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

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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 in the presence of financial frictions both inflation might be higher and monetary policy might be less effective.

Keywords: Price distribution, financial frictions, menu cost model
JEL-Codes: E31, E44

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 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. the presence and the direction of individual price changes 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 as well as 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 in certain regions 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. At the same time, high liquidity ratios are an indicator that these firms could have difficulties obtaining additional credit in the future and would then possibly increase their prices. These firms are picked up by the indirect measures of financial constraints.

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

[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 contribution 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.

and price setting. Here, we extend the standard menu-cost model[3] with heterogeneous firms by adding a working capital constraint.[4] When financial frictions are present, the individual firm's profit function becomes of more concave and more asymmetric at 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 introduction of the financial constraint tends to increase the firm's incentives to change prices and also has very asymmetric effects on the willingness to increase or decrease prices depending on the current state of the firm. In particular, for relatively high levels of idiosyncratic productivity, the maximum of the profit function coincides with the point where the financial constraint starts to bind. As a consequence, firms enjoying a favourable productivity shock have a relatively stronger incentive to increase or decrease prices and are more likely to end up being financially constraint as they tend to adjust their prices towards the maximum of the profit function and thus to hit the constraint. This implication is consistent with our empirical findings suggesting that the financially constrained firms adjust their prices more frequently both, up and down than their unconstrained counterparts.

Our theoretical prediction that financially constrained firms do not only adjust prices more often upwards but also downwards contrasts to the implications of the DSGE model developed by Gilchrist et al. (2013a) where higher financial frictions increase the probability for an upward while reducing that for a downward adjustment. Nevertheless, the implications of the two theoretical set-ups with respect to the intensive margin of price adjustment are very similar. In both models, financially constrained firms are forced to set higher prices than they would absent the constraint. More specifically, the working capital constraint in our model induces firms with initially low prices to increase prices and produce less. 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. In addition, high-productivity firms with initially high prices adjust their prices downward and increase production until the working capital constraint is binding, i.e. they are more likely to be financially constrained. These firms decrease their prices by less and produce less than without financial constraints. Furthermore, there may be firms for which the working capital constraint binds but which do not satisfy demand. In this case, increasing the price would relax the financial constraint and increase output, but this is not profitable due to the menu cost. These firms do not change their price and ration output.

Overall, our results suggest that prices are higher with than without financial frictions, while output is lower. This poses a conflict of interest to a central bank wanting to target inflation and output at the same time. Taking into account firms that decrease or do not change prices, these effects may be even stronger than what has been highlighted by Gilchrist et al. (2013a). In addition, since price flexibility increase, monetary policy may be less effective in the presence of financial frictions.

To illustrate this point, we use the partial equilibrium model to simulate the response of average prices and the price distribution to aggregate inflation disturbances. The latter may stem from unanticipated monetary policy shocks or sudden shifts in aggregate demand. The results show that in a world with

[3] Nakamura and Steinsson (2008) 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 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.

financial frictions aggregate deflationary shocks lead to a weaker decline in average prices as compared to an economy without financial imperfections. This is due to the overly muted price reductions undertaken by the majority of financially constrained firms. Consequently, in the presence of financial frictions, monetary policy might lead to stronger output responses and thus, be relatively more effective. Or taking a different view, deflationary pressures are likely to be smaller in a demand driven recession that leads to a fall in aggregate inflation when financial constraints are present. We show that both, the financial friction per se and its interaction with the endogenous price stickiness are important for these results. We are aware that our theoretical findings are obtained without takin into account several general equilibrium effects. In particular, we neglect the response of wages and aggregate demand. We nevertheless believe this to be an instructive exercise as wages might be sticky in the short run.

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.[5] In this data, we have monthly information about the extensive margin of price adjustment - i.e. whether and in what direction firms adjust prices[6]. More precisely, firms answer to the question: "Have you in the last month increased, decreased or left unchanged your prices?". The ifo survey also encompasses information about financial constraints 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. 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 very 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.

[5]The ifo survey starts as early as the 1950's, but our sample is restricted by the fact that the survey question about financial constraints was added only in 2002.

[6]These prices are home country producer prices for all products of a particular firm. Most "firms" in our sample are single-product plants, so prices refer to one product only. Bachmann et al. (2013b) have used the same dataset to assess the effect of uncertainty shocks on price setting.

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.

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.

We further decompose this correlation into within and between firm effects using the following specification

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

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 estimation suggest that financially constrained firms change their prices significantly more often in both

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

[8] To control for heteroscedasticity and within sector correlation of the residuals we compute robust standard errors clustered wit respect to sectors.

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 according to our survey questions. However, the correlations between the balance sheet measures and

[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.

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 show that the documented empirical facts can be replicated in a simple partial-equilibrium menu cost model with a working capital constraint. We document our baseline model in section 3.1 and discuss our basic intuition which follows from the static equilibrium. We then calibrate and simulate the dynamic model in section 3.2.

3.1 Baseline model

Firms problem. Our model consists of a firms' problem only. Firms produces output y with a single input h and the production technology $F(h;s) = z(s)h$, where $z(s)$ is the firm's idiosyncratic productivity, s denotes the firm's idiosyncratic state. We allow inflation to be stochastic and denote the growth rate of aggregate prices by by $\pi = P/P_{-1} - 1$. Aggregate prices evolve according to an exogenously given law of motion that we describe below in the quantitative section 3.2. Firms therefore also form expectations over future aggregate inflation.[10] The recursive problem of the firm can be written as:

$$V(s;p) = \qquad \max\{V^A(s;p) - f, V^{NA}(s;p)\} \tag{2}$$

where

$$V^A(s;p) = \max_{y,q\neq p} \left\{ \left(q - \frac{w}{z(s)}\right) y + \beta E_{s',\pi'} V\left(s'; \frac{1}{1+\pi'} q\right) \right\} \tag{3}$$

subject to

$$y \leq \left(\frac{1}{q}\right)^{\frac{1}{\omega}} C \tag{4}$$

$$\frac{w}{z(s)} y \leq \xi \tag{5}$$

[10]This means that if a firm chooses a relative price $p(s) = P(s)/P$ today, next period the relative price previous to adjustment is given by $P(s)/P'$ or $p(s)/(1+\pi')$.

and

$$V^{NA}(s;p) = \max_{y} \left\{ \left(p - \frac{w}{z(s)} \right) y + \beta E_{s',\pi'} V \left(s'; \frac{1}{1+\pi'} p \right) \right\} \tag{6}$$

subject to

$$y \leq \left(\frac{1}{p} \right)^{\frac{1}{\omega}} C \tag{7}$$

$$\frac{w}{z(s)} y \leq \xi \tag{8}$$

The demand function in equation (4) from a standard Dixit-Stiglitz aggregator with elasticity of substitution $\frac{1}{\omega}$. In our specification, we closely follow Nakamura and Steinsson (2008). The only constraint that we add to the model is the working capital constraints given by equations (5) and (8); Within each period firms need to take up a loan in order to finance the labor input needed for production. The limit up to which the firm can borrow ξ will be the same for all firms in our baseline simulation, but then vary by firm in an extension of the model. In each period, the firms decides whether to adjust or not to adjust the price, given s, z ξ, the process for inflation, and given the menu cost f it has to pay in case of adjustment.

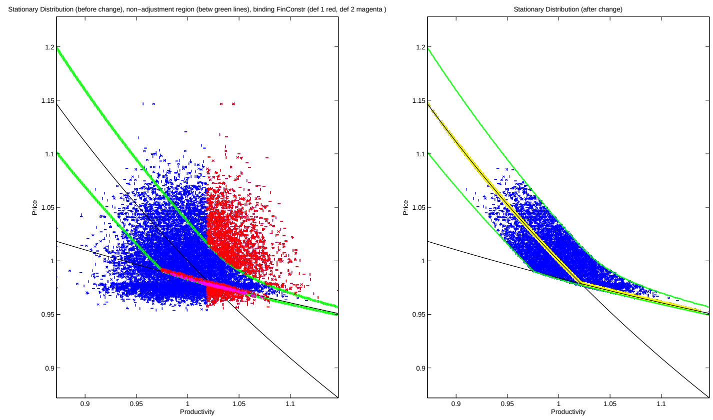
Intuition from the static model. The most important insights from the model can already be discussed in a simpler, static version of the model. In this model, we set $\beta = 0$ and do not allow for inflation. The static model can be solved in closed form.[11] Figure 1 illustrates the static model for 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, firms start with a certain initial price p and a productivity z. Note that in this graph we want to highlight the price-productivity combinations that have some positive mass in the stationary distribution (prior to price adjustment); we do not display here the respective mass, i.e., you should think of each blue dot corresponding to a single firm with a certain price-productivity combination prior to adjustment.[12] The right hand side graph shows the situation after price adjustment. The steeper black line exhibits the optimal price in an economy without financial constraints, the flatter black line corresponds to the financial constraint. The yellow line here is the optimal price for each productivity level z. One can see that the optimal price is no longer feasible for low price and high productivity firms. We call firms financially constrained when the financial constraint binds after price adjustment. 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. One can show that when firms adjust their price, they will adjust the prices such that they always satisfy demand. Then, there are two cases: The financial constraint is binding or the financial constraint is not binding. For a given initial distribution of z and p, 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 high productivity z will be constrained. Out of the constrained firms, those with a low initial price sell and produce a lot and would like to increase their price. Since all firms need to finance the

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

[12] 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 productivities and using the policy function of the firm to get the joint distribution.

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.

inputs used for production, these firms may not be able to finance output at their desired price and will be forced to increase their price by more than without financial constraints. Out of the constrained firms, those with a high initial price would like to decrease their price. However, they may not decrease their price down to the desired level, since they run into the financial constraint at some point. Likewise, for a given value of ξ, firms with a low productivity z will not be constrained. These firms to not produce enough such that financing the necessary inputs violates the financial constraint.

With menu costs, firms trade off the gain in revenue from changing the price and the cost of adjusting the price. If, for a given z and initial p, firms are not too far away from the optimal price, they will choose not to adjust their price. This is marked by the green region in Figure 1. Financial constraints shape the adjustment region of the firm. Compared to an economy without financial constraints, some firms that would not have adjusted their price previously, now have to adjust their prices (up). Some other firms that would have adjusted their prices down, now do not adjust their prices. In addition, the distribution of price and productivity of firms is different in the two economies. For a given ξ, the financial constraints will not be binding for some firms. These firms satisfy demand at their initial price. For other firms, the financial constraint is binding. Then, demand is not necessarily satisfied and the situation is called rationing. These firms are marked with magenta in the left-hand side plot of the figure.

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 firm. Already in this static version, our model supports the empirical findings (see quantitative results below).

3.2 Quantitative results from the dynamic model

Compared to the static version, the first order conditions change when prices are adjusted, not when prices they are not adjusted. As a consequence, the non-adjustment region changes in the dynamic version. When adjusting prices, firms take into account the effect of their price change on next periods starting condition (i.e., the initial price) and its impact on future outcomes. Through adjusting their prices, they can also affect whether they are financially constrained or not. In the static model, it was not optimal to increase prices by more or decrease prices by less and, hence, to produce less than given by the constraint. Now, the foregone revenue this period is traded off with the better relative starting position next period. Regardless of financial constraints, firms prefer to be located in the center of the non-adjustment region, since this decreases their chances to having to adjust their prices and paying the menu cost in the future. Hence, by setting their prices accordingly, some firms will choose not to be financially constrained and opting for a price in the center of the adjustment region. Hence, fewer firms will be financially constrained in the dynamic compared to the static model. The more productive the firms and the smaller the menu costs, the more likely are firms to be financially constrained in this setup. Figure A-1 illustrates this.

The dynamic version of 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

$$\ln z_t = \rho_z \ln z_{t-1} + \varepsilon_t \tag{9}$$

$$\ln \xi_t = \mu_\xi + \rho_\xi \ln \xi_{t-1} + u_t \tag{10}$$

Our baseline model will have shocks to productivity only and fix ξ at the same value for all firms. Then we add the shock to the financial constraint. In addition, and in line with Nakamura and Steinsson (2008), we allow for shocks to the aggregate price level

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

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.	ω^{-1}	4	NS (2010)
wage rate	w	$(1-\omega)$	NS (2010)
fixed cost price adjust.	f	0.0024	NS (2010)
pers. productivity	ρ_z	0.66	NS (2010)
sd productivity	σ_ε	0.02	match avg % firms with $\Delta p = 0$
average inflation	μ	0.001	Germany 1991-2014
sd price level innovations	σ_η	0.002	Germany 1991-2014
financial constraint	ξ	0.78	match % FC firms

Table 3 shows our calibration. In general, we stay very close to Nakamura and Steinsson (2008). The real wage is set equal to the wage of the flexible price version with constant aggregate consumption, $w = (\theta - 1)/\theta$. The standard deviation of productivity is set such as to match the number of firms that adjust prices in our data. Since only very few firms, about 20%, adjust prices in Germany, the standard deviation of the shock is a lot smaller than in the original Nakamura and Steinsson calibration for the US. Average inflation and the standard deviation of price shocks also targets the respective German values in our sample. Finally, μ_ξ is set such as to match the average number of financially constrained firms in our economy.

Table 4 shows the results from our simulation exercise using a model with productivity shocks only and with productivity shocks and shocks to the financial constraint. The first two rows of the table show the following moments from the data for the sample average and the peak of the recession in

Table 4: Comparing moments in model and data

	FC firms	$\Delta p = 0$		$\Delta p < 0$	
		FC firms	UC firms	FC firms	UC firms
Data					
2001 - 2014	0.05	0.75	0.80	0.12	0.08
2009	0.09	0.73	0.78	0.22	0.17
Model without heterogeneity in financial conditions					
$\xi = 0.78$	0.05	0.84	0.81	0.13	0.06
$\xi = 0.75$	0.09	0.81	0.80	0.14	0.05
Model with heterogeneity in financial conditions (shock to ξ)					
$\mu_\xi = 0.78$					
$\sigma_\xi = 0.02$					
$\rho_\xi = 0$	0.10	0.64	0.81	0.20	0.05
$\rho_\xi = 0.66$	0.09	0.68	0.8	0.18	0.06
no menu cost ($f = 0$)	0.36	0.025	0.013	0.6	0.39

2009 using the production shortage measure from the survey: The fraction of constrained firms, the fraction of financially constrained and unconstrained firms that leave their price unchanged and those that decrease their price. The subsequent rows exhibit the equivalent moments for various versions of the model. One can see that the model with productivity shocks only matches the average moments in the data surprisingly well. In particular, the model replicates our central fact: financially constrained firms adjust prices down more often than their unconstrained counterparts. This also holds when tightening the financial constraint to a value such that the model matches the number of constrained firms in 2009.

Note that the baseline model does not generate that financially constrained firms adjust prices up more often. In order to generate this finding, we need to introduce (either transitory and persistent) shocks to the financial constraint. When financial constraints vary for each firm, more firms will find themselves to be in a situation where given last periods price and current productivity, they cannot finance their production and need to adjust prices up. Hence, the fraction of financially constrained firms that increase their price increases, while the fraction of constrained firms that decrease their price is unaffected, and overall, financially constrained firms adjust price more often than financially unconstrained firms.

When the menu cost is zero, prices are flexible. As shown by the last row labeled 'no menu cost' in table 4, qualitatively the results in the flexible price model are very similar to the model with menu costs. The only difference is that constrained firms now leave prices constant more often than unconstrained firms.

3.3 Aggregate shocks

In this section we study the implications of aggregate inflation shocks on average prices and the price dispersion in the partial equilibrium economy. One can best view this exercise in our partial equilibrium model as the response of one specific 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. By averaging over all firms, we display the average response and price dispersion. We do so

Table 5: Average price changes, by financial constrainedness

	Avg. $\|\Delta p\|$		Avg. $\Delta p > 0$		Avg. $\Delta p < 0$	
	FC firms	UC firms	FC firms	UC firms	FC firms	UC firms
model, no heterogeneity in financial conditions						
$\mu_\xi = 0.78$	1.517	2.293	0.207	1.872	-1.566	-1.361
$\mu_\xi = 0.75$	1.563	1.809	0.377	1.484	-1.843	-1.069
model, heterogeneity in financial conditions (shock to ξ)						
$\mu_\xi = 0.78$ $\sigma_\xi = 0.02$ $\rho_\xi = 0.66$	1.768	2.252	0.800	1.895	-2.896	-1.264
$\mu_\xi = 0.78$ $\sigma_\xi = 0.02$ $\rho_\xi = 0.66$ no menu cost ($f = 0$)	1.038	1.617	0.660	1.706	-1.265	-1.475

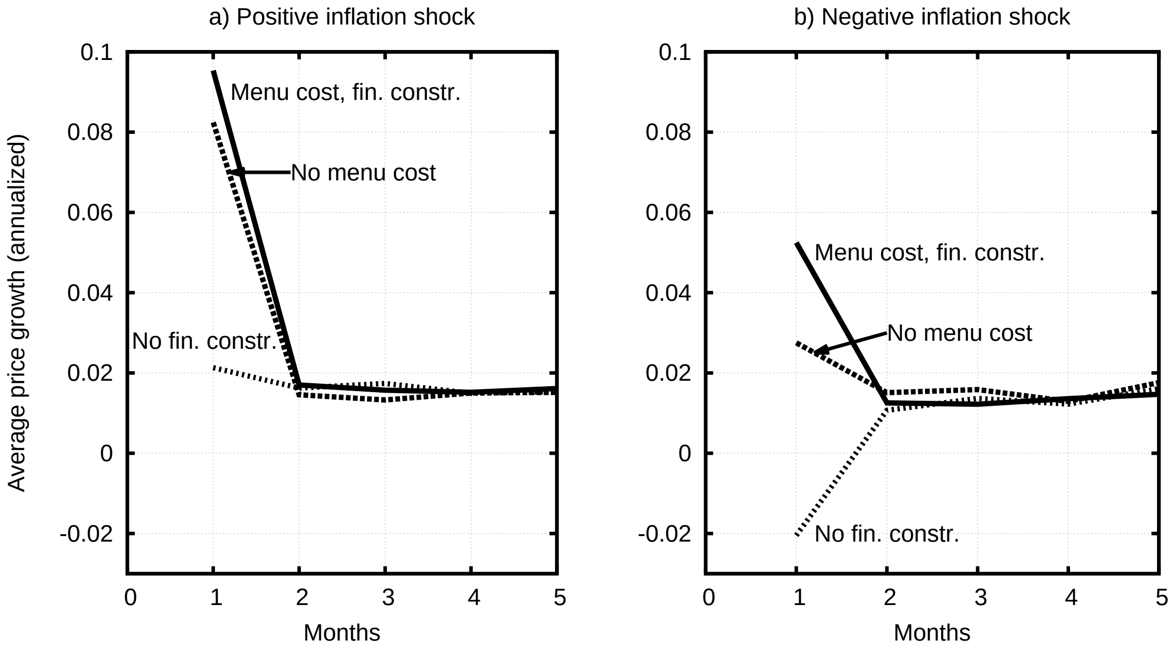
for the benchmark model as summarized in calibration table 3 and shocks to firms' financial constraints; to study the relative contribution of nominal rigidities and financial constraints, respectively, we then report the responses for two counter-factual scenarios: one in which we shut down the nominal 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.').

Figure 2 shows the response of average price levels, panel (a) reports the impulse responses averaged across firms (drawing from the stationary distribution) to positive aggregate price level shocks in period 1. Panel (b) reports the response of average prices following a negative shock aggregate prices. The solid lines displays the response in the benchmark model where both menu costs and shocks to financial constraints are present. The long dashed line displays the response for the model with flexible prices by setting the menu costs to zero. The short dashed lines display average prices in the model where we remove the financial constraints, i.e. essentially the standard menu-cost model.

Two observations stand out. First, financially constraints have a large impact on the level of average prices both aggregate price increases and decreases. Comparing the responses in the model with financial frictions to the model without financial frictions, the response to negative shocks to the aggregate price level, changes sign from negative (no financial frictions) to positive. This means, in the model with financial frictions, firms on average increase their prices even though the aggregate price level is falling. This result goes in the same direction as the result found by Gilchrist et al. (2013a) for the Great Recession in the U.S.: firms in sectors with tighter financial constraints increase their prices and therefore putting inflationary pressure even though aggregate prices are falling and therefore potentially dampening the overall deflation.

Second, nominal rigidities are also important for average price dynamics, in particular, for the dynamics following a negative aggregate price shock. In panel (b), the on impact response of the model with flexible prices ('no menu cost') is positive but approximately only half as large as in the model with nominal rigidities in form of menu costs. In addition, comparing panel (a) to panel (b), the effects of positive and negative aggregate price shocks are asymmetric: the difference between the menu-cost model and the flexible price model are larger for aggregate price decreases than for price increases. We therefore conclude that nominal rigidities and financial frictions do not only separately play a role for

Figure 2: Average inflation response following unexpected aggregate inflation shock

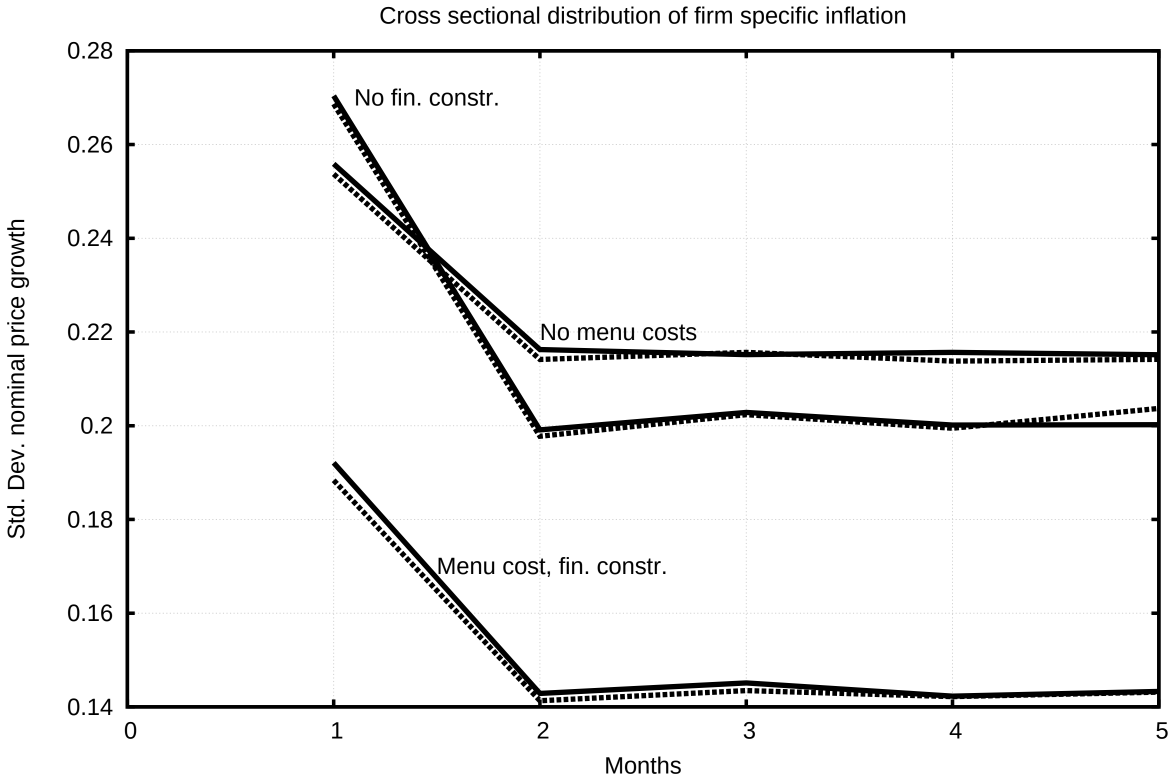


average prices but also their interaction.

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 3: 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 shock to aggregate inflation. Solid lines: positive aggregate inflation shock; dashed lines: negative aggregate inflation shock.

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A Appendix

A.1 The static model

A.1.1 Problem of the firm

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

where

$$V^A(s;p) = \max_{y,q\neq p} \quad \left\{ y\left(q - \frac{w}{z(s)}\right) - fw \right\}$$

subject to

$$y \leq \left(\frac{1}{q}\right)^{\frac{1}{\omega}} C(s) \qquad (\phi)$$

$$\frac{w}{z(s)} y \leq \xi \qquad (\mu)$$

and

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

subject to

$$y \leq \left(\frac{1}{p}\right)^{\frac{1}{\omega}} C(s) \qquad (\phi)$$

$$\frac{w}{z(s)} y \leq \xi \qquad (\mu)$$

A.1.2 No price adjustment

First order conditions

$$0 = \left(p - \frac{w}{z(s)}\right) - \phi - \frac{w}{z(s)}\mu$$

$$y \leq \left(\frac{1}{p}\right)^{\frac{1}{\omega}} C(s) \qquad \perp \qquad \phi \geq 0$$

$$\frac{w}{z(s)} y \leq \xi \qquad \perp \qquad \mu \geq 0$$

for $pz(s) > w$. Otherwise

$$y = 0$$

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

$$\begin{aligned} y &= \left(\frac{1}{p}\right)^{\frac{1}{\omega}} C(s) \\ \phi &= \left(p - \frac{w}{z(s)}\right) \end{aligned}$$

Note that in this case it has to be true that

$$z(s) > \frac{w}{\xi}\left(\frac{1}{p}\right)^{\frac{1}{\omega}} C(s)$$

which is satisfied for sufficiently high values of ξ.

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

$$\begin{aligned} y &= \xi \frac{z(s)}{w} \\ \mu &= \frac{z(s)}{w}\left(p - \frac{w}{z(s)}\right) \end{aligned}$$

Note that in this case it has to be true that

$$z(s) \leq \frac{w}{\xi}\left(\frac{1}{p}\right)^{\frac{1}{\omega}} C(s)$$

A.1.3 Price adjustment

First order conditions for prices, hours, and output

$$\begin{aligned} 0 &= y - \phi \frac{1}{\omega} q^{-\frac{1}{\omega}-1} C(s) \\ 0 &= \left(q - \frac{w}{z(s)}\right) - \phi - \frac{w}{z(s)}\mu \\ y &\leq \left(\frac{1}{q}\right)^{\frac{1}{\omega}} C(s) \perp \phi \geq 0 \\ \frac{w}{z(s)} y &\leq \xi \perp \mu \geq 0 \end{aligned}$$

Consider the following cases

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

$$\begin{aligned} y &= \left(\frac{1}{q}\right)^{\frac{1}{\omega}} C(s) \\ 0 &= y - \phi \frac{1}{\omega} q^{-\frac{1}{\omega}-1} C(s) \\ \phi &= \left(q - \frac{w}{z(s)}\right) \end{aligned}$$

so that

$$
\begin{aligned}
0 &= 1 - \frac{1}{\omega}\left(q - \frac{w}{z(s)}\right)q^{-1} \\
0 &= \omega - 1 + \frac{w}{z(s)}q^{-1} \\
q &= \frac{1}{1-\omega}\frac{w}{z(s)}
\end{aligned}
$$

For this case, it must be true that

$$
\xi > (1-\omega)^{\frac{1}{\omega}} \left(\frac{w}{z(s)}\right)^{1-\frac{1}{\omega}} C(s)
$$

2. Both constraints are binding. Then

$$
\begin{aligned}
y &= \xi \frac{z(s)}{w} \\
q &= \left(\frac{C(s)}{y}\right)^{\omega} \\
\phi &= \omega \frac{y}{C(s)} q^{1+\frac{1}{\omega}} \\
\mu &= \frac{z(s)}{w}\left(\left(q - \frac{w}{z(s)}\right) - \phi\right)
\end{aligned}
$$

or

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

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 true that

$$
\begin{aligned}
1 &\leq (1-\omega)\left(\frac{C(s)}{y}\right)^{\omega}\frac{z(s)}{w} \\
y &\leq (1-\omega)^{\frac{1}{\omega}}\left(\frac{z(s)}{w}\right)^{\frac{1}{\omega}} C(s) \\
\xi &\leq (1-\omega)^{\frac{1}{\omega}}\left(\frac{z(s)}{w}\right)^{\frac{1}{\omega}-1} C(s)
\end{aligned}
$$

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

$\phi = 0$ and

$$y = \xi \frac{z(s)}{w}$$
$$0 = y$$
$$0 = \left(q - \frac{w}{z(s)}\right) - \frac{w}{z(s)}\mu$$

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

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	1.000		
	(0.000)			
Liquidity ratio	-0.065	-0.070	1.000	
	(0.000)	(0.000)		
Cash flow ratio	-0.028	-0.041	-0.002	1.000
	(0.079)	(0.009)	(0.883)	
Interest coverage ratio	-0.013	-0.030	-0.036	0.251
	(0.410)	(0.052)	(0.022)	(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	-0.0525*	0.00987	-0.00503
		(0.0278)	(0.0283)	(0.0297)	(0.0303)
↑	FC	0.140***	0.172***	0.0888***	0.113***
		(0.0230)	(0.0234)	(0.0244)	(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: The dynamic model with financial constraints

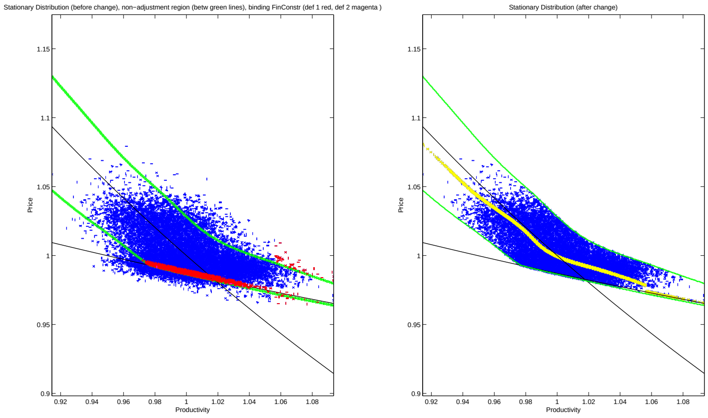
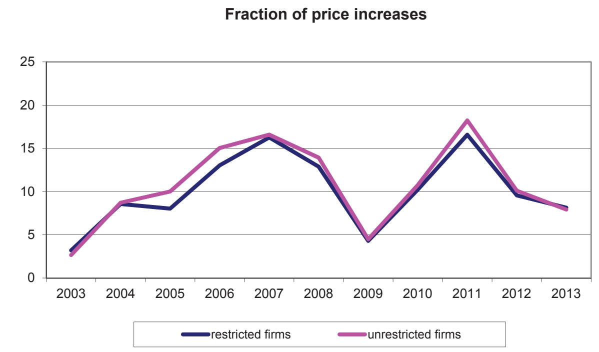


Figure A-2: Fraction of restricted firms over time

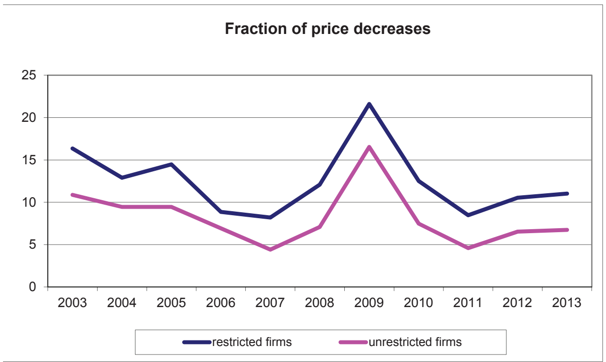
Notes: Fraction of firms answering "restrictive" to bank lending survey question in all firms in a given month.

Figure A-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.