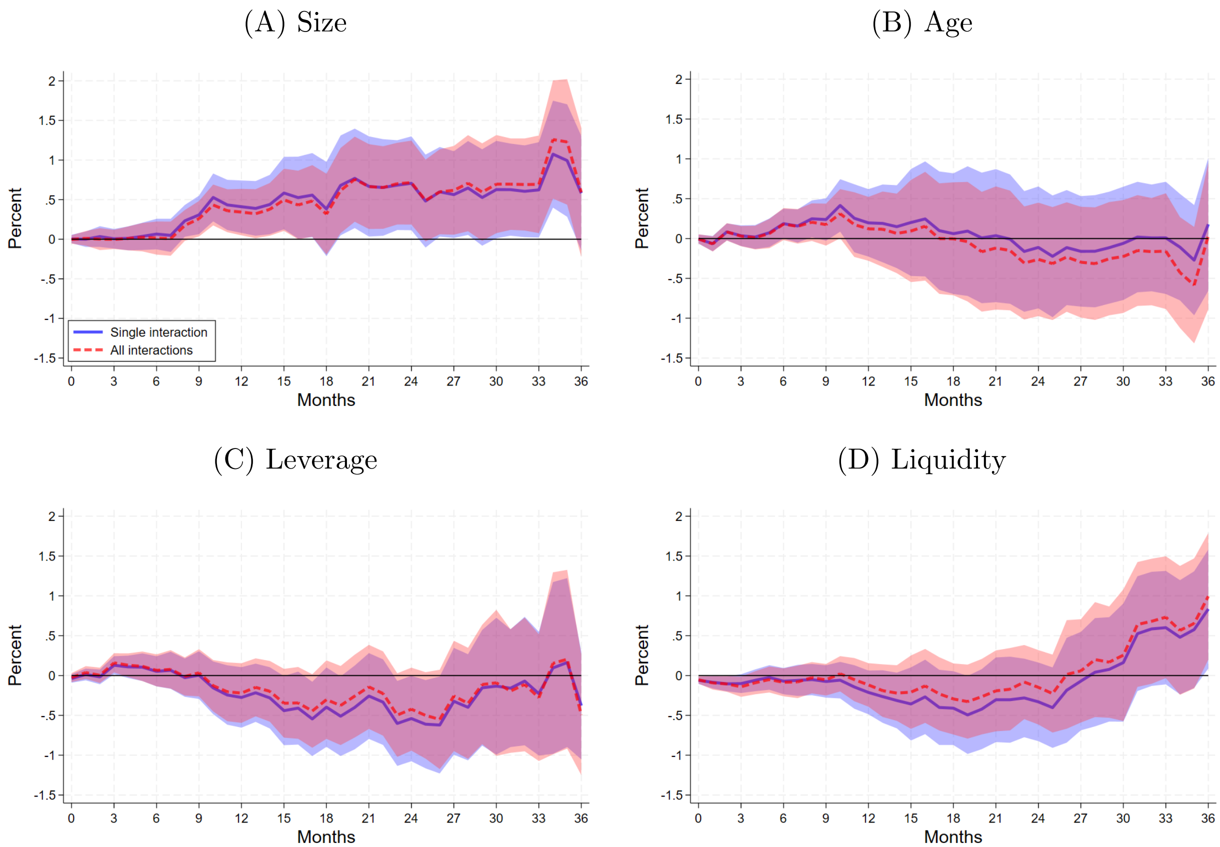
which differ from the previous panel regression in equation (3) in that we add time fixed effects $\alpha_{t,h}$, drop macro controls that vary only by time, and replace the shock with an interaction with $FC_{j,t-1}$, one of four different measures of financial constraint for producing firm j, i.e., size, age, leverage, or liquidity. We use the previous year's measure of financial constraint, which we also include in the set of firm-level controls $Z_{j,t-1}$, to ensure it is predetermined with respect to the shock in period t. Because the panel regression includes time fixed effects, we cluster standard errors at the firm level.

To facilitate comparison, we standardize the measures of financial constraints and use the negative of size, age, and liquidity, so that the estimated interaction coefficients are easy to interpret. They correspond to the differential price response of firms that are one standard deviation smaller, younger, more leveraged, or less liquid than the average firm. Our sign conventions are based on earlier studies on firm-level investment heterogeneity, which show that these types of firms behave as if they are more financially constrained.

We also estimate an alternative regression specification that includes all interaction effects jointly,

$$\begin{aligned} \Delta_h ln(P_{i,t+h}) = \alpha_{i,h} + \alpha_{t,h} - \beta_{1,h}(mps_t \times Size_{j,t-1}) - \beta_{2,h}(mps_t \times Age_{j,t-1}) \\ +\beta_{3,h}(mps_t \times Leverage_{j,t-1}) - \beta_{4,h}(mps_t \times Liquidity_{j,t-1}) + \Gamma'_h Z_{j,t-1} + u_{i,t+h}. \end{aligned} \tag{5}$$

Figure 3: Differential Price Response of Constrained Firms to Monetary Policy Shock



Dynamics of the interaction coefficients between financial constraint proxies and a 25 bp unexpected tightening of monetary policy on prices. Blue solid lines report point estimates when the interactions are estimated separately using the panel local projections in equation (4) and red dashed lines when they are estimated together using equation (5). Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

These estimates account for the potential correlation among the four measures of financial constraints and show whether each measure has a distinct role independent of the others.

Figure 3 shows how the price response to a 25 bp unexpected tightening of monetary policy varies depending on size, age, leverage, and liquidity of the producing firms. We plot the impulse response functions for both specifications: The blue solid lines show the response estimated using equation (4) with one interaction effect at a time, and the red dashed lines show the responses based on equation (5) when all interactions are jointly estimated. The two specifications yield similar impulse responses, indicating that the four measures are largely independent.

The key result in Figure 3 is that smaller firms exhibit a more muted price decline after a tightening, as evident in Panel (A). The heterogeneous price response is present in both specifications and statistically significant at most horizons from eight to 36 months.

The difference in the price response of smaller firms is also economically significant. The peak differential response is 1.3 percentage points, occurring at the 34–month horizon. At the 21–month horizon, where the average price response reaches its trough of 2.8% (Figure 2), firms one standard deviation smaller than the mean lower prices by 0.7 percentage points less than the average firm, implying a muted response of about 25%. Overall, the magnitude of the estimated interaction effects is large relative to the average impulse response. Below, in Section 3.4, we provide evidence on the aggregate macroeconomic importance of this response heterogeneity across small and large firms.

Other measures of financial constraints do not capture meaningful heterogeneity in the firm-level price response. Panels (B)–(D) show no significant differences across the age, leverage, or liquidity distributions. The point estimates for leverage and liquidity are close to significant at some horizons and suggest that more constrained firms lower prices by *more* than other firms, opposite to the theoretical prediction discussed in Section 4. However, these responses become essentially flat under the more demanding sector-by-time fixed effects specification (Figure C.1), and the estimated heterogeneities are mostly statistically insignificant. As we discuss in Section 4.2, size may be a more reliable proxy for financial constraints than balance-sheet measures such as leverage and liquidity, especially in our empirical setting.

3.4 Heterogeneity: Semi-Parametric Estimates

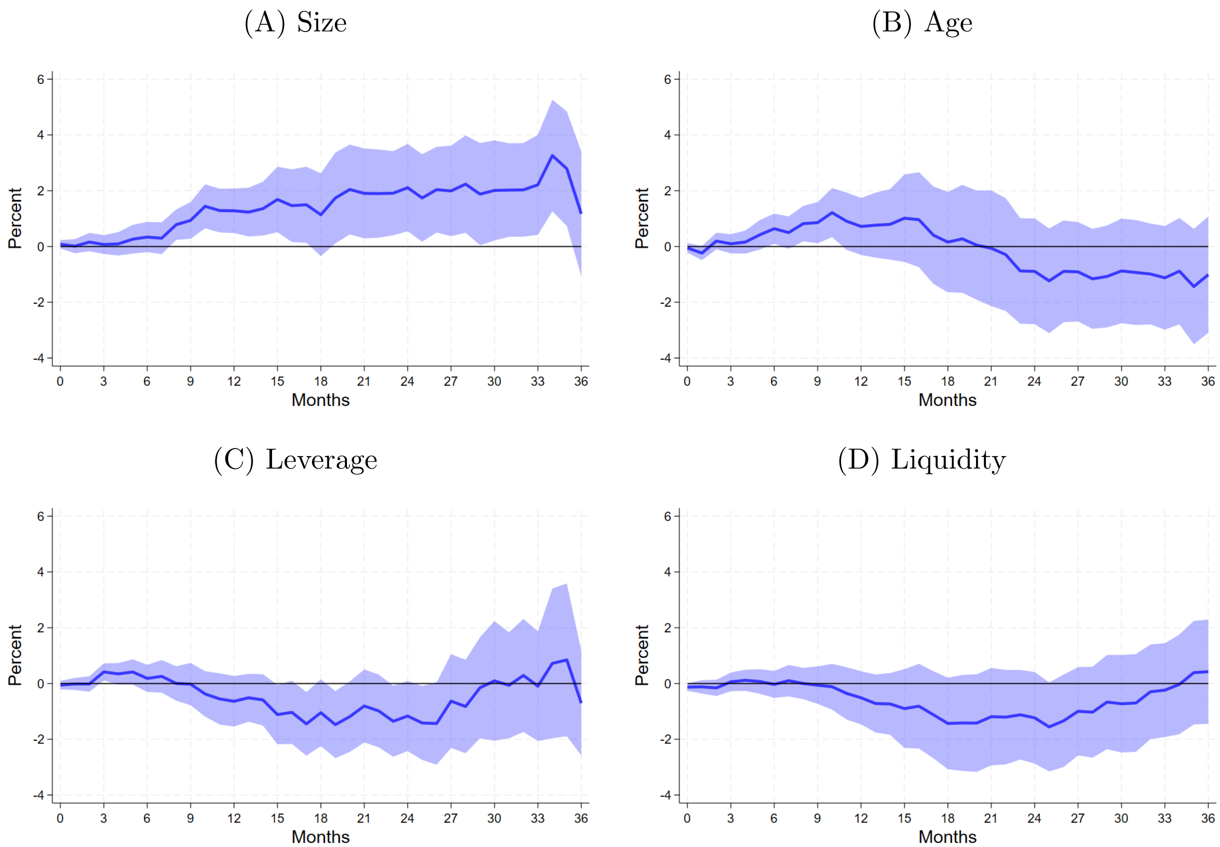
Linear interaction effects based on firm characteristics impose strong parametric restrictions on the possible patterns of heterogeneity. To investigate the heterogeneous price response without imposing linearity, we estimate a "semi-parametric" specification similar to Cloyne et al. (2023). The basic idea is to compare price observations for which the producing firms are most financially constrained with those for which they are least constrained.

Specifically, we split the product-level price observations into quartiles based on the characteristics of the producing firm, and then compare the response of the top and bottom quartiles. We again consider size, age, leverage, and liquidity as proxies for financial constraints to estimate interaction effects. We estimate the local projections

$$\Delta_h ln(P_{i,t+h}) = \alpha_{i,h} + \alpha_{t,h} + \beta_h(mps_t \times I^{FC}_{j,t-1}) + \Gamma'_h Z_{j,t-1} + u_{i,t+h}, \tag{6}$$

where $I^{FC}_{j,t-1}$ is an indicator variable that takes on the value one if a given proxy for financial constraints indicates that the firm is most constrained, i.e., belongs to the smallest, youngest, most leveraged, or least liquid firms. The indicator is zero for the quartile of prices set by the least constrained firms, and price observations in the middle two quartiles are excluded.

Figure 4: Differential Price Response of Constrained Firms: Semi-Parametric Estimates



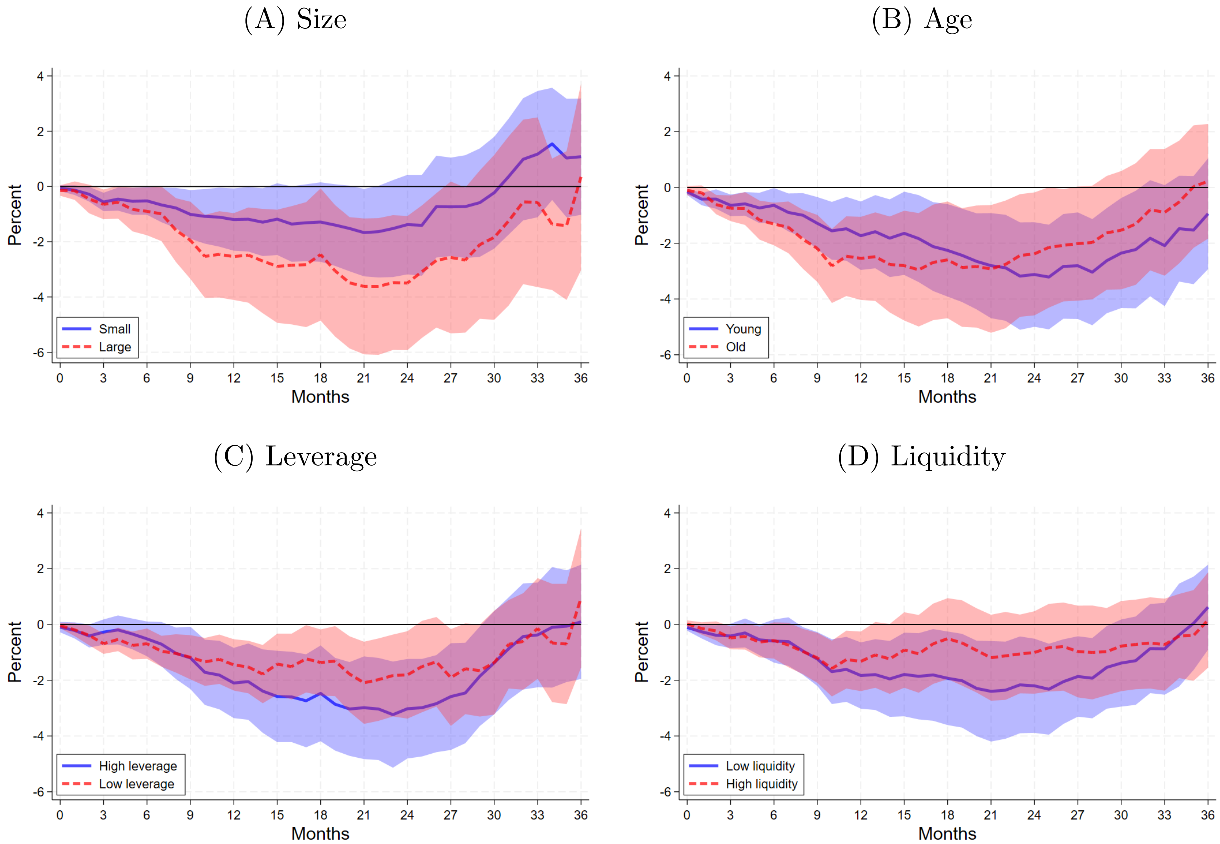
Dynamics of the semi-parametric interaction coefficients between financial constraint proxies and a 25 bp unexpected tightening of monetary policy on prices. Blue solid lines report point estimates from equation (6). Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

The vector of lagged firm-level controls, $Z_{j,t-1}$, contains size, sales growth, leverage, liquidity, and $I^{FC}_{j,t-1}$. As before, the estimation includes product and time fixed effects.

Figure 4 shows the resulting differential price response to a contractionary monetary policy. The impulse responses in Panel (A) confirm that the prices of small firms are significantly less responsive to monetary policy than those of larger firms. These semi-parametric estimates yield empirical patterns similar to the earlier estimates with linear interaction effects. At the peak differential response, which occurs at the 34–month horizon, the prices of products produced by the smallest firms are about 3 percentage points higher than those of the largest firms.

The semi-parametric approach also allows for the estimation of the group-specific impulse

Figure 5: Group-Specific Price Responses



Impulse response functions of prices for the top and bottom quartiles of the size, age, leverage, and liquidity distributions to a 25 bp unexpected tightening of monetary policy. Blue solid lines show the estimated price response for the most constrained firms and red dashed lines show price responses for the least constrained firms, based on regression (7). Shaded regions report 90% confidence bands clustered two-way at the firm and time levels. Sample: monthly data from 2001:1 to 2023:12.

response, using the panel local projections

$$\Delta_h ln(P_{i,t+h}) = \alpha_{i,h} + \alpha_{m,h} + \beta_{1,h}(mps_t \times I^{FC}_{j,t-1}) + \beta_{2,h}(mps_t \times I^{UC}_{j,t-1}) + \Gamma'_{1,h} X_{t-1} + \Gamma'_{2,h} Z_{j,t-1} + u_{i,t+h}, \tag{7}$$

where the indicator variable $I^{UC}_{j,t-1}$ captures product-level observations in the quartile produced by the least constrained firms, that is, the largest, oldest, least leveraged, or most liquid firms, and $I^{FC}_{j,t-1}$ corresponds to the most constrained firms. The vector of lagged firm-level controls, $Z_{j,t-1}$, contains size, sales growth, leverage, liquidity, $I^{FC}_{j,t-1}$, and $I^{UC}_{j,t-1}$. Since we want to estimate the group-specific response to mps_t, we need to drop time fixed effects, and so we add the macro controls X_{t-1} back in. The panel regression includes product (i) and calendar-month (m) fixed effects.

The impulse responses in Panel (A) of Figure 5 show that both small and large firms lower prices on average, but that small firms cut prices less after a tightening. These estimates also speak to the quantitative importance of this heterogeneity: across a wide range of horizons, the price responsiveness of large firms is about twice as large as that of small firms. Our evidence on magnitudes—here and in Section 3.3 above—suggests that financial constraints meaningfully impede the transmission of monetary policy to the prices of smaller firms.

The gap between the group-specific responses in Figure 5 is similar to the differential effect estimated directly from equation (6), which includes time fixed effects. This stability indicates that general equilibrium feedbacks—which are absorbed by the time fixed effects—do not materially distort the relative price response across the size distribution. We can therefore use the group-specific level responses to assess aggregate implications without a "missing intercept" problem (Wolf, 2023).

The results for age, leverage, and liquidity in the other panels of Figure 4 and Figure 5 lead to the same conclusions as the earlier linear interaction estimates. These measures yield largely insignificant differences in price sensitivity to monetary policy.

3.5 Robustness

Our evidence so far has established that firm size is an important source of heterogeneity in the price response to monetary policy, in contrast to other standard proxies for financial constraints. We now turn to robustness checks for these main results. Appendix C reports all additional estimates.

Industry-level heterogeneity could partially account for our results. Durante et al. (2022) show that the investment response to monetary policy differs across sectors, and a similar pattern may be present for the price response. If firm size is correlated with differences in sector-specific demand elasticities, this could drive the differential price response across the size distribution. To test for this, we replace the time fixed effects in our baseline panel regressions (4) and (5) with two-digit product group-by-time fixed effects and estimate the interactions between the measures of financial constraints and monetary policy. Figure C.1 shows that the main results are robust to including these sector-by-time fixed effects. Heterogeneity in the price response across industries therefore does not appear to be an important driver of our estimated size heterogeneity.

The high-inflation period from 2021 to 2023 was driven primarily by supply-side shocks, raising the concern that the transmission of monetary policy to prices operates differently when inflation is elevated and cost pressures dominate. We show in Figure C.2 that our baseline results are robust to excluding this period by ending the sample in December 2020.

Figure C.3 examines whether the semi-parametric estimates are sensitive to the choice of

Table 2: Size Interaction Across Specifications

	Linear: $mps_t \times Size_{j,t-1}$			Non-linear: $mps_t \times I^{Size,C}_{j,t-1}$		
	(1)	(2)	(3)	(4)	(5)	(6)
β_{21}	0.67**	0.65**	0.71**	1.90*	1.47**	1.96**
	(0.33)	(0.30)	(0.33)	(0.98)	(0.66)	(1.00)
R^2	0.29	0.37	0.29	0.32	0.44	0.31
Obs.	246,773	246,577	231,152	121,098	120,662	113,229
Time fixed effects	Yes	No	Yes	Yes	No	Yes
Sector-by-TFE	No	Yes	No	No	Yes	No
End sample 2020:12	No	No	Yes	No	No	Yes

Coefficients from the estimated interaction between size and a 25 bp unexpected tightening of monetary policy on prices across different specifications at the 21–month horizon. The coefficients in columns (1)-(3) are estimated using the linear specification in equation (5) and the coefficients in columns (4)-(6) are estimated using the non-linear specification in equation (6). Standard errors clustered at the firm level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sample: monthly data from 2001:1 to 2023:12 or 2020:12.

cutoff for defining constrained and unconstrained groups. Results are qualitatively robust to comparing the top and bottom 33 and 50 percent of the respective firm characteristic, though the largest quantitative difference across the size distribution comes from the top and bottom quartiles.

We further analyze the differential price response between small and large firms across several regression specifications. For each, Table 2 shows the estimated interaction coefficient for firm size at the 21–month horizon. The first three columns report the baseline regression with different fixed effects and sample periods, and the last three columns report estimates for specifications with non-linear interactions. The interaction coefficient remains stable across specifications and statistically significant.

3.6 Aggregate Implications

The quantitative importance of the heterogeneous price response across the size distribution raises two interrelated questions. First, how much do the price responses of large and small firms, respectively, contribute to the aggregate PPI response to monetary policy? Second, how much would prices fall on average in a counterfactual scenario where firms are not financially constrained?

To answer these questions, we follow a methodology similar to that of Gertler and Gilchrist (1994) and Krusell et al. (2026). Our calculation uses the group-specific impulse responses of large and small firms estimated from equation (7). While these are obtained without time fixed effects, our results above suggest that this issue—essentially the "missing intercept" problem of Wolf (2023)—is negligible in our setting, since the differential estimates with and without time fixed effects are similar (Section 3.5). Moreover, Krusell et al. (2026) show that for monetary policy shocks, unlike for TFP shocks, general equilibrium feedbacks do not offset firm-level composition effects, because the interest rate path is pinned by the central bank. We can therefore quantify the aggregate importance of the size heterogeneity using our reduced-form estimates, without requiring a structural model to account for general equilibrium effects.

The first question concerns the contributions of different firm groups to the aggregate price response. To calculate these contributions, we take the average weight of each firm group in the aggregate PPI, which is 22% for the smallest quartile and 35% for the largest quartile.[15] We focus on the 21-month horizon, where the average micro PPI response, shown in Figure 2, reaches its trough of 2.8 percent. The average effect implied by the separate responses and weights of each quartile is 2.9 percent, and we use this as the baseline for our comparisons.[16] At the 21-month horizon, prices for the largest firms fall by 3.9 percent, which accounts for 47 percent of the trough decline in the PPI. Prices for the smallest firms fall by 2.1 percent, which accounts for 16 percent of the aggregate decline. Thus, even though the prices of products produced by small firms constitute a non-negligible share of the total PPI weight, their contribution to the overall response is limited; the aggregate response is disproportionately driven by products produced by large firms.

The second question concerns the macroeconomic importance of financial constraints. We consider two counterfactual scenarios to answer it.

In the first scenario, the smallest, financially constrained firms have a price sensitivity equal to that of the largest, arguably unconstrained firms. Focusing again on the 21-month horizon, the group-specific estimates from regression (7) imply that the price response of small firms would increase in magnitude from 2.1 to 3.9 percent. Given the 22% PPI weight of small firms, this increased price sensitivity would contribute an additional 0.4 percentage points to the aggregate PPI decline after a contractionary policy shock, for a total of 3.3 percent. This counterfactual suggests that absent financial constraints on small firms, the aggregate price effect of monetary policy would be 14% larger.

If size is a key determinant of financial constraints, consistent with our results and much of the earlier related literature, then firms in the second and third size quartiles may also

[15] These average weights are computed as follows: First, we calculate the weight of a firm quartile in each time period, dividing the sum of the weights of the products in this quartile by the sum of the weights of all products in the sample. Second, we take the average of this weight across all time periods.

[16] The Q2 and Q3 point estimates and weights at $h = 21$ are -2.8% (weight 0.21) and -2.25% (weight 0.22), respectively.

be somewhat constrained. We therefore consider a second counterfactual scenario, in which prices for all firms respond like those of firms in the top quartile. In this case, the aggregate PPI response equals the group-specific response of the largest firms. At the 21-month horizon, prices would decline by 3.9 percent instead of the implied 2.9 percent, meaning that the price decline would be 34% larger. This second scenario provides an upper bound, as it attributes all size-related heterogeneity to financial constraints.

In both counterfactual scenarios, monetary policy has materially stronger effects on aggregate prices. While these partial-equilibrium calculations are necessarily suggestive, they indicate that without financial constraints the aggregate price effect of monetary policy could be on the order of 14–34% larger. Other studies that quantify the aggregate importance of firm heterogeneity for macroeconomic transmission report magnitudes in a similar range. Gertler and Gilchrist (1994) find that small firms account for over half of aggregate manufacturing declines despite constituting less than a third of sales. Renkin and Züllig (2024) estimate that credit supply shocks explain about 40% of the "missing disinflation" during the Danish financial crisis. Krusell et al. (2026) find that firm age composition reduces aggregate investment responsiveness to monetary policy by about 15% in general equilibrium. Regardless of which counterfactual scenario is viewed as more realistic, heterogeneity in the price response across the size distribution is a quantitatively meaningful factor for the aggregate transmission of monetary policy to prices.

Overall, our results establish a robust and quantitatively important differential price response to monetary policy depending on firm size. The next section investigates the economic mechanism behind this size heterogeneity.

4 Understanding the Mechanism

Customer markets and financial frictions provide a natural rationalization for the size heterogeneity documented above: when the external finance premium rises after a monetary tightening, more constrained firms cut prices less to preserve cash flows, sacrificing future market share. Since smaller firms are more likely to be financially constrained, the theory predicts a muted price response for small firms. This section first lays out the theory and then provides supportive evidence on the heterogeneous response of sales, debt, marginal costs, and profit margins. We also rule out alternative explanations based on differential price adjustments, working capital, market share, and export share.

4.1 Theory: Customer Markets and Financial Frictions

Models of customer markets and financial frictions (Gottfries, 1991; Chevalier and Scharfstein, 1996; Gilchrist et al., 2017) can rationalize our central empirical finding that small firms exhibit a muted price response to contractionary monetary policy. In this class of models, the customer base is an asset in which firms can invest. By setting lower prices today, firms can increase their market share and thus future revenues at the expense of current revenues. Financial frictions reduce investment in the customer base because firms have a greater incentive to maintain current cash flows and profits when external finance is costly. This mechanism is particularly strong for firms that experience a larger increase in credit costs following an interest rate increase.

Gilchrist et al. (2017) develop a New Keynesian model with customer markets and financial frictions that clarifies the mechanisms through which financial and demand shocks affect pricing decisions, inflation, and output. In their model, firms face a sticky customer base due to deep habits in households' consumption. A lower price can therefore be viewed as an investment in the customer base that yields higher market share and profits over the longer run. At the same time, firms face costly external finance, that is, a wedge between the interest rate on external financing and the risk-free rate. Gilchrist et al. (2017) model this as an equity issuance friction, but similar implications arise under alternative modeling choices, such as borrowing limits (Gottfries, 1991). Firms thus face a steeper trade-off between investing in the customer base—generating future profits and market share—and extracting current revenue, as financial frictions raise the shadow value of internal funds. Constrained firms may then find it optimal to set relatively higher prices to generate current revenue and avoid the external finance premium, even at the cost of future market share.

An equivalent way to state the mechanism is in terms of demand elasticities (Renkin and Züllig, 2024). Because the customer base is sticky, the short-run demand elasticity facing a firm is smaller than its long-run elasticity: raising the price today generates a large increase in current revenue with only a small immediate loss of sales, while over time the higher price erodes market share. Financial frictions raise the shadow value of internal funds and tilt constrained firms toward exploiting the smaller short-run elasticity, at the cost of future revenue.

The model of Gilchrist et al. (2017) makes predictions about the price response to shocks. Financial shocks are modeled as changes in firms' external financing costs and demand shocks as preference shifts in households' utility. The model predicts that the firm-level price response to these shocks depends on the financial strength of the firm. Following a contractionary shock that lowers aggregate output, financially constrained firms lower prices by less compared to unconstrained firms, or even raise them. As a result, constrained firms suffer a stronger decline in output. In the aggregate, financial frictions therefore amplify the output loss and dampen the decline in inflation following a contractionary shock. The empirical evidence in Gilchrist et al. (2017) on pricing behavior during the Great Financial Crisis of 2008 supports this channel: unconstrained firms cut their prices in 2008, whereas constrained firms actually raised theirs despite the large drop in aggregate output.[17]

Our empirical findings on the heterogeneous price responses to monetary policy can be viewed through the lens of this model. In Gilchrist et al. (2017), a contractionary monetary policy shock operates through the same balance sheet channel as an adverse demand shock, which they model as a household discount-factor shock, and generates qualitatively similar differential responses across constrained and unconstrained firms. As overall output falls, the balance sheet position of financially constrained firms deteriorates, the external finance premium rises, and constrained firms become more myopic, that is, less forward-looking.[18] Relying on their sticky customer base, constrained firms choose higher markups and set higher prices than unconstrained firms in order to boost current revenue. As a consequence, constrained firms lose market share to the unconstrained firms and sacrifice future revenue.[19]

These models provide a natural explanation for the heterogeneous price response that we document. In these and related theories (Bernanke et al., 1999; Ottonello and Winberry, 2020), the degree of a firm's financial constraints is typically linked to liquidity, net worth, or leverage. But this does not mean that these balance sheet quantities are necessarily the best empirical proxies for financial constraints, as we discuss next in Section 4.2. Firm size is a widely used and more reliable proxy for financial constraints, capturing cross-sectional variation in external finance premia. The underlying theory links heterogeneous pricing to the shadow cost of external funds regardless of which observable firm-level variables proxy for that cost. Our joint hypothesis is therefore that size proxies for the severity of financial constraints, and that customer markets with financial frictions explain the differential pricing behavior we estimate.

To assess this explanation, we consider several testable implications. First, because smaller firms set relatively higher prices and forgo investment in their customer base in response to a monetary contraction and the resulting tightening of financial constraints, their sales

[17] The prediction that constrained firms reduce investment in the customer base is consistent with the larger decline of investment in the capital stock in response to a monetary contraction documented by Jeenas (2026) and others.

[18] Empirical evidence confirms that credit spreads rise following monetary tightening: Gertler and Karadi (2015) document this at the aggregate level, and Anderson and Cesa-Bianchi (2024) show that the increase is larger for more constrained firms. See also Bauer et al. (2023) for the response of the external finance premium and risk premia to monetary policy.

[19] See also Gilchrist and Zakrajšek (2016), who show that customer markets and financial frictions have material effects on price-setting even if the original model is calibrated to more normal times, instead of the crisis episode that was the focus of Gilchrist et al. (2017).

should fall by more than those of larger firms.[20] We will therefore investigate the differential response of firm-level sales to monetary policy shocks.

Second, if financial constraints play an important role in the size heterogeneity, we should also see differences in the debt response to monetary policy. In particular, the debt of smaller firms should be more sensitive to changes in monetary policy than that of larger firms, reflecting a larger sensitivity of the external finance premium. Existing research has documented that smaller, financially constrained firms reduce their debt more strongly in response to tighter monetary policy (Gertler and Gilchrist, 1994; Oliner and Rudebusch, 1996; Cloyne et al., 2023). We reassess this pattern in our data.

Third, the mechanism implies that the muted price response of smaller firms reflects markup behavior rather than cost structure. In response to a monetary tightening, smaller firms should compress markups less than larger firms, or even raise them. Furthermore, if their marginal costs are at least as responsive to monetary policy as those of larger firms, this rules out alternative cost-side explanations of differential price setting. We investigate each of these predictions in turn.

4.2 Firm Size as a Proxy for Financial Constraints

The results in Section 3 raise the question why firm size yields pronounced, theory-consistent heterogeneity while other standard proxies for financial constraints do not. We address this question by comparing small and large firms along two dimensions: their price-setting behavior and their exposure to financial constraints and credit-market access.

Table 3 reports various firm-level statistics for the four size quartiles. Before turning to financial measures, we begin in Panel (A) by reporting statistics related to price changes, to rule out that the heterogeneous price responses arise from differences in price adjustment patterns across firms. Models of rational inattention or costly information acquisition predict that firms with coarser pricing policies respond less to aggregate shocks (Stevens, 2020), and some empirical evidence suggests that smaller firms adjust prices less frequently than larger firms (Apel et al., 2005). This explanation is inconsistent with our data. As shown in Panel (A) of Table 3, the frequency of price adjustment is virtually identical across the size distribution: firms in every quartile change prices in 47 percent of months, and the average size of price changes is also similar. Moreover, the group-specific impulse responses for the top and bottom size quartiles in Figure 5 show that prices in both quartiles react with similar persistence, with the smaller firms simply showing a smaller response. The differential

[20] For the financial shock of 2008, Gilchrist et al. (2017) indeed show prices of constrained firms do not fall like those of unconstrained firms, and that their sales fall by more. They measure financial constraints using the firms' liquidity, among other proxies.

Table 3: Summary Statistics by Size Group

Size group	Q1	Q2	Q3	Q4
(A) Monthly Prices				
100Δln(Price)	0.20	0.20	0.20	0.24
Share of price changes	0.47	0.47	0.47	0.47
Size of price changes	3.03	2.86	2.81	3.00
Products per firm	1.37	2.11	3.62	8.37
(B) Yearly Firm Characteristics				
Debt to credit institutes	0.28	0.19	0.14	0.09
Collateral over total debt	1.14	0.75	0.47	0.25
Utilized credit lines	0.40	0.36	0.37	0.24
Default probability (%)	0.65	0.56	0.53	0.50
Age	34.1	38.9	44.1	52.7
Leverage	0.40	0.39	0.39	0.40
Liquidity	0.07	0.06	0.05	0.04
(C) Yearly Financial Constraint Indices				
FCP index	-0.98	-1.16	-1.25	-1.35
WW index	-0.10	-0.15	-0.19	-0.27
SA index	-2.39	-3.20	-3.85	-4.76

Mean values of selected characteristics of the firms in our matched PPI dataset for each quartile of the size distribution. Debt to credit institutes is expressed as a fraction of total debt. Sample: monthly price data and yearly firm characteristics from 2001 to 2023.

response of small firms to monetary policy is therefore unlikely to be driven by differences in the frequency of price adjustment.

Empirically and theoretically, size appears to capture a firm's structural position in credit markets more accurately than the current state of its balance sheet. Larger firms have broader access to external finance, including capital markets, while smaller firms have limited capital market access and rely more heavily on bank lending. As shown by Gertler and Gilchrist (1994) and Oliner and Rudebusch (1996), small firms are disproportionately dependent on bank lending and cannot easily substitute toward market-based financing when monetary policy tightens. Leverage and liquidity, by contrast, reflect equilibrium outcomes of corporate financial decisions that can be high or low for reasons unrelated to the severity of financial constraints. For example, high leverage may reflect a firm borrowing up to its limit or enjoying favorable access to cheap debt, and low leverage may equally reflect strong internal cash flow or an inability to access credit. Moreover, leverage and liquidity themselves respond to monetary policy, so ex-post heterogeneity in these measures reflects, in part, the response to the shock rather than pre-existing constraint status. Size is far more persistent and less shock-sensitive, making it a cleaner sorting variable.

This distinction is consistent with Hadlock and Pierce (2010), who find that size and age are the most reliable predictors of financial constraint status, while balance-sheet-based measures perform poorly, motivating their widely used SA-index. Our results show that size drives the heterogeneity of the price responses, while age contributes little additional information. One possible interpretation, following Krusell et al. (2026), is that age proxies for the distance from the firm's optimal size rather than for financial constraints.

A potential concern raised by Hurst and Pugsley (2011) is that small firms include many mature businesses with no growth ambitions rather than genuinely constrained ones. Two features of our analysis limit this concern. First, our sector-by-time fixed effects absorb industry-level differences in the prevalence of such niche firms. Second, the differential price response of small firms is robust to controlling for age, so the effect is not driven by mature niche firms.

Size also has better measurement properties. Total assets is a highly persistent firm characteristic that is straightforward to measure, while leverage and liquidity depend on balance sheet positions that are more volatile and subject to accounting discretion. This concern is amplified in samples that include privately held firms, as ours does. Private firms face lighter reporting and auditing requirements, which introduces additional noise into balance-sheet-based measures. Farre-Mensa and Ljungqvist (2016) test five popular constraint indices (KZ, HP/SA, WW, dividend payer, credit ratings) and reject the null of inelastic capital supply for U.S. public firms in every case. On private firms their tests do have power, and it is the smallest firms whose behavior is consistent with binding constraints.[21] In samples including many private firms, such as ours, size is the empirically preferred proxy, and balance-sheet indices are not. The null results for liquidity and leverage in our sample likely reflect attenuation from noisy measurement.

Direct evidence from our sample supports the interpretation of size as a proxy for financial constraints. Panel (B) of Table 3 shows that size is negatively related to the share of bank debt, defined as the value of short- and long-term debt to credit institutes over total short- and long-term debt.[22] The smallest firms, in the bottom size quartile, have a mean share of bank debt that is more than three times as large as that of firms in the top quartile. Bank

[21]Their Table 5 exploits staggered state corporate income tax increases as a shock to the value of debt tax shields; only the smallest private firms fail to raise leverage in response, and small private firms cut payouts when raising equity, in contrast to the equity recycling of public firms.

[22]These firm-level bank debt shares are lower than the roughly 70% aggregate share of bank debt for non-financial Swedish corporations (Sveriges Riksbank, 2024). Two factors mainly account for the difference. First, unconsolidated firm-level balance sheets include intra-group loans in the debt denominator, inflating total debt relative to the consolidated sector aggregates. Second, aggregate NFC borrowing in Sweden is dominated by property companies, which are more heavily bank-financed than manufacturing firms.

debt is generally subject to stronger information asymmetries and a larger external finance premium (Gertler and Gilchrist, 1994). Since bank-dependent firms cannot easily substitute toward public capital markets when credit conditions tighten, they face a larger increase in the external finance premium after a monetary contraction (Kashyap and Stein, 2000).

Three additional indicators point in the same direction. First, small firms pledge more collateral per unit of debt: the mean ratio of collateral to total debt is 1.14 in the bottom size quartile and 0.25 in the top, consistent with tighter lending standards for smaller borrowers. Second, small firms have higher credit-line utilization rates (0.40 versus 0.24), meaning that they are closer to their borrowing limit. Third, default probabilities, based on UC's scoring model, are moderately higher for smaller firms (though these unconditional probabilities are generally low, below one percent). Together with the bank-debt evidence, these patterns support the view that firm size is closely related to the severity of financial constraints and the sensitivity of the external finance premium to monetary policy.[23]

The remaining Panel (B) rows show that size is strongly positively related to firm age, essentially unrelated to leverage, and modestly negatively related to liquidity. The patterns for bank debt and liquidity mirror those Crouzet and Mehrotra (2020) document for U.S. manufacturing firms using Census microdata. As discussed above, balance-sheet ratios like leverage and liquidity are endogenous outcomes of firms' financial decisions and may therefore be unreliable proxies for the severity of financial constraints.

As a further check, we compute three composite financial-constraint indices widely used in the literature and report average values for each size quartile: the financial-constraint-probability (FCP) index of Schauer et al. (2019), the Whited and Wu (2006) (WW) index, and the size-age (SA) index of Hadlock and Pierce (2010). Construction details are given in Appendix D. Panel (C) of Table 3 shows that all three indices are monotonically related to size, with small firms classified as the most constrained. Since each index also incorporates cash flow, leverage, profitability, or dividend behavior beyond size itself, this monotonicity confirms that firm size summarizes what these composite measures capture, consistent with the conclusion of Hadlock and Pierce (2010) that size is the single most reliable predictor of constraint status.

Having established that size proxies for financial constraints in our sample, we now test the customer-markets channel by examining differential responses of sales, debt, marginal costs, and markups.

[23] Data on collateral are available for 13,883 of the 16,919 firm-year observations, and data on utilized credit lines for 4,756.

4.3 Sales

As discussed above, the theory predicts that constrained firms sacrifice future market share to preserve current cash flows. We therefore expect the sales of small firms to fall by more than those of large firms after a monetary tightening.

To investigate the sales response, we use monthly firm-level sales data from the microdata underlying the official Swedish Industrial Production Index (*Industriproduktionsindex, IPI*) maintained by SCB. The IPI data consist of total nominal net sales for a sample of firms. We merge the IPI data with our cleaned PPI dataset, keeping only firms for which we also have monthly prices and yearly firm characteristics. Our matched IPI dataset consists of 143,330 month-firm observations, which means that we have sales data for 73 percent of the 197,394 unique month-firm observations in our cleaned PPI data set.[24]

To construct real (inflation-adjusted) firm-level sales in our final IPI dataset, we deflate firms' nominal sales by the firm-level average price. Given the relatively large monthly volatility of sales data, we winsorize cumulative monthly sales at the top and bottom five percent. In addition, we follow Ahlander et al. (2024) and smooth the data by taking a three-month centered moving average.[25]

To test the hypothesis that the sales of small firms are more responsive to changes in monetary policy, we use the same approach as for the price response. In particular, we estimate the panel local projections

$$\Delta_h ln(Sales_{j,t+h}) = \alpha_{j,h} + \alpha_{t,h} - \beta_h(mps_t \times Size_{j,t-1}) + \Gamma'_h Z_{j,t-1} + u_{j,t+h}, \tag{8}$$

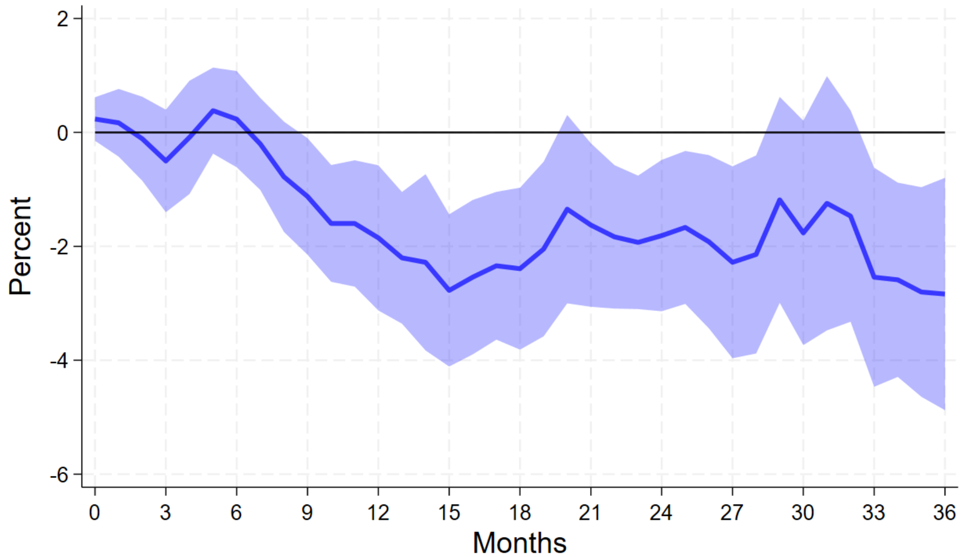
where the outcome variable is the cumulative log change in real net sales of firm j and $\alpha_{j,h}$ are firm fixed effects. The specification otherwise follows equation (4), with the same controls, time fixed effects, and firm-level clustering.

Figure 6 shows how the differential response of real firm-level sales to a 25 bp unexpected tightening of monetary policy depends on firm size. The differential response is persistently

[24] Appendix Table D.1 compares the yearly firm characteristics of the firms for which we are able to match the IPI and PPI data to those firms in our cleaned PPI dataset we are not able to match. While the firm characteristics for both groups are generally comparable, the firms for which we have both sales and prices are on average somewhat larger, older, less leveraged, and faster growing compared to the ones we cannot match. Since the matched sample skews toward larger firms, the estimated size heterogeneity in the sales response likely understates the true differential, though the bias could in principle go either way.

[25] Appendix Figure D.1 shows the impulse response functions of sales to an unexpected tightening of monetary policy of smoothed and non-smoothed firm-level sales as well as the aggregate IPI index. The figure shows that all three measures of sales fall significantly and persistently on average. Both the smoothed and non-smoothed firm-level responses are close to the response of the aggregate index in terms of magnitude and persistence. However, smoothing the data helps reduce the month-to-month volatility of the firm-level response.

Figure 6: Differential Sales Response by Firm Size



Dynamics of the interaction coefficients between size and a 25 bp unexpected tightening of monetary policy on sales. The blue solid line shows the estimated interaction coefficient from the panel local projection in equation (8). Shaded regions are 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

negative and statistically significant for most horizons from 9 to 36 months. The trough occurs 35 months after the shock, where sales of firms one standard deviation smaller than the average fall by an additional 3.1 percentage points relative to the average firm.

The estimated differential sales response supports the explanation of our main results via financial frictions and differential investment in the customer base. Consistent with the model's prediction, small firms that lower prices less after a monetary contraction subsequently lose market share and sales relative to larger firms.

The timing of the estimated responses provides further support for the mechanism. The theory predicts that the pricing decisions of smaller firms lead to a *future* loss of customers and revenue. The differential price response in Figure 3 builds up noticeably earlier than the differential sales response in Figure 6, consistent with firms trading off current liquidity against future losses of sales.

Taking the price and sales responses together, the implications for monetary policy can be quantified using the sacrifice ratio (Ball, 1994). Because smaller firms exhibit both a muted price and an amplified sales response, monetary tightening achieves less disinflation per unit of output loss among these firms. We calculate group-specific sacrifice ratios, defined as the cumulative sales decline divided by the cumulative price decline in response to a monetary policy shock.[26] Depending on the horizon, the sacrifice ratio for small firms ranges from 0.9 to 1.9, while for larger firms it ranges from 0.3 to 0.4. At the 21-month horizon, the central bank must accept roughly five times as much output loss to achieve a given reduction in prices among constrained firms. An economy with a larger share of financially constrained firms therefore faces a less favorable aggregate output-inflation trade-off.

4.4 Borrowing Behavior

The theory of firm-level financial frictions predicts that smaller firms should reduce debt more in response to a monetary tightening, reflecting their greater sensitivity to the external finance premium. Existing research is consistent with this prediction (Gertler and Gilchrist, 1994; Oliner and Rudebusch, 1996; Cloyne et al., 2023), but the evidence for U.S. manufacturing firms is mixed (Crouzet and Mehrotra, 2020). We reassess this pattern in our data by estimating panel local projections analogous to those before, using the yearly log change in total debt as the outcome variable (winsorized at the one-percent level). The monetary policy surprises are summed to annual frequency.

Figure 7 shows that the debt response to a 25 bp unexpected tightening depends significantly on firm size: small firms reduce debt more following the interest rate increase. Firms one standard deviation smaller than the average firm lower debt by 1.3 percentage points more than the average firm at the one-year horizon. The response is persistent with coefficients of -1.5 and -0.8 at the two- and three-year horizons and significant at the one- and two-year horizons.

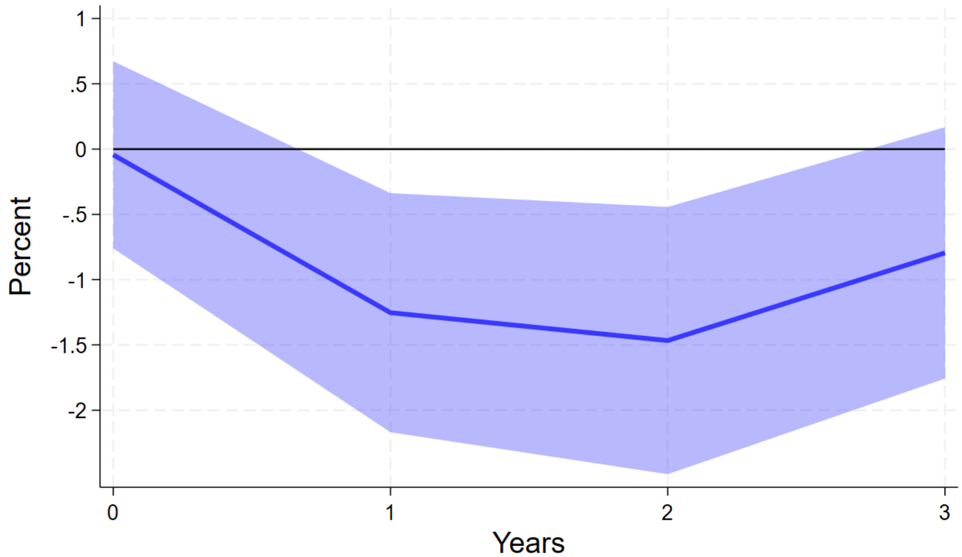
This response is consistent with the theoretical prediction that the cost of external finance increases relatively more for smaller firms following a monetary tightening, leading them to reduce debt holdings relative to less constrained firms. The differential debt response thus provides additional evidence that size proxies for financial constraints in our dataset.[27]

A natural concern is that the differential debt response reflects weaker credit demand rather than tighter credit supply: since smaller firms experience larger sales declines, they may need less working capital, so debt could fall for demand-side reasons alone. Two features of the data argue against this interpretation. First, small firms hold a substantially higher share of bank debt (Table 3, Panel B), and bank-dependent borrowers are directly exposed

[26] The traditional macro sacrifice ratio is defined as the cumulative output loss per percentage point of disinflation (Ball, 1994). Our firm-level analogue replaces aggregate output with firm sales and aggregate inflation with the firm's price response to a monetary policy shock. We estimate separate local projections for the top and bottom size quartiles for both sales and prices. Because these estimates are volatile across horizons, we average the cumulative impulse responses from $h = 0$ to H before taking their ratio. The details are in Table D.2 in the appendix.

[27] Figure D.2 shows that debt falls on average following an unexpected tightening of monetary policy.

Figure 7: Differential Debt Response by Firm Size



Interaction coefficients between size and a 25 bp unexpected monetary tightening, showing the differential response of debt for small firms vs. large firms. The blue solid line shows the estimated interaction coefficient and the shaded regions report 90% confidence bands clustered at the firm level. Sample: yearly data from 2001 to 2023.

to monetary-policy-induced shifts in lending standards. Second, small firms pledge more collateral per unit of debt and utilize a larger share of granted credit lines, both lender-side indicators of binding constraints unrelated to working-capital demand. Together, these features suggest that supply-side forces contribute meaningfully to the differential debt response, even if part of the effect operates through demand.[28]

Our evidence for a size-dependent debt response contrasts with Crouzet and Mehrotra (2020), who investigate the role of size for cyclical patterns by comparing small and large manufacturing firms in microdata from the U.S. Census and find no statistically significant differential debt response to monetary policy shocks. Based on this and related evidence, Crouzet and Mehrotra question whether size proxies for financial constraints in explaining cyclical differences. Several factors may account for the different findings. First, Crouzet and Mehrotra split firms at the 99th percentile of the asset distribution, while we consider specifications with a linear interaction with log-assets that have greater power to detect effects concentrated among the smallest firms. Second, in contrast to the Romer-Romer monetary policy shocks used by Crouzet and Mehrotra, our high-frequency shocks incorporate forward guidance and may transmit more directly to lending rates and the external finance

[28] A more direct test would examine the response of credit spreads or lending standards to monetary policy in Sweden. We leave this to future work.

premium. Third, in Sweden's more bank-based financial system, manufacturing firms have fewer non-bank alternatives, which could lead to a stronger differential lending response to monetary policy changes.

More broadly, Crouzet and Mehrotra (2020) caution that size correlates with many firm characteristics simultaneously, so differential responses attributed to financial constraints could in principle reflect other confounds. Our baseline specifications include product and time fixed effects, which absorb time-invariant product-level differences and common macroeconomic shocks. Our robustness specification with sector-by-time fixed effects (Section 3.5) further absorbs industry-level variation in technology, concentration, or export orientation. What these specifications cannot rule out are firm-level attributes that vary independently of sector and time and are correlated with size at the firm level. We turn next to these remaining candidates.

4.5 Alternative Channels

So far we have argued that a financial frictions channel is consistent with the differential price response. Section 4.2 already ruled out that heterogeneity in the frequency or size of price changes drives the results. However, other alternative channels could produce similar patterns.

The working capital channel of Christiano and Eichenbaum (1992) and Christiano et al. (2015) can lead to differences in firm-level sensitivity to monetary policy. The idea is that firms must pre-fund part of their variable production—their working capital—so that an increase in interest rates raises marginal cost and hence prices. For firms with a larger share of working capital, the negative price effects of monetary policy would be muted. If size is correlated with working capital share, this could potentially explain the heterogeneity we document.

To assess this hypothesis, we follow Barth and Ramey (2002) and measure working capital as the sum of inventories and accounts receivable net of payable over total nominal sales. We then estimate its interaction with the monetary policy shocks, using a specification analogous to equation (4), to test whether working capital share explains heterogeneity in the price response to policy shocks.[29] Figure D.3 shows the results. Panel (A) reveals no evidence for the working capital channel: firms with a higher share of working capital do not set higher prices after a contractionary monetary policy shock. The point estimates are even negative at some horizons, suggesting a stronger negative price response, though they are insignificant at most horizons. Because differences in working capital do not explain heterogeneous monetary

[29]As for the other firm characteristics, we winsorize working capital at the top and bottom one percent.

transmission to firm-level prices in our dataset, this channel cannot account for our main heterogeneity results based on firm size. Panel (B) confirms this by showing that the size interaction is robust to adding the interaction between working capital and the monetary policy surprises as an additional control.

Since size and market share are correlated, a natural concern is that differential market power rather than financial constraints explains the heterogeneous price response. In models of variable markups (Atkeson and Burstein, 2008; Amiti et al., 2019), large firms have higher market shares and stronger strategic complementarities, leading them to absorb cost shocks into markups rather than passing them through to prices. While the existing evidence pertains primarily to cost and exchange-rate shocks, the prediction that large firms exhibit more muted pass-through extends to monetary policy shocks as well. This mechanism predicts a more muted price response for large firms, not for small ones. We test it using a specification similar to equation (4), augmented with the firm's market share interaction. Consistent with the variable-markup prediction, Figure D.4 shows that firms with higher market share adjust prices less after a monetary policy shock. The size interaction is even stronger when we control for market share, confirming that market power works in the opposite direction and cannot account for our results.

In a small open economy like Sweden, export exposure is another firm characteristic that correlates with size and may shape price-setting behavior. Since larger firms are more likely to be exporters, export share and size are likely positively correlated. The hypothesis is that large exporting firms may find it optimal to set relatively lower prices in response to a tightening of monetary policy and an appreciation of the Swedish krona in order to remain competitive, consistent with the results in Czarnota (2025). We estimate an analogous specification, replacing market share with the firm-level export share. Figure D.5 shows that firms with a higher export share indeed lower prices by more following a contractionary policy shock. But the estimated size heterogeneity in the price response is robust to adding the interaction with the firm-level export share as an additional control. Furthermore, our robustness specification with sector-by-time fixed effects (Section 3.5) absorbs any sector-level variation in export intensity (as well as concentration or any other industry characteristics) that might correlate with size, and the size interaction remains robust in that specification.

4.6 Marginal Costs and Markups

While the preceding tests rule out various alternative explanations of the differential price response, they do not distinguish between changes in marginal costs and changes in markups. If the marginal costs of smaller firms are less responsive to monetary policy, their prices would respond less simply because of cost pass-through. By contrast, customer-markets theory with financial frictions predicts that small, constrained firms respond to an adverse demand shock by setting higher markups than unconstrained firms, generating liquidity from current profits at the expense of future revenues. We discriminate between these explanations by estimating the differential responses of proxies for marginal costs and markups.

We construct a measure of marginal cost following Gagliardone et al. (2025). They show that a firm's nominal log marginal cost equals the log of average cost plus a term reflecting short-run returns to scale. Under Cobb-Douglas production, the latter term is constant and can be controlled for using firm fixed effects.[30] Firms' average variable costs therefore serve as a proxy for marginal cost. We measure average variable costs as total variable costs over real sales. Total variable costs, in turn, are measured as the sum of personnel costs (wages and social security contributions), raw materials and necessities, trading goods, and other external expenses, all from the UC data. Real sales are measured as total sales over a firm-specific yearly price index. The price index is the firm-weighted average of the nominal value of output over quantity sold, both from SCB's Industrial Production Index (*Industrins varuproduktion, IVP*). Our measure of marginal cost is available for 7,343 of the 16,919 unique firm-year observations in our matched PPI sample.[31]

We estimate the role of size in the transmission of monetary policy to marginal cost using local projections analogous to those before, with log changes in annual marginal cost as the outcome variable. Panel (A) of Figure 8 plots the differential marginal-cost response by firm size. The point estimates are negative at all horizons, indicating that the marginal costs of smaller firms are *more responsive* and decline more after a contractionary shock than those of larger firms.[32] The estimates are statistically significant for the impact effect and the one-year response.

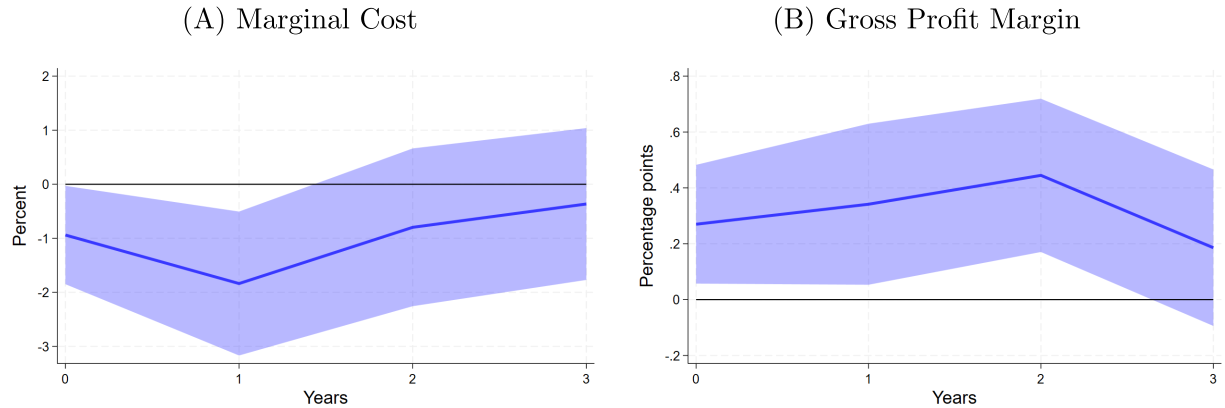
One concern is that our marginal-cost measure excludes interest costs, which the cost channel of monetary policy emphasizes as a direct way through which higher rates raise marginal costs and prices (Barth and Ramey, 2002). Smaller, more bank-dependent firms could face a larger differential increase in financing costs that our measure does not capture. For the cost channel to explain our results, however, this differential would have to be large

[30] Gagliardone et al. (2025) show, using data on Belgian manufacturing firms, that their results on the pass-through of marginal cost to prices are robust to relaxing this assumption and allowing for a CES production function.

[31] The firms without marginal cost data are somewhat larger and older on average, but the monthly price data and the other yearly firm characteristics are similar across the two subsets. If anything, the overrepresentation of larger firms in this subsample works against finding a significant size interaction, suggesting that our estimates may be conservative.

[32] Panel (A) of Figure D.6 shows that marginal cost falls on average following an unexpected tightening of monetary policy.

Figure 8: Differential Marginal Cost and Gross Profit Margin Responses by Firm Size



Dynamics of the interaction coefficients between size and a 25 bp unexpected tightening of monetary policy on marginal cost and gross profit margin. The blue solid line shows the estimated interaction coefficient and the shaded regions report 90% confidence bands clustered at the firm level. Sample: yearly data from 2001 to 2023.

enough to flip the sign of the marginal-cost gap in Panel (A). This seems unlikely given that interest costs are typically a small share of firms' total costs.[33]

These results rule out the alternative explanation that a weaker sensitivity of small firms' marginal costs to monetary policy drives the differential price response in Figure 3. Taken together, the estimated price and marginal cost responses in fact imply that smaller firms lower markups by less in response to a monetary contraction than larger firms, or even raise them, in line with theories of customer markets and financial frictions. Next, we provide direct evidence for this pattern.

To proxy for firm-level markups, we follow Renkin and Züllig (2024) and use gross profit margins, defined as total nominal sales net of total variable costs, divided by total nominal sales. Gross margins are an imperfect proxy for economic markups because they depend on how variable and fixed costs are allocated in the accounting data, but their movements over the business cycle are informative about the direction of markup adjustment. Panel (B) of Figure 8 plots the differential response of the gross margins of smaller firms to a monetary policy shock. The estimates are positive and statistically significant up to the two-year horizon. The point estimates indicate that the gross margin of a firm one standard deviation smaller than the average firm falls by about 0.3 to 0.4 percentage points less than that of the average firm. This differential is essentially the same magnitude as the average decline in gross margins, implying that small firms' gross margins are approximately flat while larger

[33] Renkin and Züllig (2024) provide a back-of-the-envelope calibration for a comparable sample of firms and find a direct effect on marginal cost on the order of a few tenths of a percent, which is well below the magnitude of the differential marginal-cost response in Panel (A) of Figure 8.

firms' margins fall.[34] This is direct evidence that small firms compress their markups less than large firms following a monetary contraction.

By compressing markups less than larger firms, or even raising them, smaller firms generate additional liquidity rather than investing in their customer base, exactly as the customer-markets channel predicts. The gross-margin evidence also speaks against the cost channel: under that mechanism, small firms would face higher costs and therefore lower, not higher, markups. This heterogeneous markup behavior may also help explain the finding of Nekarda and Ramey (2020) that the aggregate markup does not fall after contractionary monetary policy shocks, contrary to the standard New Keynesian prediction.

Taken together, the evidence in this section strongly supports the interpretation that financial constraints shape the transmission of monetary policy to firm-level prices. Smaller firms set relatively higher prices after a monetary tightening, lose market share as a result, reduce debt more sharply, and compress markups less than larger firms.[35] Each of these patterns is consistent with theories of customer markets and financial frictions, but not with alternative channels such as working capital, market power, export exposure, or differential cost sensitivity.

5 Conclusion

Understanding how monetary policy transmits to prices is a central question in monetary economics. This paper provides new evidence using detailed Swedish firm-level microdata. Small, financially constrained firms exhibit a muted price response to monetary policy. The evidence points to a mechanism combining customer markets and financial frictions: tighter policy raises the external finance premium for small firms, which compress markups less to preserve cash flows, sacrificing market share in the process. This heterogeneity has macroeconomic importance: financial constraints seem to materially dampen the aggregate producer-price response to monetary policy. Our estimates are robust to controlling for market share, export share, and working capital, showing that the size interaction is not accounted for by these correlated firm attributes. Relative to earlier work on price setting after financial shocks (Gilchrist et al., 2017; Renkin and Züllig, 2024), we show that this heterogeneity operates as part of standard monetary transmission. In contrast to the investment literature,

[34] Panel (B) of Figure D.6 shows the average response of gross profit margins for all firms after a contractionary monetary policy shock. The estimates are all negative, though not individually significant at conventional levels.

[35] In contrast, unreported analysis showed no persistent significant difference across the age, leverage, or liquidity distributions in the response of sales, debt, or markups. These insignificant responses are consistent with the insignificant differential price responses across the age, leverage, and liquidity distributions we document.

where financial constraints generally amplify the response to monetary policy (e.g., Cloyne et al., 2023; Jeenas, 2026), we find that they dampen the price response.

Our findings imply that the strength of monetary transmission to inflation depends on the degree and distribution of financial constraints across firms. Financial constraints also worsen the inflation-output trade-off, since constrained firms exhibit a weaker price response but a stronger quantity response, raising the sacrifice ratio. These considerations are especially relevant during periods of financial stress, when the external finance premium rises and the dampening effect on prices becomes more pronounced. The converse also applies: when financial stress is muted, the dampening channel should be weaker. The post-pandemic tightening, during which the banking system remained well-capitalized and credit continued to flow, may represent such an episode, consistent with the swift disinflation achieved without a recession (Hajdini et al., 2025).

Our paper points to several promising directions for future research. Our work focuses on Swedish manufacturing firms, and extending the analysis to U.S. firm-level price data seems particularly valuable given the paucity of evidence on financial frictions and monetary transmission to prices. Our results also raise the question of whether monetary policy has persistent effects on market structure. If monetary tightening causes constrained firms to lose market share that they do not fully recover, it could shift activity toward larger firms and reduce competition over time. Investigating such hysteresis and reallocation effects is an important avenue for future work.

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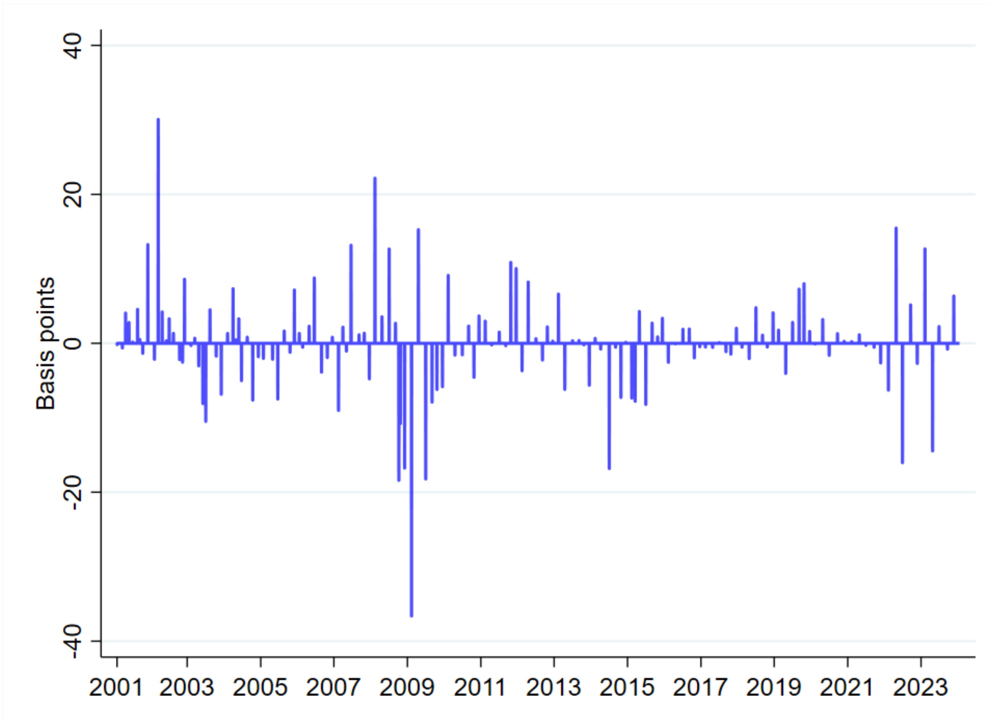
Online Appendix (not for publication)

A Monetary Policy Surprises

Figure A.1: Monetary Policy Surprises Over Time



Monetary policy surprises, calculated as the first principal component of daily changes around monetary policy announcements in forward rate agreements covering the subsequent four quarters. Sample: daily data 2001:1 to 2023:12.

Table A.1: Predictive Regression of Monetary Policy Surprises

Variable	Coefficient
Employment growth (12m)	0.011**
	(0.005)
Δ CPI inflation	-0.006*
from 6m previous	(0.004)
Δ KIX2 CPI inflation	0.004
from 6m previous	(0.003)
Δ KIX2/SEK (3m)	0.001
	(0.002)
Δ Yield curve (3m)	-0.013
	(0.025)
Δ OMXSPI (3m)	-0.001
	(0.001)
Δ BCOM (3m)	0.003***
	(0.001)
R^2	0.16
Observations	146

OLS regression of monetary policy surprises on lagged macroeconomic and financial variables. The dependent variable is the high-frequency surprise on each Riksbank announcement date. Regressors are the most recent values available before each announcement. Since employment data are revised retrospectively, we use the data vintages available at the time of each announcement. Specifically, we use the quarterly employment data reported in the Riksbank's Monetary Policy Reports published alongside the announcements. These data are publicly available on the Riksbank's website from May 2001. Heteroskedasticity-robust (White) standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Sample: 146 Riksbank announcement days from 2001:5 to 2023:12.

B Summary Statistics of the Matched PPI Dataset

Table B.1: Summary Statistics

Variable	Obs.	Mean	Std.	Min	p25	p50	p75	Max
(A) Monthly Prices								
100Δln(Price)	340,600	0.21	3.02	-15.98	0.00	0.00	0.10	17.29
Share of price changes	340,600	0.47	0.07	0.35	0.41	0.48	0.50	0.67
Size of price changes	159,908	2.92	3.24	0	0.64	1.75	3.98	17.29
Products per firm	340,600	3.87	4.88	1	1	2	4	32
(B) Yearly Firm Characteristics								
Size	16,919	19.19	1.53	16.40	18.06	19.00	20.13	25.12
Age	16,919	42.43	25.65	4.00	23.00	37.00	57.00	117.00
Leverage	16,919	0.40	0.20	0.04	0.23	0.39	0.55	0.89
Liquidity	16,919	0.06	0.09	0.00	0.00	0.01	0.08	0.46
100Δln(Sales)	16,919	3.55	17.27	-99.68	-4.18	3.84	11.80	99.75

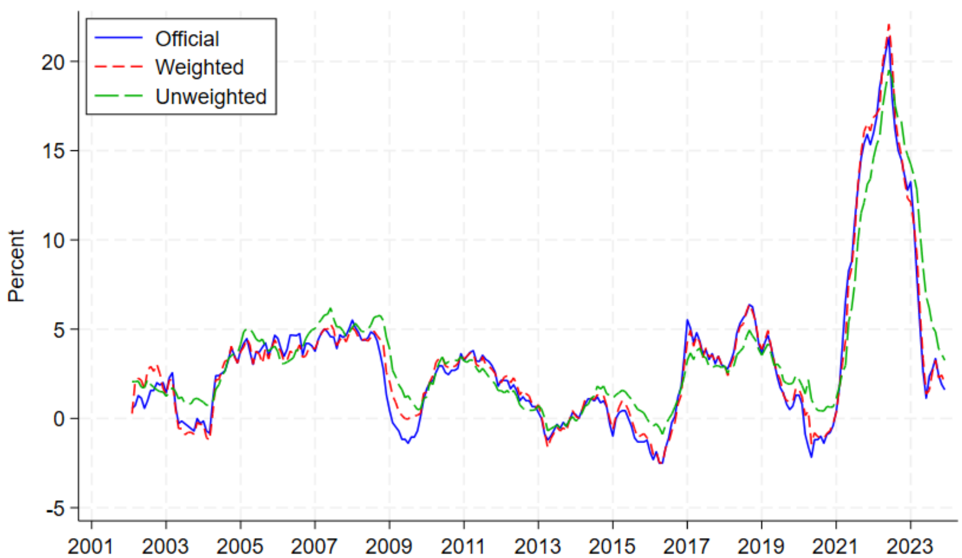
Summary statistics of the matched PPI and firm characteristics dataset. Size is measured as the log of total assets. Sample: monthly price data and yearly firm characteristics from 2001 to 2023.

Table B.2: Mean Values of PPI Firms vs. Universe of Firms

Variable	PPI sample Mean	All firms Mean
Size	19.19	14.51
Age	42.43	13.61
Leverage	0.40	0.29
Liquidity	0.06	0.31
100Δln(Sales)	2.06	2.57
Observations	16,919	5,809,661

Mean values of the firms in the matched PPI dataset compared to the universe of Swedish firms. Size is measured as the log of total assets. All variables are winsorized at the top and bottom one percent except for sales growth which is capped at an absolute value of 100 percent. Sample: yearly firm characteristics from 2001 to 2023.

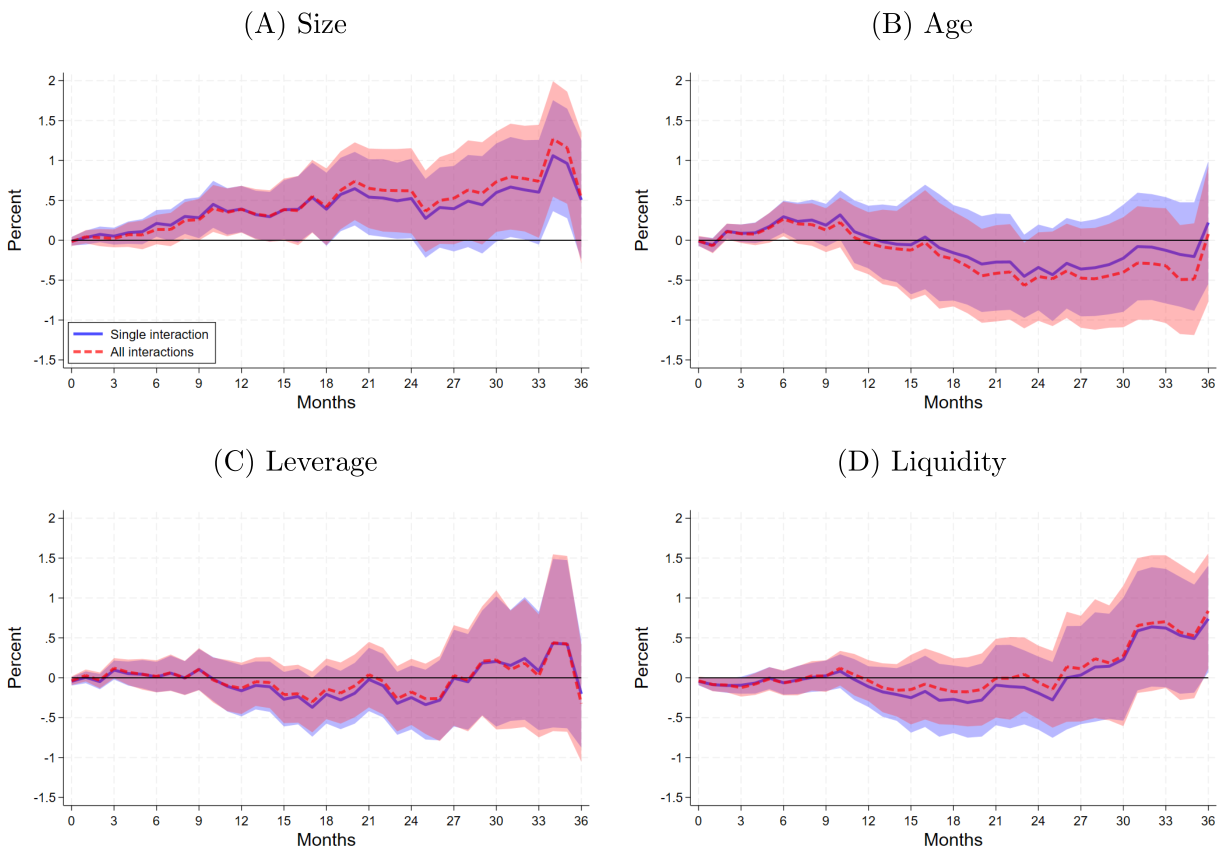
Figure B.1: Producer Price Inflation Rates



Year-on-year inflation rates from the official PPI index for the manufacturing sector published by SCB (blue solid line), the index recreated with the same weighting procedure using our final (cleaned) dataset (red dashed line), and the unweighted index using our final dataset (green dashed line). Sample: monthly data from 2001:1 to 2023:12.

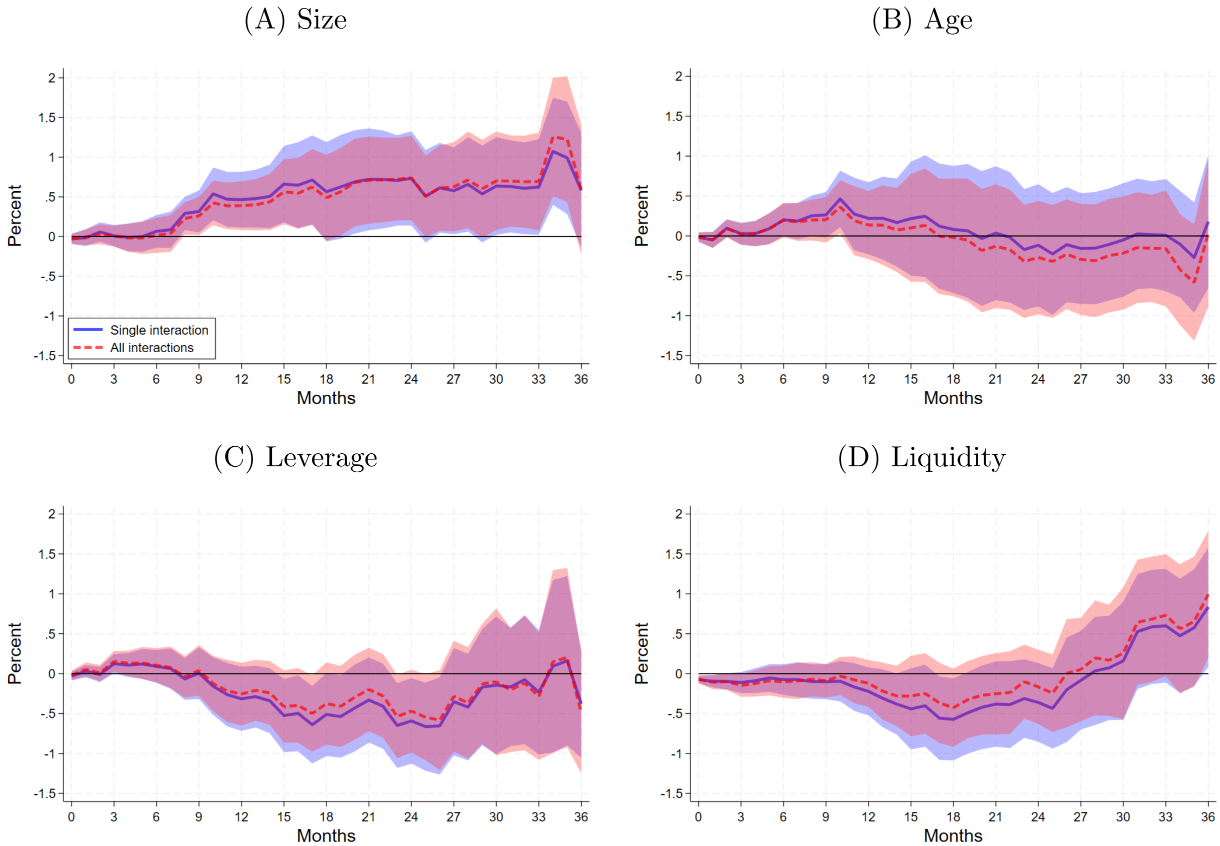
C Robustness of the Price Responses

Figure C.1: Differential Price Response of Constrained Firms to Monetary Policy Shock: Two-Digit Product Group-by-Time Fixed Effects



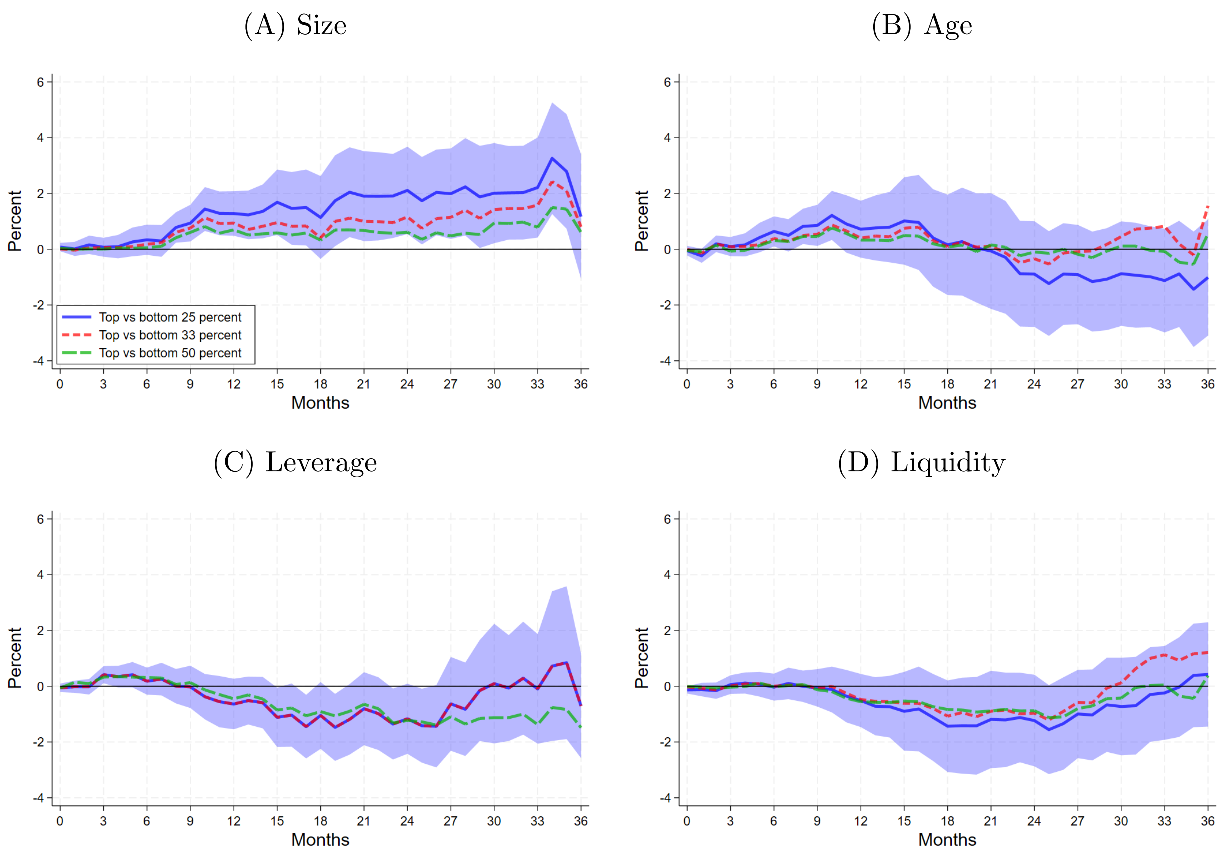
Dynamics of the interaction coefficients between financial constraint proxies and a 25 bp unexpected tightening of monetary policy on prices. Blue solid lines report point estimates when the interactions are estimated separately using the panel local projections in equation (4) and red dashed lines when they are estimated together using equation (5). In both equations, the time fixed effects have been replaced with two-digit product group-by-time fixed effects. Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

Figure C.2: Differential Price Response of Constrained Firms to Monetary Policy Shock: Excluding the High-Inflation Period



Dynamics of the interaction coefficients between financial constraint proxies and a 25 bp unexpected tightening of monetary policy on prices. Blue solid lines report point estimates when the interactions are estimated separately using the panel local projections in equation (4) and red dashed lines when they are estimated together using equation (5). Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2020:12.

Figure C.3: Semi-Parametric Estimates of Differential Price Responses: Alternative Group Splits



Dynamics of the semi-parametric interaction coefficients between financial constraint proxies and a 25 bp unexpected tightening of monetary policy on prices. Blue solid lines report point estimates from equation (6). Shaded regions report 90% confidence bands clustered at the firm level. Red and green dashed lines report point estimates from equation (6) when the respective distribution has been split into the top and bottom 33 and 50 percent, respectively. Sample: monthly data from 2001:1 to 2023:12.

Table D.1: Summary Statistics: Non-Missing vs. Missing Observations

Variable	Obs.	Mean	Std.	Min	p25	p50	p75	Max
(A) Non-missing								
Size	143,330	19.49	1.54	16.40	18.38	19.32	20.40	25.12
Age	143,330	43.61	25.94	4.00	24.00	38.00	59.00	117.00
Leverage	143,330	0.39	0.20	0.04	0.23	0.38	0.54	0.89
Liquidity	143,330	0.05	0.09	0.00	0.00	0.01	0.07	0.46
100Δln(Sales)	143,330	4.00	16.78	-96.66	-3.66	4.11	12.12	99.75
(B) Missing								
Size	54,094	18.46	1.27	16.40	17.57	18.23	19.12	24.74
Age	54,094	39.63	24.72	4.00	21.00	35.00	53.00	117.00
Leverage	54,094	0.40	0.21	0.04	0.23	0.40	0.56	0.89
Liquidity	54,094	0.06	0.10	0.00	0.00	0.01	0.08	0.48
100Δln(Sales)	54,094	2.34	18.28	-99.67	-5.49	3.14	10.98	99.16

Summary statistics of firm characteristics of the firms in the matched PPI-IPI sample and the characteristics of the unique firms in our cleaned PPI sample for which the IPI data are not available. Size is measured as the log of total assets. Sample: yearly firm characteristics from 2001 to 2023.

D Additional Results for Section 4

Construction of Composite Financial-Constraint Indices

The composite indices reported in Panel (C) of Table 3 are constructed as follows:

$$\begin{aligned}
\mathrm{FCP}_{j,t} &= -0.123 \times \mathrm{Size}_{j,t} - 0.024 \times \text{Interest coverage}_{j,t} - 4.404 \times \mathrm{ROA}_{j,t} - 1.716 \times \text{Cash holdings}_{j,t}, \\
\mathrm{WW}_{j,t} &= -0.091 \times \mathrm{Cashflow}_{j,t} - 0.062 \times \text{Dividend dummy}_{j,t} + 0.021 \times \mathrm{Leverage}_{j,t} \\
&\quad - 0.044 \times \mathrm{Size}_{j,t} + 0.102 \times \mathrm{ISG}_{j,t} - 0.035 \times \mathrm{SG}_{j,t}, \\
\mathrm{SA}_{j,t} &= -0.737 \times \mathrm{Size}_{j,t} + 0.043 \times \mathrm{Size}^2_{j,t} - 0.040 \times \mathrm{Age}_{j,t}.
\end{aligned}$$

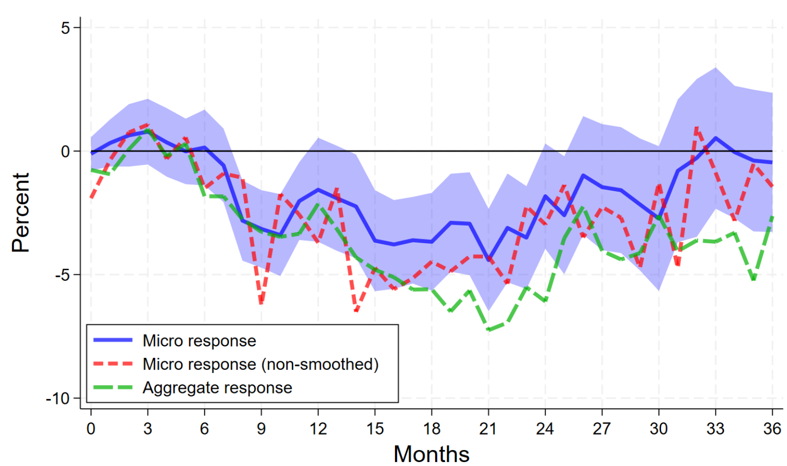
Interest coverage is EBIT over interest expenses, ROA is net income over total assets, and cash holdings is cash over previous year's total assets. Cashflow is operating income and depreciation over previous year's total assets, dividend dummy takes the value of one if the firm pays cash dividends, leverage is long-term debt over total assets, and ISG and SG denote three-digit industry and firm sales growth, respectively. Size is measured in millions of USD, values of interest coverage above (below) 100 (0) are set to 100 (-0.1) (Schauer et al., 2019), and cashflow is capped at -10 and 10.

Table D.2: Group-Specific Sacrifice Ratios by Firm Size

	$H = 9$	$H = 12$	$H = 15$	$H = 18$	$H = 21$	$H = 24$
Large firms (top size quartile)						
Avg. prices	-0.82	-1.21	-1.49	-1.68	-1.91	-2.11
Avg. sales	-0.37	-0.50	-0.52	-0.66	-0.66	-0.62
Sacrifice ratio	0.45	0.42	0.35	0.39	0.35	0.29
Small firms (bottom size quartile)						
Avg. prices	-0.50	-0.65	-0.76	-0.84	-0.94	-1.01
Avg. sales	-0.46	-0.88	-1.18	-1.51	-1.78	-1.72
Sacrifice ratio	0.92	1.35	1.56	1.79	1.90	1.71

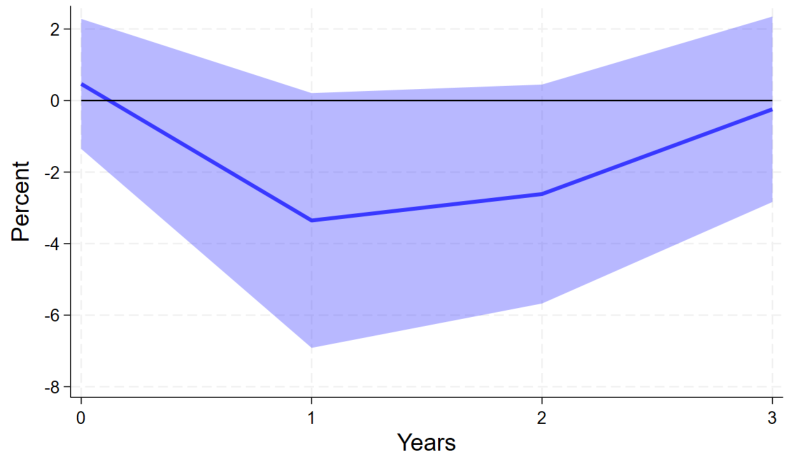
Group-specific sacrifice ratios by firm size. Avg. prices and avg. sales report the average cumulative impulse response over horizons $h = 0, \ldots, H$. Responses are to a 25 bp monetary policy tightening surprise estimated from separate local projections for each size group. The sacrifice ratio is the ratio of average cumulative sales to average cumulative prices for a given size quartile. A higher sacrifice ratio indicates a less favorable output-inflation trade-off. Sample: monthly, 2001:1–2023:12.

Figure D.1: Impulse Response Functions of Firm-Level and Aggregate Sales



Average firm-level sales response to a 25 bp monetary tightening from the panel local projection in equation (3), with sales smoothed by a three-month centered moving average (blue solid) and non-smoothed (red dashed). Green long-dashed line shows the aggregate IPI response from equation (2). Shaded regions report 90% confidence bands clustered two-way at the firm and time levels. Sample: monthly data from 2001:1 to 2023:12.

Figure D.2: Impulse Response Function of Average Firm-Level Debt to Monetary Policy

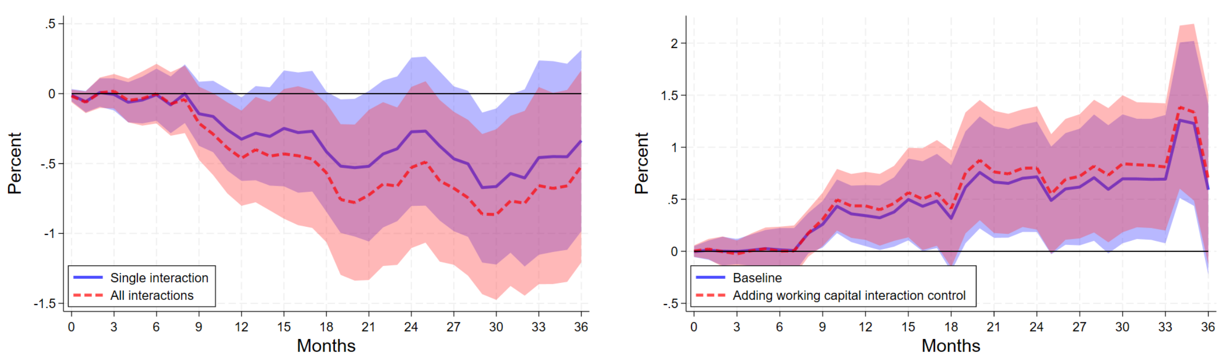


Average firm-level debt response to a 25 bp monetary tightening from the panel local projection in equation (3) applied to log debt, with mps_t the yearly sum of monetary policy surprises and aggregate controls aggregated to yearly averages. Shaded regions report 90% confidence bands clustered two-way at the firm and time levels. Sample: yearly data from 2001:1 to 2023:12.

Figure D.3: Differential Price Response to Monetary Policy: Working Capital

(A) Working Capital Interaction

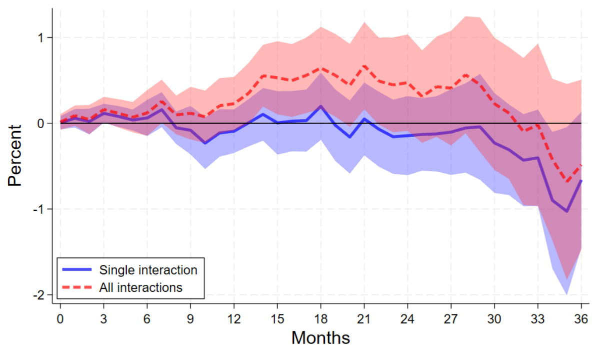
(B) Size Interaction



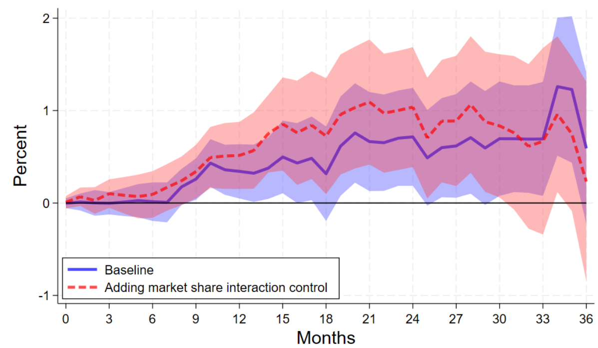
Panel (A): Working-capital interaction estimated separately (blue solid) and jointly with the financial-constraint proxies (red dashed) from equation (5) augmented with the working-capital interaction. Panel (B): Analogous size interaction. Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

Figure D.4: Differential Price Response to Monetary Policy: Market share

(A) Market Share Interaction



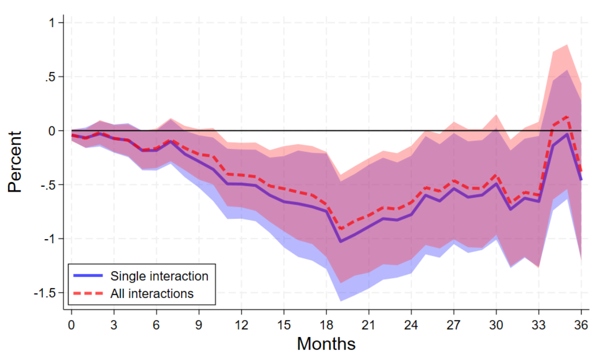
(B) Size Interaction



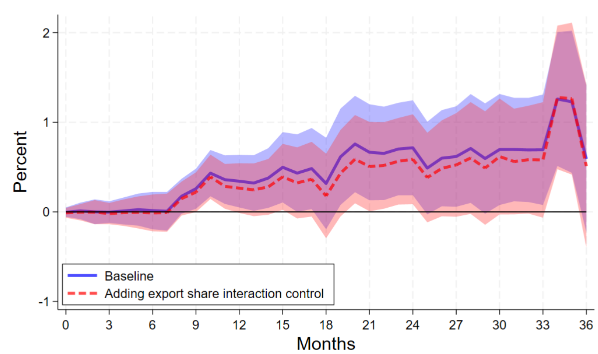
Panel (A): Market-share interaction estimated separately (blue solid) and jointly with the financial-constraint proxies (red dashed) from equation (5) augmented with the market-share interaction. Panel (B): Analogous size interaction. Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

Figure D.5: Differential Price Response to Monetary Policy: Export Share

(A) Export Share Interaction



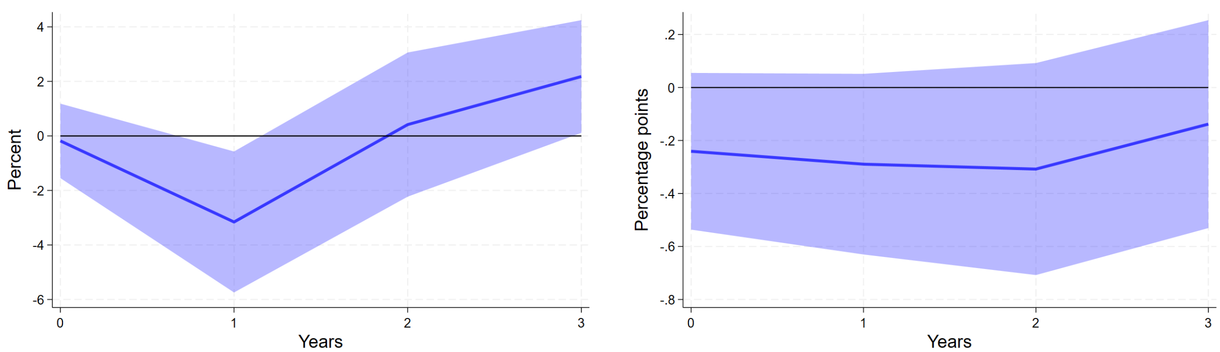
(B) Size Interaction



Panel (A): Export-share interaction estimated separately (blue solid) and jointly with the financial-constraint proxies (red dashed) from equation (5) augmented with the export-share interaction. Panel (B): Analogous size interaction. Shaded regions report 90% confidence bands clustered at the firm level. Sample: monthly data from 2001:1 to 2023:12.

Figure D.6: Average Responses of Marginal Cost and Gross Profit Margin to Monetary Policy

(A) Marginal Cost (B) Gross Profit Margin



Average firm-level responses to a 25 bp monetary tightening from the yearly version of equation (3) applied to log marginal cost (Panel A) and log gross profit margin (Panel B). Shaded region: 90% confidence bands clustered two-way at the firm and time levels. Sample: yearly data from 2001:1 to 2023:12.