SVERIGES RIKSBANK
WORKING PAPER SERIES

447

ChaMP

SVERIGES RIKSBANK

The Inflationary Effects of Quantitative Easing

Mathias Klein and Xin Zhang

February 2025

WORKING PAPERS ARE OBTAINABLE FROM

www.riksbank.se/en/research
Sveriges Riksbank • SE-103 37 Stockholm
Fax international: +46 8 21 05 31
Telephone international: +46 8 787 00 00

The Inflationary Effects of Quantitative Easing*

Mathias Klein *Xin Zhang*

Sveriges Riksbank Sveriges Riksbank

February 24, 2025

Sveriges Riksbank Working Paper Series No. 447

Abstract

We provide new evidence on the inflationary effects of Quantitative Easing (QE) using Swedish administrative data at the bank, firm, and product level. For identification, we rely on bank-firm lending relationships and the heterogeneous participation rates of banks in the government bond purchase program by the Swedish central bank. Our results show that the bond purchase program led to a significant and persistent increase in producer prices. Importantly, we find that the degree of financial frictions considerably influences firms' price response: low leverage firms do not change their prices, whereas high leverage firms raise their prices significantly. This divergent pricing behaviour can be rationalized by a significant increase in long-term borrowing and interest rate expenses among high leverage firms. The difference in price responses across high and low leverage firms is less pronounced for exogenous changes in the repo rate implying that the transmission mechanism of QE differs from the one of conventional interest rate policy.

*For valuable comments and suggestions, we thank Niklas Amberg, Christoph Bertsch, Olivier Coibion, Jens Christensen (discussant), Luca Dedola, Michael Ehrmann, Martin Ellison, Zeno Enders, Francesco Furlanetto, Georgios Georgiadis, Boris Hofmann, Peter Karadi, Ryan Kim (discussant), Gisle Natvik, Mathieu Pedemonte (discussant), Vincenzo Quadrini, Federico Ravenna, Anna Rogantini Picco, Timo Reinelt, Raphael Schoenle, Daniel Streitz, Felix Strobel (discussant), Yannick Timmer, Tomasz Wieladek, Roland Winkler, Jing Cynthia Wu and Francesco Zanetti as well as conference and seminar participants at the ChaMP Research Network Workshop, the 23rd IWH-CIREQ-GW Macroeconometric Workshop, 4th European Midwest Micro/Macro Conference, PRISMA/ESCB Workshop on Firm-level price setting and inflation dynamics, the Federal Reserve Day Ahead Conference on Financial Markets and Institutions, the Innsbruck Workshop in Empirical Macroeconomics, and the Bank of Canada and the University of Toronto's Inflation Workshop. The views expressed in this paper are those of the author and they do not necessarily reflect the views of Sveriges Riksbank.

Keywords: Quantitative easing, price dynamics, financial frictions.

***JEL* Classification:** E31, E51, E58.

1 Introduction

As many central banks across the globe have reached the zero lower bound (ZLB) on nominal interest rates, unconventional monetary policies like large-scale asset purchases have become a popular tool to stimulate private demand and raise prices. These policies were implemented by many central banks around the world, however, their effects and transmission mechanisms are still unsettled questions. While some papers provide evidence in favor of significant positive effects of unconventional monetary policies (Lewis, 2019; Gambacorta et al., 2014; Boeckx et al., 2020), others find only small or even negative effects (Lenza et al., 2010; Carlstrom et al., 2017). Most of these studies use aggregate data to trace out the dynamic impact of unconventional monetary policies. However, relying on aggregate time series faces the challenges of first, limited time variation given the relatively short period during which unconventional monetary policies were implemented and, second, the lack of proper identification as economies are hit by different aggregate shocks at the same time.

This paper provides new estimates on the inflationary effects of quantitative easing (QE) using detailed micro level data on the Swedish economy. In particular, we merge official data underlying the aggregate producer price index (PPI) with administrative bank and firm level data. We construct a linked database of granular bank-firm-product-price information. For identification, we use the different exposure of banks to the government bond purchase program by the Swedish central bank (Sveriges Riksbank) and construct an individual firm treatment measure based on bank-firm relationships in the spirit of Acharya et al. (2019). The measure relies on the typical bank lending channel of monetary policy and is constructed such that firms having a relationship with banks more active in the QE program are more exposed to the unconventional monetary policy intervention compared to firms having a relationship with less active banks.

Our analysis at the very granular level has several important advantages compared to studies at the aggregate level. First, the large cross sectional variation can be used for identification and should thus result in more precise estimates. As our proposed QE exposure measure varies across time and between firms, the impact of unconventional monetary policy can be studied at the micro level. Secondly, using the comprehensive information on firm characteristics, potential heterogeneities can be investigated in a straight forward way. Indeed, we show that the degree of firms' financial frictions is crucial for understanding the price response to QE.

Our main results show that large scale asset purchases are an effective tool to increase prices in the economy. We find that the government bond purchase program by the Riksbank led to a significant increase in producer price inflation that lasts for more than a year. A 1 billion SEK QE exposure leads to a one year increase in producer prices by more than 1%. Thus, QE might indeed serve as an adequate tool to produce inflationary pressure when the ZLB restricts conventional interest rate policy.

Importantly, we detect strong heterogeneities in the price setting behaviour across firms. First, much in line with D'Acunto et al. (2018); Gilchrist et al. (2017); Renkin and Zuellig (2023), we show that financial frictions are a central determinant of a firms' pricing behaviour unconditional on the bond purchase innovation. High leverage firms have a larger price changing frequency than low leverage ones implying more flexible prices for financially constrained firms. Secondly, we show that the degree of financial frictions significantly influences how firms adjust their prices following the central banks' bond purchases. Low leverage firms do not change their prices by a significant amount. In stark contrast, high leverage firms raise their prices significantly. The increase in prices among high leverage firms is driven by a rise in both price-setting margins: a higher price change frequency and a larger price change magnitude. Low leverage firms reduce both price-setting margins. Thus, the inflationary effects of QE are mainly driven by financially constrained firms.

To better understand the underlying driver of this leverage-dependent price response to unconventional monetary policy interventions, we make use of our granular matched dataset and run additional regressions at the firm level on real and financial variables. We find that high leverage firms significantly increase their long-term debt position and face higher interest rate expenses following the QE intervention. Thus, borrowing costs of high leverage firms rise, which puts upward pressure on their pricing decision. The additional borrowing is mainly used to finance investments in fixed assets. Because such assets can typically be used a collateral for debt, increasing fixed assets could be explained by an incentive among high leverage firms to loosen borrowing constraints in the future. Moreover, high leverage firms do not gain from any positive aggregate demand effects which results in higher inventories and no significant change in revenues for these firms. In contrast, investment in R&D, machines, and equipment by low leverage firms increases which mitigates any positive price pressure for these firms. In addition, low leverage firms experience an increase in profits and revenues and thus are able to raise their market share.

Notably, we also show that the difference in price responses across high and low leverage firms is less pronounced for conventional monetary policy interventions. An exogenous fall in the repo rate leads to price increases among both low and high leverage firms. This suggests that the transmission mechanism of QE to inflation is different to the one of conventional interest rate policy. Our estimates imply that a government bond purchase program of 1.3% of GDP induces a similar-sized price increase than an exogenous fall in the repo rate by 25 basis points. Overall, our findings intend to inform theoretical analyses on the impact of QE and on the importance of financial frictions for understanding how unconventional monetary policy shapes the economy.

Related literature. A number of papers investigate the impact of QE on inflation in Japan, the Euro Area, U.K. and U.S.. Fabo et al. (2021) provide a survey of 54 studies on how QE impacts output and inflation. They find that the average (median) effect on the price level consists in an increase by 1.42% (0.93%). Standardizing the QE intervention to 1% of GDP, the average (median) effect on the price level is 0.19%

(0.11%). What's more, they find that the inflationary effect of QE is strongest in the U.S..[1] The surveyed papers employ either DSGE models or VAR models to estimate the impact of quantitative easing. In our paper, we are among the first to evaluate the impact of QE on inflation exploring very detailed micro data on producer prices and linking them with firm characteristics and bank lending relationships.

There are a few well established transmission channels of QE to financial markets and to the real economy. Our paper is related to the classical bank lending channel of monetary policy transmission, as first introduced by Bernanke et al. (1988).[2] Under the bank lending channel, bank deposits are negatively affected when central banks tighten the policy rate, leading to a reduction of bank credit in the economy. A few recent works focus on unconventional monetary policy and the bank lending channels, including Joyce and Spaltro (2014), Buttz et al. (2015) and Bowman et al. (2015). These papers present evidence of stimulatory effects of QE but with various degrees of significance. It is thus important to relate the QE program to the economic condition and the financial market structure. In our study, we show that unconventional monetary policy transmits through the bank-firm credit relationship in Sweden, which contributes to the increase in producer prices and the heterogeneous price responses across financially constrained and unconstrained firms.

A few papers in the literature document the heterogeneous impacts of QE on banks (Rodnyansky and Darmouni, 2017; Sims and Wu, 2021), households (Cui and Sterk, 2021), and firms R&D decisions (Grimm et al., 2021). To the best of our knowledge, we are the first to document firms' heterogeneous price responses to QE. Our work is also related to Sims and Wu (2021). They present a model in which financial intermediaries, as in Gertler and Karadi (2018), can hold long-term bonds issued by firms or the government, and interest-bearing reserves. Within the model, the QE program leads to a change of portfolio holdings of banks and eases its balance sheet constraints, which

[1]It is worth mentioning that the authors find substantial differences in the results among different countries and different researchers.

[2]Morais et al. (2019) show that there exists an international bank lending channel. As a result, Quantitative Easing programs in the U.K., U.S. and Euro Area generate significant spillovers to emerging market economies.

enables financial institutions to buy more privately issued bonds.

Our paper is broadly related to the literature on how firm heterogeneity shapes the monetary policy transmission mechanism. Ehrmann and Fratzscher (2004), Gorodnichenko and Weber (2016) and Ippolito et al. (2018) show that firms with different characteristics have heterogeneous sensitivities to monetary policy shocks and monetary policy communications. We contribute to this strand of the literature by focusing on the inflationary effects of unconventional monetary policy, which is an important policy tool when conventional monetary policy is constrained by the ZLB. We further highlight the differences of price responses across constrained and unconstrained firms and rationalize our findings by divergent adjustments of long term debt positions and interest rate expenses. When the floating-rate channel of Ippolito et al. (2018) is not active at the ZLB, we find that long-term debt can serve as an important transmission channel of unconventional monetary policy.

Finally, our paper relates to recent studies which investigate the relationship between price-setting behaviour and firms' financial conditions (Gilchrist et al., 2017; D'Acunto et al., 2018; Renkin and Zuellig, 2023; Kim, 2021). We contribute to this literature by showing that firms' financial position is key to understand how unconventional monetary policy interventions transmit to inflation.

Institutional background. The Riksbank started the QE program after an extend period of low inflation in Sweden. In response to the low inflation environment after the Great Financial Crisis and the European Debt Crisis, Sveriges Riksbank lowered the policy rate to zero and implemented negative interest rates later on. In February 2015, the Riksbank introduced the QE program to purchase Swedish government bonds. By April 2020, it owned more than half of the outstanding nominal bonds and around one-fourth of the inflation-linked ones. In April 2022, the Riksbank held Swedish government bonds of SEK 401 billion. According to the evaluation of the Riksbank, these purchases successfully lowered interest rates which, in turn, led to a boost in aggregate demand and stimulated the economy. During the Corona pandemic, the Riksbank further extended the purchase to include covered bonds, municipality bonds, and qualified corporate bonds, to support market liquidity and market functions.[3] The Riksbank has conducted more than 450 auctions of nominal and real Swedish government bonds in the period between February 2015 and June 2021. The QE purchase transactions happen at a higher frequency than the auctions. In the paper, we utilize a proprietary dataset of Riksbank bond purchase allocations among participating banks to investigate the inflationary effects of the QE program through bank-firm credit relationships.

Structure of the paper. The paper proceeds as follows. Section 2 presents our main dataset and the identification strategy. Section 3 describes our econometric approach and Section 4 discusses the main empirical results on the firms' pricing responses to the Riksbank QE program, the underlying transmission mechanism, and compares the main findings to the ones in response to conventional monetary policy interventions. Section 5 presents the results of several robustness checks. Finally, Section 6 concludes.

2 Data

In this section, we describe the main data used in our empirical exercise. In particular, we merge several different Swedish databases: the micro price data underlying the official Producer Price Index, the banks' participation in the Riksbank QE program, banks' balance sheet information, all firms' financial and accounting variables, and the bank-firm exposure in banks' loan portfolios. As far as we know, it is the first attempt in the literature to create a linked database of such granular bank-firm-price information. While our main identification relies on the detailed bank-firm relationships, the main outcome variable consists in the firms' pricing decision. In addition, we include several macroeconomic control variables in the regressions.

[3]In our study, we do not investigate the Coronavirus pandemic QE program.

2.1 Price data

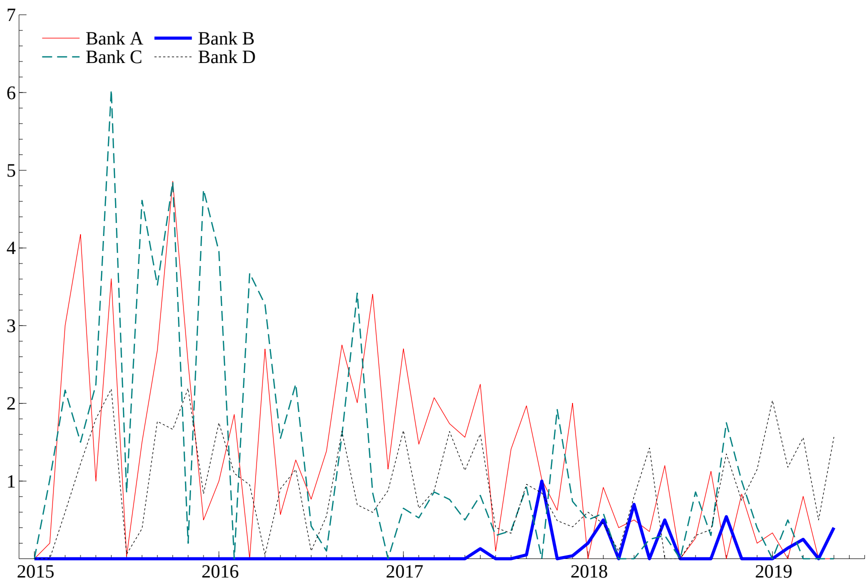
We use administrative product-level data from Statistics Sweden (SCB), comprising all products underlying the Swedish producer and import price index (PPI). The PPI is calculated as a weighted average of observed monthly prices on individual product offerings by product group level according to the Swedish Standard of Industry Classification (SPIN), and may then be aggregated to final indices within each market (domestic, import and export) as well as for all Swedish-made products. Thus, both product-specific and product group-specific weights are used in the construction of the official PPI. The data covers the period January 1992 to December 2017 and includes roughly 1.44 million price observations in total.

We filter out observations with negative prices as well as duplicated products, and exclude a SPIN group for the entire year whenever the group has missing observations within that specific year. Moreover, we restrict the analysis to manufactured products sold at the Swedish domestic market. After these cleaning steps, we are left with more than 51,000 price observations which amounts to roughly 80% of the raw data available for our baseline sample of the QE program which covers the period 2015M2-2017M12.

2.2 Bank and firm data

We obtain the bond purchase auction and sales history in the Riksbank Quantitative Easing program that started in 2015. Several banks participated in the bond auction. We observe the bidding amount, price information from each bank in each round of the QE program, and we have information on the final bond sales allocation and the corresponding price. We sum up bank b's QE sales at month t as its QE participation $QE_{b,t}$. Figure 1 provides a time series plot of randomly selected banks' QE participation. It shows that the bank participation is highly volatile over time and different in the cross-section which helps our identification strategy that combines variation in banks' QE participation with bank-firm credit relationships. For example, we can see that Bank B is not involved in the QE sales for more than half of the sample period,

Figure 1: Banks' QE activities



whereas Bank C is very active in the first half of the sample and show less activity in the later periods.

Banks can either sell QE eligible government bonds from their own bond holdings, or sell bonds for their customers. The different nature of the bond sales could affect banks' balance sheet differently. If the bank is selling bonds in their own portfolio, it will strengthen the liquidity position, and free up capital for other risk-taking businesses, such as expanding corporate lending. If the bank is helping its customers to sell bonds in the QE program, it is very likely that bank deposits increase. The bank can thus increase lending to firms or other financial institutions. SCB provides a detailed database of banks' balance sheet at the monthly frequency covering our sample period. Therefore, we can link banks' QE activities to changes of treasury (government bond) holdings and the deposits from other non-monetary financial institutions (Non-MFIs).

For the corporate sector, we have a large comprehensive database covering the whole universe of Swedish firms, provided by the credit registry UC, for the period 1990–2019. We observe all firm balance sheet items, including financial, accounting, and real variables at the annual frequency. The database covers all registered firms in

Sweden, so it doesn't suffer from any bias in coverage across firm size or age. Below, we will use a number of firm level variables to investigate heterogeneous responses of firms to QE. Because the PPI microdata include a unique firm identifier, we can match the UC data with the price data. For our period of interest (2015M2-2017M12), the match covers around 1,100 firms. Table 2 provides the summary statistics of the main firm variables used in the paper.

The final dataset is a hand-collected bank credit portfolio with detailed contract-level information. Here we observe the bank-firm lending relationship from the beginning of 2007 to the end of 2015. Unfortunately, the data collection process stopped at the beginning of 2016. However, it seems reasonable to assume that bank relationships are relatively sticky. In our main regression specification, we will use the bank-firm link variable just before the implementation of QE, to ease the concern that the QE participation is endogenous to the bank lending decision.

2.3 Measure firms' exposure to QE

We define firm i's exposure to QE at month t through bank b, through its credit relationship exposure from bank b. The credit relationship variable $\omega_{i,b,t}$ is the fraction of credit from bank b over the total credit firm i borrows at month t.

Given bank b's bond sales amount in the QE program at t as $QE_{b,t}$, we can calculate a measure of firm QE exposure as

$$\text{Expo}_{i,t} = \sum_{b} \omega_{i,b,t} \cdot QE_{b,t}. \tag{1}$$

The underlying assumption is that banks will channel more credit to its relationship firms after acquiring additional deposits from sales of government bonds through the QE program. Put differently, firms that have a relationship with banks more active in the QE program are more exposed to the unconventional monetary policy intervention than firms that have a relationship with less active banks. Thus, we rely on the well know bank-lending channel of QE very much in line with the approach suggested by

Table 1: Bank-firm credit relationship weights between 2008 and 2015

Correlation	$\omega_{i,b,t}$	$\omega_{i,b,t-12}$	$\omega_{i,b,t-24}$	$\omega_{i,b,t-36}$	$\omega_{i,b,t-48}$	$\omega_{i,b,t-60}$	$\omega_{i,b,t-72}$
$\omega_{i,b,t}$	1.000						
$\omega_{i,b,t-12}$	0.929	1.000					
$\omega_{i,b,t-24}$	0.869	0.920	1.000				
$\omega_{i,b,t-36}$	0.806	0.850	0.908	1.000			
$\omega_{i,b,t-48}$	0.754	0.793	0.841	0.907	1.000		
$\omega_{i,b,t-60}$	0.703	0.735	0.775	0.830	0.893	1.000	
$\omega_{i,b,t-72}$	0.635	0.659	0.682	0.723	0.775	0.845	1.000

Acharya et al. (2019). We fix the weight $\omega_{i,b,t}$ at $t = t_0$, as the credit relationship ratio in January 2015, right before the Riksbanks' QE program started.

There are a few reasons to weight the firm exposure with a predetermined share through banks' QE sales. First of all, the bank lending relationship in Sweden is quite stable, especially for large firms. Obviously, it takes time to establish a credit relationship between banks and firms. We elaborate on the point by examining the bank-firm credit relationships in our sample 2008–2015 using quarterly snapshots of the relationship mapping. Table 1 shows that the bank firm relationship, measured by $\omega_{i,b,t}$ as the fraction of firm i's total loans coming from bank b at t, is highly correlated over the 12-month , 24-month, and 36-month window. The correlation coefficient between the contemporaneous weight, $\omega_{i,b,t}$, and the weight three years ago, $\omega_{i,b,t-36}$ is 0.806 and highly statistically significant. If we only look at the main bank, which is defined as the bank that firm i borrows most credit from, none of the firms switched their main bank after 6 years. It is thus reasonable to assume that the share of loans from various banks turn out to be constant over time. Thus, the time variation in the firms' exposure measure is coming from the bank's decision regarding their activity in the QE program only. This decision should be exogenous to the firms given their limited power in influencing the banks' participation in the bond purchases which supports our identification strategy.

Secondly, we want to rule out that the weights are affected by the endogenous adjustments of banks' credit issuance. If banks follow the strategy to adjust the credit portfolio to favor certain firms, for instance riskier firms as in the risk taking channel of monetary policy, it is possible that banks' QE and credit decisions are decided jointly.

This would lead to possible endogeneity issues regarding firms' pricing decisions and credit availability. In our analysis, we fix the credit allocation weights in the month prior to the QE program, January 2015. Thus, we can rule out the possible endogenous response of credit re-allocation due to the QE program.

Table 2: Summary statistics

	count	mean	sd	p25	p50	p75
Cash flow / Total liabilities	9864	0.252	0.295	0.057	0.180	0.383
Labour cost / revenue	9094	0.134	0.079	0.072	0.124	0.188
Working capital / revenue	9827	0.176	0.202	0.045	0.137	0.261
Inventory / revenue	9825	0.123	0.092	0.051	0.109	0.179
Current liabilities / revenue	9825	0.266	0.162	0.157	0.218	0.319
Total Debt	9994	6.550	7.927	0.000	0.000	15.719
Long-term Debt	9996	4.698	7.204	0.000	0.000	14.323
Short-term Debt	9994	5.269	7.240	0.000	0.000	14.108
External interest expense	10037	11.393	3.863	10.309	12.301	13.769
Long-term leverage ratio	9992	0.039	0.078	0.000	0.000	0.028
R&D expenses	2894	5.393	7.976	0.000	0.000	15.375
Total sales	9992	19.188	1.419	18.243	19.086	20.097
ω_{i,b,t_0}	9524	0.250	0.423	0.000	0.000	0.493
$\text{Expo}_{i,t}$	121431	0.845	1.089	0.000	0.491	1.272

3 Empirical specification

To evaluate the effects of quantitative easing on producer prices, we use panel local projections (Jordà, 2005) at the individual product level and estimate for each horizon $h = 0, ..., 12$, the following equation:

$$log(y_{i,j,t+h}) - log(y_{i,j,t-1}) = \alpha_{j,h} + \alpha_{m,h} + \beta_h \text{Expo}_{i,t} + \gamma_h X_{i,t} + u_{i,j,t+h}, \tag{2}$$

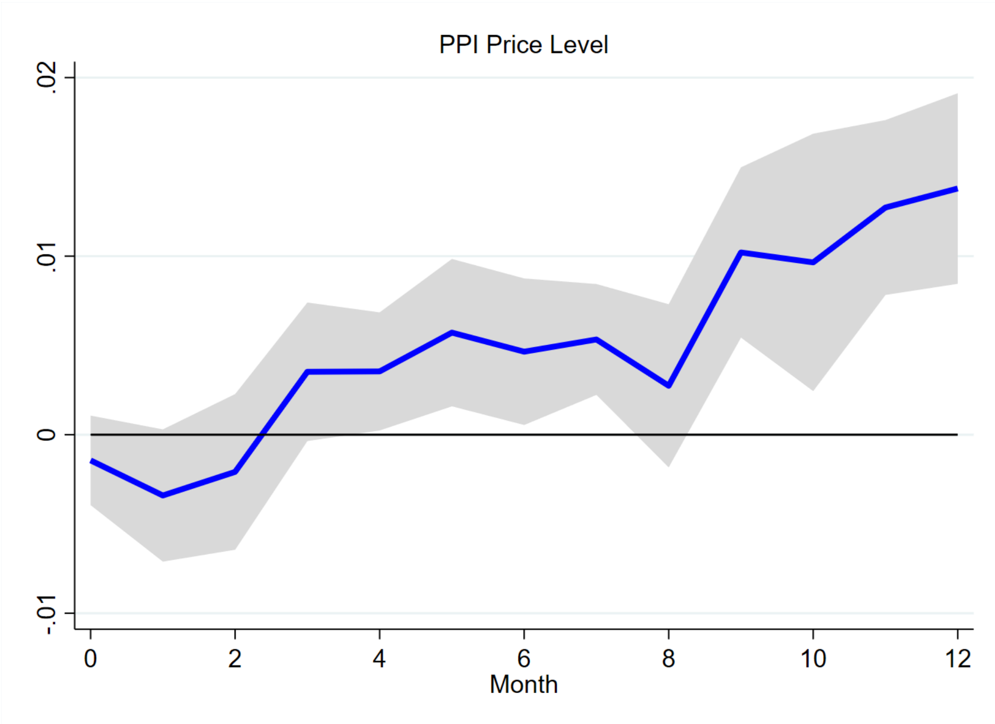
where $y_{i,j,t}$ is the price of firm i for product j at month t. $\alpha_{j,h}$ are product group fixed effects to filter out any unobserved heterogeneity across product groups. $\alpha_{m,h}$ are monthly fixed effects to control for seasonal price movements. $X_{i,t}$ is a vector of additional control variables and $u_{i,j,t+h}$ is the standard error term. $Expo_{i,t}$ is the quantitative easing exposure measure as already described earlier which varies between firms and over time. Our focus lies on the coefficient β_h which directly yields, for each horizon h, the firms' price response to the quantitative easing exposure measure. The coefficient measures the relative price responses of QE exposed firms to those of firms not exposed. In the baseline model, $X_{i,t}$ includes 12 lags of the exposure measure, the aggregate unemployment rate, and the logarithm of the aggregate industrial production index to control for common movements in aggregate demand. Thus, the overall aggregate effect of quantitative easing is partly accounted for. As additional firm controls we also include one-year lags of the leverage ratio, defined as the ratio between the sum of short and long-term debt to total assets, the liquidity ratio, and the logarithms of total assets and total sales. Throughout, we use Driscoll and Kraay (1998) standard errors, which take into account the potential residual correlation across firms, as well as serial correlation and heteroskedasticity among the residuals over time.

To investigate whether the price response depends on the financial conditions of a firm, we extend the linear specification (2) by an interaction term $I_{i,t}$:

$$\begin{aligned} log(y_{i,j,t+h}) - log(y_{i,j,t-1}) = & I_{i,t-1}\left[\beta_h^A \text{Expo}_{i,t} + \gamma_h^A X_{i,t}\right] \\ & + (1 - I_{i,t-1})\left[\beta_h^B \text{Expo}_{i,t} + \gamma_h^B X_{i,t}\right] \\ & + \alpha_{j,h} + \alpha_{m,h} + u_{i,j,t+h}. \end{aligned} \quad (3)$$

$I_{i,t}$ is a dummy variable that takes a value of one if firm i has a high leverage ratio and zero otherwise. We will describe the particular leverage definition and threshold values for $I_{i,t}$ below. We include a one-period lag of $I_{i,t}$ in the estimation to minimize the contemporaneous correlation between the exposure measure and changes in the indicator variable. By interacting the exposure measure with the leverage dummy, β_h^A provides the price response of high leverage firms following the unconventional monetary policy intervention, whereas β_h^B gives the price response of low leverage firms.

Figure 2: Producer prices and QE exposure



4 Empirical results

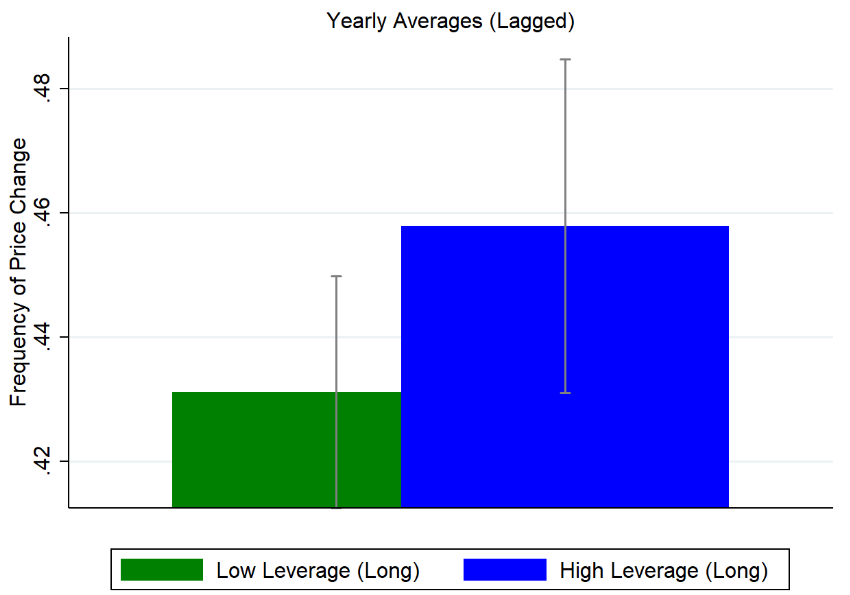
4.1 Producer price inflation

Figure 2 presents our main results from estimating equation (2). The solid line shows the point estimate β_h over a horizon of 12 months. The shaded areas are 90% Driscoll and Kraay (1998) adjusted confidence bands.

For the first two months after the bond purchase, prices decline, although the response is insignificant. Afterwards, the price response turns positive and becomes significant after around four months. One year after the unconventional monetary policy intervention, prices are around 1.2% above their pre-shock level. Thus a 1% GDP bond purchase in the QE program leads to a one year increase in producer prices around 0.8%. [4] Overall, we find that quantitative easing leads to a significant and persistent price increase. Further, producer prices relatively quickly respond to the QE intervention leading to considerable price pressure within the year of the policy

[4] On average, the QE allocation ratio per bank is 0.070, and the average of ω_{i,b,t_0} is 0.250. Thus, 1% GDP purchase around 40 billion SEK leads to 0.8% increase of the producer price.

Figure 3: Price changing frequency and firm leverage



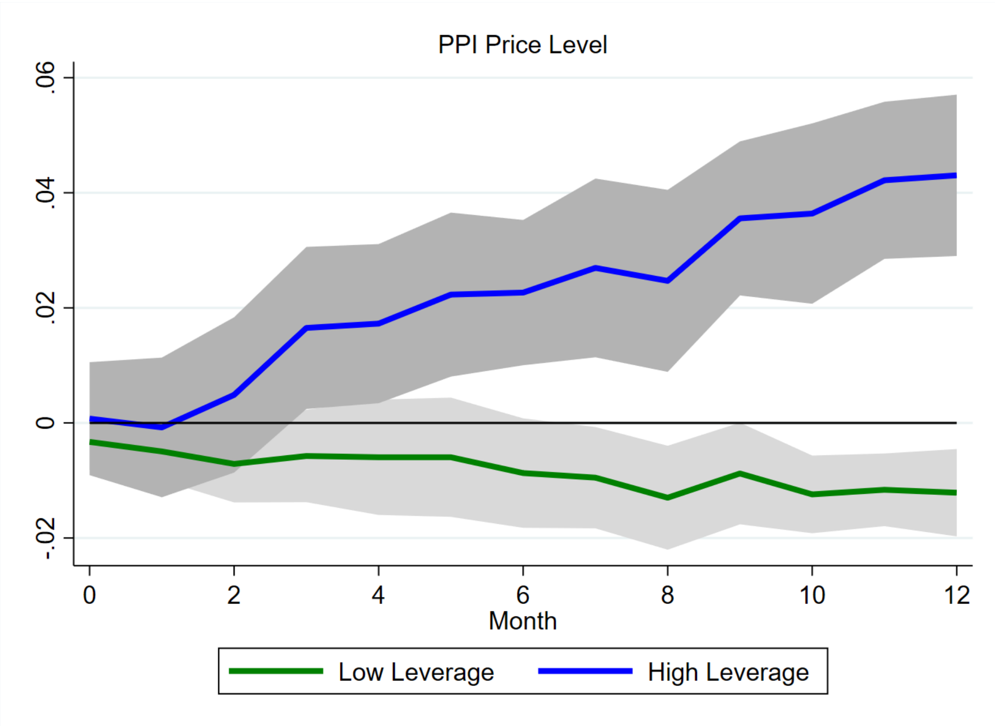
change. Thus, bond purchases might serve as an effective tool to raise inflation when the ZLB restricts conventional interest rate policy.[5] Our micro price analysis supports related studies at the aggregate level which show that unconventional monetary policy has expansionary effects by boosting economic activity and pushing up prices (Lewis, 2019; Gambacorta et al., 2014; Boeckx et al., 2020).

An important advantage of our detailed micro data compared to studies at the aggregate level is the large cross-sectional variation that allows for investigating whether the transmission of unconventional monetary policy significantly differs across firm characteristics. While Figure 2 shows the inflationary effects of quantitative easing by assuming a common price response across all firms, it might well be argued that the way firms change their prices following a monetary policy intervention is influenced by specific factors. In the following, we therefore test for important heterogeneous price responses across firms.

An obvious candidate that could affect a firms' pricing behavior is the degree of financial frictions. Indeed, there is evidence that more financially constrained firms

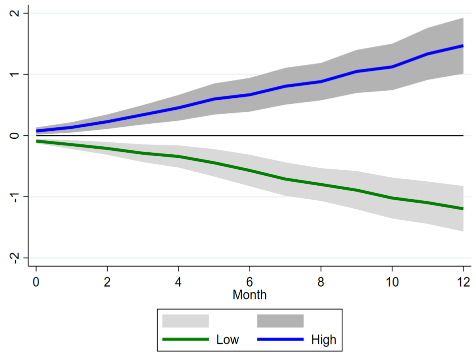
[5]Below, we further elaborate on this issue by comparing the inflationary effects of the QE intervention to an exogenous change in the repo rate.

Figure 4: Producer prices, QE exposure, and firm leverage

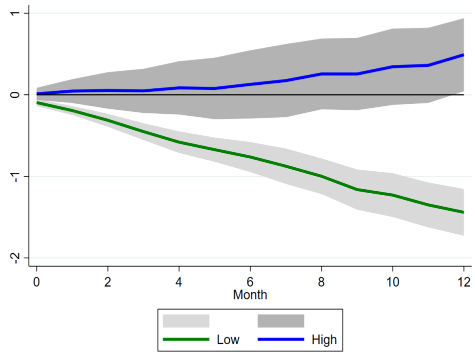


change their prices more often and by a larger magnitude (D'Acunto et al., 2018; Gilchrist et al., 2017; Renkin and Zuellig, 2023). To investigate whether financial frictions also influence the price response to our quantitative easing exposure measure, we first calculate for each firm the leverage ratio (defined as the sum of short term and long term debt to total assets) and then define a low (high) leverage firm, depending on whether an individual firms' leverage ratio is below (above) the mean leverage ratio across all firm in the previous year. We also calculate the frequency of price adjustment at the good level following the approach suggested by (D'Acunto et al., 2018). In particular, the price changing frequency is defined as the ratio of price changes to the number of sample months. For example, if an observed price path is SEK40 for two months and then changes to SEK50 for another three months, one price change occurs during five months, and the frequency of price adjustment is 1/5. As presented in Figure 3, our data show that high leverage firms have a larger price changing frequency compared to low leverage firms which is very much in line with earlier literature. Put differently, prices of high leverage firms are more flexible than prices of low leverage

Figure 5: Decomposing price changes among high and low leverage firms



(a) Frequency price increase

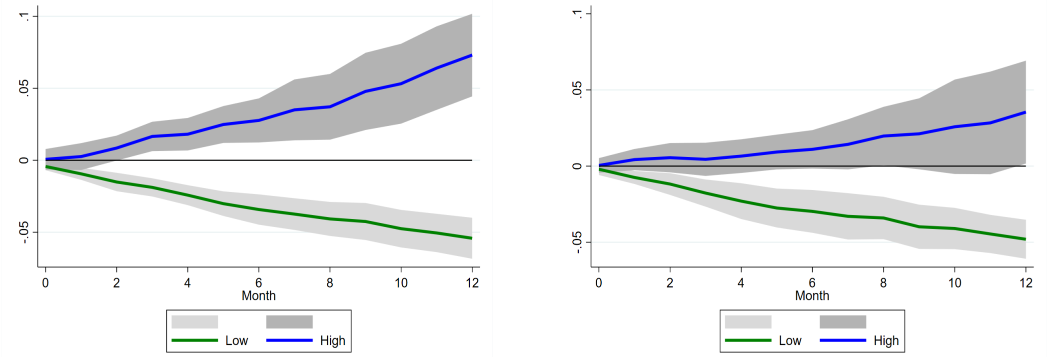


(b) Frequency price decrease

ones which suggests that the degree of financial frictions significantly influences firms' price setting behavior.

Next, we estimate equation (3) allowing for a different price reaction coefficient to the QE exposure measure for low and high leverage firms. The estimates are presented in Figure 4. The results clearly demonstrate that the degree of financial frictions significantly influences how firms adjust their prices following the central banks' bond purchase. In particular, low leverage firms do not change their prices by a significant amount in the short run and even show a slight tendency to decrease prices at longer horizons. In stark contrast, high leverage firms raise their prices significantly leading to a price increase after 12 months of around 4%. Thus, the inflationary effects of quantitative easing documented in Figure 2 seem to be mainly driven by financially constrained firms whereas firms with solid financial positions do not raise prices in response to the unconventional monetary policy intervention.

As shown by Klenow and Kryvtsov (2008), prices changes can be expressed as the product of the frequency of price change, the extensive margin, and the average size of those price changes, the intensive margin. In addition, the frequency of price change can be further decomposed into terms due to price increases and price decreases. Similarly, the average size of price changes can be decomposed into terms due to price increases and price decreases. Figure 5 shows the responses of the price change frequency and the average size of price changes separately for price increases and price



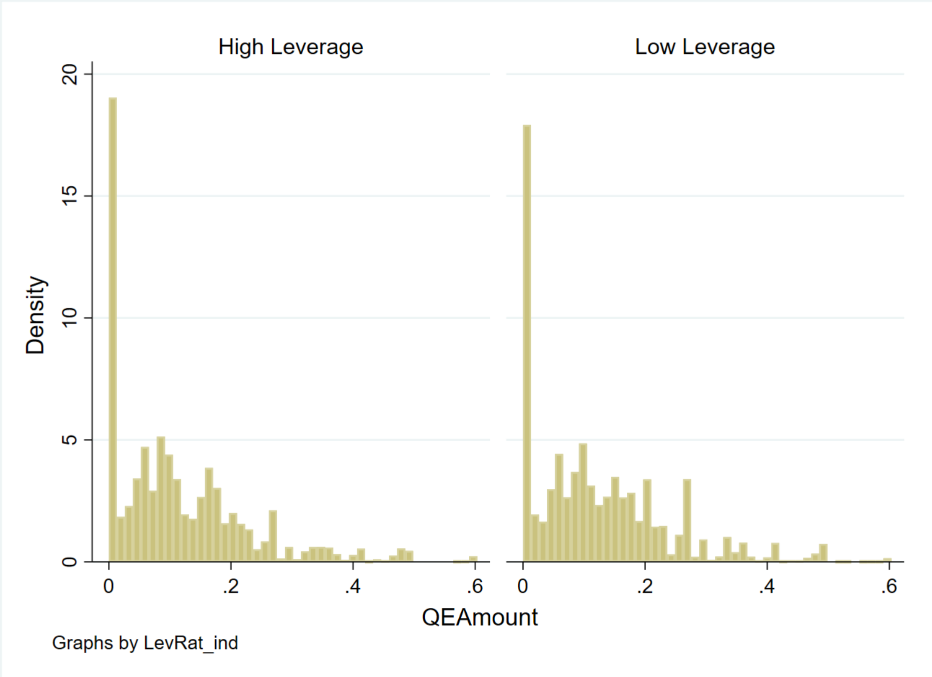
(a) Size price increase (b) Size price decrease

decreases between high and low leverage firms. In response to the QE intervention, high leverage firms adjust both price-setting margins: they significantly increase the price change frequency and raise the average size of price changes. Thus, following the bond purchase by the Riksbank, high leverage firms adjust prices more often and adjust actual prices by a larger magnitude. These effects are particularly strong for price increases which explains the strong increase in prices as shown in Figure 4. In contrast, low leverage firms significantly reduce the price change frequency and the average size of price changes. We do not find strong differences between price increases and price declines which rationalizes the rather flat price response of low leverage firms presented in Figure 4.

Our result of a leverage-dependent price response could be driven by the fact that high and low leverage firms are differently affected by the QE exposure measure. For example, if high leverage firms are much more exposed to QE than low leverage ones, our results might be biased because of different treatment intensities across firms. However, Figure 6 shows that this hypothesis is not supported by the data. The figure presents the distribution of our QE exposure measure for high and low leverage firms, respectively. It is evident that both distributions are relatively similar, thus ruling out that our results might be driven by significantly different treatment effects.

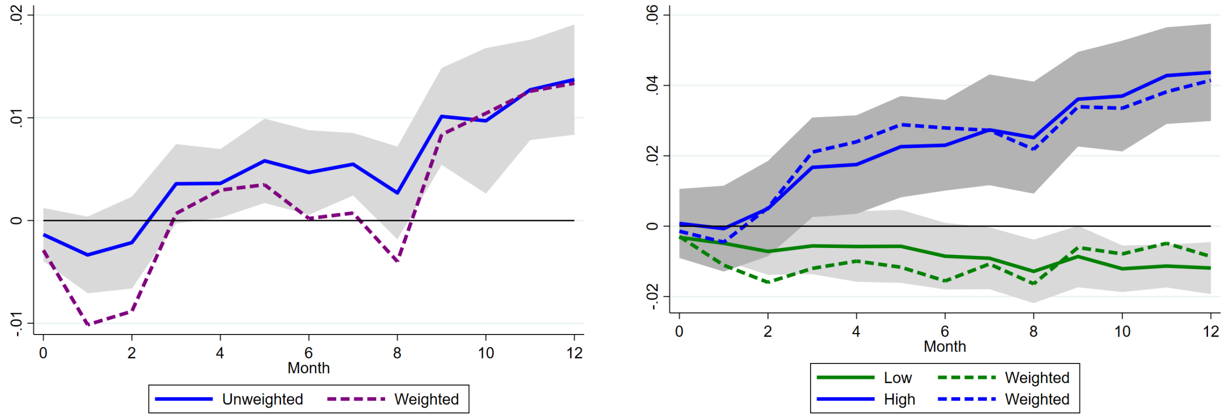
While we use unweighted price observations in our baseline regressions, our dataset also includes the actual weights used to construct the official aggregate producer price index. To rule out that our main findings are driven by large price swings of products

Figure 6: QE exposure distribution for high and low leverage firms



with small weights, we re-estimate our local projections but weight product prices with their actual weights. Figure 7 presents the results, whereas the left panel shows the average price response across firms and the right panel presents the responses for high and low leverage firms, respectively. Solid lines correspond to the baseline (unweighted) regressions and dashed lines to the regressions using weighted observations. Moreover, shaded areas correspond to the confidence intervals of our baseline estimates. The shapes of the weighted responses are very similar to our baseline estimates. In particular, QE leads to an increase in average producer prices independent whether we weight price observations or not. However, the price increase is somewhat smaller for the weighted regressions especially in the early periods of the forecast horizon. Most importantly, there is a strong divergent price response between high and low leverage firms also when using weighted price observations. Prices of high leverage firms increase following the QE intervention whereas low leverage firms do not change their prices significantly. Thus, our main findings are robust to using weighted (instead of unweighted) price information in the local projections.

Figure 7: Baseline versus weighted price observations



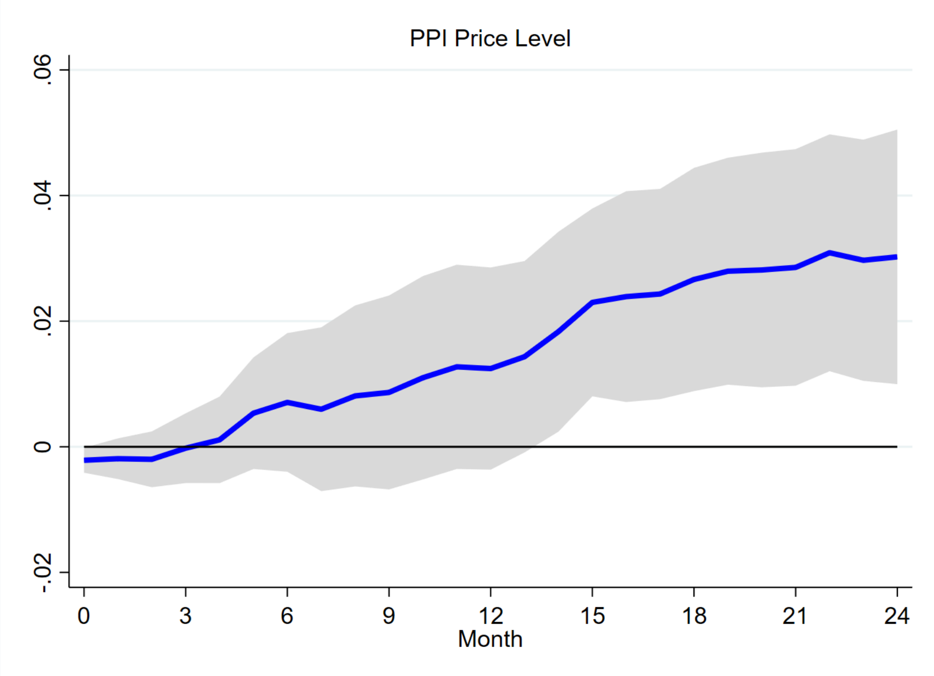
4.2 Comparison to conventional monetary policy shocks

Next, we investigate whether the leverage-dependent price response detected for the QE exposure measure also prevails when studying the effects to conventional monetary policy. In doing so, we re-estimate equation (2) but replace the QE exposure measure by an aggregate Swedish monetary policy shock series. The monetary policy shock series is taken from Amberg et al. (2021) who construct a monetary policy surprise series following a high-frequency identification strategy similar to those used in the recent literature on monetary non-neutrality (Gertler and Karadi, 2015; Jarociński and Karadi, 2020).

Figure 8 shows the estimates for the local projection not conditioning on firm leverage and Figure 9 presents the different price responses for low and high leverage firms, respectively. In both figures the shock is normalized such that the repo rate falls by 25 basis points in the impact period.

An exogenous expansionary monetary policy shock has a delayed effect on producer price inflation which becomes significant after around 1 year. Two years after the shock materialized, inflation is more than 2% above its pre-shock level. Thus, similar to the bond purchase program, expansionary conventional monetary policy also pushes up producer prices. Importantly, as shown in Figure 9, the price responses of low and high leverage firms are rather similar. Both, low and high leverage firms significantly

Figure 8: Producer prices and monetary policy shocks



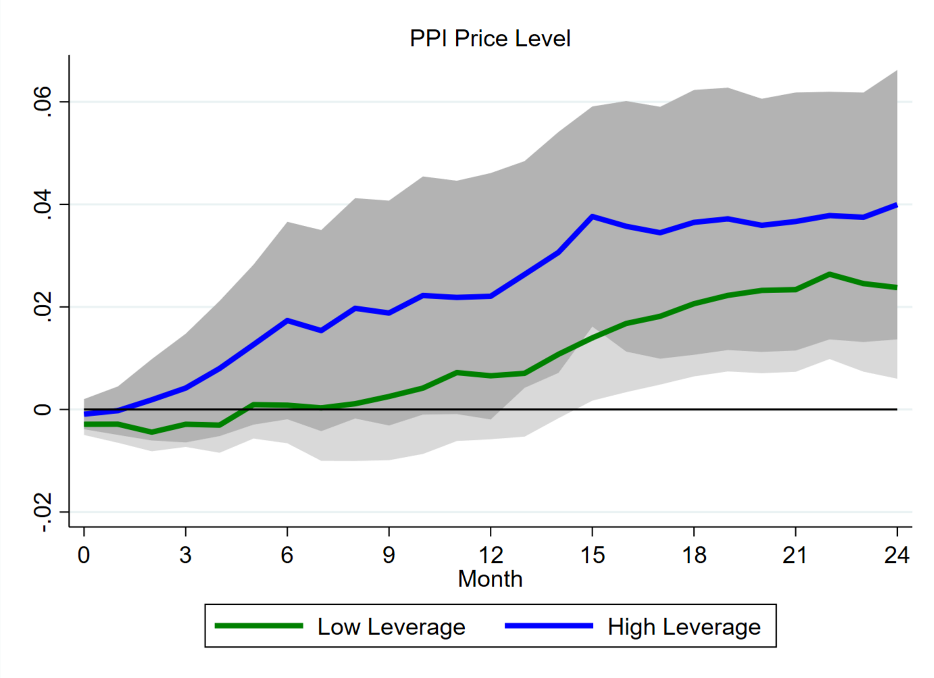
increase their prices following an expansionary monetary policy shock. Although, high leverage firms raises their prices by a larger amount, the respective confidence bands clearly overlap. Thus, the documented heterogeneous price reaction to the QE shock is unique in the sense that it is not observed for conventional monetary policy. Put differently, the transmission mechanism of QE to inflation is different to the one of conventional interest rate policy.

We can further use these estimates to compare the inflationary effects of QE to conventional monetary policy. If we do a simple back-of-the envelope calculation, our estimates imply that in order to replicate the similar-sized price response at the 12 month horizon of a exogenous reduction in the repo rate by 25 basis points, the Riksbank would need to implement a government bond purchases program of 1.3% of GDP.

4.3 Understanding leverage-dependent price responses

What might explain the leverage-dependent price responses? In this section, we provide evidence that firms' borrowing and investment decisions following QE can rationalize

Figure 9: Producer prices, monetary policy shock, and firms leverage



the divergent price reaction of firms with high and low leverage. In doing so, we run the following panel regression on the individual firm data:

$$y_{i,yr} = \alpha_i + \alpha_{ind,yr} + \delta \sum_{yr} \text{Expo}_{i,t} + \gamma X_{i,yr-1} + \epsilon_{i,yr}. \tag{4}$$

The dependent variable $y_{i,yr}$ for firm i in year yr measures a particular variable of interest like debt holdings, debt interest rate expenses or investment expenditures. We include firm fixed effects, α_i, industry-year fixed effects, $\alpha_{ind,yr}$, and a few firm level control variables with a one period lag, including total asset, cash flow over total liability, labour cost over total revenue, working capital over total revenue, inventory over total revenue, and current liability normalized by revenue. Because the firm balance sheet data are only available at the annual frequency, we accumulate the monthly QE exposure measure to the annual aggregate value.

The firms debt and interest rate expense responses might be important for understanding the firms' price response to the QE exposure because an higher (lower) outstanding debt raises (reduces) borrowing costs and thus firms' marginal financial costs which increases (lowers) price pressure. In a similar vein, an increase (decrease) in investment and in particular R&D investment, should be associated with higher (lower) productivity in the future which reduces (raises) marginal costs and thus product prices.

We report the regression results on total debt, long-term and short-term debt in Table 3. In order to show that the results are robust to different empirical specifications, we include firm fixed effects together with, either industry fixed effects and time fixed effects or industry-time fixed effects. Columns (1) and (2) show that all firms' total debt increases following QE, although the level of significance varies a bit. Importantly, Columns (3) and (4) show that firms' long-term debt increases significantly.[6] The estimated coefficient from Column (4) implies that a 1 billion SEK QE exposure leads to a 2.3% increase in firm's long-term debt (roughly 530 thousand SEK). Thus, the QE impact on long-term debt is both economically and statistically significant. In contrast, Columns (5) and (6) indicate that short-term is not significantly affected by the QE intervention. Therefore, the increase in total debt across firms is mainly driven by a strong raise in long-term liabilities.

We further explore the heterogeneous responses across firms, by re-estimating regression (4) but splitting the sample between high and low leverage firms. In particular, we are interested in the response of their debt structure and business activities. We use as dependent variables the logarithm of long-term bank debt (LT Debt), short-term bank debt (ST Debt), external interest expenses, inventories, revenues, investment in R&D (R&D inv), and machines and equipment (M&E), and fixed-asset investment (FA Inv). We also run separate regressions with the contemporaneous QE exposure variable and the 1 year lagged exposure variable, to capture the effects on slow-moving variables. For instance, interest expenses may adjust slowly due to a change in the maturity structure.

The regression results are summarized in Table 4. Columns (1) and (2) report the

[6] Our sample covers only those firms also covered in the micro price data between the years 2015 and 2019. However, the results can be generalized to a larger sample of firms.

Table 3: Firm debts and QE exposures

	(1) Tot Debt	(2) Tot Debt	(3) LT Debt	(4) LT Debt	(5) ST Debt	(6) ST Debt
$\text{Expo}_{i,t}$	0.0150*	0.0158	0.0191**	0.0226**	0.0116	0.0080
	(0.0082)	(0.0104)	(0.0089)	(0.0105)	(0.0093)	(0.0106)
Cash flow / Total liab.	0.0015	0.0034	-0.0178	-0.0131	0.0037	0.0032
	(0.0238)	(0.0232)	(0.0157)	(0.0112)	(0.0239)	(0.0230)
Labour cost / revenue	0.1196	1.3216	0.0509	0.3490	0.0957	1.1274
	(0.0848)	(1.1414)	(0.0611)	(0.9408)	(0.0705)	(0.9088)
Working capital / revenue	-0.0021	-0.0049*	-0.0009	-0.0018	-0.0013	-0.0032*
	(0.0014)	(0.0026)	(0.0010)	(0.0022)	(0.0009)	(0.0017)
Inventory / revenue	0.0239	0.0431*	0.0137	0.0177	0.0181	0.0402*
	(0.0196)	(0.0242)	(0.0125)	(0.0186)	(0.0152)	(0.0212)
Current liab. / revenue	-0.0007	-0.0033	-0.0003	-0.0010	-0.0005	-0.0025
	(0.0005)	(0.0023)	(0.0003)	(0.0020)	(0.0003)	(0.0018)
No of obs	9013	8239	9015	8241	9013	8239
Adj. R2	0.774	0.783	0.771	0.771	0.738	0.748
Control	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Ind. FE	YES	NO	YES	NO	YES	NO
Time FE	YES	NO	YES	NO	YES	NO
Ind-Time FE	NO	YES	NO	YES	NO	YES
Cluster SE	IND	FIRM	IND	FIRM	IND	FIRM

Notes: This table reports the results of regression 4 in the paper, with dependent variables as logarithm value of total bank debt (Tot Debt), short-term bank debt (ST Debt), and long-term bank debt (LT Debt). We include a few commonly used firm level control variables in the regression, with one period lag, including cash flow over total liability and labour cost/working capital/inventory/current liability normalized by revenue. Note that the results are robust to removing the additional controls and with/without standard error clustering. Industry-level (IND) or Firm-level clustered standard errors are reported in parentheses. *,**, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

results on the firms' debt structure. We find that the increase in long term debt is primarily driven by an increase in long-term debt for firms with a high leverage ratio, while the increase for low leverage firms is not statistically significant. The magnitude of the long-term debt increase is more than 3 times higher for high leverage firms compared to low leverage ones. The changes in short-term debt are not statistically significant across both firm groups. As a result of the strong increase in long term debt, high leverage firms also experience a significant delayed rise in their interest rate expenses (see Column (3)). In contrast, interest rate expenses of low leverage firms do not respond significantly. Thus, the QE intervention induces an rise in borrowing costs among constrained firms which, in isolation, puts upward pressure on these firms' pricing decisions.

If we investigate the response of inventories and revenues for the two firm groups, as shown in Columns (4)–(5), we also find quite opposite results for high and low leverage firms. In particular, inventories (revenues) significantly increase (decline) for high

Table 4: Firm decisions and QE exposures

	(1) LT Debt	(2) ST Debt	(3) Int. Exp.	(4) Inventory	(5) Revenue	(6) R&D Inv	(7) M&E	(8) FA Inv
Panel A: All firms								
$\text{Expo}_{i,t}$	0.0226**	0.0080	0.0022	0.0231**	0.0061	-0.0007	0.0312**	0.0092*
	(0.0105)	(0.0106)	(0.0032)	(0.0097)	(0.0068)	(0.0010)	(0.0138)	(0.0052)
$\text{Expo}_{i,t-1}$	0.0559	-0.0315	-0.0018	-0.0021	0.0106	-0.0013	0.0016	0.0079
	(0.0411)	(0.0350)	(0.0051)	(0.0163)	(0.0151)	(0.0011)	(0.0229)	(0.0088)
Panel B: High-Lev firms								
$\text{Expo}_{i,t}$	0.0626*	0.0504	-0.0013	0.0242*	-0.0088	-0.0031*	0.0080	0.0239*
	(0.0348)	(0.0326)	(0.0015)	(0.0136)	(0.0079)	(0.0018)	(0.0188)	(0.0141)
$\text{Expo}_{i,t-1}$	0.0276	-0.0007	0.0022*	0.0042	-0.0096*	-0.0001*	-0.0603*	0.0044
	(0.0684)	(0.0581)	(0.0012)	(0.0136)	(0.0053)	(0.0001)	(0.0327)	(0.0087)
Panel C: Low-Lev firms								
$\text{Expo}_{i,t}$	0.0103	-0.0182	-0.0033	0.0162	0.0193*	0.0013	0.0344*	0.0143*
	(0.0235)	(0.0285)	(0.0107)	(0.0106)	(0.0106)	(0.0013)	(0.0193)	(0.0082)
$\text{Expo}_{i,t-1}$	0.0343	-0.0404	0.0127	0.0052	0.0240	-0.0008	0.0286	0.0129
	(0.0597)	(0.0460)	(0.0193)	(0.0089)	(0.0170)	(0.0020)	(0.0369)	(0.0131)
Control	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Ind-Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Cluster FE	FIRM	FIRM	FIRM	FIRM	FIRM	FIRM	FIRM	FIRM

Notes: This table reports the results of regression 4 in the paper, with dependent variables as logarithm value of long-term bank debt (LT Debt), short-term bank debt (ST Debt), Interest expense over total bank debt (Int. Exp.), inventory, revenue, R&D investment (R&D inv), Machine and Equipment (M&E) and Fixed-asset investment (FA Inv). We include a few commonly used firm level control variables in the regression, with one period lag, including total asset (in log term), cash flow over total liability and labour cost/working capital/inventory/current liability normalized by revenue. Note that the results are robust to removing the additional controls and with/without standard error clustering. Industry-time fixed effects and firm fixed effects are included. Firm-level clustered standard errors are reported in parentheses. *,**, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

leverage firms, which can be interpreted as a consequence of lower demand for products of high leverage firms after the increase in product prices. On the other hand, low leverage firms experience an increase in their revenues suggesting that unconstrained firms raise their market share based on a relative decrease in their product prices compared to high leverage competitors. These results are confirmed by the change in costs of sold goods reported in Column (6).

In addition, we examine the investment decisions of high and low leverage firms. We aim to understand whether firms adjust their investment horizon and the type of investment expenditures. As a start, we treat expenditures on Research and Development (R&D) investment as a proxy for long-term investment. R&D activities have a very long duration of investment horizon, and might lead to higher productivity. We find that high leverage firms significantly decrease their R&D expenditures which should lower their productivity path. Such a fall in productive investment can be interpreted as a negative supply shock, which according to standard theory, implies an increase in prices. In contrast, R&D investment expenditures of low leverage firms raise although the estimated coefficient is not significantly different form zero. At the same time, low leverage firms invest more in their machines and equipment, most likely to expand their production. Low leverage firms also start to invest more in fixed assets. In addition, high leverage firms expand their fixed asset investment expenditures more than low leverage firms. Because such assets can typically used a collateral for debt, increasing fixed assets investments among high leverage firms could be explained by the incentive to stock up the available collateral and loosen borrowing constraints in the future.

Through the additional firm level regressions, we find that high leverage firms significantly increase their long-term debt position following the QE intervention. In isolation this raises their marginal borrowing costs which is well in line with the observed significant increase in interest rate expenses among high leverage firms. Moreover, high leverage firms experience higher inventories and no significant change in revenues. The additional borrowing in long term debt is mainly used to increase fixed assets investment, most likely to raise the collateral value of the firm. In contrast, investment in R&D, machines, and equipment by low leverage firms increases which helps them to increase productivity. In addition, it enables low leverage firms to gain higher profits and revenues while increasing their market share. Thus, the leverage-dependent price response might be rationalized by QE raising marginal costs for high leverage firms while lowering marginal costs for low leverage firms.

We have explored several dimensions of firm heterogeneity, for instance size, age, and total debt. However, none of the other heterogeneities generate a distinct response pattern as observed along the leverage ratio dimension. These findings suggest that firms' dependence on long term debt is an important factor in shaping the transmission of QE shocks.[7]

[7]Detailed results of these additional analyses are available from the authors upon request.

5 Robustness checks

In this section, we demonstrate that our main results are robust to different robustness checks. First, we show that placebo tests do not reproduce our baseline estimates implying that our insights can not be attributed to a random exposure treatment. Second, we show that the main findings remain when utilizing a IV strategy commonly applied in the literature.

5.1 Placebo test

The results provided in the previous sections show that firms' pricing decisions and other real outcomes are affected by their exposure to the QE program through the relationship banks. One potential concern is that the results we find are driven by other characteristics of the bank or the firm. In this section, we present evidence against this hypothesis placebo tests. For the placebo tests, we compute two alternative measures of QE exposures utilizing different simulations. The first measure is computed by assigning a vector of weights to each firm for their bank relationship. The weights are drawn randomly and sum up to 1. We use the true bond sales allocation of banks in the QE program. The second measure is computed by keeping the actual bank-firm relationship weights but with simulated banks' QE bond sales. We draw the banks' QE bond sales amount randomly, and make sure that the total amount sums up to the actual bond sales each month. Note that we will not change banks' participation decision, so banks not selling bonds in a month will stay as inactive in the simulation. The estimation results when using these two alternative exposure measures are show in Figure 10.

Figure 10 shows that producer prices do not significantly respond to the randomly generated QE exposure measures. In particular, we do not see different price responses for high and low leverage firms. It is an insightful exercise because we used the true bank QE bond sales or the true bank-firm link information to simulate the firm's QE exposure. It provides another piece of evidence that the price dynamics responding to firms' QE exposure is not a byproduct of an unobserved aggregate trend or omitted firm characteristics. We need both the true bank QE sales and the bank-firm link data to generate meaningful QE price responses. It holds for both the cross-sectional group results and the aggregate producer price pattern.

5.2 Banks' deposits and QE exposures

Past studies indicate that banks are not the main holders of outstanding government bonds. To participate in the QE program, banks can sell the bonds from their own government bond holdings, or they sell the bonds to the central bank on behalf of their clients. The latter case is very common, because banks use government bonds as collateral and are usually not flexible in adjusting the holding positions. On the other hand, non-bank financial institutions such as pension funds and insurance companies can sell bonds to the central bank and search for higher yields elsewhere. Buttz et al. (2015) argue that the deposits created by QE transactions are an exogenous source of variation to banks' deposits from non-bank financial institutions. To further demonstrate the robustness of our results, we follow that argument and instrument the banks' QE participation in each month with the change of deposits from other financial companies.

The two-stage instrumental variable regressions are

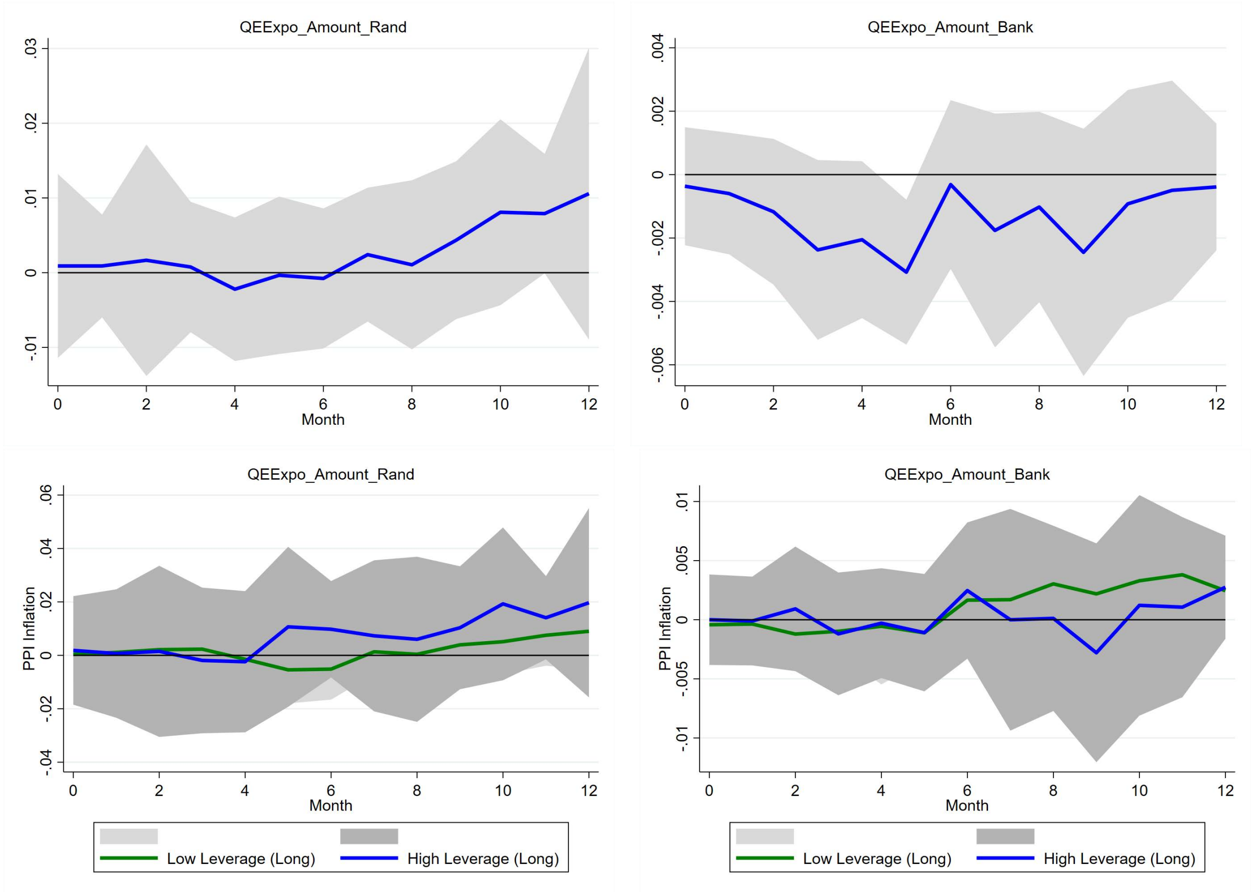
$$QE_{b,t} = \alpha_t + \alpha_b + \beta \Delta \mathrm{Dep}_{b,t} + \varepsilon_{b,t}, \quad (5)$$

$$y_{i,yr} = \alpha_i + \alpha_{ind,yr} + \delta \sum_{yr} \hat{\mathrm{Expo}}_{i,t} + \gamma X_{i,yr-1} + \epsilon_{i,yr}. \quad (6)$$

where $\hat{\mathrm{Expo}}_{i,t} = \sum_b \omega_{i,b,t_0} \cdot \hat{QE}_{b,t}$ is the weighted QE participation amounts fitted using the monthly changes of other financial institutions' deposits $\Delta \mathrm{Dep}_{b,t}$. The instrumental variable regression provides evidence on the bank lending channel under the assumption that the sales of government bonds by other financial institutions will create new deposits in the banking sector. However, we hold the view that these deposits will not leave banks immediately, because the Swedish financial institutions with a strong

Figure 10: placebo tests: firm price responses to simulated QE exposures

We plot the firms' price responses to two simulated QE exposure measures. Panels on the left shows the results for QE measures with simulated bank-firm link weights and real bank QE purchases. Panels on the right present the results for QE measures with simulated banks' QE sales amounts and the real bank-firm relationship. The first row shows the aggregate price responses, and the second row shows the separate price reactions for firms with high / low leverage ratio.



home bias could re-invest in domestic financial assets through the same relationship bank. The deposits change, as a proxy, measures how much the banks could benefit from the additional deposits.

Table 5: Bank QE and other financial institutions' deposits

	(1)	(2)	(3)	(4)
		$QE_{b,t}$		
$\Delta \text{Dep}_{b,t}$	19.3324	26.8157*	26.3202*	21.8071*
	(21.0176)	(15.4104)	(15.3994)	(12.3934)
ΔTreasuryHolding		-0.0234		
		(2.5327)		
No of obs	235	235	235	235
Adj. R2	-0.002	0.534	0.537	0.658
F-stat.	0.846	5.413	5.529	11.359
Bank FE	NO	YES	YES	NO
Time FE	NO	YES	YES	YES
Bank-Year FE	NO	NO	NO	YES
Standard Errors	ROBUST	ROBUST	ROBUST	ROBUST

Notes: This table reports the results of regression 5 in the paper, with dependent variables as monthly QE allocated amount for each bank. We include a few fixed effects, and the key independent variable changes of other financial companies' deposits. Robust standard errors are reported in parentheses. *,**, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

We show the first stage regression results in Table 5. The changes of other financial institutions' deposits are positively correlated with the banks' QE activities, as presented in columns (2)-(4). It suggests that banks' deposits from other financial institutions increase after the QE sales. We also tried to include the changes of banks' own treasury holdings as an additional control variable. The banks' bond holding positions coefficient is not statistically significant. It supports the common view that banks are acting as the intermediary for their customers to get engaged in the central bank government bond purchase program. We take the fitted QE amount for each bank from the first stage regressions and use them to compute the measure of firms' QE exposure through their relation banks. The results of the corresponding second state regressions are presented in Table 6. We find that the main results of the IV regressions are similar to the OLS results of our baseline specification. The estimated coefficients on firms' QE exposure are smaller, but still statistically significant.

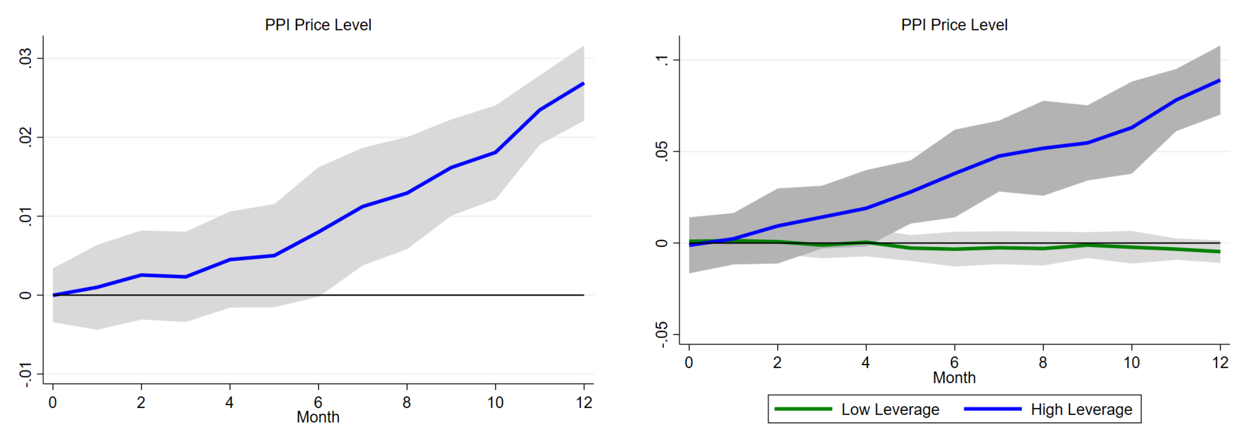
We further demonstrate the robustness of the firms' price responses to QE if we

Table 6: Firm debts and QE exposures: two-stage regressions

	(1) Tot Debt	(2) Tot Debt	(3) LT Debt	(4) LT Debt	(5) ST Debt	(6) ST Debt
$\hat{\text{Expo}}_{i,t}$	0.0163**	0.0137	0.0140**	0.0183**	0.0095	0.0069
	(0.0076)	(0.0095)	(0.0070)	(0.0090)	(0.0081)	(0.0097)
Cash flow / Total liab.	0.0011	0.0030	-0.0186	-0.0136	0.0033	0.0030
	(0.0238)	(0.0232)	(0.0157)	(0.0109)	(0.0240)	(0.0230)
Labour cost / revenue	0.1184	1.3090	0.0482	0.3279	0.0943	1.1209
	(0.0844)	(1.1435)	(0.0609)	(0.9448)	(0.0699)	(0.9093)
Working capital / revenue	-0.0021	-0.0049*	-0.0009	-0.0017	-0.0013	-0.0031*
	(0.0014)	(0.0026)	(0.0010)	(0.0022)	(0.0009)	(0.0017)
Inventory / revenue	0.0252	0.0436*	0.0149	0.0183	0.0189	0.0404*
	(0.0196)	(0.0243)	(0.0124)	(0.0188)	(0.0151)	(0.0212)
Current liab. / revenue	-0.0007	-0.0033	-0.0003	-0.0010	-0.0005	-0.0025
	(0.0005)	(0.0023)	(0.0003)	(0.0020)	(0.0003)	(0.0018)
No of obs	9013	8239	9015	8241	9013	8239
Adj. R2	0.774	0.783	0.771	0.771	0.738	0.748
Control	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES
Ind. FE	YES	NO	YES	NO	YES	NO
Time FE	YES	NO	YES	NO	YES	NO
Ind-Time FE	NO	YES	NO	YES	NO	YES
Cluster SE	IND	FIRM	IND	FIRM	IND	FIRM

Notes: This table reports the results of regression 4 in the paper, with dependent variables as logarithm value of total bank debt (Tot Debt), short-term bank debt (ST Debt), and long-term bank debt (LT Debt). We include a few commonly used firm level control variables in the regression, with one period lag. Note that the results are robust to removing the additional controls and with/without standard error clustering. Industry-level (IND) or Firm-level clustered standard errors are reported in parentheses. *,**, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Figure 11: Producer prices and fitted QE exposure



use the fitted QE amount from the instrumental variable regressions. We take the weighted QE participation amounts, fitted in the regression (5), and run the same local projection as in (2). We can see from Figure 11 that the price responses are similar to the main results as shown in Section 4.1. Producer prices increase as a response to higher exposure to QE through firms' relationship banks. There is strong heterogeneity in the price response for firms with high and low leverage. As shown in the right panel of Figure 11, we can see that the instrumental variable regression fitted QE exposures generate clear differences in firms' pricing responses with high leverage firms significantly increasing their prices whereas low leverage firms do not significantly change prices.

It is important to note that we cannot conclude that the bank lending channel underlies these results. There are other potential explanations which are in line with our empirical findings as well. For instance, if other financial institutions' deposits move out of the financial intermediaries, the investors might purchase other longer term bonds issued by the corporate sector, as they are searching for yields or they are looking for exposure to certain duration risk. If we assume that the banks act as the intermediary for the corporate bond issuance and purchase, we capture the effect of portfolio rebalancing of the large financial institutions. Given the importance of relationship banking and modern full-service banking, it is plausible that the bank's customers are likely to use other services provided by their relationship banks.

6 Conclusion

We have presented new empirical evidence on the inflationary effect of QE using administrative Swedish data. Our results indicate that QE has led to a significant increase in producer prices. However, we detect strong heterogeneities across firms' pricing decisions following the unconventional monetary policy intervention. In particular, high leverage firms significantly increase prices whereas low leverage firms do not show a tendency to significantly change their prices. Further, firm level regressions confirm that high leverage firms borrow more long-term credit from banks and thus face a significant increase in interest rate expenses following the QE intervention. Thus, they experience higher borrowing costs which might explain their price increase. Investment in R&D, machines, and equipment by low leverage firms increases which helps them to increase productivity. In addition, it enables low leverage firms to gain higher profits and revenues while increasing their market share.

Our study contributes to the literature by investigating firms' product price adjustments responding to QE, with a micro database that links bank-firm-product price data and proprietary QE program auction information. The granularity of the data allow us to document, for the first time, that firms' price setting decisions are influenced by their QE program exposure through their relationship banks. The main channel tends to come from the bank lending expansion in longer-term debt. The significant difference in price responses across high and low leverage firms is less pronounced when looking at conventional interest rate policy interventions. Future research can be extended to examine the employer-employee links and the consequential household welfare reaction to QE activities.

References

Acharya, V. V., T. Eisert, C. Eufinger, and C. Hirsch (2019). Whatever it takes: The real effects of unconventional monetary policy. *Review of Financial Studies 32*, 3366–3411.

Amberg, N., T. Jansson, M. Klein, and A. R. Picco (2021). Five facts about the distributional income effects of monetary policy shocks. *American Economic Review: Insights*, forthcoming.

Bernanke, B. S., A. S. Blinder, et al. (1988). Credit, money, and aggregate demand. *American Economic Review 78*(2), 435–439.

Boeckx, J., M. de Sola Perea, and G. Peersman (2020). The transmission mechanism of credit support policies in the euro area. *European Economic Review 124*, 103403.

Bowman, D., F. Cai, S. Davies, and S. Kamin (2015). Quantitative easing and bank lending: Evidence from japan. *Journal of International Money and Finance 57*, 15–30.

Buttz, N., R. Churmz, M. McMahon, A. Morotzz, and J. Schanz (2015). QE and the Bank Lending Channel in the United Kingdom. Economic Research Papers 270021, University of Warwick.

Carlstrom, C. T., T. S. Fuerst, and M. Paustian (2017). Targeting long rates in a model with segmented markets. *American Economic Journal: Macroeconomics 9*, 205–42.

Cui, W. and V. Sterk (2021). Quantitative easing with heterogeneous agents. *Journal of Monetary Economics 123*, 68–90.

Driscoll, J. C. and A. C. Kraay (1998). Consistent Covariance Matrix Estimation With Spatially Dependent Panel Data. *The Review of Economics and Statistics 80*(4), 549–560.

D'Acunto, F., R. Liu, C. Pflueger, and M. Weber (2018). Flexible prices and leverage. *Journal of Financial Economics 129*, 46–68.

Ehrmann, M. and M. Fratzscher (2004). Taking stock: Monetary policy transmission to equity markets. *Journal of Money, Credit and Banking*, 719–737.

Fabo, B., M. Jančoková, E. Kempf, and Ľuboš Pástor (2021, 5). Fifty shades of qe: Comparing findings of central bankers and academics. *Journal of Monetary Economics 120*, 1–20.

Gambacorta, L., B. Hofmann, and G. Peersman (2014). The effectiveness of unconventional monetary policy at the zero lower bound: A cross-country analysis. *Journal of Money, Credit and Banking 46*(4), 615–642.

Gertler, M. and P. Karadi (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics 7*, 44–76.

Gertler, M. and P. Karadi (2018). Qe 1 vs. 2 vs. 3...: A framework for analyzing large-scale asset purchases as a monetary policy tool. *29th issue (January 2013) of the International Journal of Central Banking*.

Gilchrist, S., R. Schoenle, J. Sim, and E. Zakrajšek (2017). Inflation dynamics during the financial crisis. *American Economic Review 107*, 785–823.

Gorodnichenko, Y. and M. Weber (2016). Are sticky prices costly? evidence from the stock market. *American Economic Review 106*(1), 165–99.

Grimm, N., L. Laeven, and A. A. Popov (2021). Quantitative easing and corporate innovation.

Ippolito, F., A. K. Ozdagli, and A. Perez-Orive (2018). The transmission of monetary policy through bank lending: The floating rate channel. *Journal of Monetary Economics 95*, 49–71.

Jarociński, M. and P. Karadi (2020). Deconstructing monetary policy surprises—the role of information shocks. *American Economic Journal: Macroeconomics 12*, 1–43.

Jordà, O. (2005). Estimation and inference of impulse responses by local projections. *American Economic Review 95*(1), 161–182.

Joyce, M. and M. Spaltro (2014). Quantitative easing and bank lending: a panel data approach.

Kim, R. (2021). The effect of the credit crunch on output price dynamics: The corporate inventory and liquidity management channel. *The Quarterly Journal of Economics 136*(1), 563–619.

Klenow, P. J. and O. Kryvtsov (2008). State-Dependent or Time-Dependent Pricing: Does it Matter for Recent U.S. Inflation?*. *The Quarterly Journal of Economics 123*, 863–904.

Lenza, M., H. Pill, L. Reichlin, and M. Ravn (2010). Monetary policy in exceptional times [with discussion]. *Economic Policy 25*, 295–339.

Lewis, D. J. (2019). Announcement-specific decompositions of unconventional monetary policy shocks and their macroeconomic effects. Staff Report 891.

Morais, B., J.-L. Peydró, J. Roldán-Peña, and C. Ruiz-Ortega (2019). The international bank lending channel of monetary policy rates and qe: Credit supply, reach-for-yield, and real effects. *The Journal of Finance 74*(1), 55–90.

Renkin, T. and G. Zuellig (2023). Credit supply shocks and prices: Evidence from danish firms. *American Economic Journal: Macroeconomics*, forthcoming.

Rodnyansky, A. and O. M. Darmouni (2017). The effects of quantitative easing on bank lending behavior. *The Review of Financial Studies 30*(11), 3858–3887.

Sims, E. and J. C. Wu (2021). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics 118*, 135–160.

Recent Working Papers:

For a complete list of Working Papers published by Sveriges Riksbank, see www.riksbank.se

The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result *by Jesper Lindé and Andrea Pescatori*	2019:363
Biased Forecasts to Affect Voting Decisions? The Brexit Case *by Davide Cipullo and André Reslow*	2019:364
The Interaction Between Fiscal and Monetary Policies: Evidence from Sweden *by Sebastian Ankargren and Hovick Shahnazarian*	2019:365
Designing a Simple Loss Function for Central Banks: Does a Dual Mandate Make Sense? *by Davide Debortoli, Jinill Kim and Jesper Lindé*	2019:366
Gains from Wage Flexibility and the Zero Lower Bound *by Roberto M. Billi and Jordi Galí*	2019:367
Fixed Wage Contracts and Monetary Non-Neutrality *by Maria Björklund, Mikael Carlsson and Oskar Nordström Skans*	2019:368
The Consequences of Uncertainty: Climate Sensitivity and Economic Sensitivity to the Climate *by John Hassler, Per Krusell and Conny Olovsson*	2019:369
Does Inflation Targeting Reduce the Dispersion of Price Setters' Inflation Expectations? *by Charlotte Paulie*	2019:370
Subsampling Sequential Monte Carlo for Static Bayesian Models *by David Gunawan, Khue-Dung Dang, Matias Quiroz, Robert Kohn and Minh-Ngoc Tran*	2019:371
Hamiltonian Monte Carlo with Energy Conserving Subsampling *by Khue-Dung Dang, Matias Quiroz, Robert Kohn, Minh-Ngoc Tran and Mattias Villani*	2019:372
Institutional Investors and Corporate Investment *by Cristina Cella*	2019:373
The Impact of Local Taxes and Public Services on Property Values *by Anna Grodecka and Isaiah Hull*	2019:374
Directed technical change as a response to natural-resource scarcity *by John Hassler, Per Krusell and Conny Olovsson*	2019:375
A Tale of Two Countries: Cash Demand in Canada and Sweden *by Walter Engert, Ben Fung and Björn Segendorf*	2019:376
Tax and spending shocks in the open economy: are the deficits twins? *by Mathias Klein and Ludger Linnemann*	2019:377
Mind the gap! Stylized dynamic facts and structural models *by Fabio Canova and Filippo Ferroni*	2019:378
Financial Buffers, Unemployment Duration and Replacement Labor Income *by Mats Levander*	2019:379
Inefficient Use of Competitors' Forecasts? *by André Reslow*	2019:380
How Much Information Do Monetary Policy Committees Disclose? Evidence from the FOMC's Minutes and Transcripts *by Mikael Apel, Marianna Blix Grimaldi and Isaiah Hull*	2019:381
Risk endogeneity at the lender/investor-of-last-resort *by Diego Caballero, André Lucas, Bernd Schwaab and Xin Zhang*	2019:382
Heterogeneity in Households' Expectations of Housing Prices – Evidence from Micro Data *by Erik Hjalmarsson and Pär Österholm*	2019:383
Big Broad Banks: How Does Cross-Selling A Affect Lending? *by Yingjie Qi*	2020:384
Unemployment Fluctuations and Nominal GDP Targeting *by Roberto Billi*	2020:385
FAQ: How do I extract the output gap? *by Fabio Canova*	2020:386

Inflation Targeting or Fiscal Activism? *by Roberto M. Billi*	2022:412
Trading volume and liquidity provision in cryptocurrency markets *by Daniele Bianchi, Mykola Babiak and Alexander Dickerson*	2022:413
DISPERSION OVER THE BUSINESS CYCLE: PASSTHROUGH, PRODUCTIVITY, AND DEMAND *by Mikael Carlsson, Alex Clymo and Knut-Eric Joslin*	2022:414
Electoral Cycles in Macroeconomic Forecasts *by Davide Cipullo and André Reslow*	2022:415
The Curious Incidence of Monetary Policy Across the Income Distribution *by Tobias Broer, John Kramer and Kurt Mitman*	2022:416
Central Bank Mandates and Monetary Policy Stances: through the Lens of Federal Reserve Speeches *by Christoph Bertsch, Isaiah Hull, Robin L. Lumsdaine, and Xin Zhang*	2022:417
The Political Costs of Austerity *by Ricardo Duque Gabriel, Mathias Klein and Ana Sofia Pessoa*	2022:418
Central bank asset purchases: Insights from quantitative easing auctions of government bonds *by Stefan Laséen*	2023:419
Greenflation? *by Conny Olovsson and David Vestin*	2023:420
Effects of foreign and domestic central bank government bond purchases in a small open economy DSGE model: Evidence from Sweden before and during the coronavirus pandemic *by Yildiz Akkaya, Carl-Johan Belfrage, Paola Di Casola and Ingvar Strid*	2023:421
Dynamic Credit Constraints: Theory and Evidence from Credit Lines* *by Niklas Amberg, Tor Jacobson, Vincenzo Quadrini and Anna Rogantini Picco*	2023:422
Stablecoins: Adoption and Fragility *by Christoph Bertsch*	2023:423
CBDC: Lesson from a Historical Experience *by Anna Grodecka-Messi and Xin Zhang*	2023:424
Do Credit Lines Provide Reliable Liquidity Insurance? Evidence from Commercial-Paper Backup Lines *by Niklas Amberg*	2023:425
Price Pass-Through Along the Supply Chain: Evidence from PPI and CPI Microdata *by Edvin Ahlander, Mikael Carlsson and Mathias Klein*	2023:426
Cash for Transactions or Store-of-Value? A comparative study on Sweden and peer countries *by Carl Andreas Claussen, Björn Segendorf and Franz Seitz*	2023:427
Fed QE and bank lending behaviour: a heterogeneity analysis of asset purchases *by Marianna Blix Grimaldi and Supriya Kapoor*	2023:428
Monetary policy in Sweden after the end of Bretton Woods *by Emma Bylund, Jens Iversen and Anders Vredin*	2023:429
Banking Without Branches *by Niklas Amberg and Bo Becker*	2024:430
Climate impact assessment of retail payment services *by Niklas Arvidsson, Fumi Harahap, Frauke Urban and Anissa Nurdiawati*	2024:431
Four Facts about International Central Bank Communication by *Christoph Bertsch, Isaiah Hull, Robin L. Lumsdaine, and Xin Zhang*	2024:432
Optimal Monetary Policy with r* < 0 *by Roberto Billi, Jordi Galí, and Anton Nakov*	2024:433
Quantitative Easing, Bond Risk Premia and the Exchange Rate in a Small Open Economy *by Jens H. E. Christensen and Xin Zhang*	2024:434
Supply-Chain Finance: An Empirical Evaluation of Supplier Outcomes *by Niklas Amberg, Tor Jacobson and Yingjie Qi*	2024:435
Optimal Contracts and Inflation Targets Revisited *by Torsten Persson and Guido Tabellini*	2024:436
Potential Climate Impact of Retail CBDC Models *by Niklas Arvidsson, Fumi Harahap, Frauke Urban and Anissa Nurdiawati*	2024:437
Do we need firm data to understand macroeconomic dynamics? *by Michele Lenza and Ettore Savoia*	2024:438

Sveriges Riksbank
Visiting address: Brunkebergs torg 11
Mail address: se-103 37 Stockholm

Website: www.riksbank.se
Telephone: +46 8 787 00 00, Fax: +46 8 21 05 31
E-mail: registratorn@riksbank.se