Financial Market Imperfections and the Pricing Decision of Firms: Theory and Evidence

Almut Balleer[1], Nikolay Hristov[2], Michael Kleemann[3], and Dominik Menno[4]

[1] *RWTH Aachen and IIES at Stockholm University*
[2] *Ifo Institute for Economic Research, Munich*
[3] *Deutsche Bundesbank*
[4] *University of Michigan*

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Abstract

This paper investigates how financial market imperfections and nominal rigidities interact. Based on new firm-level evidence for Germany, we document that financially constrained firms adjust prices more often than their unconstrained counterparts. In particular, financially constrained firms do not only increase prices, but also decrease prices more often. We show that these empirical patterns are consistent with a partial equilibrium menu-cost model with financial frictions. Our results suggest that tighter financial constraints are associated with a lower rigidity in individual firms' nominal prices, higher average prices, less price dispersion and lower output. Furthermore, financial recessions may induce very different dynamics than normal recessions if the relative size of unexpected financial shocks is large relative to aggregate price shocks.

Keywords: Price distribution, financial frictions, menu cost model
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1 Introduction

This paper investigates the interaction between financial frictions and the price setting of firms. Financial frictions and price setting may affect each other in two ways: On the one hand, being financially constrained may affect the pricing decision of a firm: firms with initially low prices that sell large quantities may not be able to finance their production inputs and may therefore find it optimal to scale down production and adjust prices up. On the other hand, firms seeking to gain market share may want to lower their prices. However, by doing so, they may run into financial constraints when expanding production. We show empirically and theoretically that both of these mechanisms are important for understanding the frequency, the direction, the size and the dispersion of individual firms' price changes. Moreover, the explicit interaction between financial frictions and the cross-sectional distribution of prices turns out to be of crucial relevance for the behavior of aggregate price rigidity over time and thus, for the transmission of macroeconomic shocks as well as the effectiveness of monetary policy.

We explore rich plant-level data for Germany: the ifo Business Survey, a monthly representative panel of 3600 manufacturing firms covering the years 2002-2014. The survey contains information about the extensive margin, i.e., whether and in what direction individual firms change prices, alongside two direct firm-specific measures of financial constraints. In particular firms give appraisals of their access to bank credit which is the predominant way of financing operational costs and investment. Firms also report whether they are experiencing production shortages due to financial constraints. In contrast, most of the existing literature has focused on price adjustment along the intensive margin,[1] while, at the same time, relying on indirect measures of individual financial conditions such as the state of the business cycle or balance sheet measures.[2] Since we have balance sheet information for a subset of firms in our sample, we can compare direct and indirect measures of financial constraints and document important differences.

Using our survey measures, we show that financially constrained firms adjust their prices more frequently than financially unconstrained firms. Moreover, constrained firms adjust their prices down more often than their unconstrained counterparts. In contrast, the existing studies highlight that financially constrained firms tend to decreases their prices less often (Bhaskar et al., 1993) or increase their prices more often than unconstrained firms (Gilchrist et al., 2013a), at least in recessions. We document that the latter effect is due to using balance sheet information, e.g. liquidity or cash flow ratios, in order to indirectly measure financial frictions. Generally, a low liquidity ratio can be the result of easy access to credit, while not affecting production possibilities of firms. It may therefore not measure financial constraints per se. For example, consider a firm experiencing a sudden decline in its marginal costs. Such a firm will typically decrease its prices and try to scale up the level of operation. If expanding the production capacity requires external funding, the firm may hit the upper limit of its financial constraint, but may still enjoy a relatively high liquidity ratio. Hence, one may wrongly conclude that it is financially unconstrained today.

Our interpretation of the empirical facts is guided by a partial-equilibrium menu cost model with financial frictions which provides an explicit rationale for the interactions between financial constraints and price setting. Here, we extend the standard menu-cost model[3] with heterogeneous firms by adding

[1]See for example Chevalier and Scharfstein (1996) for the US or Gottfries (2002) and Asplund et al. (2005) for Sweden. An exception is Gilchrist et al. (2013b) in a study for the US.

[2]The study closest to our paper that uses balance sheet measures is Gilchrist et al. (2013a). Only Bhaskar et al. (1993) use a small-sample cross-sectional survey for small firms in the UK.

[3]Gilchrist et al. (2013a) calibrate a partial equilibrium menu-cost model to match US consumer price data. Most studies developing general equilibrium versions of the model with Ss pricing focus on the implied degree of monetary non-neutrality. For example Caplin and Spulber (1987), Dotsey et al. (1999) and Golosov and Lucas (2007) resort to the standard menu-cost model, extensions as stochastic idiosyncratic menu costs and leptokurtic productivity shocks are analysed in Dotsey and King (2005) and Midrigan (2005) respectively, multi-sector and multi-product versions of the model

a working capital constraint.[4] When financial frictions are present, the curvature of the individual firm's profit function increases around the relative price below which the constraint binds. Since the shape of the profit function is a crucial determinant of the gains from price adjustment in a menu-cost environment, the presence of a financial constraint affects the firms' pricing decisions. In particular, for relatively high levels of idiosyncratic productivity, the optimal price is associated with a binding financial constraint. Accordingly, firms with a relatively high productivity tend to adjust their prices more frequently due to the higher curvature of the profit function. Furthermore, most of those firms end up being financially constrained after adjusting their prices since their optimal price coincides with the one for which the borrowing constraint is just binding. This implication is consistent with our empirical findings suggesting that the financially constrained firms adjust their prices more frequently, both up and down, compared to their unconstrained counterparts. In other words, prices of financially constrained firms tend to be relatively less rigid. Accordingly, our model implies that if the borrowing constraints become tighter and thus, the fraction of financially constrained firms increases, individual firms' prices become more flexible on average with important consequences for monetary policy.

We further consider the response of the average price changes, average prices and price dispersion to shocks to the aggregate price level. In our partial-equilibrium model, these shocks can be interpreted as responses of a single sector to aggregate business cycle shocks. Doing so, we obviously ignore important general equilibrium effects, in particular the response of wages. We nevertheless believe this to be an instructive exercise as wages might be sticky in the short run. In particular, we consider the responses when negative price shocks are combined with an unexpected tightening of the financial constraint, i.e., a financial recession. When negative price shocks are large and financial tightening relatively small the dynamics resemble those in German manufacturing during the Great Recession. In particular, constrained firms decrease their prices more often., but overall nominal rigidities increase, since unconstrained firms change their prices less often. In contrast, when financial shocks are large relative to aggregate price shocks, average prices fall by less as compared to the case without financial constraints. This model implication is very similar to what has been highlighted as the "cost channel" of financial frictions by Gilchrist et al. (2013a), albeit with a completely different mechanism.

The remainder of the paper is organized as follows. Section 2 documents the data and the empirical relationship between financial frictions and the price setting of firms. Section 3 presents the model and quantitative results. Section 4 concludes.

2 Empirical Evidence

2.1 Data

We use data from the ifo Business Survey which is a representative sample of 3600 plants in the German manufacturing sector in 2002-2014. The survey starts as early as the 1950's, but our sample is restricted by the fact that the questions about financial constrainedness was added in 2002. The main advantages of the dataset relative to data used in other studies on price stickiness are twofold. First it enables us to link individual plant's pricing behavior both to direct survey-based measures of the plant-specific degree

are developed by Nakamura and Steinsson (2010) and Alvarez and Lippi (2013), while Vavra (2013) and Bachmann et al. (2013a) investigate the consequences of uncertainty shocks for the price distribution and the effectiveness of monetary policy.

[4] In contrast, existing studies on the interaction between financial frictions and pricing decisions consider the intensive margin only, i.e., the fraction of firms that adjust prices is always equal to one, see e.g. Gottfries (1991), Chevalier and Scharfstein (1996) or Lundin and Yun (2009). Up to our knowledge, there so far exists no menu-cost model with financial frictions.

of financial constrainedness and to indirect proxies for the financial situation based on balance sheet information. Second, the survey is conducted on a monthly basis which enables us to track important aspects of a plant's actual behavior over time as it undergoes both, phases of easy and such of subdued access to credit while, at the same time, facing the alternating states of the business cycle. Since plants respond on a voluntary basis and, thus, not all plants respond every month, the panel is unbalanced.

In particular, we have monthly information about the extensive margin of price adjustment - i.e. whether and in what direction firms adjust prices.[5] More precisely, firms answer to the question: "Have you in the last month increased, decreased or left unchanged your prices?". We unfortunately do not have information about the intensive margin of price adjustment in our dataset. While our empirical analysis is limited to the extensive margin, our model in section 3 will have implications about size of price adjustments as well as price dispersion. More than 97% of the cross-sectional units in our sample are single-product plants. Additionally, some plants fill in a separate questionnaire for each product (product group) they produce. In what follows, we use the terms "firm", "plant" and "product" interchangeably.[6]

The ifo survey encompasses two questions regarding the financial constrainedness of firms. In the monthly survey, firms are asked about their access to bank lending: "Are you experiencing restrictive, normal or accommodating willingness of banks to lend?" We flag firms as financially constrained when they answer that bank lending is restrictive. Note that this answer might imply that firms experience restrictive bank lending in general, but do not necessarily need to borrow more, i.e., they are potentially not restricted in the way they invest, hire or produce. Figure A-1 in the Appendix shows a time-series plot of this measure of financial constraints. One can see that the fraction of constrained firms increases in a boom and decreases in a recession. A second question in the survey gets closer to this notion of financial constraints: "Are you experiencing production shortages due to financial constraints?". This question is very close to the actual definition of financial constraints in the economic model that we present below. However, it is only available at quarterly frequency.

Table 1 shows the relationship between price adjustments and being financially constrained. According to the bank lending question, 32% of all firms are financially constrained. According to the production shortage question, only 5% of firms are constrained on average. Clearly, the last measure can be viewed as a lower bound for the fraction of firms facing difficulties in obtaining external funds. In general few German firms adjust their prices on a monthly basis - a little more than 20%. However, if financially constrained, firms adjust their prices relatively more often. Furthermore, the fraction of price decreases is higher among financially constrained firms than among their unrestricted counterparts. This is true for both measures of financial constrainedness. With respect to price increases, the fraction of firms raising prices is higher for unconstrained than for constrained firms when using the bank lending measure, while the opposite is true when considering production shortages.

Based on this finding, one would like to know whether financially constrained and unconstrained firms are systematically different in some important aspect. The literature has discussed that small rather than large firms tend to be financially constrained.[7] Table A-1 in the Appendix documents that this is not the case for our sample. In fact, the size distribution within financially constrained and unconstrained firms is very similar.

Figures A-2 to A-4 show time-series plots of pricing decisions of financially constrained and unconstrained firms respectively using the bank lending question. One can see that all firms decreases prices

[5] These prices are home country producer prices for all products of a particular firm. Bachmann et al. (2013b) have used the same dataset to assess the effect of uncertainty shocks on price setting.

[6] Restricting our sample to the single-product cases only leaves our quantitative results unchanged. Results are available upon request.

[7] See Carpenter et al. (1994) for an early contribution on the topic.

Table 1: Financial Constraints and Price Setting

	unconstrained	constrained
Bank lending		
Fractions	0.68	0.32
$\Delta p = 0$	0.80	0.76
$\Delta p < 0$	0.08	0.14
$\Delta p > 0$	0.13	0.10
Production shortage		
Fractions	0.95	0.05
$\Delta p = 0$	0.80	0.75
$\Delta p < 0$	0.08	0.12
$\Delta p > 0$	0.11	0.13

Source: ifo Business Survey, 2002-2014. Numbers shown are sample averages of fractions of constrained and unconstrained firms in all firms and fractions of price changes within unconstrained and constrained firms. Numbers for production shortage question are based on quarterly data, interpolated to monthly frequency.

more often and increase prices less often in a recession. Over time, financially constrained firms decrease prices more often than unconstrained firms, regardless of the business cycle state. While the differences between price increases of constrained and unconstrained firms is small, more unconstrained firms leave prices constant relative to constrained firms in a recession compared to outside a recession. Clearly, the time series variation of pricing decisions may be driven by two facts: the business cycle itself and a possible selection of firms over the business cycle.

We further decompose the correlation between price changes and financial constrainedness into within and between firm effects using the following specification

$$P(\Delta p_{ijt} \lesseqgtr 0 | x_{ijt}) = \beta_0 + \beta_1 FC_{ijt} + c_j + \theta_t + u_{ijt}. \quad (1)$$

We estimate this equation using a Mlogit specification in which the dependent variable measures whether prices increase or decrease relative to no price changes. The right-hand side contains one of our two survey measures of financial constraints as well as sector and time fixed effects.[8] The coefficient β_1 then measures the within-firm variation over time between being financially constrained and the probability of adjusting price up or down. Note that this coefficient should not be interpreted as causal, since it may well be that price adjustments influence whether a firm is financially constrained or not (as is motivated in the introduction and documented in detail in section 3 below). Instead, this specification seeks to control for variation over time, i.e., business cycle effects, as well as possible selection of firms into being financially constrained or not that could have influenced the unconditional moments in Table 1.

Table 2 shows the results for this specification using either the question concerning restrictive bank lending (upper panel) or production shortages as measures of financially constrained firms (lower panel). One can see that in both cases, the finding that financially constrained firms decrease their prices more often than their unconstrained counterparts is robust with respect to the measure of the firm's financial situation as well as controlling for sector and time fixed effects. In the case of price increases, the results are more mixed. Nevertheless, when including time and sector fixed effects, financially constrained firms increase their prices more often than financially unconstrained firms. Overall, the results of the Mlogit

[8] To control for heteroscedasticity and within firm correlation of the residuals we compute robust standard errors clustered by firm. Clustering by sector delivers the same results regarding the significance of the estimated coefficients.

estimation suggest that financially constrained firms change their prices significantly more often in both directions, upwards and downwards. Furthermore, linear regressions or separate logit models for price increases or price decreases deliver essentially the same results. Finally, estimating the link between the price change in the current month Δp_{ijt} and the access to bank lending in the previous month also confirm our baseline estimates.

Table 2: Financial Constraints and Price Setting: Within Firm Effects

Restrictive bank lending					
price	variable	no fixed effects	time fixed effects	sector fixed effects	time & sector fixed effects
↓	FC	0.650***	0.473***	0.654***	0.476***
		(0.0256)	(0.0266)	(0.0271)	(0.0282)
↑	FC	-0.225***	0.0345	-0.236***	0.0391
		(0.0265)	(0.0277)	(0.0279)	(0.0293)
Production shortage					
price	variable	no fixed effects	time fixed effects	sector fixed effects	time & sector fixed effects
↓	FC	0.415***	0.308***	0.366***	0.251***
		(0.0517)	(0.0526)	(0.0543)	(0.0554)
↑	FC	0.203***	0.261***	0.277***	0.339***
		(0.0497)	(0.0509)	(0.0519)	(0.0534)

Notes: MLOGIT estimation: Base outcome is prices unchanged. Sample: January 2002 - December 2013. Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Includes only observations for which balance sheet data are available. Monthly data for restrictive bank lending, quarterly data (interpolated) for production shortages.

In a related paper, Gilchrist et al. (2013a) show that US firms that are financially constrained increase prices more often than their unconstrained counterparts, but do not decrease their prices more often. While the first finding is supported using our dataset, sample and specification, the second finding is not. A potential source of this difference is the measure of financial constrainedness of firms. While we use direct survey questions to identify financially constrained firms, Gilchrist et al. employ an indirect measure based on balance sheet information of firms. In line with Gilchrist, financial constraints may be measured in three possible ways: liquidity ratios (cash and other liquid assets over total assets), cash flow ratios (operating income over total assets) and interest coverage ratios (interest expenses over total assets). The lower the liquidity and cash flow ratio and the higher the interest coverage ratio, the more constrained a firm. Constrained firms are then those with liquidity or cash flow ratios below, or interest rate coverage ratios above the median value of all firms.

For a subsample of the firms in our survey, we have access to balance sheet information and we can calculate the respective indicators on an annual basis[9]. Tables A-2 to A-4 in the Appendix show that liquidity and cash flow ratios are lower and interest coverage ratios higher for firms that are constrained

[9]The data source here is the EBDC-BEP (2012): Business Expectations Panel 1/1980 12/2012, LMU-ifo Economics and Business Data Center, Munich, doi: 10.7805/ebdc-bep-2012. This dataset links firms' balance sheets from the Bureau van Dyk (BvD) Amadeus database and the Hoppenstedt database to a subset of the firms in the ifo Business Survey. See Kleemann and Wiegand (2014) for a detailed description of this data source.

according to our survey questions. However, the correlations between the balance sheet measures and our survey questions are very small. Moreover, of those firms that are unconstrained according to the production shortage question, close to 50% are constrained according to balance sheet measures. These may be firms that have already borrowed a lot, possibly due to good access to credit, but being indebted does not affect their production possibilities. Since this last aspect is usually key for most economic effects of financial frictions, our data suggest that using indirect balance sheet measures of financial frictions might be problematic.

Table A-5 in the Appendix shows that replacing the survey measures of financial constraints with the liquidity ratio measure in the Mlogit replicates the results of Gilchrist et al. for Germany. This means that the balance sheet measure picks up more of the price increases than of the price decreases compared to the survey measure. In our model in section 3, firms that decrease prices and are financially constrained are those with an initially high price and productivity. Even though not modelled explicitly, it makes sense that these firms do not exhibit low liquidity ratios and could therefore not be picked up by the respective measures. However, these firms are financially constrained in their pricing and production decisions and therefore qualify to be counted as financially constrained.

3 Model

In this section, we develop a simple partial-equilibrium able to replicate the empirical facts presented in the previous section. In particular, the model incorporates menu costs as a source of price rigidity and a working capital constraint. Section 3.1 discusses the theoretical setup and develops the economic intuition based on a static version of the model. Section 3.2 is devoted to the implications of the dynamic version of the model. Finally, we simulate the response of the price distribution to aggregate shocks in section 3.3.

3.1 Baseline model

Firms problem. Our model consists of a firms' problem only. There is a continuum of firms in the economy indexed by i. Each of them faces an exogenous idiosyncratic productivity level z_i. A firm's output y_i is produced by using the production technology $y_i = z_i \bar{k}_i h_i^{\alpha}$. Here, h_i is firm specific labor input, while $\bar{k}_i$ is fixed capital input and can be thought of as a normalizing constant. We assume that demand c_i for the good produced by firm i is given by

$$c_i = C \left(\frac{p_i}{P}\right)^{-\theta}, \tag{2}$$

where p_i is the nominal price for this good and θ is the elasticity of substitution between different goods.[10] Aggregate consumption C and the aggregate nominal price level P are exogenously given. Below, we will specify an stochastic process for P implying a non-zero aggregate inflation.

Working hours are hired at a real wage w. Following Nakamura and Steinsson (2008), w is assumed to be constant and equal to

$$w = \frac{W}{P} = \frac{\theta - 1}{\theta}, \tag{3}$$

[10] The demand function reflects the optimal decision of the consumer if her consumption basket is given by the CES index:

$$C = \left(\int_{i=0}^{1} C(i)^{\frac{\theta}{\theta-1}} di\right)^{\frac{\theta-1}{\theta}}.$$

where W denotes the nominal wage.[11]

The first friction included in our theoretical set-up is a standard menu-cost. That is, the firm has to pay a fixed cost f in case it decides to adjust its price. For simplicity, we assume that a fixed cost f has to be paid at the end of the period after revenues have been realized.

The second friction is a financial one and enters the model via a working capital constraint, i.e., we assume that payments of wages, wh_i, are made prior to the realization of revenues. Accordingly, the firm faces a cash flow mismatch during the period and has to raise funds amounting to $l_i = wh_i$ in the form of a intra-period loan. However, the firm cannot borrow more than the liquidation value of its capital

$$wh_i \leq \xi_i \bar{k}_i, \tag{4}$$

where $0 \leq \xi_i \leq 1$ measures the tightness of the borrowing constraint. We allow ξ_i to be firm specific and to follow an exogenous stochastic process. As in Jermann and Quadrini (2012), we assume that debt contracts are not enforceable as the firm can default. Default takes place at the end of the period before the intra-period loan has to be repaid. In case of default, the lender has the right to liquidate the firm's assets. However, the loan l_i represents liquid funds that can be easily diverted by the firm in case of default. We assume that firms can divert all the revenues so lenders cannot access the cash-flow generated by the firm. The only asset left is then physical capital $\bar{k}_i$. The tighter the constraint, the less of $\bar{k}_i$ can be liquidated. Our working capital constraint can therefore be viewed as an enforcement constraint.

Firms start the period with a given nominal price p_i and observe the exogenous realizations of the aggregate nominal price level P as well as idiosyncratic shocks to productivity z_i and the tightness of the financial constraint xi_i, respectively. Before producing, they choose whether to change the price to $q_i \neq p_i$ or to leave the nominal price unchanged. Given the new price, the demand function then pins down the desired level of output and the necessary amount of labor associated with that level of output. The financial constraint, in turn, determines whether the desired demand level can be satisfied or not.

The formal structure of the firm's optimization problem is as follows: Given (p_i, P, z_i, ξ_i), the firm's real profits are then given by

$$\Pi(p_i, P, z_i, \xi_i) = \frac{p_i}{P} y_i - wh_i = \frac{p_i}{P} z_i \bar{k}_i h_i^{\alpha} - wh_i. \tag{5}$$

The associated value function is

$$V(p_i, P, z_i, \xi_i) = \max\{V^A(P, z_i, \xi_i), V^{NA}(p_i, P, z_i, \xi_i)\} \tag{6}$$

with

$$\begin{aligned} V^A(P, z_i, \xi_i) = \max_{h_i, q_i \neq p_i} & \left\{\Pi(q_i, P, z_i, \xi_i) - f + \beta E_{P', z_i', \xi_i'} V(q_i, P', z_i', \xi_i')\right\} \\ \text{s.t.} \qquad & z_i \bar{k}_i h_i^{\alpha} \leq c_i \qquad wh_i \leq \xi_i \bar{k}_i \end{aligned} \tag{7}$$

[11] This expression of the real wage would arise in the steady state of a general equilibrium model with a linear aggregate production function depending only on labor input, monopolisitic competition among firms in the goods market and a good specific demand function given by (2).

and

$$V^{NA}(p_i, P, z_i, \xi_i) = \max_{h_i} \left\{ \Pi(p_i, P, z_i, \xi_i) + \beta E_{P', z_i', \xi_i'} V(p_i, P', z_i', \xi_i') \right\}$$
$$\text{s.t.} \qquad z_i \bar{k}_i h_i^{\alpha} \leq c_i \qquad w h_i \leq \xi_i \bar{k}_i \tag{8}$$

where V^A and V^{NA} are the firm's value functions in the case of nominal price adjustment or an unchanged nominal price, respectively.[12] The fix cost f needs to be paid if the firm decides to change its price. Note that through $y_i \leq c_i$ we allow the firm to occasionally produce less than the amount of goods demanded. As we show in the static model below, the situation can arise when the financing constraint is very tight and the firm does not adjust its price. In this case, the firm rations demand due to the financial constraint.

As noted above, the model also allows for two types of disturbances: firm-specific productivity shocks and firm-specific shocks to the financial constraint. The laws of motion for these two disturbances are given by

$$\ln z_{i,t} = \rho_z \ln z_{i,t-1} + \varepsilon_{i,t} \tag{9}$$
$$\ln \xi_{i,t} = \mu_\xi + \rho_\xi \ln \xi_{i,t-1} + u_{i,t} \tag{10}$$

In addition, and in line with Nakamura and Steinsson (2008), we allow for shocks to the aggregate price level

$$log(P_t) = \bar{\pi} + log(P_{t-1}) + \eta_t, \tag{11}$$

where $\bar{\pi}$ is the average inflation rate in the economy.

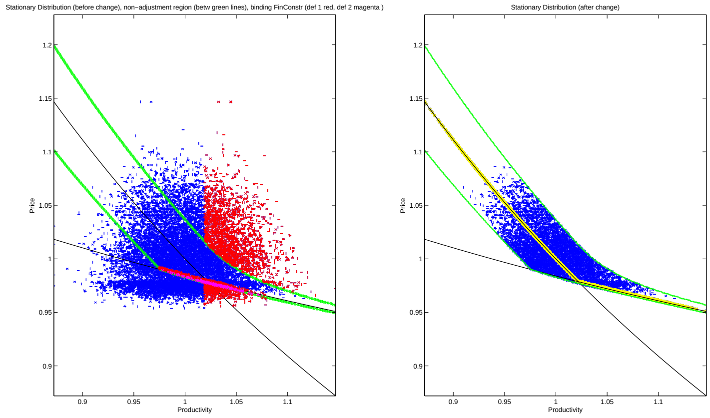
Intuition from the static model. The most important insights from the model can already be discussed in a simpler, static version of the model, in which the discount factor is set to zero, $\beta = 0$, and the aggregate nominal prices level P is assumed to be constant. ξ_i is is fixed at μ_ξ for all firms and there is no autocorrelation in the idiosyncratic productivity shock. The static model can be solved in closed form.[13] Figure 1 illustrates the static model for a given parametrisation (see our baseline calibration in subsection 3.2). The left hand side of the figure shows the situation before the price decision: Given P and $\xi_i = \xi$, firms start with a certain initial nominal price p_i and a productivity level z_i. The right hand side graph shows the situation after price adjustment. The x-axis displays productivity levels z_i and the y-axis shows the *real* price of the firm $\tilde{p_i} = p_i/P$ (or $\tilde{q_i} = q_i/P$ if the price is changed). Each dot in this graph corresponds to a real-price-productivity combination that have some positive mass in the stationary distribution. Since we do not display the respective mass of firms, one should not think of each dot representing a single firm.[14] In the graph, the steeper black line exhibits the optimal relative price in an economy without menu costs (i.e. under flexible prices) and without financial constraints. The flatter black line shows for each possible productivity level the lowest relative price at which a firm is financially constrained. Accordingly, relative-price-productivity combinations exactly at as well as

[12] Note, that the beginning of period nominal price p_i is a relevant state variable only if the firm does not change its price. Accordingly, the value function in the case of price adjustment, V^A, is independent of p_i.

[13] Please see Appendix A.1 for the respective equations.

[14] Notice that a stationary distribution exists since firms still maximize the sum of expected future dividends. However, since they do not care about the future, the problem is essentially static. We can still obtain the stationary distribution by simulating the economy for a long time (or a large cross-section of firms) by starting with an initial draw of idiosyncratic productivity and using the policy function of the firm to obtain the joint stationary distribution of p, z given P and xi.

Figure 1: The static model with financial constraints



Notes: Left hand panel shows situation before pricing decision, but after realization of idiosyncratic productivity shock. Right hand panel shows situation after price adjustment.

strictly below the steeper black line are associated with a binding financial constraint. The yellow line in the right-hand side plot shows the optimally chosen price for each productivity level z_i in the presence of financial constraints. To the right of the intersection of the two black lines, the firm's profit function has a new unique maximum which coincides with the relative price at which the borrowing constraint starts to bind. Hence, in that region, the relative price associated with the steeper black line is no longer optimal. The reason why there is a new optimum in the right part of the diagram is that for relative prices at or below the steeper black line the level of production is determined by the financial constraint and thus independent of the relative price. Accordingly, for a given productivity level, the firm specific profit falls linearly as one moves downwards from the steeper black line. As a consequence, to the right of the intersection of the two black lines, it is optimal for firms to adjust prices up or down to the point where the financial constraint is just binding. We count such price-adjusting firms as financially constrained. Price-productivity combinations for these firms are shown in red in the left-hand side plot.

As in the dynamic model, firms decide whether to adjust their prices or not given their initial price and productivity and given the fixed cost of adjustment. Without menu costs, firms will always adjust their price to the yellow line. One can show that when firms change their price, they will set the new price such that demand is satisfied. Then, there are two cases: The financial constraint is binding or the financial constraint is not binding. For a given initial distribution of z_i and p_i, the number of constrained firms depends on the value of ξ. The higher ξ, the fewer firms are constrained. For a given value of ξ, firms with a sufficiently high productivity z_i will be constrained. The intuition is straightforward: A relatively high productivity level implies relatively lower marginal costs and thus a stronger relative competitiveness position. Such high productivity firms would like to expand by lowering prices and thus attracting more demand. However, the desired expansion is associated with an increased labor input and thus, with a higher wage bill, necessitating a higher level of borrowing. As a consequence, for sufficiently high productivity levels hiring and thus production will be restricted by the borrowing constraint. In that case, as explained above, it is optimal to chose the highest nominal (and thus relative) price for which the financial constraint is binding.

In particular, out of the high productivity firms, those with a high initial price would like to decrease their price. However, they may not decrease their price down to the steeper black, but only to the flatter black line (coinciding with the yellow line in the right part of the diagram). In other words, such firms run into the financial constraint. Likewise, firms with a high productivity and a very low initial price sell and produce a lot. In a frictionless economy, they would like to increase their prices up to the steeper black line. However, if that price-productivity combination is associated with a binding financial constraint, the firms will find it optimal to set higher prices. In particular, they will choose the price lying at the flatter black line at which the borrowing constraint is just binding.

With menu costs, firms trade off the gain in revenue from changing the price and the cost of adjusting the price. That gain is determined by the curvature of the profit function, especially in a neighbourhood of the flex-price optimum where most firms will be located. The higher the curvature, the stronger the incentives to pay the menu costs in order to adjust one's price towards the flex-price optimum. Accordingly, firms will adjust prices more frequently (as a reaction to smaller shocks) if their profit function declines more steeply to the left and to the right of the flex-price maximum. A convenient graphical measure of the incentives to adjust prices is the so called inaction region. The latter lies between the green lines in the Figure 1. A firm will only adjust its price if the combination of aggregate and idiosyncratic shocks throw it outside the inaction region. Correspondingly, the region between the green lines corresponds to the real prices of those price-productivity combinations for which firms do not change their nominal price p_i. Financial constraints shape the adjustment region of the firms. In particular, the individual firm's profit function becomes steeper for relative prices associated with a binding borrowing constraint. Accordingly, the curvature of the profit function increases around the point where the constraint starts to bind as compared to a situation without a financial restriction. This is particularly relevant for sufficiently high productivity levels, where the relative price implying a just binding borrowing constraint is associated with the profit maximum. The higher curvature of the profit function in this region implies that deviations from the profit maximizing relative price are more painful. Accordingly, there is a much narrower inaction region for relatively high productivity levels where the profit maximum is associated with a just binding financial constraint and is given by the flatter black line in the right part of the diagrams in Figure 1. As a consequence, high productivity firms face stronger incentives to adjust their prices towards the optimum both upwards and downwards. Since this optimum is characterized by a binding financial constraint, our model is consistent with our main empirical finding that financially constrained firms change their prices more often not only upwards but also downwards.

In order to compare the output from the static (and later the dynamic) model to the empirical evidence, one then compares the fractions of financially constrained firms that adjust prices up or down relative to all financially constrained firms to the respective fractions within the unconstrained firms. Already in this static version, our model supports the empirical findings (see Table 4).

3.2 Quantitative results from the dynamic model

In a dynamic set-up, firms take into account the effect of their pricing decisions on next periods starting condition (i.e., the initial price next period) and its impact on future outcomes. Through adjusting their prices, they can also affect whether they are financially constrained or not. Unlike the static economy, in a dynamic world the flex-price optimum does no longer coincide with the maximum of the current profit function. When setting prices, firms now rather take into account that their position in the productivity-relative-price diagram will automatically change in the following months due to both, the autoregressive structure of idiosyncratic productivity and the positive average aggregate inflation. In particular, as a result of average inflation, each firm tends to shift downwards in the diagram. The autoregressive nature of productivity on the other hand, tends to push the firm to the right in the case of below average current productivity and to the left otherwise. Accordingly, in the case of price adjustment, the firm

Table 3: Parametrization of the dynamic model

Parameter		**Value**	
discount factor	β	0.9966	NS (2010)
agg. consumption	C	1	NS (2010)
demand elast. of subst.	θ	4	NS (2010)
fixed cost price adjust.	f	0.018	NS (2010)
average inflation	$\bar{\pi}$	0.001	Germany 1991-2014
sd price level innovations	σ_η	0.002	Germany 1991-2014
sd productivity	σ_ε	0.067	
pers. productivity	ρ_z	0.66	
financial constraint	μ_ξ	0.92	
sd fin. shock	σ_ε	0.04	
pers. fin. shock	ρ_ξ	0.66	

Table 4: Comparing moments in model and data

	fraction of financially constrained	fraction of constant prices among: fin. constrained	unconstrained	fraction of price decreases among: fin. constrained	unconstrained
Data: 2002-2014					
Production shortage	0.05	0.75	0.80	0.12	0.08
Bank lending	0.32	0.76	0.80	0.14	0.08
Baseline model					
	0.05	0.75	0.80	0.20	0.08
Sensitivity of parameters					
$\xi = 0.6$	0.32	0.70	0.86	0.13	0.03
no fin. shocks	0.05	0.84	0.80	0.13	0.08
no fin. constr.			0.79		0.10
no menu cost	0.22	0.03	0.03	0.66	0.41
Static model					
	0.10	0.34	0.82	0.64	0.04

faces an additional trade-off between adjusting exactly to the maximum of the current profit function and choosing another price but staying for a longer period of time in the inaction region (and thus reducing the present value of future menu costs). Figure A-5 in the Appendix illustrates this where the dynamic flex-price optimum is shown by the yellow line.

Table 3 shows our parametrization. In general, we stay very close to Nakamura and Steinsson (2008). In addition to the parameters in the table, this implies setting $\bar{k} = 1$ and $\alpha = 1$ in the production function. Average inflation and the standard deviation of price shocks targets German producer price developments in the manufacturing sector[15]. We set the standard deviation of productivity and the financial shock as well as the mean value of ξ such that we match the number of constrained firms as well as the fraction of financially constrained and unconstrained firms that do not change their price in the economy. Our baseline calibration targets the overall moments using the production shortage question from our survey.

Table 4 shows the moments in the data produced using both survey questions about financial constraints and the results from our simulation exercise. Even though not targeted, our baseline calibration

[15] The data is provided by the German statistical office.

matches the frequency of price decreases that we observe in the data relatively well. In addition to the baseline calibration, we consider how financial frictions and menu costs affect model outcomes. One can see that the fact that financially constrained firms decrease their prices more often than their unconstrained counterparts is driven by the financial constraint, not by the menu costs in the model. The reason is that the financial constraint compresses possible prices from below in the stationary distribution and it is more likely to end up above rather than below the constraint in the region where it is binding.

When tightening the financial constraint (see row labeled $\xi = 0.6$), more firms are ceteris paribus constrained and more of these adjust their nominal price. The reason is that a tighter financial constraint implies an even higher curvature of the firms' profit function and thus, makes the adjustment region smaller in the area where the optimum coincides with the relative price at which the borrowing constraint is just binding. Overall, individual firms prices change more frequently and thus, nominal rigidities become weaker for a tighter constraint.

The introduction of idiosyncratic shocks to the degree of financial tightness, ξ_i increases the frequency of price increases among financially constrained firms while leaving the likelihood of price decreases among those same firms virtually unchanged. To understand the intuition, recall first that the financially constrained firms are those with a relatively high productivity and are clustered in the narrow inaction region in the right part of the diagrams in Figures 1 and A-5. In this region, the optimal relative price largely coincides with the one for which the financial constraint is just binding (represented by the flatter black line in the graphs). Second, note that the flatter black line lies in the lower part of the inaction region in the right part of the diagrams. As a consequence, the lion's share of high productivity firms is concentrated in the lower part of the inaction region - exactly on the flatter black line or slightly below it. Finally, recall that a financial shock implying a tightening of the borrowing constraint, shifts the flatter black line and the lower green line upwards while the opposite happens in the case of a financial loosening. Consequently, an unfavourable financial shock, will leave a relatively larger fraction of highly productive firms, most of which were previously financially constrained, below the new inaction region. All of them will optimally adjust their nominal prices upwards towards the relative price at which the financial constraint is just binding. Thus, these firms will find them financially constrained (again). In contrast, a financial loosening, shifting the flatter black line in in Figures 1 and A-5 downwards, will leave most high productivity firms inside the new inaction region. As a result, such a favourable financial shock has barely any effects on the frequencies of price adjustment. Overall, due to the inclusion of idiosyncratic financial shocks, the fraction of financially constrained firms that increase their prices gets larger, while the fraction of constrained firms that decrease their price is almost unaffected.

Table 5 shows the average price changes in the model. Financially constrained firms change their prices by less than unconstrained firms. This stems mainly from the fact that the constrained firms increase their prices by less than their unconstrained counterparts which is, again, due to the increased curvature of the current profit function in the region where the constraint is effective. The difference between financially constrained and unconstrained firms increases without financial shocks. Comparing two economies with tight and lax financial constraints (low and high μ_ξ), prices are on average higher and price changes smaller in the economy with tight constraints. Consequently, the dispersion of prices decreases in economies with tighter financial constraints (see also Figure A-6).

3.3 Aggregate shocks

In this section we study the implications of aggregate inflation shocks on prices, the price dispersion and the fraction of price changes, averaged over financially constrained and unconstrained firms in the

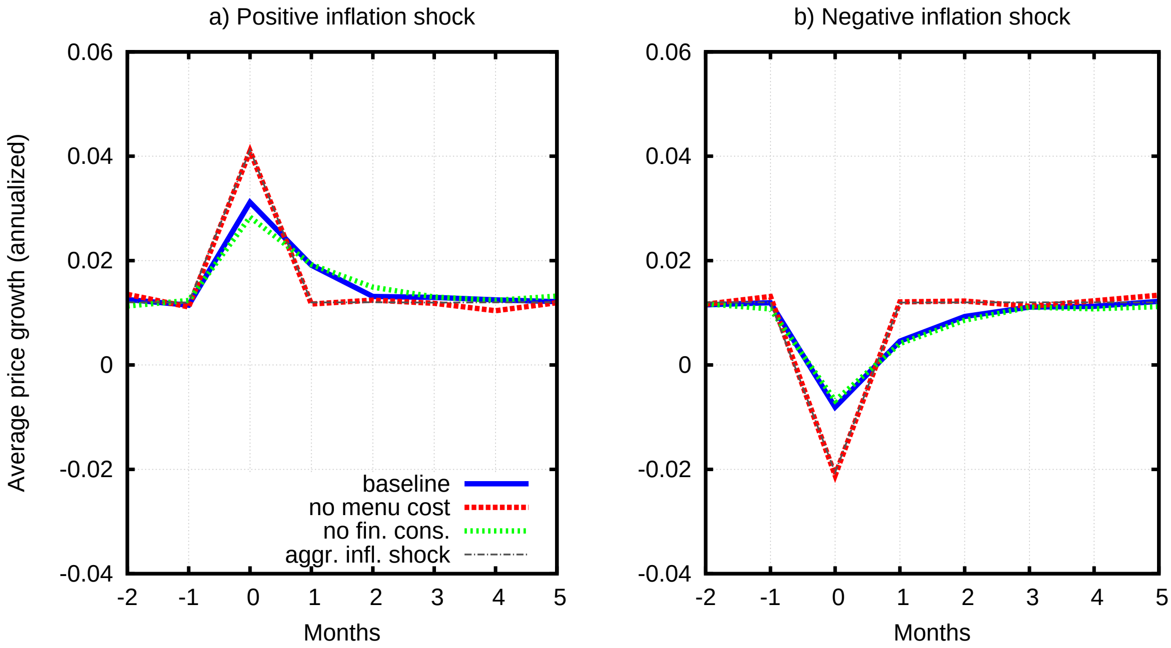
Table 5: Average price changes

	Avg. $\lvert\Delta p\rvert$		Avg. $\Delta p > 0$		Avg. $\Delta p < 0$	
	constrained	unconstrained	constrained	unconstrained	constrained	unconstrained
Baseline model						
	6.880	9.334	2.081	7.894	-7.986	-7.025
Sensitivity of parameters						
$\xi = 0.6$	4.295	4.449	2.510	3.692	-4.925	-2.189
no fin. shocks	6.146	9.740	1.397	8.403	-7.437	-7.212
no fin. constr.		11.258		9.313		-8.331
no menu cost	3.562	5.500	1.565	5.548	-4.452	-5.427
Static model						
	12.982	11.597	0.262	10.535	-13.231	-5.008

stationary distribution. In our partial equilibrium model, one can best view this exercise as the response of a single sector to an aggregate price level shock. We simulate the response of firm-specific prices to a one standard deviation shock to the aggregate price level in our baseline calibration. To study the relative contribution of nominal rigidities and financial constraints, respectively, we then report the responses for two counter-factual scenarios: one in which we shut down the nominal rigidities by setting the menu cost to zero (labeled 'no menu cost') and one in which we remove the financial constraints (labeled 'no fin. constr.'). The last scenario essentially represents the impulse responses in the standard menu cost model. Figure 2 shows the response of the average price level to positive aggregate price level shocks in period 1 in panel (a) and to the corresponding negative shocks in panel (b). Figure 3 shows the corresponding response of nominal rigidities, i.e., the average fraction of price changes. Figures A-6 and A-7 in the Appendix further show the dispersion of prices as well as the responses of financially constrained and unconstrained firms price decisions separately.

Figure 2 documents that the model replicates the conventional business cycle pattern of average price decreases in a recession and price increases in a boom. In a model without menu costs, inflation shocks are offset one-to-one by the price changes of firms. This response is dampened when nominal rigidities are present. Comparing an economy with menu costs, but with and without financial constraints, there is hardly any difference in the response of average prices. If anything, the presence of financial constraints slightly increases the sensitivity of average prices to aggregate inflation shocks. Interestingly, the change in sensitivity turns out to be asymmetric - it is more pronounced in the case of positive innovations to aggregate inflation. The reason for average prices becoming more responsive is straightforward: The introduction of the financial constraint narrows the inaction region for a wide range of possible idiosyncratic states (see Figure 1). Accordingly, the average price in this market tends to become slightly less rigid. The reason why the financial constraint makes the reaction of the average price level to aggregate inflation shocks asymmetric is easily understood by noting that the constraint lies very close to the lower boundary of the non-adjustment region, especially for relatively high productivity levels (see Figure 1). Hence, a relatively large fraction of financially constrained firms is clustered near the lower boundary of the inaction region. Accordingly, in the case of a negative shock to aggregate inflation, which shifts the overall pre-adjustment distribution of firms upwards in Figure 1, a relatively large fraction of previously constrained firms (typically those with high productivity) are likely to end up in the non-adjustment region, above their desired individual price. The opposite happens in the case

Figure 2: Average inflation response for unexpected aggregate inflation shock

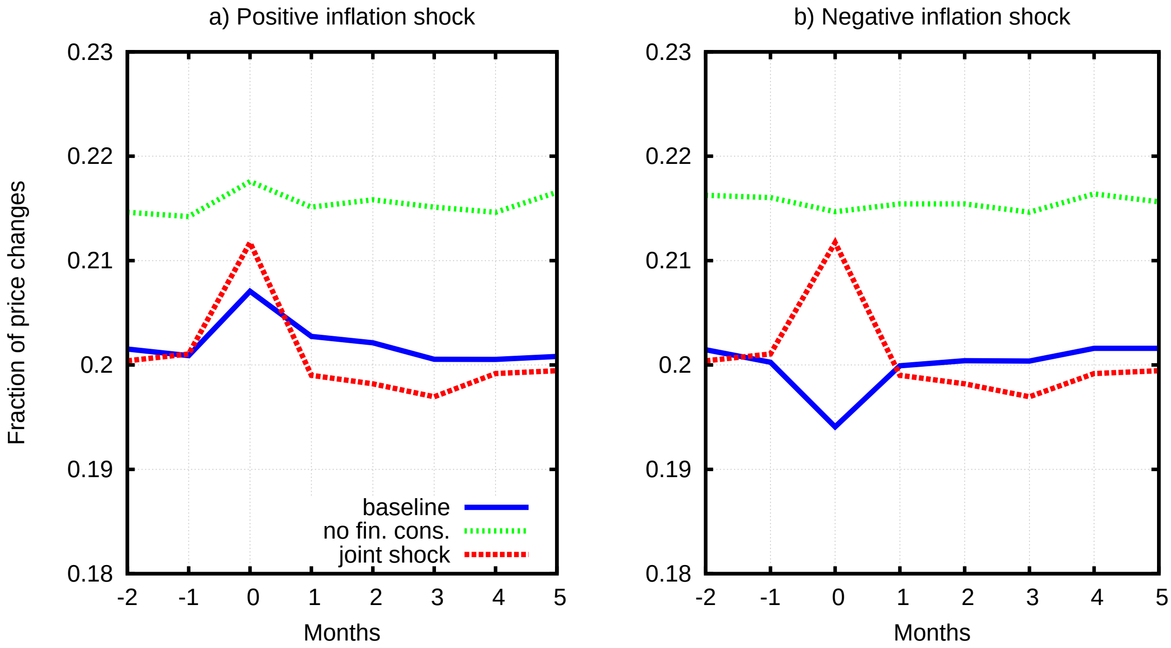


of positive innovations to aggregate inflation which shift the overall pre-adjustment distribution of firms downwards in Figure 1. In this case the bulk of the previously financially constrained firms find them below the lower boundary of the inaction region and have to increase their prices. As a consequence, in the case of positive shocks to aggregate inflation there are relatively more firms willing to change their prices (see Figure 3) while the fraction of price adjusters even decreases in the case of negative innovations to inflation. This difference mainly reflects the asymmetric behavior of firms which have relatively high productivity levels and thus are either financially constrained or their idiosyncratic state is relatively close to the region where the financial restriction starts to bind.

We further compare the responses to a negative inflation shock (normal recession) to the case in which a one-standard deviation negative financial shock hits the economy at the same time (financial recession). Figure 4 documents our various scenarios for the response of average price growth for a positive shock to the aggregate price level (panel (a)) and a corresponding negative shock (panel (b)). A financial tightening induces that firms decrease prices less in a recession and more in a boom. This result goes in the same direction as argued by Gilchrist et al. (2013a) for the Great Recession in the U.S.: tightening financial constraints in a recession counteract the deflationary pressures of a normal recession. The presence of menu costs intensifies this effect. Two things are important to note here: First, contrary to a normal recession, nominal rigidities decrease. Unlike in Gilchrist et al. this effect mainly stems from unconstrained firms increasing their prices more often. Put differently, the presence of (changing) financial constraints affects the behavior of both constrained and unconstrained firms. The latter are firms that have not adjusted their prices previously, but due to the tightening financial constraint now adjust the prices up. Since these firms are unconstrained, this means that they adjust their prices optimally such that their resulting price is higher than it would be on the constraint. Second, since prices are higher for both constrained and unconstrained firms, the corresponding output is even lower.

The depicted combination of negative aggregate price and financial shock explains the U.S. experience

Figure 3: Response of frequency of price adjustment to aggregate inflation shock, all firms



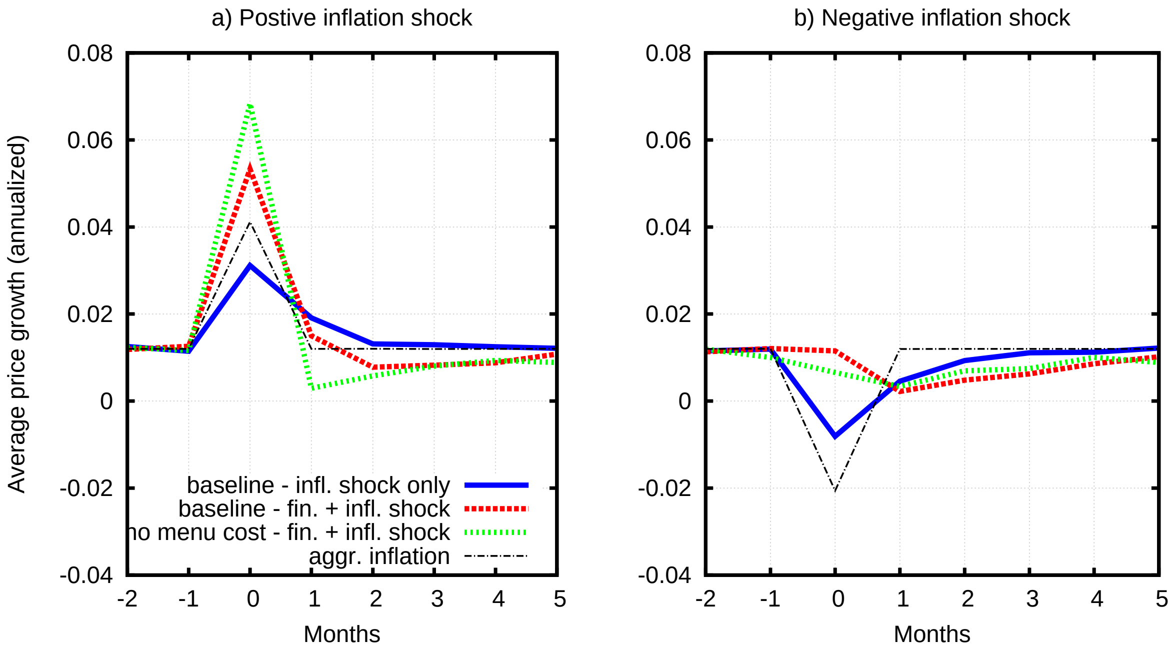
Notes: This figure displays the response of frequencies of price adjustment following a one standard-deviation unexpected negative shock to aggregate inflation. Left panel: positive shock to aggregate inflation. Right panel: negative shock to aggregate inflation. Blue solid lines refer to the responses in the baseline model. Red dashed line refers to the joint shock scenario; that is, the negative shock to aggregate inflation is accompanied by an aggregate tightening of financial conditions. Green line refer to the model version where financial frictions are absent.

in the Great Recession well, albeit with a different mechanism than in Gilchrist et al. (2013a). Even though the fraction of financially constrained firms has increased in Germany, too, aggregate dynamics around 2009 have resembled a normal recession much more than a financial recession (see Figures A-1 to A-4 in the Appendix). In order to replicate the German business cycle facts, we combine the negative financial shock with a very large negative shock to the price level. In fact, producer prices have fallen dramatically in 2009, while the increase in financially constrained firms has been moderate. Figures A-8 and A-9 in the Appendix document the resulting dynamics and highlight that not only the presence of different shocks, but also their relative size matters for aggregate outcomes.

4 Conclusion

This paper investigates the interaction between financial frictions and the price setting of firms. Financial frictions and price setting may affect each other in two ways: On the one hand, being financially constrained may affect the pricing decision of a firm: firms with initially low prices that sell large quantities may not be able to finance their production inputs and may therefore find it optimal to scale down production and adjust prices up. On the other hand, firms seeking to gain market share may want to lower their prices. However, by doing so, they may run into financial constraints when expanding production. We show empirically and theoretically that both of these mechanisms are important for understanding the frequency, the direction, the size and the dispersion of individual firms' price changes.

Figure 4: Average response of firm price growth for unexpected aggregate inflation shock and contemporaneous tightening of financial conditions



Notes: This figure displays the response of firms' average price growth following a one standard-deviation unexpected shock to aggregate inflation. The left panel shows the response to a positive aggregate inflation shock. The right panel shows the responses for a negative aggregate inflation shock. In both panels it is assumed that the aggregate inflation shock comes together with an aggregate tightening of financial conditions, that is, a decrease in ξ for all firms.

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A Appendix

A.1 The static model

A.1.1 Problem of the firm

Here for simplicity we assume that the aggregate price level P is normalized to one. Note that this implies so the firm's nominal price p is also its real price. In addition, we normalize the aggregate consumption level $C = 1$. For the production function, we normalize $\bar{k} = 1$ and assume a constant return to scale technology, i.e. $\alpha = 1$. To save on notation, denote by $s = (z, \xi)$ the idiosyncratic state of the firm. The problem of the firm can then be written as

$$V(p,s) = \qquad \max\{V^A(p,s), V^{NA}(p,s)\}$$

where

$$V^A(p,s) = \max_{h, q \neq p} \quad \left\{ zh\left(q - \frac{w}{z}\right) - f \right\}$$

subject to

$$zh \le q^{-\theta} \qquad (\phi)$$
$$wh \le \xi \qquad (\mu)$$

and

$$V^{NA}(p,s) = \max_{h} \quad zh\left(p - \frac{w}{z}\right)$$

subject to

$$zh \le p^{-\theta} \qquad (\phi)$$
$$wh \le \xi \qquad (\mu)$$

A.1.2 No price adjustment.

Conditional on not adjusting the price, the firm chooses hours to maximize profits. The first order conditions read as

$$0 = \left(p - \frac{w}{z}\right) - \phi - \frac{w}{z}\mu$$
$$zh \le p^{-\theta} \qquad \perp \qquad \phi \ge 0$$
$$wh \le \xi \qquad \perp \qquad \mu \ge 0$$

for $pz > w$. Otherwise $h = y = 0$. Now, consider the following cases

1. Demand satisfied while the financial constraint is not binding. Complementary slackness requires

$\mu = 0$. From the demand equation we have

$$h = \frac{1}{z} p^{-\theta}$$
$$\phi = \left(p - \frac{w}{z}\right)$$

Note that in this case it has to be true that

$$z > \frac{w}{\xi} p^{-\theta}$$

which is satisfied for sufficiently high values of ξ, given p; or for given ξ for sufficiently high prices p.

2. Demand is (weakly) not satisfied while the financial constraint is binding. Then we have

$$h = \frac{\xi}{w}$$
$$\mu = \frac{z}{w}\left(p - \frac{w}{z}\right)$$

Note that in this case it has to be true that

$$z \leq \frac{w}{\xi} p^{-\theta}$$

A.1.3 Price adjustment

First order conditions for prices, hours, and output

$$0 = zh - \phi\theta q^{-\theta-1}$$
$$0 = \left(q - \frac{w}{z}\right) - \phi - \frac{w}{z}\mu$$
$$zh \leq q^{-\theta} \perp \phi \geq 0$$
$$wh \leq \xi \perp \mu \geq 0$$

Consider the following cases

1. Financial constraint is not binding and demand is satisfied. This implies that $\mu = 0$ and

$$h = \frac{1}{z} q^{-\theta}$$
$$0 = zh - \phi\theta q^{-\theta-1}$$
$$\phi = \left(q - \frac{w}{z}\right)$$

so that

$$0 = 1 - \theta\left(q - \frac{w}{z}\right) q^{-1}$$

or

$$q = \frac{\theta}{\theta - 1} \frac{w}{z}$$

which is the standard result that price is a constant mark-up $\theta/(\theta - 1)$ over marginal costs w/z. For this case to arise, it must be the case that the parameter ξ that measures financial tightness is sufficiently large or

$$\xi > \left(\frac{\theta - 1}{\theta}\right)^{\theta} \left(\frac{w}{z}\right)^{1-\theta}.$$

2. Both constraints are binding. Then

$$\begin{aligned} h &= \frac{\xi}{w} \\ q &= (zh)^{-\frac{1}{\theta}} \\ \phi &= \frac{1}{\theta} zhq^{1+\theta} \\ \mu &= \frac{z}{w}\left(\left(q - \frac{w}{z}\right) - \phi\right) \end{aligned}$$

or

$$\begin{aligned} q &= \xi^{-\frac{1}{\theta}} \left(\frac{w}{z}\right)^{\frac{1}{\theta}} \\ \phi &= \frac{1}{\theta}\left(\frac{w}{z\xi}\right)^{\frac{1}{\theta}} \\ \mu &= \frac{\theta - 1}{\theta}\left(\frac{w}{z\xi}\right)^{\frac{1}{\theta}} \frac{z}{w} - 1 \end{aligned}$$

For this case, it must be true that $\phi, \mu \geq 0$. Note that $\phi > 0$ is always satisfied. For $\mu \geq 0$, it must be the case that

$$1 \leq \frac{\theta - 1}{\theta}\left(\frac{w}{z\xi}\right)^{\frac{1}{\theta}} \frac{z}{w}$$

or

$$\xi \leq \left(\frac{\theta - 1}{\theta}\right)^{\theta} \frac{w}{z\xi} \left(\frac{z}{w}\right)^{\theta}$$

3. The financial constraint is binding and the demand function is slack. In this case by hypothesis

$\phi = 0$ and

$$
\begin{aligned}
h &= \frac{\xi}{w} \\
0 &= zh \\
0 &= \left(q - \frac{w}{z}\right) - \frac{w}{z}\mu
\end{aligned}
$$

Unless $\frac{\xi}{w} = 0$ the optimality conditions lead to a contradiction, assuming that productivity is always positive $z > 0$. We exclude this case by assuming that $w, \xi > 0$.

A.1.4 Summary.

The previous discussion can be summarized as follows. In case the firm finds it optimal to adjust its price, it will always satisfy demand. When the working capital constraint is slack, this is the standard case and the prices is a constant mark-up over marginal costs. This scenario arises when the firm has access to sufficient funds to pay the hired workers, that is, given z for a sufficiently high ξ or - given ξ - for a sufficiently low z. On the other hand, if the working capital constraint is binding the firm can hire less workers, so output is lower. The firm then finds it optimal to increase the price further so that demand at this price is equal output that can be produced given the financial constraint. This situation arises, for given ξ, if the firm is very productive (large z) or - given z - faces tight financial conditions (low ξ).

In case the firm finds it optimal not to adjust its price, there are two possible scenarios. In case the working capital constraint is slack, the firm hires labor so to produce the amount that satisfies demand at that price. On the other hand, if the constraint is binding, the firm cannot hire more labor than is prescribed by the constraint; in this case, the firm will not be able to satisfy demand.

The price adjustment decision is then made anticipating the possible scenarios as discussed above. Note that absent menu-costs the firm always finds it optimal to adjust the price.

A.2 Additional Tables and Figures

Table A-1: Descriptive Statistics: Baseline sample

	unconstrained	constrained
Constrained status (1)		
Number of observations	47,788	22,992
Fraction of observations	0.68	0.32
Firm size (employees) (2)		
Average	542.2	572.9
Median	120.0	110.0
Small (≤ 50)	0.26	0.28
SME $\in 50, 250$	0.44	0.41
Medium $\in 250, 500$	0.15	0.14
Large (> 500)	0.15	0.16

Notes: Sources: ifo Business Survey;(1) based on bank lending survey question, (2) Number of persons employed by the reporting firm/enterprise

Table A-2: Balance sheet information

	unconstrained	constrained
Total assets (1)	10,579,276	10,081,000
Bank lending		
Liquidity ratio (2)	0.061	0.034
Cash flow ratio (3)	0.055	0.010
Interest coverage ratio (4)	0.008	0.012
Production shortage		
Liquidity ratio (2)	0.046	0.017
Cash flow ratio (3)	0.044	0.000
Interest coverage ratio (4)	0.009	0.018

Sources: EBDC-BEP (2012): Business Expectations Panel 1980:1 to 2012:12; (1) total assets (end of year); (2) cash and cash equivalents over total assets (both end of year); (3) operating profit (end of year) over total assets (beginning of year); (4) interest expenses over sales (both end of year)

Table A-3: Correlations between different measures of financial constraints

Variables	Production shortage	Restrictive bank lending	Liquidity ratio	Cash flow ratio
Restrictive bank lending	0.262 (0.000)	1.000		
Liquidity ratio	-0.065 (0.000)	-0.070 (0.000)	1.000	
Cash flow ratio	-0.028 (0.079)	-0.041 (0.009)	-0.002 (0.883)	1.000
Interest coverage ratio	-0.013 (0.410)	-0.030 (0.052)	-0.036 (0.022)	0.251 (0.000)

Sources: ifo Business Survey and EBDC-BEP (2012)

Table A-4: Overlap between different measures of financial constraints

Production shortage:	unconstrained	constrained
Restrictive bank lending		
Constrained (fraction)	0.281	0.827
Unconstrained (fraction)	0.719	0.173
Fraction constrained		
Liquidity ratio	0.490	0.671
Cash flow ratio	0.489	0.746
Interest coverage ratio	0.491	0.723
Fraction unconstrained		
Liquidity ratio	0.510	0.329
Cash flow ratio	0.511	0.254
Interest coverage ratio	0.509	0.277

Sources: ifo Business Survey and EBDC-BEP (2012)

Table A-5: Financial Constraints and Price Setting: Within Firm Effects for Liquidity Ratios

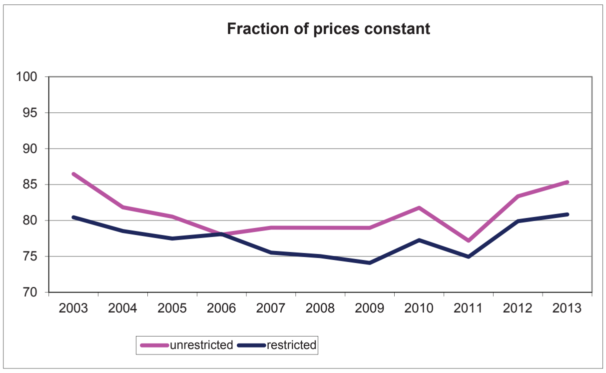
		Liquidity ratio			
price	variable	no fixed effects	time fixed effects	sector fixed effects	time & sector fixed effects
↓	FC	-0.0449 (0.0278)	-0.0525* (0.0283)	0.00987 (0.0297)	-0.00503 (0.0303)
↑	FC	0.140*** (0.0230)	0.172*** (0.0234)	0.0888*** (0.0244)	0.113*** (0.0249)

Notes: MLOGIT estimation: Base outcome is prices unchanged. Sample: January 2002 - December 2013. Standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Includes only observations for which balance sheet data are available. Yearly data (interpolated).

Figure A-1: Fraction of restricted firms over time

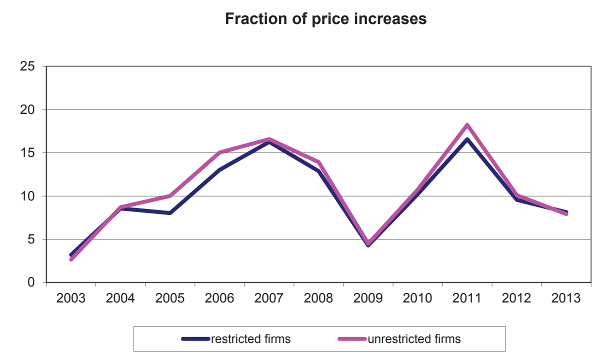
Notes: Fraction of firms answering "restrictive" to bank lending survey question in all firms in a given month.

Figure A-2: Fraction of prices constant over time



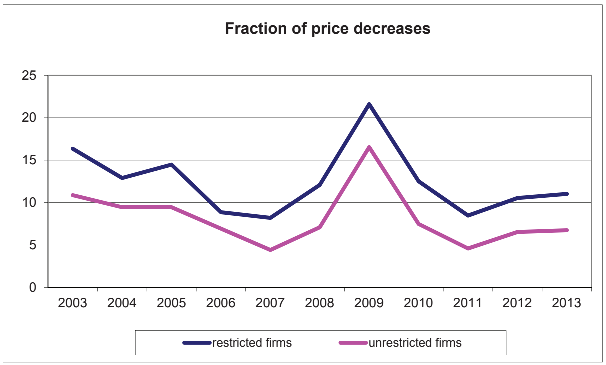
Notes: Fraction of firms not changing prices within restricted and unrestricted firms using the bank lending survey question.

Figure A-3: Fraction of price increases over time



Notes: Fraction of firms increasing prices within restricted and unrestricted firms using the bank lending survey question.

Figure A-4: Fraction of price decreases over time



Notes: Fraction of firms decreasing prices within restricted and unrestricted firms using the bank lending survey question.

Figure A-5: The dynamic model with financial constraints

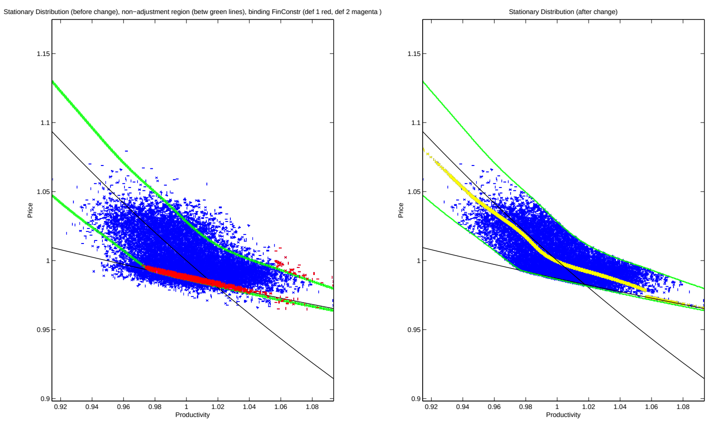
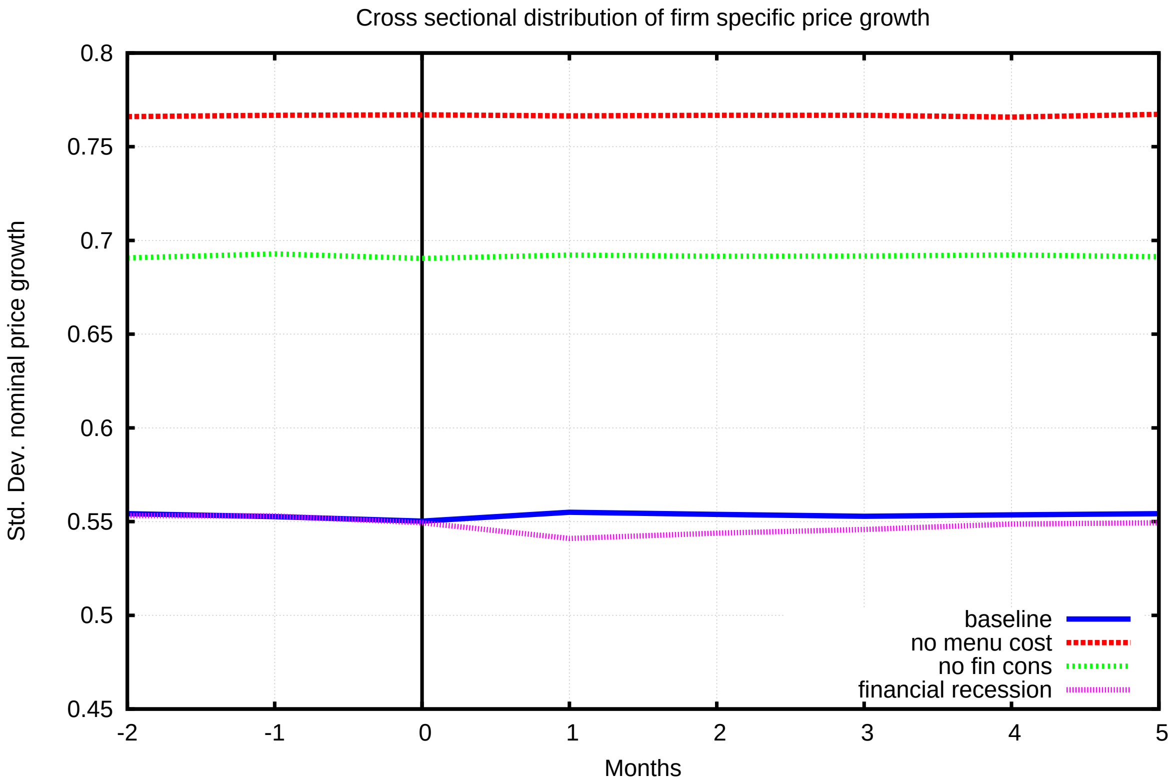
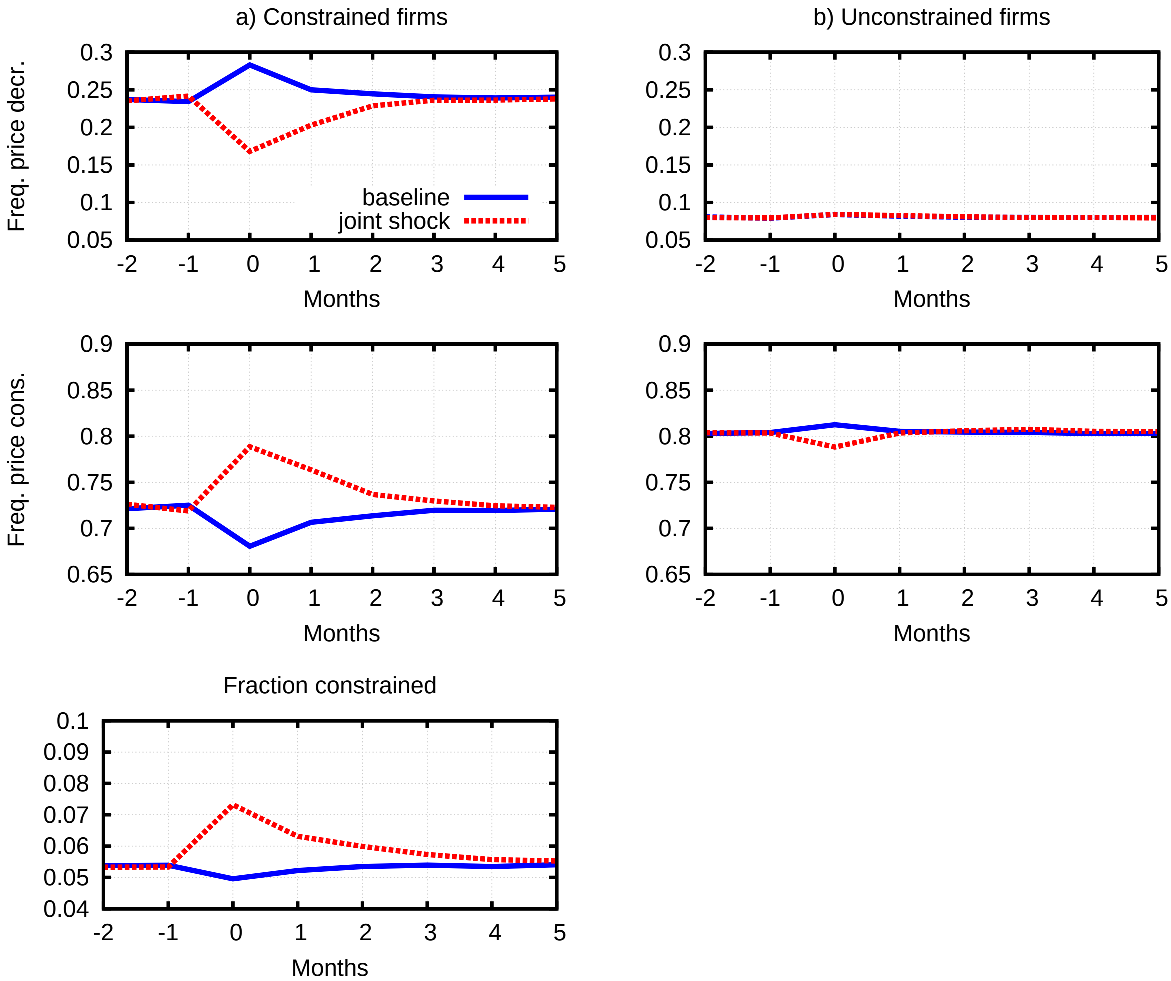


Figure A-6: Response to negative inflation shock: cross sectional distribution of firm specific inflation



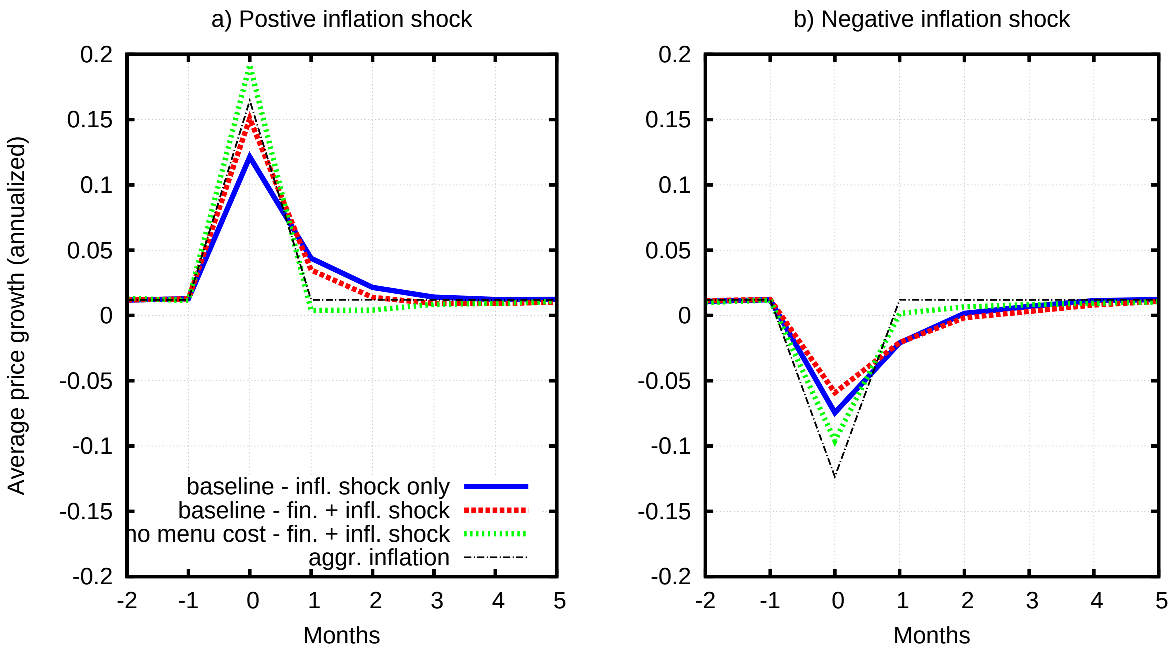
Notes: This figure displays the response of the cross sectional distribution of firm-specific inflation growth rates (annualized) following a one standard-deviation unexpected negative shock to aggregate inflation for different model specifications.

Figure A-7: Response of frequencies to a negative aggregate inflation shock



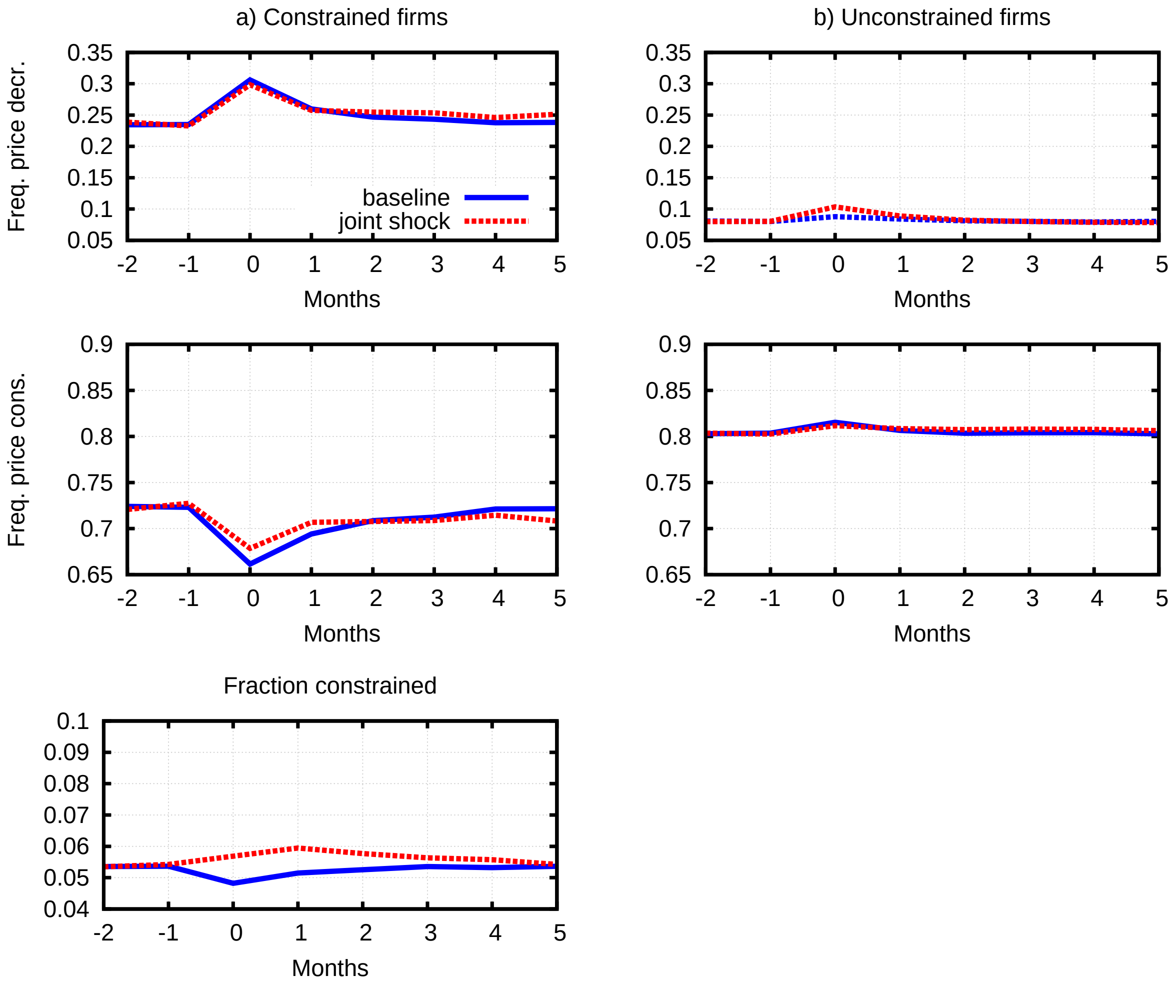
Notes: This figure displays the response of frequencies of price adjustment following a one standard-deviation unexpected negative shock to aggregate inflation. Left panel: financially constrained firms. Right panel: financially unconstrained firms. Blue solid lines refer to the responses in the baseline model. Red dashed line refers to the joint shock scenario; that is, the negative shock to aggregate inflation is accompanied by an aggregate tightening of financial conditions.

Figure A-8: Average response of firm price growth for large aggregate inflation shock and contemporaneous tightening of financial conditions



Notes: This figure displays the response of firms' average price growth following an unexpected shock to aggregate inflation of -15%. The left panel shows the response to a positive aggregate inflation shock. The right panel shows the responses for a negative aggregate inflation shock. In both panels it is assumed that the aggregate inflation shock comes together with an aggregate tightening of financial conditions, that is, a decrease in ξ for all firms.

Figure A-9: Response of frequencies to a large negative aggregate inflation shock



Notes: This figure displays the response of frequencies of price adjustment following an unexpected negative shock to aggregate inflation of -15%. Left panel: financially constrained firms. Right panel: financially unconstrained firms. Blue solid lines refer to the responses in the baseline model. Red dashed line refers to the joint shock scenario; that is, the negative shock to aggregate inflation is accompanied by an aggregate tightening of financial conditions.