Firms' Pass-Through Dynamics: A Survey Approach*

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Abstract

This paper uses a new survey approach to empirically characterize the dynamics of pass-through at the firm level and explores them in a price-setting model. We directly elicit price pass-through of cost shocks, both in the field and in survey experiments. We find gradual pass-through dynamics due to infrequent adjustments (nominal rigidities) and high costs of deviating from competitors' prices (micro real rigidities), especially when the shock is expected to be less persistent. The experiments provide direct causal evidence for micro real rigidities: Firms raise prices several times in response to a permanent aggregate shock, and idiosyncratic shocks of the same size have a lower pass-through than aggregate shocks. Further, our approach enables us to compute the slope of the Phillips curve, which decreases significantly once allowing for micro real rigidities. Finally, we quantify the role of real and nominal rigidities in a general equilibrium price-setting model based on our empirical results and find a substantial degree of both.

Keywords: pass-through, cost shocks, heterogeneous expectations, firm survey, nominal rigidities, real rigidities.
JEL codes: E24, E31, E50, E60.

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1 Introduction

Price stickiness plays a crucial role in New Keynesian models and has been extensively studied empirically (e.g., Klenow and Kryvtsov 2008; Nakamura and Steinsson 2008). However, even with rich granular pricing data at hand, it is challenging to analyze price dynamics, especially at the firm level. Therefore, the understanding of frictions in price-setting is still incomplete. For instance, nominal rigidities, as measured by the frequency of price changes, are not sufficient to explain strong monetary non-neutrality. One way to generate more monetary persistence is to introduce micro real rigidities creating strategic complementarities that impose costs on firms when they set prices that deviate from those of their competitors (Ball and Romer, 1990). While these micro rigidities are often used in theoretical models, their quantitative significance is still in question (e.g., Klenow and Willis 2016). Moreover, the empirical literature provides little insight into the importance of expectations for pricing decisions, such as the expected persistence of shocks, even though future marginal costs are a key determinant in standard price-setting models.

We use a new approach to study price dynamics by *directly* eliciting pass-through of cost increases in a large-scale business survey. We integrate the advantages of a quantitative measure with the richness of firm characteristics and beliefs captured in the survey to provide a complete picture of how firms adjust prices after cost increases. Eliciting price adjustments across multiple horizons in response to the same initial shock allows for a comprehensive examination of pass-through *dynamics* and enables a direct mapping to impulse responses in general equilibrium price-setting models.

We proceed in three steps. First, we document five facts about pass-through in the field, emphasizing the sluggishness of pass-through due to a combination of observed nominal rigidities—infrequent price adjustments—and micro real rigidities—multiple small price increases due to competition. The sluggishness amplifies when firms believe that the shock is less persistent. Second, our tailored survey experiments provide new causal insights into the importance of real rigidities: Firms raise prices multiple times in response to a permanent aggregate shock, and idiosyncratic shocks of the same size have a lower pass-through than aggregate shocks. Further, we find that firms' pass-through is significantly lower for more transitory shocks but is similar across different economic environments. Our survey design maps directly to a sufficient statistic by Auclert et al. (2023), allowing us to compute the slope of the Phillips curve, which declines significantly due to micro real rigidities relative to naively using the price setting frequency on impact as the sole calibration target. Third, we use our empirical estimates to discipline menu costs and real rigidities in a general equilibrium price-setting model. The observed sluggish

pass-through requires a high degree of both nominal and real rigidities, bringing us a big step closer to the high persistence of monetary non-neutrality found in other studies.

We start with evidence from the ifo Institute's business survey panel, a monthly survey covering 6,500 firms across all sectors of the German economy. We directly ask about the pass-through of higher prices for energy, raw materials, and intermediate inputs multiple times since the onset of the cost surge in 2021 in a backward- and forward-looking manner for the next six months. The survey also contains information on the business's current standing and outlook and unique supplementary questions, such as subjective beliefs about the duration of supply chain disruptions.

We present five facts based on our novel survey approach. First, firms pass through cost increases only gradually over time. This is due to a combination of nominal and micro real rigidities. Competitive pressure is most often mentioned as a limiting factor for pass-through. Second, there is substantial variation across and especially within narrowly defined industries. Understanding this heterogeneity is the goal of the analysis that follows. In our third set of facts, we focus on the expected persistence of shocks. Specifically, we are the first to document that pass-through increases in the firm's expected duration of the shock. In turn, a longer duration of the shock also increases the probability that firms actually raise prices. Fourth, we demonstrate that pass-through increases with the firm's idiosyncratic uncertainty, shedding light on a theoretically ambiguous relationship (Vavra, 2014). Fifth, leveraging the survey's panel dimension, we establish a strong, positive link between pass-through and ex-ante price-setting frequency.

To further investigate the causal link between the nature of the shock and pass-through, we conduct survey experiments in the ifo Management-Survey in the second part of the paper. We confront firms with hypothetical scenarios about facing an exogenous global supply shock raising costs by 20%, but varying the nature of the shock. In the style of supplementary questions in the first part of the paper, we ask firms about the extent to which they pass on these cost increases to customers over specific time horizons of one to 24 months. By exploiting within-firm variation, we discern the marginal effect of shock duration (permanent vs. transitory) and micro real rigidities, comparing idiosyncratic vs. aggregate shocks. Between-firm variation allows us to analyze the effects of economic conditions (low vs. high demand). We are the first paper to provide causal evidence on the relevance of these factors and the economic size of pass-through at different horizons.

We find a concave increase in pass-through over time for all hypothetical scenarios at the aggregate level. In the first three months, pass-through evolves similarly, independent of the duration of the shock, driven primarily by the extensive margin. In the medium term, the permanent shock scenario shows significantly higher pass-through compared to the

temporary and uncertain shock duration scenario. Most firms exhibit gradual pass-through increases instead of immediate adjustments, with lower pass-through for idiosyncratic shocks, supporting the presence of micro real rigidities. The results indicate no strong state dependence, with similar price dynamics for two assumed economic conditions: low and high aggregate demand. Using our findings, we can calculate the slope of the Phillips curve based on the sufficient statistics of Auclert et al. (2023), which significantly flattens when real rigidities are taken into account. Nevertheless, the implied slope is slightly steeper than recent empirical estimates (Hazell et al. 2022). Although relying on a different method and survey, the results of the survey experiments corroborate our empirical analysis in the first part. This demonstrates the robustness of our direct elicitation approach. Both sets of results emphasize the existence of nominal and, especially, real rigidities, as well as the important role of the expected nature of the shock for pass-through.

In the third part, we introduce micro real rigidities into an otherwise standard general equilibrium price-setting model (Nakamura and Steinsson, 2013). We discipline the degree of nominal and real rigidities in the model by targeting the pass-through dynamics of a permanent aggregate shock and the price-setting frequency based on our empirical results. As an external validation, we compare the pass-through dynamics of transitory aggregate shocks and the difference in pass-through relative to idiosyncratic shocks. In both cases, the model predictions closely align with the empirical counterparts. The implied real effects of monetary policy in the estimated model are sizable. This is mainly due to micro real rigidities, which brings us already a long way to the estimated persistence of monetary policy in other studies (see, e.g., Christiano et al. 1999, Romer and Romer 2004, or Jarociński and Karadi 2020). However, a remaining gap leaves room for other factors like macro real rigidities and imperfect and heterogeneous information about the shock's nature.

Related Literature. Our results contribute to four strands of the literature. First, we provide new evidence to the literature that empirically characterizes price dynamics (Beck and Lein, 2020; Bils et al., 2012; Eichenbaum et al., 2011, 2014) and estimates pass-through (Amiti et al., 2019; Auer and Schoenle, 2016; Dedola et al., 2021; Garetto, 2016; Gopinath and Itskhoki, 2010; Joussier et al., 2022). These papers estimate quantitative pass-through based on granular administrative price data and typically focus on exchange rate pass-through.[1] Mostly, they find incomplete and—if dynamics are estimated—sluggish pass-through. However, these studies frequently face limitations in analyzing underlying mechanisms due to missing additional data and challenges in precise pass-through estimation. Complementarily, there is a literature employing surveys to improve the understanding of price-setting (Bachmann et al., 2019; Blinder et al., 1998; Bunn et al., 2022; Fabiani et al.,

[1] Smets and Wouters (2003) estimate the degree of micro real rigidities using aggregate data.

2005; Loupias and Sevestre, 2013). However, these papers do not provide dynamic and quantitative pass-through estimates. A key contribution of this paper is the ability to bridge both approaches by providing quantitative firm-level estimates of pass-through, while taking advantage of the survey approach to understand the observed dynamics. Importantly, this is the first paper leveraging experimental methods to inform the literature about the underlying mechanisms.[2]

Second, our findings on pass-through are of first-order importance for the degree of monetary non-neutrality. Our contribution to the literature is twofold. First, we provide evidence for the microfoundation in New Keynesian models that often rely on strong micro real rigidities to generate monetary non-neutrality (e.g. Smets and Wouters 2007). Second, our hypothetical vignette allows us to infer the slope of the Phillips curve (Auclert et al., 2023). Thereby, we contribute an estimate based on an entirely different approach compared to the literature (e.g., Ball and Mazumder 2011; Coibion and Gorodnichenko 2015; Hazell et al. 2022; Phillips 1958).

From a methodological perspective, we contribute to a third strand of the literature on using hypothetical scenarios to retrieve crucial economic mechanisms that are otherwise difficult to assess (see Fuster and Zafar 2023 for an overview). So far, most papers apply hypothetical vignettes in household surveys. For instance, this method is used to improve the estimates and understanding of the marginal propensity to consume (Colarieti et al., 2024; Fuster et al., 2021; Jappelli and Pistaferri, 2014, 2020), education choices (Wiswall and Zafar, 2021), late-in-life savings (Ameriks et al., 2020), subjective models of the macroeconomy (Andre et al., 2022), or the effect of monetary policy on consumption (Roth et al., 2023). Only few papers employ this approach in business surveys (de Bruin et al., 2023; Dibiasi et al., 2021; Drechsel et al., 2022). We add to this emerging literature by analyzing pass-through dynamics after cost shocks using designed vignettes.

Lastly, we speak to a literature on modeling firms' price-setting in general equilibrium (Aruoba et al., 2022; Beck and Lein, 2020; Blanco et al., 2022; Golosov and Lucas, 2007; Karadi and Reiff, 2019; Klenow and Willis, 2016; Midrigan, 2011; Nakamura and Steinsson, 2013; Wang and Werning, 2022). We contribute by augmenting a standard menu-cost model with micro real rigidities and mapping it to our novel survey results.

The remainder of this paper is structured as follows. Section 2 documents five facts based on the novel survey approach. Section 3 presents the survey experiment results. Section 4 estimates a general equilibrium price-setting model. Section 5 concludes.

[2]In parallel and independent work, de Bruin et al. (2023) study pass-through using a hypothetical vignette. In contrast to them, we elicit pass-through (i) directly, (ii) across multiple horizons, and (iii) distinguish between aggregate and idiosyncratic shocks. Importantly, our scenarios are independent of the current economic stance and vary the nature of the shock.

2 Empirical Results

This section documents five stylized facts about firms' pass-through over time and space in response to a historic supply shock.

2.1 Data

We build on the well-established ifo Institute's business survey panel data.[3] The monthly representative business survey covers approximately 6,500 firms across all sectors of the economy, containing information on the business's current standing and expectations about the business's outlook (Sauer et al. 2023). At the heart of our analysis is a *supplementary* quantitative pass-through question posed at three points in time since the beginning of the surge in input prices as illustrated in Figure A.1 (June 2021, April 2022, and October 2022). The specific wording of the question is:

> *"To what extent do you [the firm] pass through higher prices for energy, raw material, and intermediate inputs to your customers? ___%"*

Notably, the October 2022 survey further differentiates between pass-through so far and planned pass-through over the next six months, asking in a backward- and forward-looking manner while holding the firm information set constant.[4] Conceptually, we can summarize the elicited pass-through of cost increases at the firm level for the two dates, PT_t and $\mathbb{E}_t[PT_{t+6}]$, as follows:[5]

$$PT_t = \frac{\partial \log P_t}{\partial \log mc_t} = f(\mathbf{s}, \mathbb{E}_t[\mathbf{x}|\Omega_t]); \quad \mathbb{E}_t[PT_{t+6}] = \frac{\partial \log P_{t+6}}{\partial \log mc_t} = g(\mathbf{s}, \mathbb{E}_t[\mathbf{x}|\Omega_t])$$

Pass-through is a function of $\mathbf{s}$, reflecting perfectly observable state variables (e.g., current marginal costs mc_t and the degree of competition), and $\mathbb{E}_t[\mathbf{x}|\Omega_t]$, the expected path of marginal costs and other relevant price determinants in the future. Importantly, a given firm reports pass-through for t and $t+6$ based on the same state variables and information set Ω_t. This allows us to analyze pass-through at two points in time for the same underlying shock.

In addition, we explore other supplementary questions, such as subjective beliefs about the expected duration of supply chain disruptions. We refer to Appendix A for more details.

[3] For example, Bachmann et al. (2019, 2013) use the ifo Institute's business survey panel data to study the role of firm-level uncertainty for price setting and economic activity.

[4] Gödl-Hanisch and Menkhoff (2022) summarize insights on the gradual pass-through in a policy report.

[5] We interpret $\partial \log mc_t$ as the increase in input prices and $\partial \log P_t$ as the respective price change since the onset of the supply shock in January 2021 at the firm level.

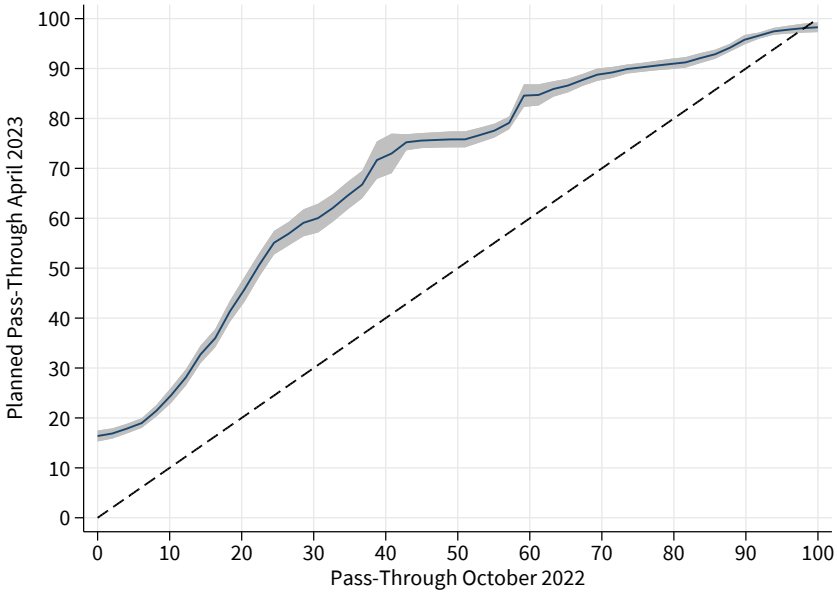
Our survey approach has the key advantage of directly asking firms about the level of pass-through, as opposed to imputing pass-through measures from potentially imperfectly measured cost shocks and price estimates. Moreover, it allows to account for potential heterogeneity across firms and industries, which is challenging to gauge in other data sets, particularly micro-level pricing data. Nonetheless, a potential limitation to our approach is that firms might strategically underreport their true pass-through. We offer three reasons why this is unlikely to be the case in our survey. First, the survey is incentivized by providing granular survey results for participants whose own weight is too small to affect average results. Second, past supplementary questions in the survey suggest that firms do not answer strategically. For instance, Bachmann et al. (2022) elicited potential production reductions in response to a 10% (or 50%) cut in gas supply. The median firm reported no decline in production (or a 25 % decline). These comparatively low numbers suggest no strategic reporting on average. Furthermore, if firms differed in the extent of strategic reporting, one would expect a positive correlation between a high reported decline in production in the case of a gas supply cut and a low reported pass-through in the cross-section. However, no such relationship is evident (see Figure A.2). Third, our estimates align with other pass-through estimates in the literature as shown in Figure B.1.[6]

2.2 Five facts about pass-through dynamics

Pass-through dynamics over time. We start by examining the dynamics of aggregate pass-through over time. The average pass-through for the entire sample is around 34% in October 2022 and is expected to increase by 17 percentage points (p.p.) in the following six months (see Table 1). The gradual increase in average pass-through could be entirely driven by the extensive margin. To further illustrate the gradual increase in pass-through over time, Figure 1 shows the planned pass-through by April 2023 as a function of the level of pass-through by October 2022. The difference between the smoothed line and the 45-degree line corresponds to the planned change in pass-through. Firms with an incomplete pass-through by October 2022 expect to increase pass-through by April 2023. For instance, firms at a pass-through level of 20% in October 2022 plan to increase pass-through by another 20 p.p. to 40% over the next six months. Similarly, firms at a zero pass-through level plan to increase pass-through by almost 20 p.p. To put these numbers in perspective,

[6]To further validate pass-through estimate reliability, we explore the connection between firm pass-through and return on sales (ROS) as a profitability indicator. We expect firms reporting low pass-through to show reduced ex-post ROS. Monopoly theory also predicts a negative correlation between ex-ante profitability and pass-through.Table A.1 indicates that pass-through is positively linked with ex-post ROS and negatively with ex-ante ROS, using October 2022 pass-through regression on 2019 and 2022 ROS data.

Figure 1: Pass-through dynamics over time



Notes: The figure shows the average planned pass-through by April 2023 as a function of the level of pass-through by October 2022, conditional on cost changes until October 2022. The gray shaded area is the 95% confidence interval. Source: ifo Institute's business survey.

a constant pass-through rate of 20 p.p. increase every six months would imply that firms would reach full pass-through over the course of 2.5 years.

The substantial share of zero adjustments in October 2022 indicates that firms face nominal rigidities such as menu costs. In standard price-setting models, firms base their pricing decisions on the discounted sum of expected marginal costs. While nominal rigidities can lead to incomplete pass-through, as firms might expect only a transitory cost increase (see Fact 3), firms would not plan a gradual increase of pass-through given the same information set. Hence, the gradual and sluggish adjustment over time supports the additional presence of micro-real rigidities, primarily affecting the intensive margin of adjustment and leading to a lower adjustment per price hike and over time. Micro real rigidities imply strategic complementarities in price setting between firms and thereby disproportional costs of deviating prices from competitors.

To gain a deeper understanding of incomplete pass-through, we ask the participants directly about the limiting factors in the October 2022 survey. We distinguish between competition, weak demand, long-term contracts, administrative effort/burden, regulatory reasons, and other factors. About 70% of firms report that competition limits their potential to adjust prices, a further indication of the importance of micro real rigidities (Figure A.3).

Similarly, about 45% listed that weak demand limits pass-through. Also, factors related to nominal rigidities are present: About 35% report that long-term contracts limit pass-through, and administrative burden and regulation have a share of less than 10%.

Accordingly, we can summarize our first fact as follows:

> *Fact 1: Firms pass through cost increases only gradually over time due to nominal and real rigidities.*

Pass-through dynamics within and across industries. Direct elicitation in the representative survey allows us to study pass-through dynamics at a disaggregated level, both within and across industries. There is substantial heterogeneity in the degree of pass-through across firms: While about 30% of firms have not passed through any cost changes by October 2022, 12% have passed through 50% of cost changes, and less than 10% of firms fully pass through cost increases to their customers (Figure A.4). The pattern looks similar for the planned pass-through until April 2023, but we observe a right shift. Almost 30% of firms now expect to fully pass through cost increases to customers. At the same time, the share of firms with zero pass-through declined from 30% to 15%, indicating an important role of nominal rigidities, particularly in the short run. Figure A.5 delivers similar evidence for the survey rounds in June 2021 and April 2022.

Table 1 presents the average pass-through levels across broadly defined industries. We observe the lowest pass-through for services firms (19% until October 2022) and the highest pass-through for manufacturing firms (48% until October 2022). The difference is mainly explained by the extensive margin: 91% of manufacturing firms pass through costs at least to some extent, while this is true for less than half of the firms in the services industry (46%). Revisiting planned pass-through until April 2023 as a function of pass-through until October 2022, we find that the pass-through shape holds for all industries: manufacturing, services, and trade, as shown in Figure A.6, with the trade sector exhibiting a slightly slower pass-through pace.

Table 1: Pass-through over time across industries

	Total	Manufacturing	Trade	Services	Construction
October 2022	34%	48%	36%	19%	40%
April 2023	51%	65%	50%	33%	65%
N	6407	1960	1445	2177	825

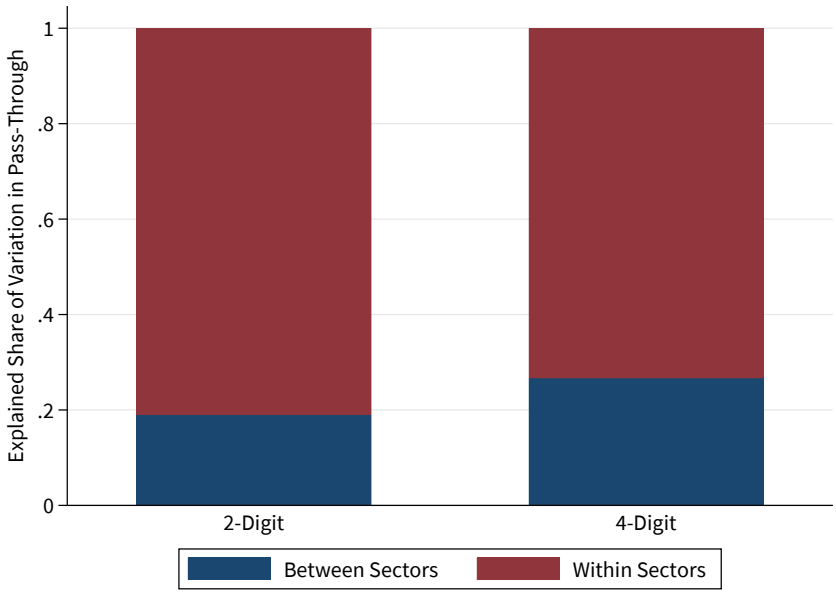
Notes: The table displays the average pass-through of cost changes to sales prices in October 2022 and planned pass-through until April 2023 in percent by industry. Source: ifo Institute's business survey.

Even within narrowly defined industries, there remains substantial cross-sectional variation. Decomposing the total variation into within-industry and between-industry variation shows that the former outweighs the latter in Figure 2. At the 2-digit industry level, between-industry variation explains roughly 20%, and within-industry the remaining 80%. By construction, the between-component gains slightly higher importance at the 4-digit industry level, but still, the within-industry variation explains roughly 75% of variation in pass-through. One potential concern is that measurement errors bias the within component upwards. To address this point, we restrict our sample to respondents who spent sufficient time on the question following Giglio et al. (2021). Figure A.7 shows similar estimates when cutting out the bottom 25% of the time spent distribution.[7]

Accordingly, we can summarize our second fact as follows:

Fact 2: There is substantial heterogeneity in pass-through across and within industries.

Figure 2: Cross-sectional variation in pass-through within and between industries



Notes: The stacked bar figure shows the R^2 of pass-through in October 2022 explained by industry fixed effects at 2-digit and 4-digit levels (blue). The remaining variation is within industries (red). Source: ifo Institute's business survey.

In the following, we focus on several factors to understand the significant differences in pass-through across and within industries.

[7] As there is no information about time spent for each question, we proxy this by the total time spent on the survey (only available for firms who participate online, around 3/4 of all participants). Figure A.8 shows the distribution of time spent in October 2022.

Pass-through and firm's expectations about the duration of the shock. As firms set prices based on their discounted sum of expected marginal costs, beliefs about the persistence of the shock are of first-order importance. To the best of our knowledge, we are the first to investigate this empirically at the firm level by examining the influence of firms' beliefs about the expected duration of the supply shock for the extent of pass-through. For this analysis, we turn to firms in the manufacturing sector, where the expected duration of supply shortages in months has been elicited in October 2021 (mean: eight months) and June 2022 (mean: ten months). We view supply shortages as an instance of a supply shock since shortages imply higher marginal costs in inputs of production to clear the inputs market. There is large heterogeneity between firms regarding the expected duration, with a standard deviation of five (seven) months in October 2021 (June 2022). To estimate the effect of firms' expected duration of the shock on pass-through, we regress pass-through, PT_i, of firm i in industry j on firms' expected duration of the supply shortage, $Exp.Duration_i$, controlling for the range of orders in months, capacity utilization, the qualitative change in revenues, orders, production expectations, log employees, cost changes, and energy intensity (X_i), as well as 4-digit industry fixed effects α_j:[8]

$$PT_i = \alpha_j + \beta Exp.Duration_i + \gamma X_i + \varepsilon_i, \tag{1}$$

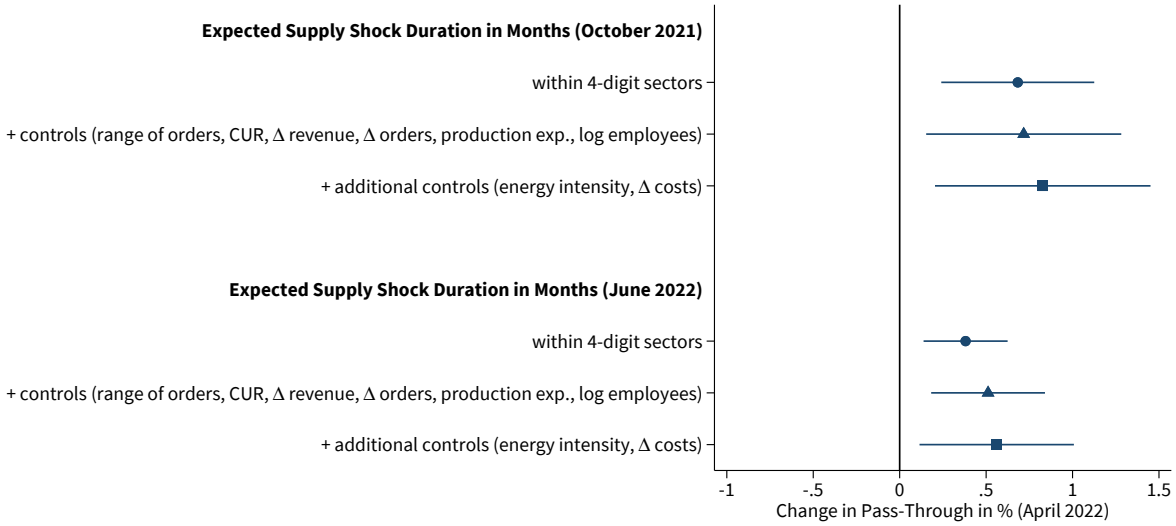
Figure 3 shows a positive relationship between the firm's expected duration of supply shortages and pass-through in April 2022. In terms of magnitude, pass-through increases by 6.8 to 8.3 p.p. to a ten-month increase in the expected duration of supply shortages, depending on the model specification. This result underlines the economic significance of the beliefs about the duration of the underlying shock for pass-through. In an alternative specification, we exploit the panel dimension and analyze whether an update of the expected duration at the firm level due to changes in the information set Ω translates into changes in pass-through. Indeed, we find that an increase in the expected duration of supply shortages from October 2021 to June 2022 is significantly associated with a higher pass-through until April 2023, conditional on the reported pass-through in April 2022, see Table C.3.

As the survey also contains information on the extensive margin of price decisions, we can establish a connection between the expected shock duration and the actual price decisions.[9] By conducting an event study, we ensure that the expected shock duration is not

[8]Including industry fixed effects also allows us to control for other factors, such as competition (e.g., Afrouzi 2023; Coibion et al. 2018), that affect firms' expectations about macro variables, the duration of supply chain disruptions, and thereby the pass-through.

[9]The ifo business survey elicits the extensive margin of realized price changes compared to the previous month. In the manufacturing sector, the aggregated survey responses show a high correlation with the

Figure 3: Expected duration of the shock and pass-through in April 2022



Notes: The figure reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices in April 2022 on the expected duration of supply shortages in months (elicited in October 2021 and June 2022) in the manufacturing sector. All specifications contain 4-digit industry fixed effects. The respective second specification controls for the range of orders in months, capacity utilization in percent, the qualitative change in revenues, qualitative change in orders, qualitative production expectations, and log employees. The respective third specification additionally controls for the energy intensity (measured as the share of energy costs in terms of revenues) and cost changes between March and May 2021. Table C.2 displays the respective coefficients and discusses the coefficient of the control variables. Appendix A provides the wording of the specific questions. Standard errors are clustered at the 4-digit industry level. The whiskers reflect the 95% confidence interval. Source: ifo Institute's business survey.

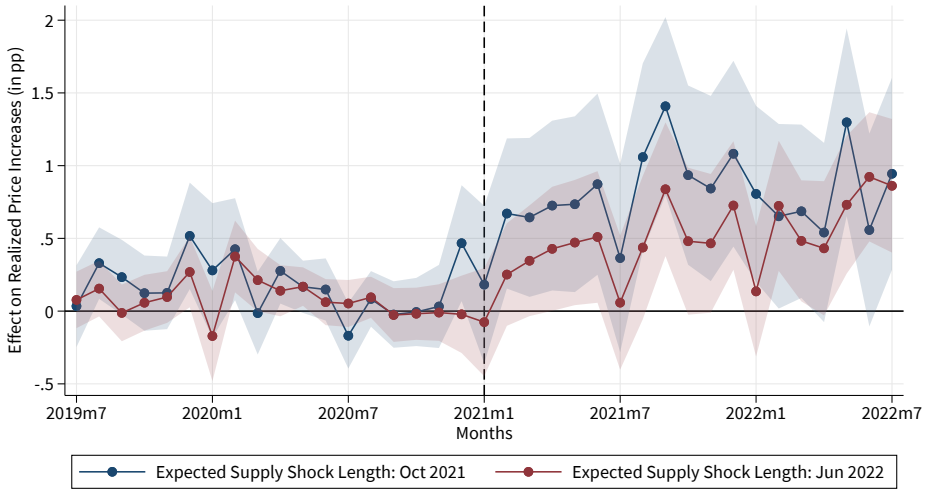
systematically related to other firm characteristics that shape price decisions. Concretely, the panel dimension allows us to verify common pre-trends prior to the supply shock. We define an indicator for a realized price increase in the respective month t ($\mathbb{1}[P_{i,t} > 0]$) as outcome variable. For the period June 2019 to July 2022, we estimate the following linear probability model for the expected shock duration elicited in October 2021 and June 2022 separately for each month, controlling for the change in revenues, orders, production expectations, and log employees ($X_{i,t}$), as well as 4-digit industry fixed effects α_j:

$$\mathbb{1}[P_{i,t} > 0] = \alpha_{j,t} + \beta_t Exp.Duration_{i,2021m10/2022m6} + \gamma X_{i,t} + \varepsilon_{i,t}, \tag{2}$$

Figure 4 plots the estimated β_t over time, which informs us about the importance of expected duration for firms' probability of increasing prices in a given month. Reassuringly, the expected duration of the shock is not significantly related to the probability of increasing

producer price index from the German Federal Statistical Office ($\rho = 0.78$), see Balleer et al. (2024) for more information and Appendix A for the exact wording of the question.

Figure 4: Event study: Expected duration of the shock and probability to increase prices



Notes: The figure shows point estimates β in Equation 2 and corresponding 90%-confidence bounds of monthly regressions of an indicator for a realized price increase in the respective month on the expected duration of the supply shock in months (blue: elicited in October 2021; red: elicited in June 2022) for the period June 2019 to July 2022. It is controlled for the change in revenues, orders, production expectations, and log employees, as well as 4-digit industry fixed effects. Standard errors clustered at the 4-digit industry level. The vertical dashed line indicates when the supply shock begins to hit the German economy in January 2021. Appendix A lists the wording of the respective survey question. Source: ifo Institute's business survey.

prices in 2019 and 2020, the period before the economy was exposed to the historic supply shock. When the supply shock hits in 2021, firms' expectations about the duration of the shock start to predict price increases. A 12-month increase in expected shock length is associated with an approximately ten p.p. higher probability of increasing prices. Hence, the expected shock duration affects price setting at the intensive as well as the extensive margin.

Accordingly, we can summarize our third fact as follows:

Fact 3: Pass-through increases in the expected duration of the shock.

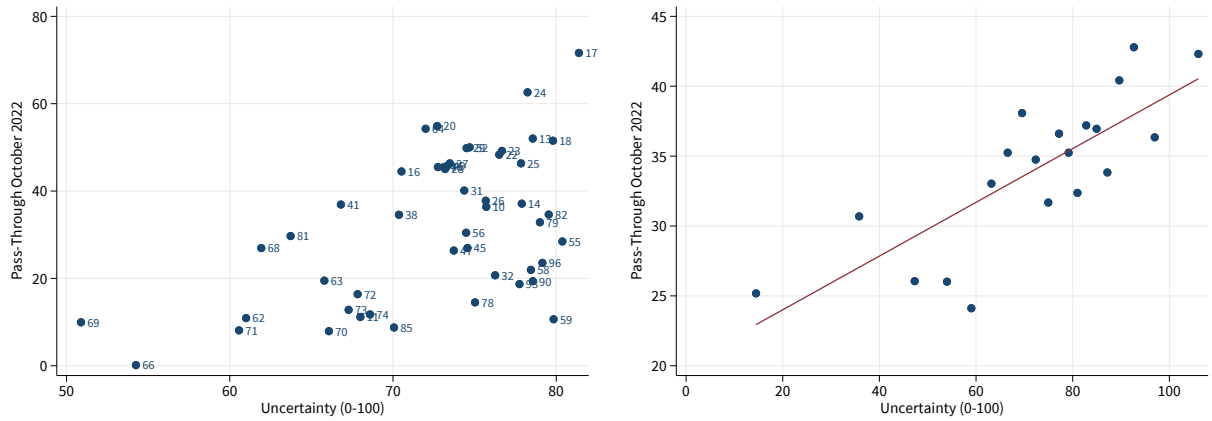
Pass-through and firm's idiosyncratic uncertainty. Another potential factor explaining pass-through differences across and within industries is firm-level uncertainty about overall business performance. Uncertainty can have ambiguous effects on firms' pricing decisions. On the one hand, higher uncertainty is associated with experiencing larger shocks, implying more flexible prices in the presence of menu costs Barro (1972).[10] On the other hand, uncertainty could also trigger a "wait-and-see"-strategy, with firms postponing

[10]Barro (1972) proposes a theory directly linking the extensive and intensive margin of adjustment to idiosyncratic uncertainty.

Figure 5: Pass-through until October 2022 and uncertainty

(a) At the industry level

(b) At the firm level



Notes: The figure relates the pass-through of cost changes to sales prices until 10/2022 to uncertainty of firms. Uncertainty is elicited on a continuous scale from 0 (low) to 100 (high). The left panel shows the relation as a scatter plot at the industry level (2 digits, at least 20 obs. per industry). The right panel shows the relation as a binned scatter plot at the firm level. It is controlled for the business situation and expectations in both panels. Table A.2 and Table A.3 display the corresponding regression tables. Appendix A lists the wording of the respective survey question. Source: ifo Institute's business survey.

further price adjustments (Vavra, 2014). Bachmann et al. (2019)—at the extensive margin—and Arndt and Enders (2023)—at the aggregate level—provide evidence for the former channel by relying on measures of volatility over time.

In contrast, we exploit the cross-sectional relation between direct and quantitative measures of uncertainty and pass-through across industries and firms. We measure subjective uncertainty at the firm level: respondents move a continuous slider between zero and 100 depending on the uncertainty about their business development in the next six months. Figure A.9 shows the average uncertainty over time. Uncertainty spikes from a value of 55 to almost 75 in the spring of 2020 when the pandemic reached Germany. A second spike is in March 2022 after Russia invaded Ukraine. A distinct feature of this measure is that it is not based on nominal values in contrast to other measures in the literature using revenue expectations (e.g., Altig et al. 2022 or Bachmann et al. 2021).

Figure 5 presents the relationship between pass-through of cost changes to sales prices until October 2022 and firms' idiosyncratic uncertainty both at the industry and firm level. In line with Bachmann et al. (2019) and Arndt and Enders (2023), we find that industries and firms with a higher idiosyncratic level of uncertainty pass through cost changes by more. The relation is quantitatively substantial: An increase in uncertainty by ten units is associated with a 13 p.p. higher pass-through at the industry level, which remains robust to controlling for the state of the business and expected business situation, see Table A.2.

Table A.3 confirms the positive relation at the firm level. However, the coefficient becomes significantly smaller, even more so when variation is absorbed at the 2-digit or 4-digit industry levels. This highlights the role of more flexible prices at the industry level for pass-through, indicating the importance of price coordination among competitors.

Accordingly, we can summarize our fourth fact as follows:

Fact 4: Pass-through increases with idiosyncratic uncertainty.

Pass-through and price-setting frequency. We next analyze the link between the intensive margin of pass-through and the average frequency of price changes. The panel dimension of the ifo survey allows us to calculate the average frequency of price changes between 2014 and 2019 at the firm level.[11] The median and mean are 11% and 19%, respectively, serving as a reduced form measure of price stickiness and indicating the degree of nominal rigidities. Our focus is on the *intensive margin* of pass-through to examine the role of real rigidities and abstract from the mechanical relation of the extensive margin with the frequency of price changes.

Figure 6 depicts this relation at the industry level (left panel) and the firm level (right panel).[12] A higher frequency of past price changes is associated with a higher pass-through at both levels.[13] Intuitively, the more often firms change their prices, the better the price coordination among them. Firms pass through cost increases to a larger extent if competitors are also more likely to be able to adjust, ensuring that the price is close to the competitors. Interestingly, firms in the trade sector—marked in red—have a comparatively low pass-through despite a high frequency of price changes. This indicates the high importance of micro real rigidities in these industries. The relation at the firm level is highly non-linear. While firms that almost never changed their prices between 2014-2019 have an average pass-through of around 45%, firms that changed their prices roughly twice a year in this period have an 8-10 p.p. higher pass-through on average. Firms that have changed their prices even more often exhibit a similar pass-through.

Accordingly, we can summarize our fifth fact as follows:

Fact 5: Pass-through increases in firms' past price-setting frequency.

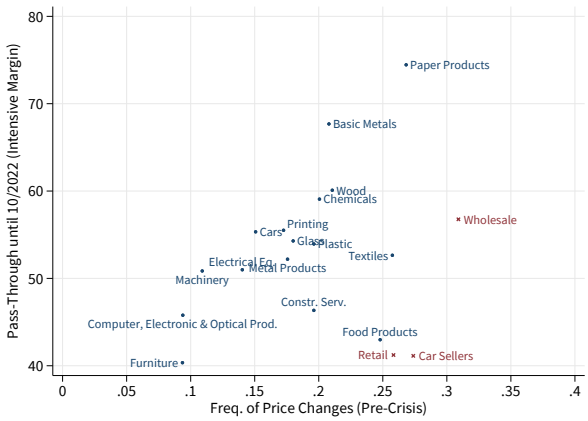
[11] We take the pre-crisis average price change frequency because it is arguably exogenous to other factors, such as shock size, exposure to the pandemic, or current idiosyncratic shocks, that influence pass-through.

[12] This analysis excludes services as the realization of price changes was not elicited until 07/2018.

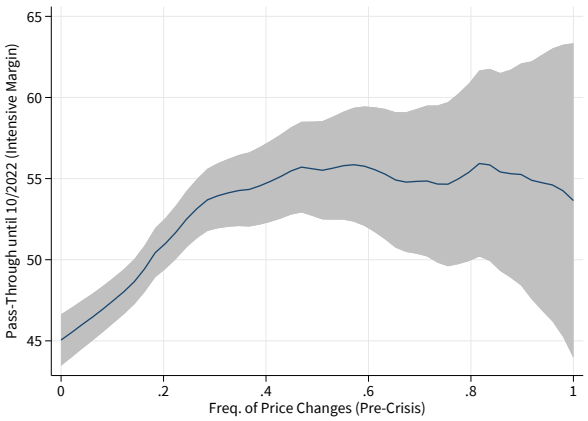
[13] Our results complement Gopinath and Itskhoki (2010) finding that the firms with a higher frequency of adjustment exhibit a higher long-run pass-through of exchange rate shocks. We document a similar pattern for a generic supply shock using an entirely different approach.

Figure 6: Intensive margin of pass-through until October 2022 and nominal rigidities

(a) At the industry level



(b) At the firm level



Notes: The figure relates the intensive margin (> 0) of pass-through until 10/2022 to the average pre-crisis frequency of price changes. The left panel shows the average frequency (2014-2019) and pass-through until 10/2022 at the industry level (2 digits, ≥ 20 obs. per industry). Blue (red) points indicate the manufacturing (trade) sector. The right panel shows the non-parametric relation between the frequency (2014-2019) and pass-through until 10/2022 at the firm level. The gray shaded area is the 95% confidence interval. Only firms with ≥ 12 obs. in the period 2014-2019 are considered in the figure. Source: ifo Institute's business survey.

3 Survey Experiments

This section turns to the survey experiments to examine the causal link between the nature of the shock and pass-through. Our objective is to quantify how firms' pass-through of a cost shock changes over time depending on the nature of the shock and the underlying economic environment. We use the new insights from the survey experiments to bridge our previous empirical evidence from the field and theoretical predictions from the literature on nominal and real rigidities.

3.1 Experimental Design

For the survey experiments, we build on the ifo Management-Survey. Since 2020, the Management-Survey asks decision-makers in German companies about current economic policy issues and changes in the macroeconomic environment (Sauer et al. 2023). The majority of respondents are the owner or CEO of the firm. The ad hoc survey covers approximately 300 firms across all sectors of the economy.[14]

We conduct hypothetical vignettes on the link between the nature of the shock and pass-

[14] 51% of the firms are in manufacturing, 27% in services, 12% in trade, and the remainder in construction. About 44% of the firms are classified as medium (50-249 employees), 26% as small with less than 50 employees, and 30% as large with more than 500 employees. We exclude decision-makers who do not deal with the firm's price-setting strategy (7.6%).

through in January and February 2023. We confront firms with the following hypothetical scenario as well as a graphical representation of the scenario, as described in detail in Appendix C:

> *"Suppose that purchase prices for [you and your competitors] in the industry [permanently] increase by 20% due to a global supply shock (see figure). All other factors, such as interest rates and fiscal policy measures, remain unchanged. Assume [good economic conditions with normal capacity utilization] for your company and the overall economy.*
>
> *To what extent would you pass through the cost increase to your customers in this scenario? Indicate the level of pass-through at the respective point in time."*

	1m	3m	6m	12m	24m
Pass-through in % after ...	☐	☐	☐	☐	☐

(no pass-through = 0%, full pass-through = 100%, disproportionate pass-through > 100%)

We vary the shock duration (permanent, transitory, uncertain duration) and the exposure to the shock (aggregate, idiosyncratic) within firms and the underlying general economic (low and high aggregate demand) across firms. Importantly, the setup ensures that i) the cost increase is exogenous to the firm and ii) the macroeconomy is held constant to control for general equilibrium effects and policy responses. We ask participants to provide quantitative pass-through estimates *across time horizons* and given different shock durations. Appendix C.1 presents the original survey questionnaire, including the hypothetical vignettes, and Appendix C.2 offers an English translation.

Our approach allows isolating the marginal effect of the nature of the shock, particularly the duration and exposure of the shock, in a *within*-firm setting by keeping all other factors the same. The within-firm design allows us to elicit quantitative pass-through dynamics over time at the firm level. This is crucial for understanding the role of real rigidities by analyzing the number of price adjustments to a permanent shock and directly comparing the pass-through between aggregate and idiosyncratic shocks. On top of that, our approach allows discerning the importance of the economic environment by comparing responses *across* firms, again keeping all other factors the same. This way, our approach comes with the advantage of abstracting from other channels that do not influence the findings.

Firms may choose not to change prices at all due to high price adjustment costs. To address this, we ask firms about their *general* threshold for adjusting prices before presenting the hypothetical scenarios. Figure C.1 displays the cumulative density function of this threshold, supporting the relevance of sizable menu costs in general but also that in

our scenario, menu costs are unlikely to play a role for the initial extensive margin decision. At a 20% cost increase, over 90% of firms typically adjust prices. Furthermore, the results cannot be influenced by macro real rigidities similar to Basu (1995), as all firms in our hypothetical vignette *directly* face a 20% cost increase. In other words, this allows us to completely abstract from any dilution in pass-through from input-output linkages. Note that the shock information is fully available to everyone. Hence, we also abstract from imperfect information (Mackowiak and Wiederholt, 2009; Phelps, 1970). Our setup has two critical advantages over existing studies: i) the respective pass-through coefficients are estimated with high precision despite a small sample size, and ii) by fixing the information set and firms' expectations, we can differentiate between the nature of the shock as well as the economic environment. This provides a clean setup to estimate the causal effect of a cost shock on pass-through dynamics.

3.2 Results

Figure 7 summarizes the main results of the survey experiment. The upper panels show the time path of the respective average pass-through of firms faced in three shock scenarios: (i) a *permanent* increase in costs by 20% (blue, solid lines) (ii) a *transitory* 20% cost increase in place for 12 months (red, dashed lines), and (iii) a 20% cost increase of *uncertain* duration with a 90% monthly survival rate (green, dotted lines), during high- and low-demand economic environments, respectively. The light-blue lines reflect Calvo-implied counterfactuals, subsequently explained in detail.

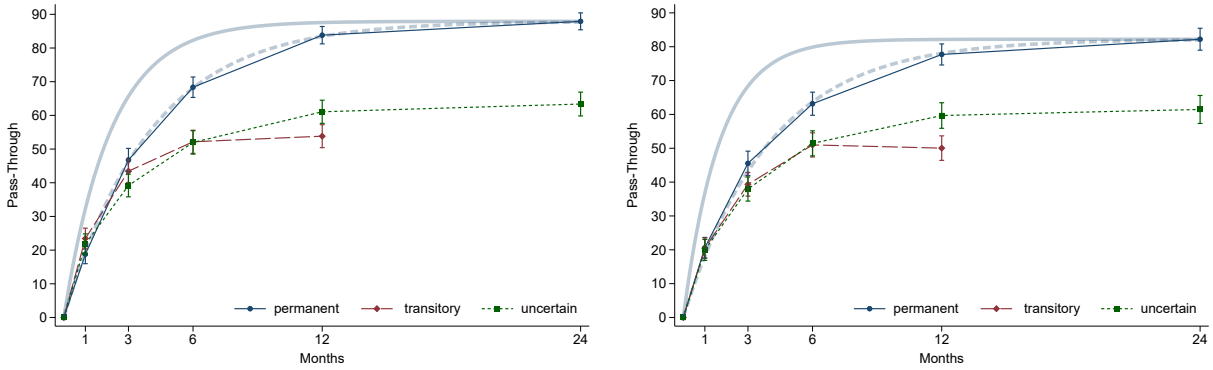
Aggregate pass-through dynamics. The overall trend observed is a gradual, concave increase in the pass-through at the aggregate level, eventually approaching a level below 100%. As a cross-validation exercise, we compare our experimental estimates with previous studies based on micro price-level data, such as, Gopinath and Itskhoki (2010), Dedola et al. (2021). Our estimates are in the range but towards the upper end compared to the literature (see Appendix B). This could be explained by the fact that our vignettes provide full information about the shock process. Imperfect information—e.g. about the persistence of the shock—can lead to further coordination failure and more gradual pass-through.

Shock duration. To what extent do expectations about the nature and duration of the shock matter for firms' pass-through of cost shocks? A comparison of the three shock scenarios - permanent, transitory, and uncertain duration - indicates no significant difference

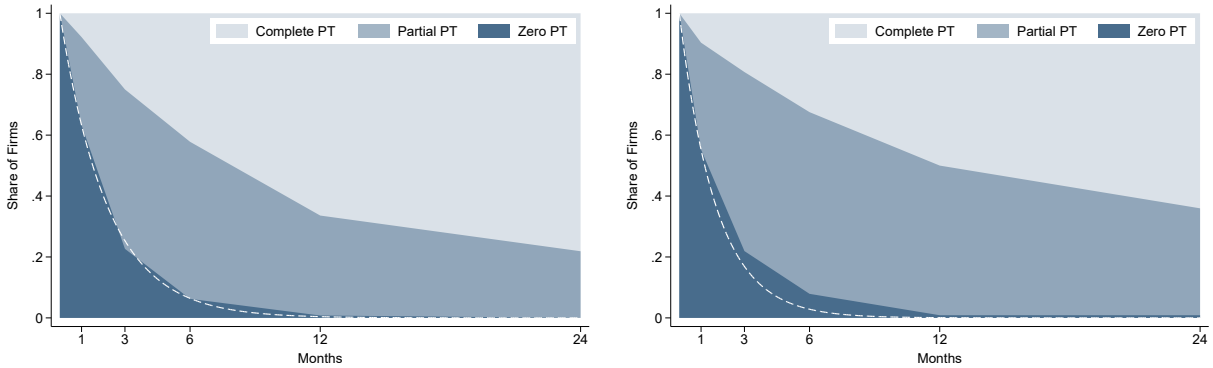
Figure 7: Pass-through of cost shocks: Main results

(a) High demand environment (b) Low demand environment

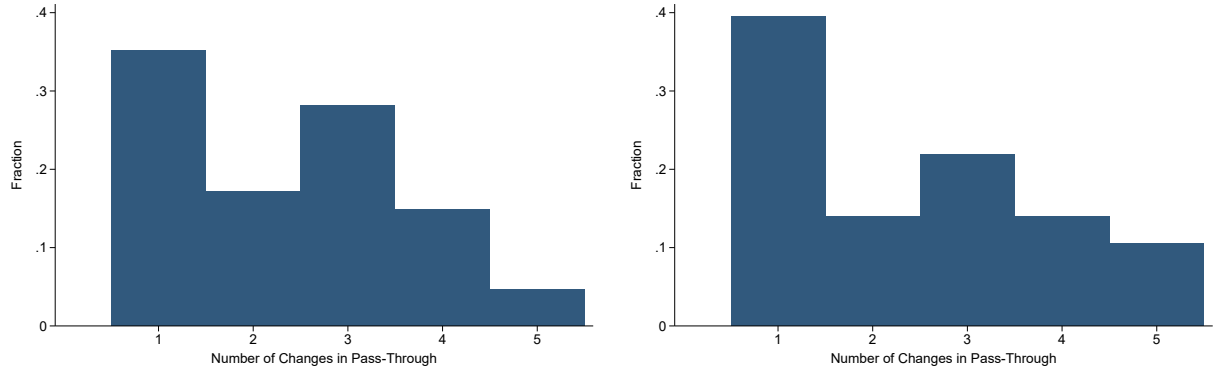
I: Average pass-through of cost shocks across horizons



II: Share of zero, incomplete, and complete pass-through (permanent cost shock)



III: Number of changes in pass-through (permanent cost shock)



Notes: The upper panels plot the pass-through of cost shocks across horizons depending on the duration of the shock, differing between permanent, transitory, and uncertain duration shocks, in blue, red, and green colors, respectively. The whiskers reflect the 68% confidence interval (one standard deviation). The light-blue lines reflect the "Calvo counterfactual" (explained in the text). The middle panels plot the shares of zero pass-through, partial pass-through (between 0 and 100), and complete pass-through (equal or above 100) of cost-push shocks across horizons depending on the economic conditions for the permanent shock scenario. The dashed lines reflect the "Calvo counterfactual." The lower panels plot histograms of the firm-level number of changes in pass-through in the permanent shock scenario. Source: ifo Institute's Management-Survey.

between them in the first three months but a consistently steep increase in pass-through of roughly 40%. This evidence is in line with the presence of *nominal* rigidities leading to a gradual increase in pass-through in the aggregate, as not all firms can change their prices immediately. Similarly, the middle panels in Figure 7 show that 63% do not increase prices at all in the first month supporting the importance of nominal rigidities at the beginning. Afterwards, the pass-through increases only slightly for the temporary shock and the shock with uncertain duration. For the permanent scenario, we observe further increases in pass-through that are significantly higher than for the other two scenarios highlighting the importance of *expectations* about the nature of the shock for the extent of pass-through. Figure C.3 confirms that the gradualness and the increasing pass-through in the shock duration are similar across sectors and along the firm size distribution. In line with the findings in the ifo business survey (see Section 2.2), pass-through is higher across all scenarios for firms in the manufacturing and construction sectors compared to services and trade. Similarly, Nakamura and Steinsson (2010) find a low magnitude of price changes for services consistent with the presence of higher micro real rigidities. There is no consistent pattern across the size distribution.

Underlying economic conditions. We next examine whether the underlying economic environment affects the decision of firms to pass through cost shocks. Comparing pass-through in times of high and low demand (left and right panels, respectively), we generally observe a very similar pattern, even quantitatively.[15] While there is a slightly lower and more gradual pass-through in the low-demand environment, we conclude that the state of the economy is not a main driving force for the characteristics of pass-through. This also demonstrates the generality of our other results.

Nominal and real rigidities. Our framework enables us to *directly* assign the observed sluggish pass-through to the presence of nominal and real rigidities. To this end, we take a closer look at pass-through changes at the firm level. While one-time increases after a permanent shock favor nominal rigidities alone,[16] several gradual increases would be consistent with additional micro real rigidities. The majority of firms change their pass-through level more than once in the given scenario, as shown in the lower panels of Figure 7.[17] Hence, this is strong evidence for an important role of real rigidities in

[15] One possible reason could be that a lower ability to pass through prices due to low demand is accompanied by the need to raise prices to ensure solvency.

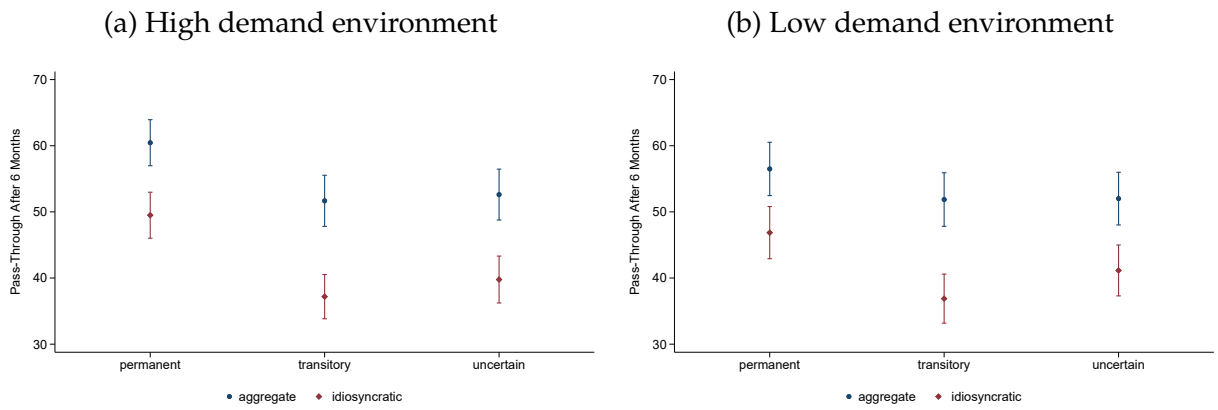
[16] Time- (e.g., Calvo) and state-dependent (e.g., menu-cost) models support a one-time adjustment.

[17] This is likely a rather conservative estimate due to potential survey fatigue. Further, this may be amplified by our data cleaning procedure, where we fill up/down the pass-through values over time if firms

the pass-through of cost shocks. Note that real rigidities alone would not lead to several adjustments since coordination would work immediately after the cost increase. Only the combination of nominal and real rigidities can explain the observed pattern.

To further quantify the importance of real rigidities, we contrast pass-through under aggregate and idiosyncratic cost shocks. The underlying idea is such: A firm facing an idiosyncratic shock bears in mind that competitors may keep their prices constant, so any price adjustment on the firm's side distorts relative prices, entailing possible customer resentment and disproportional demand drops. We confront firms with the same hypothetical scenario as before, except that firms face an idiosyncratic shock. Then, we elicit the pass-through level after six months. Figure 8 shows that the average pass-through of the idiosyncratic shock is significantly lower vs. the aggregate shock. This pattern arises robustly across the different shock scenarios and for the high- and low-demand environments. Quantitatively, the difference in pass-through of aggregate vs. idiosyncratic shocks is approx. 10-15 p.p. A particularly strong difference is visible for the transitory shock scenario. This might be due to the fact that the relative price difference exists only for a limited period of time, which further reduces the incentive to deviate from competitors. Figure C.2 shows that this pattern holds across sectors and along the firm size distribution.

Figure 8: Pass-through of aggregate vs. idiosyncratic cost shocks after six months



Notes: The figure shows the pass-through of aggregate (blue) vs. idiosyncratic (red) cost shocks after six months depending on the shock duration, differing between permanent, transitory, and uncertain duration shocks. The whiskers reflect the 68% confidence interval (one standard deviation). Source: ifo Institute's Management-Survey.

Connection to the empirical results. The survey experiment allows us to rationalize the pass-through pattern in the cross-section and over time presented in Section 2. The results from the field show that firms with a longer expected duration have a higher pass-through.

have not entered a value to all five horizons (applies to less than 10% of firms).

While, in reality, the distribution of beliefs about the duration of supply chain disruptions is continuous, the survey experiment maps this to two cases: permanent vs. transitory. Similar to the empirical results, we find a statistically significant increase in pass-through with the expected duration in the survey experiments, confirming the importance of beliefs about the duration of the shock. Note that belief updating can also affect pass-through over time and explain an increasing pass-through (even in the absence of any real and nominal rigidities). More specifically, firms' learning over time about the shock duration may lead to an adjustment in pass-through.

Likewise, the survey experiment indicates that nominal and real rigidities play an important role in the pass-through of shocks: about 60% of firms do not react on impact, and firms increase prices only gradually. These results from the experiment can be directly linked to the results from the field: (i) firms that adjust prices infrequently exhibit lower pass-through (Figure 6), and (ii) firms plan a granular increase of pass-through over six months (Figure 1). In addition, 41% of the participants in the survey experiment listed competition as a limiting factor for price setting and the main source of lack of pass-through in open-ended questions, as shown in Table C.1, aligning fully with the survey panel evidence of 40% listing competitive pressure as the main factor.[18]

Comparison to Calvo model predictions. How well would a canonical Calvo model fit the observed pass-through estimates? To compute the implied pass-through under a Calvo model, we calibrate the adjustment probability θ to match the fraction of zero pass-through on impact ($\theta = 0.37$) in the middle panels of Figure 7 and the cumulative pass-through to a permanent shock after 24 months.[19] The predicted share of zero pass-through by the Calvo counterfactual, visualized by the dashed white line in the middle panels, closely follows the empirical share of zero pass-through over time. The light-blue, solid lines in the upper panels of Figure 7 reflect the pass-through dynamics under Calvo pricing for the permanent shock scenario. The implied Calvo estimate does not fit the observed average pass-through estimates since firms adjust prices gradually. The Calvo coefficient must be lowered to match the observed pass-through estimates. θ equal to 0.22 (light-blue, dashed lines) best fits the observed pass-through estimates and closely matches the survey experiment. Hence, the Calvo coefficient based on the extensive margin is 68% too high. This "Calvo counterfactual" is a reduced-form way to quantify the role of micro real rigidities.

[18]The open-ended survey question design has the advantage of not priming respondents to a specific set of answer categories, see Haaland et al. (2024) for a review on open-ended questions.

[19]We treat average pass-through of 85% after 24 months as complete and assume firms can substitute the remaining costs. We do not want to overstate incomplete long-run pass-through, as the median is at 100%.

Quantifying the pass-through dynamics and implications for the Phillips curve. What do our pass-through results tell about inflation-output dynamics and monetary policy transmission? The pass-through estimates can be directly mapped to the slope coefficient of the Phillips curve (PC) building on Auclert et al. (2023). The pass-through matrix, Ψ, which is identified in partial equilibrium, delivers a sufficient statistic for the generalized PC slope coefficient matrix $\mathbf{K}$.[20] The PC reflects the inflation, π, response to output, $\widehat{y}$, depending on the coefficient matrix $\mathbf{K}$ and the elasticity of intertemporal substitution and intertemporal labor supply elasticity, σ and φ, respectively:

$$\pi = (\varphi + \sigma) \underbrace{(\mathbf{I} - \mathbf{L})\Psi(\mathbf{I} - \Psi)^{-1}}_{\mathbf{K}} \widehat{y}, \tag{3}$$

where Ψ reflects the pass-through matrix, a function of the adjustment probability θ and the discount factor β, $\mathbf{I}$ the identity matrix and $\mathbf{L}$ the lag-matrix.[21] The implied PC coefficients from our survey experiment are presented on a monthly level in Table 2.

Table 2: Implied coefficients of Phillips curve slope $\mathbf{K}$

	nominal rigidities	nominal + real rigidities	
		calvo counterfactual	based on idios. shock PT
	θ=0.37	θ=0.22	θ=0.37; χ=0.625
$\mathbf{K}$	0.2186	0.0628	0.1366

Notes: The table presents the implied coefficients of the Phillips curve slope based on $\mathbf{K} = (\mathbf{I} - \mathbf{L})\Psi(\mathbf{I} - \Psi)^{-1}$ for different values of θ. In the third column, the $\mathbf{K}$ based on nominal rigidities is multiplied by χ, capturing the extent of real rigidities.

In the first column, we show the implied PC coefficient based on the nominal rigidities observed in the survey experiment. The implied PC slope coefficient is with 0.22 relatively steep. In the second and third columns, we display the PC coefficients that also consider real rigidities based on two approaches: Either relying on the "Calvo counterfactual" - as described above - or using the PC coefficient based on nominal rigidities and adjusting for

[20] The formula for $\mathbf{K}$ in Equation (3) is the solution of a fixed point problem that translates nominal into real marginal costs and thereby accounts for general equilibrium effects (Auclert et al., 2023).

[21] The pass-through matrix, Ψ, for a time-dependent (e.g., Calvo) model from Auclert et al. (2023) equals:

$$\Psi \equiv \frac{1}{\sum_{s\geq 0}(1-\theta)^s \sum_{s\geq 0}\beta^s(1-\theta)^s} \begin{pmatrix} 1 & 0 & 0 & ... \\ (1-\theta)^1 & 1 & 0 & ... \\ (1-\theta)^2 & (1-\theta)^1 & 1 & ... \end{pmatrix} \begin{pmatrix} 1 & \beta(1-\theta)^1 & \beta^2(1-\theta)^2 & ... \\ 0 & 1 & \beta(1-\theta)^1 & ... \\ 0 & 0 & 1 & ... \end{pmatrix}$$

We set the discount factor β to .9966 in accordance with the monthly frequency.

micro real rigidities in a second step based on the pass-through of the idiosyncratic shock scenario.

Following Auclert et al. (2023), in an environment with micro real rigidities, the PC coefficient extends to:

$$\pi = (\varphi + \sigma)\chi \mathbf{K}\widehat{y},$$

where χ reflects the micro real rigidities for values less than one and downscales the slope of the PC. We can derive χ by using the idiosyncratic shock results presented in Figure 8. Focusing on the permanent shock, we obtain χ = 0.625 in the high-demand environment.[22] The degree of micro real rigidities is likely to be even higher in the low-demand environment or for transitory shocks (as the gap between idiosyncratic and aggregate shocks is wider in these scenarios).

The PC coefficient gets substantially flatter for both approaches that account for real rigidities. Based on the "Calvo counterfactual," it shrinks to 0.06 and based on the idiosyncratic shock PT approach to 0.14. Overall, our estimate is in the range of previous work, as summarized in Table C.4.[23] However, a recent study by Hazell et al. (2022) estimates an even flatter slope, suggesting additional frictions at play, such as macro real rigidities.

4 General Equilibrium Price-Setting Model

This section introduces a model to rationalize the observed pass-through depending on the persistence and exposure of the shock and estimates the degree of nominal and real rigidities based on our empirical results. We take an off-the-shelf menu cost model à la Nakamura and Steinsson (2010) featuring nominal rigidities (menu costs) and idiosyncratic as well as aggregate shocks and extend it to include micro-real rigidities in the form of Kimball demand (see e.g., Klenow and Willis 2016, Aruoba et al. 2022, or Beck and Lein 2020). This class of models is consistent with the empirical evidence, particularly with firms' inaction to small cost changes and the importance of competition for price setting.

4.1 The model setup

The economy consists of different types of agents: households, producers, and a monetary authority.

[22] χ is calculated as pass-through of the idiosyncratic shock divided by pass-through of the aggregate shock after 24 months (Figure 8) serving as a full pass-through counterfactual.

[23] To relate unemployment to marginal costs, we divided the unemployment coefficient by two following Auclert et al. (2023).

Households. A continuum of households consumes a composite consumption good, Y_t, composed of a continuum of differentiated goods y_t^i and assembled free of charge with a Kimball (1995) demand aggregator: $\int_0^1 G\left(\frac{y_t^i}{Y_t}\right) di = 1$, where G takes the following functional form depending on firm i's relative demand $\frac{y_t^i}{Y_t}$:

$$G\left(\frac{y_t^i}{Y_t}\right) = 1 + \left(\bar{\theta} - 1\right) exp\left(\frac{1}{\bar{\epsilon}}\right) \bar{\epsilon}^{\left(\frac{\bar{\theta}}{\bar{\epsilon}} - 1\right)} \left[\Gamma\left(\frac{\bar{\theta}}{\bar{\epsilon}}, \frac{1}{\bar{\epsilon}}\right) - \Gamma\left(\frac{\bar{\theta}}{\bar{\epsilon}}, \frac{\frac{y_t^i}{Y_t}^{\frac{\bar{\epsilon}}{\bar{\theta}}}}{\bar{\epsilon}}\right)\right], \tag{4}$$

with Γ reflecting the incomplete gamma function. $\bar{\theta}$ denotes the steady-state value of the demand elasticity, i.e., the elasticity of demand with respect to the price level, and $\bar{\epsilon}$ the super-elasticity, that is the derivative of the price elasticity with respect to the price level. While the price elasticity of demand is constant (the super-elasticity is zero) in the constant elasticity of substitution (CES) demand case, the super-elasticity is larger than zero in the presence of real rigidities via Kimball demand.

The corresponding demand function for differentiated good i is:[24]

$$y_t^i = \left[1 - \bar{\epsilon} \ln\left(\frac{p_t^i}{P_t}\right)\right]^{\frac{\bar{\theta}}{\bar{\epsilon}}} Y_t, \tag{5}$$

where demand for good i increases with overall demand for goods Y_t and decreases in the relative price $\frac{p_t^i}{P_t}$, the more so the larger the steady-state value of the super-elasticity $\bar{\epsilon}$. The demand also depends on the steady-state value of the demand elasticity $\bar{\theta}$.

In the presence of real rigidities, that is, $\bar{\epsilon} > 0$, the demand function becomes more elastic in the relative price. This relationship is particularly evident when looking at the demand and profit functions, shown in Figure D.1. The higher the degree of real rigidities, i.e., the larger $\bar{\epsilon}$, the steeper the demand function, and at very high values it becomes almost a step function. Intuitively, a steeper demand function means that consumers are more responsive to relative price changes.

Firms. A continuum of firms indexed by i produces differentiated good, y_t^i, using labor and materials as input factors. Resetting prices is costly. Firms face menu costs, which are implemented as a fixed cost proportional to labor costs. Firms produce according to a standard production function depending on firm-specific productivity, A_t^i, and a diminishing returns to scale technology in labor l_t^i and materials m_t^i: $y_t^i = A_t^i (l_t^i)^{1-sm} (m_t^i)^{sm}$,

[24]The results are robust to using the alternative demand specification of Dotsey and King (2005).

where sm reflects the share of materials. Accordingly, firms maximize the sum of the future discounted per-period profits Π_t^i:

$$\Pi_t^i = p_t^i y_t^i - w_t l_t^i - m_t^i - \chi I_t^i, \tag{6}$$

where $p_t^i y_t^i$ denotes the firm's sale revenue, $w_t l_t^i$ the firm's wage bill, m_t^i the cost for materials, χ fixed costs that the firm incurs for adjusting prices, and I_t^i an indicator function that takes the value one if the firm decides to change prices and zero otherwise. The firm's idiosyncratic productivity A_t^i with persistence ρ_A evolves according to:

$$\log A_t^i = \rho_A \log A_{t-1}^i + \varepsilon_t^A, \tag{7}$$

where ε_t^A reflects an idiosyncratic productivity shock with $\varepsilon^A \sim \mathcal{N}(0, \sigma_A^2)$, denoted hereafter as idiosyncratic shock.

After setting up the firm's problem and specifying the demand functions, we discuss the interaction of micro real rigidities, menu costs, and the persistence of shocks. Intuitively, in the presence of menu costs, firms change prices (and pass through cost increases) only when shocks are sufficiently large or persistent, and firms do not have to face disproportional losses in market share (micro real rigidities). Introducing micro-real rigidities increases firms' threshold to change prices (extensive margin), and firms raise prices more gradually (intensive margin) to minimize deviations from competitors' prices.

Monetary authority. The monetary authority determines the level of nominal demand, S_t, which equals consumption spending, $S_t = P_t C_t$, in equilibrium and evolves according to an AR(1) process:

$$\log S_t = \mu + \rho_S \log S_{t-1} + \varepsilon_t^S, \tag{8}$$

where μ reflects trend growth in nominal demand, and ε_t^S a shock to nominal demand with $\varepsilon_t^S \sim \mathcal{N}(0, \sigma_S^2)$, labeled henceforth aggregate shock. Typically, nominal demand is assumed to follow a random walk, i.e., ρ_S = 1. In light of our empirical findings and given the mean-reverting nature of interest rates, we allow ρ_S to be less than 1, implying that aggregate shocks can also be transitory.

4.2 Calibration

We calibrate the standard parameters to values in the literature and Euro Area estimates following Beck and Lein (2020), Smets and Wouters (2003) and Nakamura and Steinsson (2010). Table D.1 presents the calibration for the menu-cost model with micro real rigidities.

Targeted moments. The remaining two parameters, which determine the degree of nominal and real rigidities, are estimated based on our empirical results using the method of simulated moments. We target (i) the frequency of price changes and (ii) the level of the impulse response function to the aggregate shock. More specifically, fixed costs for changing prices, χ, are estimated to match the median frequency of price changes at the firm level in the ifo business survey panel (from 2014 and 2019): 11%, corresponding to price changes every nine months and similar to a recent estimate (12%) based on CPI micro data for euro area countries by Gautier et al. (2023). The degree of real rigidities measured by the super-elasticity $\bar{\epsilon}$ is estimated to match the average impulse response dynamic of pass-through to a permanent cost increase of 20% for horizons from one to 24 months.[25] Thereby, we implicitly assume that firms' pass-through to cost shocks is similar to nominal demand shocks - in our view, a reasonable assumption, especially since the nominal demand process is understood as a reduced-form way to capture aggregate shocks. The estimation results are shown in Table 3:[26]

Table 3: Estimation results for parameters

Parameter	Description	Value
$\bar{\epsilon}$	Super-elasticity of demand	6
χ	Fixed cost for changing price	0.0019

Notes: Fixed cost for changing price is expressed as a fraction of steady-state revenue.

Figure D.2 provides a heatmap of the target function values for a grid of menu costs and micro real rigidities. It clearly shows that a combination of both rigidities is necessary to match the data.

4.3 Results

We next shift the focus to studying the implied pass-through dynamics by the estimated degree of micro real rigidities using simulated data. We proceed in three steps: first, we compare the estimates of our simulated impulse response for the aggregate shock to its targeted empirical counterpart; second, we validate our results by comparing the untargeted impulse response to a transitory shock to its empirical counterpart and contrasting pass-through of aggregate versus idiosyncratic shocks; finally, we study counterfactual

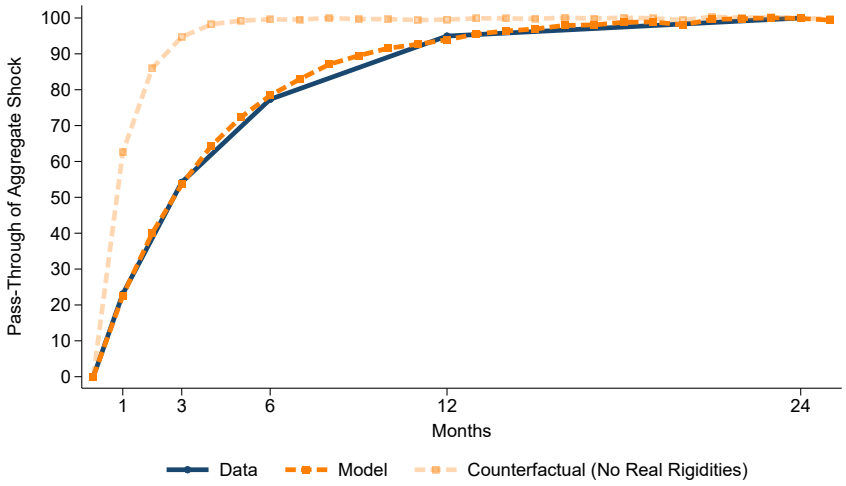
[25] To ensure monetary neutrality in the long run, we rescale the pass-through values from the hypothetical vignette such that pass-through is 100% after 24 months.

[26] See Appendix D.2 for details on the estimation.

pass-through dynamics and implications for the real economy in an environment without real rigidities ($\bar{\epsilon} = 0$). To do so, we simulate data with parameter calibrations according to Tables 3 and D.1 and estimate local projections of the price level to an aggregate or idiosyncratic shock.

We start by assessing the fit of the estimated model parameters and compare the pass-through dynamics of a permanent aggregate shock in the survey data versus the model. Figure 9 shows that the implied pass-through impulse responses almost perfectly mirror each other. The results imply that the survey responses can be reconciled for a significant degree of real rigidities ($\bar{\epsilon} = 6$), leading to a sluggish pass-through and corroborating *Fact 1*. Our estimates of the super-elasticity parameter $\bar{\epsilon}$ are in line with the literature; see, e.g., Beck and Lein (2020) for a summary. However, assuming that no real rigidities are at play ($\bar{\epsilon} = 0$), as shown in the counterfactual, leads to an overestimation of pass-through. The average estimated price change frequency is 0.11, matching the median in the survey data.

Figure 9: Data vs model: Pass-through of a permanent aggregate shock (targeted)



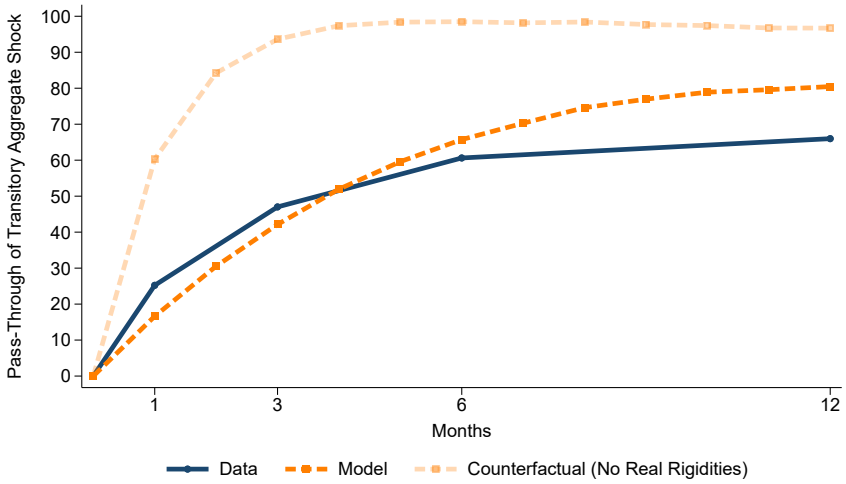
Notes: The dark-blue line reflects the pass-through impulse response to an aggregate permanent shock from the survey data. The pass-through is rescaled to 100% after 24 months to ensure monetary neutrality in the long run. The orange line is the model-implied pass-through impulse response to an aggregate permanent shock using the estimated χ (0.0019) and $\bar{\epsilon}$ (6). The light-orange line reflects counterfactual pass-through in an environment with no real rigidities $\bar{\epsilon}$=0.

Next, we turn to the untargeted moments and compare the fit of the estimated model parameters to a transitory shock (ρ_S=.9). Figure 10 shows that the model does a decent job matching the transitory shock. We observe a much more sluggish and dampened pass-through to a transitory shock in both the survey data and model, validating *Fact 3*. This is due to firms adjusting prices to the expected sum of marginal costs, which is lower

in the case of transitory shocks and affects both the intensive and extensive margins of adjustment. As before, a model without real rigidities ($\bar{\epsilon} = 0$) has a hard time matching the observed survey data and overestimates pass-through. Interestingly, the pass-through dynamics for the permanent and transitory shock are quite similar in the absence of real rigidities. Hence, there is an interaction effect when real rigidities are introduced: Transitory shocks have particularly low pass-through in this case.[27]

Another metric for evaluating our estimated model's performance is to analyze the pass-through of idiosyncratic shocks in the model. In line with the findings in the survey experiments, the pass-through of an idiosyncratic shock is significantly lower than that of an aggregate shock in the model. However, the difference in the model is even more pronounced compared to our empirical findings.

Figure 10: Data vs model: Pass-through of a transitory aggregate shock (untargeted)



Notes: The dark-blue line reflects the pass-through impulse response to an aggregate transitory shock from the survey data. We compute the average of the transitory scenario (12 months) and the uncertain duration scenario (90% monthly survival rate) from the hypothetical vignettes, see Figure 7. The orange line is the model-implied pass-through impulse response to an aggregate transitory shock ($\rho_S = .9$) using the estimated χ (0.0019) and $\bar{\epsilon}$ (6). The light-orange line reflects counterfactual pass-through in an environment with no real rigidities $\bar{\epsilon}$=0.

The model additionally captures the other facts documented in Section 2.2. Pass-through increases with the degree of uncertainty (standard deviation of shocks), resembling *Fact 4*. Pass-through also increases in the frequency of price changes (lower menu costs), as

[27]Note that the model abstracts from the possibility that firms learn about the nature of a shock over time. This is consistent with our hypothetical vignette design, where there is full information about the shock process. In reality, however, firms may learn about the persistence of a shock, leading to additional coordination failures.

indicated by *Fact 5*. Additionally, the observed heterogeneity in pass-through (*Fact 2*) can be explained by differences in expectations and real and nominal rigidities, as supported by the evidence presented earlier.

Which degree of monetary non-neutrality does the model imply? To answer this question, we study the impulse response of real output to a nominal demand shock. Figure D.3 shows that real effects based on the model without real rigidities are very short-lived. The introduction of real rigidities makes real effects significantly more persistent. For the permanent and transitory nominal demand shock, real effects die out after 1.5 years and nine months, respectively. However, estimates in the literature suggest that the real effects of monetary policy last three years or more (e.g., Christiano et al. 1999; Gertler and Karadi 2015; Jarociński and Karadi 2020; Romer and Romer 2004). Hence, additional frictions are necessary to generate a stronger persistence of nominal shocks, in line with our implication for the Phillips curve in the previous section.

5 Conclusion

We find sluggish pass-through dynamics of cost shocks to customers using a novel firm-level survey approach. The gradual pass-through attributes an important role to nominal and micro real rigidities, limiting pass-through at the firm level. Significant heterogeneity in pass-through across and within narrowly defined industries suggests that additional idiosyncratic factors play a role. In particular, we highlight the importance of firm-specific expectations about the duration of the shock and its interaction with nominal and real rigidities. Additional evidence from hypothetical vignettes confirms these results and allows a causal quantification of frictions and a direct mapping to the slope of the Phillips curve. We then use our empirical estimates to quantify the degree of nominal and real rigidities in a standard price-setting model and find a substantial degree of both.

Our results have implications for the propagation of shocks and the transmission of monetary policy. First, sluggish pass-through implies persistent effects of monetary policy. In fact, New Keynesian models that rely on a high degree of real rigidities to match the persistence of monetary shocks in the data, such as Smets and Wouters (2007), might be better empirically micro-founded than previously thought. Second, our estimates indicate that the Phillips curve becomes much flatter once accounting for the extent of real rigidities we observe in the data, bridging the wide range of previous estimates. The estimated flat Phillips curve also implies a worse trade-off between inflation and output for monetary policy, making it more costly to reduce inflation. At the same time, our empirical findings indicate that increased uncertainty acts as a counterbalancing factor, bringing the economy

towards a more flexible price equilibrium.

We deduct two avenues for future work. First, the hypothetical vignettes on dynamic pass-through could be augmented further; for instance, to learn more about potential non-linearities with respect to the shock size or asymmetries. Second, our evidence on the importance of the belief about the shock persistence could deliver another dimension of friction, leading to gradual pass-through and, in turn, a high degree of monetary non-neutrality. Here, communication about the duration of the shock could significantly affect and amplify aggregate transmission. Implementing imperfect information—-and thereby heterogeneous expectations—about shock persistence into a price-setting model would give further intuition into this mechanism, especially in combination with endogenous information acquisition (Afrouzi, 2023; Coibion et al., 2018; Gorodnichenko, 2008; Melosi, 2014).

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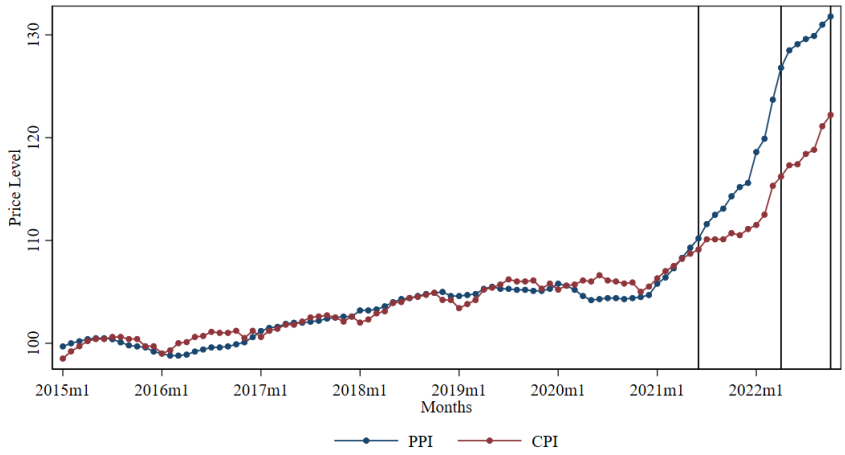
A ifo Business Survey

A.1 Survey timing and inflation dynamics

Figure A.1: Producer and consumer prices over time



Notes: German manufacturing sector's producer price index (PPI) and consumer price index (excl. energy, food). The vertical lines correspond to the dates of the supplementary pass-through questions in the ifo Institute's business survey: June 2021, April 2022, and October 2022. Source: Federal Reserve Economic Data (FRED).

A.2 Supplementary questions (translated)

Pass-through

- June 2021: "To what extent can you pass through higher purchase prices to your customers? We can pass through the higher purchase prices to our customers by ___%."
- April 2022: "To what extent can you pass through higher purchase prices for energy, raw materials, and intermediate inputs to your customers? We can pass through the higher purchase prices to our customers by ___%."
- October 2022: "To what extent have you so far passed through higher purchase prices for energy, raw materials, and intermediate inputs to your customers? ___%"
- October 2022: "To what extent do you plan to pass through higher purchase prices for energy, raw materials, and intermediate inputs to your customers in the next six months (including previous price changes)? ___%"

Limiting factors for pass-through

- What factors limit the flexibility of your firm in pricing? (Please check all that apply)
  - Competitive pressure

- Weak demand / willingness to pay
- Long-term contractual commitments
- Administrative effort
- Regulation / Pricing not under the firm's control
- Other, namely:

Duration of supply shortages

- October 2021: "If your production activity is currently limited by a shortage of raw materials or intermediate inputs: How long do you expect these supply shortages will persist?" ___ months
- May 2022: "If your production activity is currently limited by a shortage of raw materials or intermediate inputs: How long do you expect these supply shortages will persist?"___ months

Change in realized prices

- "The prices of our goods/services increased/stayed the same/decreased compared to [previous month]."

Change in revenues/demand

- "The demand situation has improved/not changed/deteriorated compared to [previous month]."

Range of orders

- "Our range of orders currently corresponds to an average production of ___ month(s)."

Capacity utilization

- "The utilization of our machines (normal full utilization = 100%) is currently" ___ % [tick box from 30% to 100 % in 5/10 p.p. steps, or enter value manually if larger than 100%]

Change in orders

- "Our range of orders increased/remained the same/decreased compared to [previous month]."

Production expectations for the next three months

- "Our production activity is expected to increase/remain roughly the same/decrease."

Energy intensity

- "What percentage share of revenue do you estimate your company spent on energy costs in 2021 (energy intensity)" ___ %

Business state, expectation, and uncertainty

- "We assess our current business state as:'" [continuous slider from 0 (bad) over 50 (satisfactory) to 100 (good)]
- "Expectations about the next six months: our expected business state in economic terms:" [continuous slider from 0 (rather worse) over 50 (the same) to 100 (rather better)]
- "We estimate the uncertainty regarding our business expectations in the next six months as:" [continuous slider from 0 (low) over 50 (average) to 100 (high)] ___ %

A.3 Supplementary questions (original)

Pass-through

- June 2021: "Zu welchem Grad können Sie die höheren Einkaufspreise an Ihre Kunden weitergeben? Wir können die höheren Einkaufspreise zu ___ % an unsere Kunden weitergeben."
- April 2022: "Zu welchem Grad können Sie höhere Einkaufspreise für Energie, Rohstoffe und Vormaterialien an Ihre Kunden weitergeben? Wir können die höheren Einkaufspreise zu ___ % an unsere Kunden weitergeben."
- October 2022: "Zu welchem Grad haben Sie die höheren Einkaufspreise für Energie, Rohstoffe und Vormaterialien bereits an Ihre Kunden weitergegeben?" ___%
- October 2022: "Zu welchem Grad planen Sie, in den kommenden 6 Monaten die höheren Einkaufspreise für Energie, Rohstoffe und Vormaterialien (inklusive bisheriger Preisanpassungen) an Ihre Kunden weiterzugeben?" ___%

Limiting factors for pass-through

- Welche Faktoren begrenzen den Spielraum Ihres Unternehmens bei der Preissetzung? (Bitte kreuzen Sie alles Zutreffende an)
  - Wettbewerbsdruck
  - schwache Nachfrage / Zahlungsbereitschaft
  - langfristige Vertragsbindung
  - administrativer Aufwand
  - Regulierung / Preissetzung liegt nicht beim Unternehmen
  - Sonstiges, und zwar:

Duration of supply shortages

- October 2021: "Falls Ihre Produktionstätigkeit zurzeit durch einen Mangel an Rohstoffen / Vormaterialien behindert wird: Was vermuten Sie, wie lange werden diese Probleme noch anhalten?" ___ Monate
- May 2022: "Falls Ihre Produktionstätigkeit zurzeit durch Mangel an Rohstoffen oder Vormaterialien/ Lieferengpässe/ Materialknappheit behindert wird: Was vermuten Sie, wie lange werden diese Probleme noch anhalten?" ___ Monate

Change in revenues/demand

- "Die Nachfragesituation hat sich im Vergleich zum [Vormonat] gebessert/nicht verändert/verschlechtert."

Range of orders

- "Unsere Auftragsbestände entsprechen derzeit einer durchschnittlichen Produktion von ___ Monat(en)"

Capacity utilization

- "Die Ausnutzung unserer Anlagen (betriebsübliche Vollausnutzung = 100%) beträgt gegenwärtig" ___ % [tick box from 30% to 100 % in 5/10 p.p. steps, or enter value manually if larger than 100%]

Change in orders

- "Unser Auftragsbestand ist im Vergleich zum [Vormonat] gestiegen/etwa gleich geblieben/gesunken"

Production expectations for the next three months

- "Unsere Produktionstätigkeit wird voraussichtlich steigen/etwa gleich bleiben/abnehmen."

Energy intensity

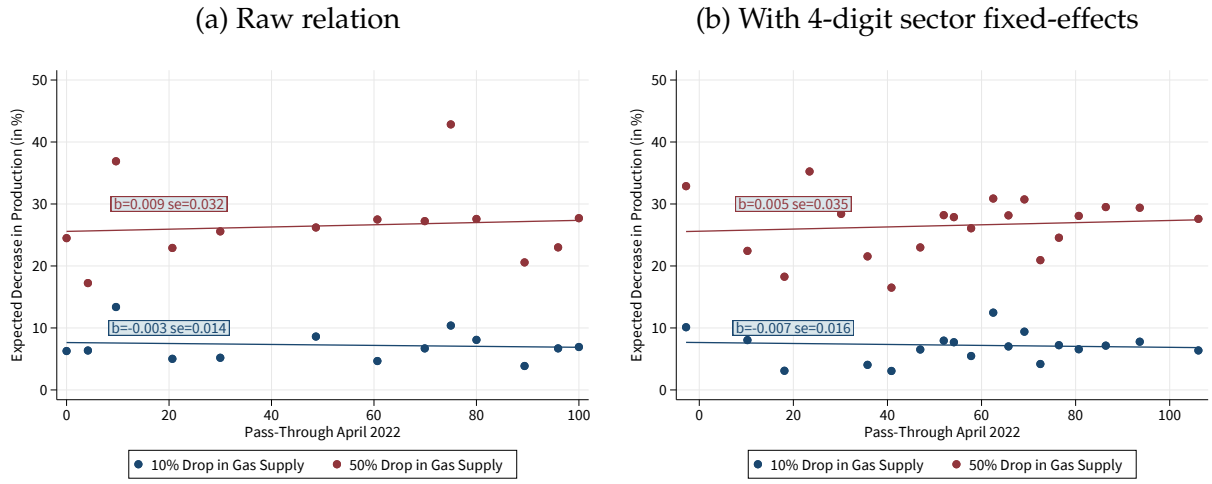
- "Was schätzen Sie, welchen Anteil des Umsatzerlöses musste Ihr Unternehmen 2021 für Energiekosten aufwenden (Energieintensität)?" ___ %

Business state, expectation, and uncertainty

- "Wir beurteilen unsere Geschäftslage als:'" [continuous slider from 0 (bad) over 50 (satisfactory) to 100 (good)]
- "Erwartungen für die nächsten 6 Monate: Unsere Geschäftslage wird in konjunktureller Hinsicht:" [continuous slider from 0 (rather worse) over 50 (the same) to 100 (rather better)]
- "Die Unsicherheit hinsichtlich unserer Geschäftsentwicklung in den nächsten 6 Monaten schätzen wir wie folgt ein:" [continuous slider from 0 (low) over 50 (average) to 100 (high)] ___ %

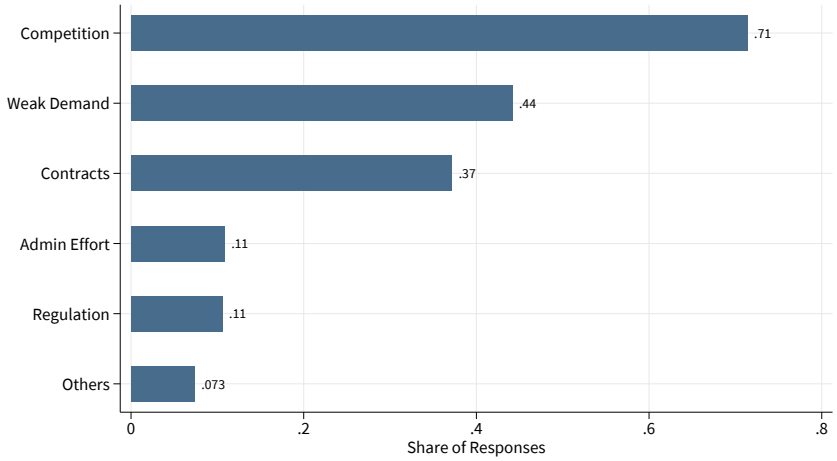
A.4 Additional Results

Figure A.2: Binned scatterplots of pass-through and expected effects of gas supply shortages



Notes: The figure shows binned scatterplots between the pass-through until 04/2022 and the expected decrease in production if gas supply were to be cut by 10% (navy) or 50% (maroon). The estimated slope coefficients and standard errors are reported in the figure. Source: ifo Institute's business survey.

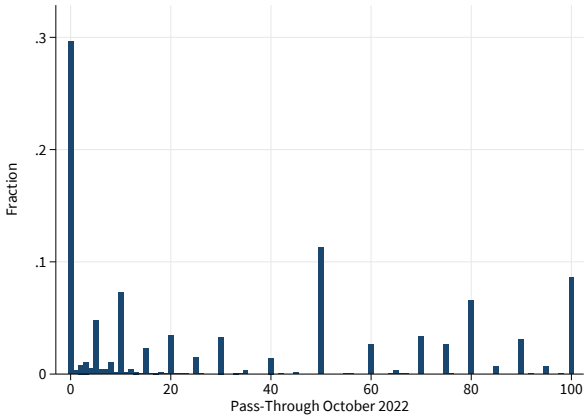
Figure A.3: Limiting factors for pass-through



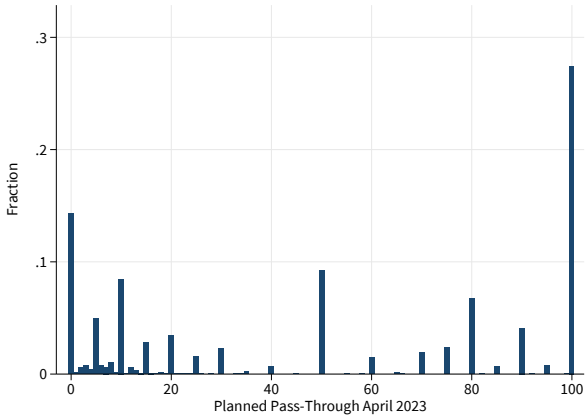
Notes: The figure presents the share of respondents reporting that the following factors limit pass-through: competition, weak demand, long-term contracts, administrative effort/burden, regulatory reasons, and others. Multiple answers possible. Source: ifo Institute's business survey.

Figure A.4: Heterogeneous pass-through across firms

(a) October 2022



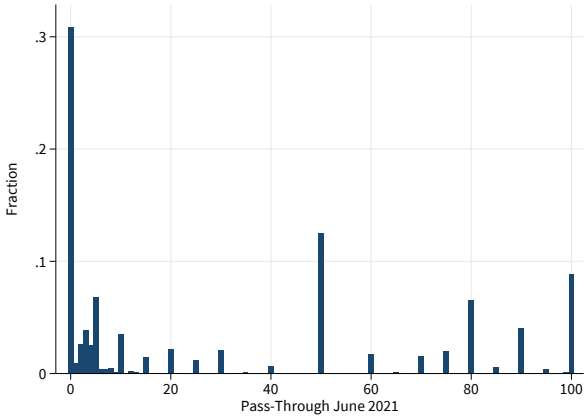
(b) April 2023



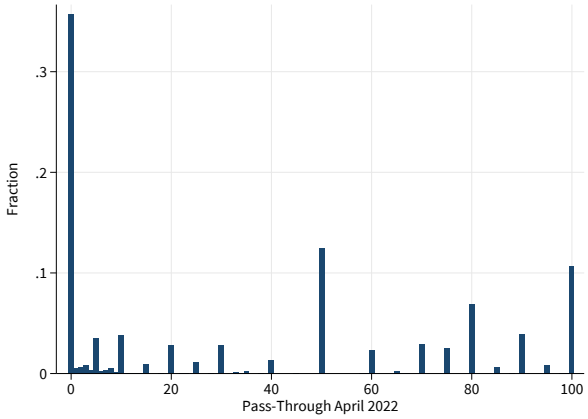
Notes: The figure shows the distribution of firm-level pass-through of cost changes to sales prices for October 2022 and planned pass-through until April 2023 (conditional on cost changes until October 2022). Source: ifo Institute's business survey.

Figure A.5: Heterogeneous pass-through across firms

(a) June 2021

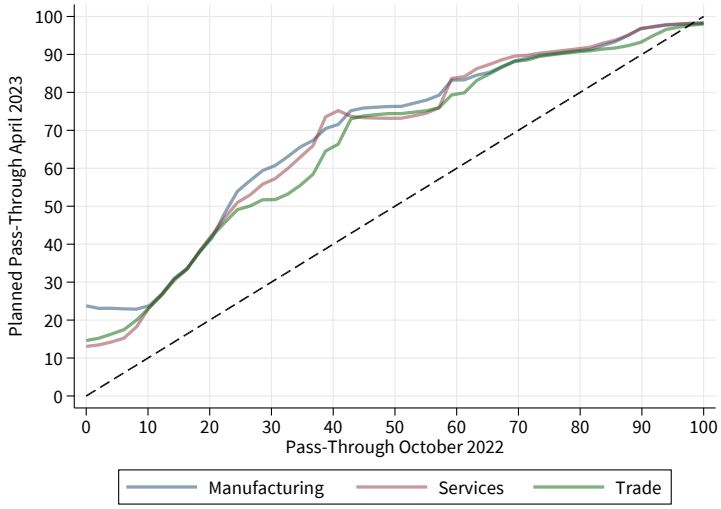


(b) April 2022



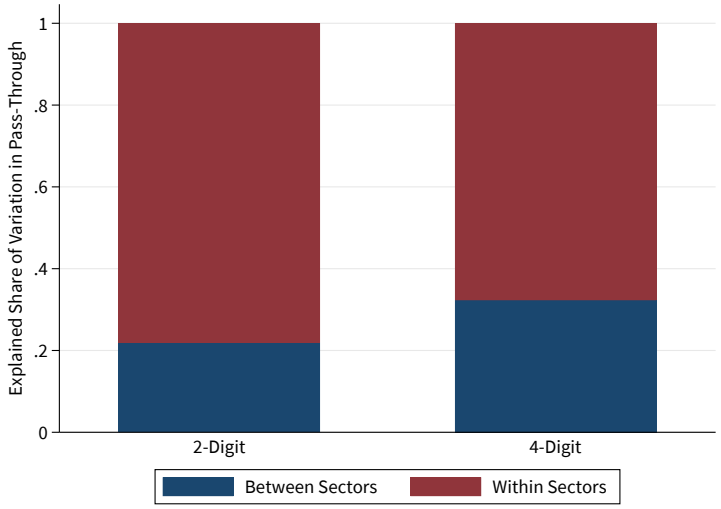
Notes: The figure shows the distribution of firm-level pass-through of cost changes to sales prices for June 2021 (only manufacturing) and April 2022. Source: ifo Institute's business survey.

Figure A.6: Gradual increase of pass-through over time (sector split)



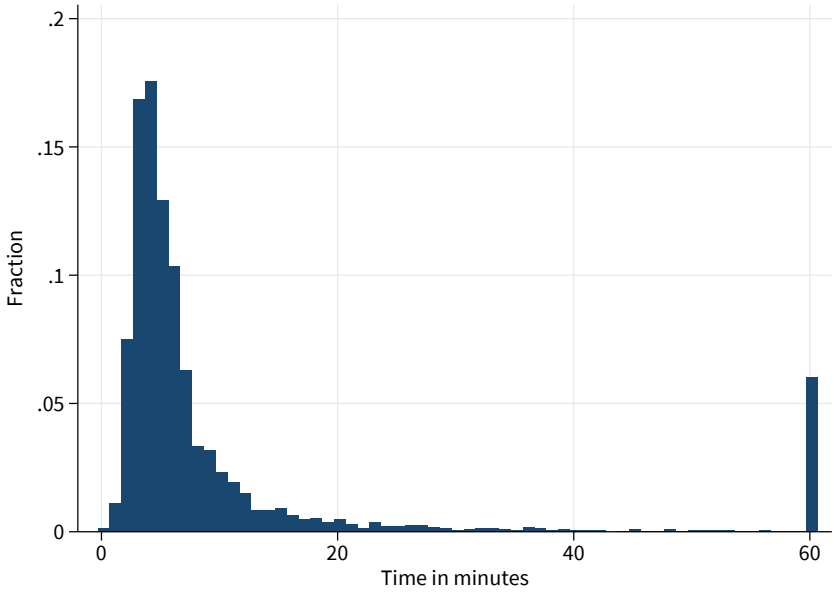
Notes: The figure shows the change in pass-through of cost changes to sales prices from October 2022 to April 2023, conditional on cost changes until October 2022, separately for the manufacturing sector, services sector, and trade sector. Source: ifo Institute's business survey.

Figure A.7: Cross-sectional variation in pass-through within and between sectors: Drop short time spent



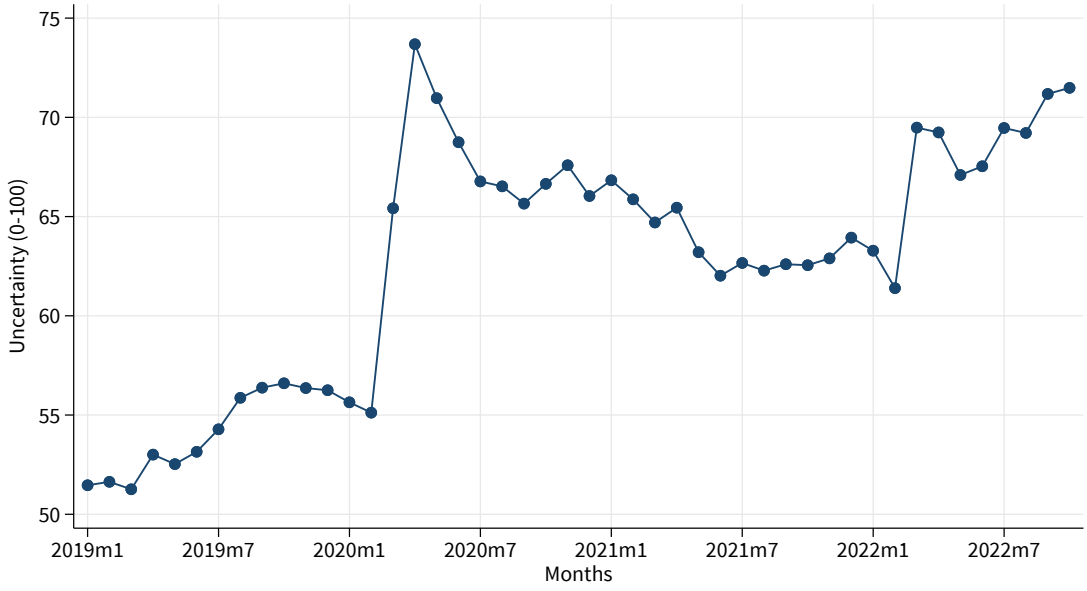
Notes: The stacked bar figure shows the R^2 of sector fixed effects on 2-digit and 4-digit level of pass-through in October 2022 (blue). The remaining variation is within sectors (red). The decomposition is based on a subsample, where time spent on the survey is observable and time spent is above the 25th percentile. Source: ifo Institute's business survey.

Figure A.8: Cross-sectional histogram time spent



Notes: The figure shows the histogram of time spent on the survey in minutes (October 2022). The information on time spent is only observable for firms who participate online. Source: ifo Institute's business survey.

Figure A.9: Time-series of average firm-level uncertainty



Notes: The figure shows the time-series of average firm-level uncertainty, measured by a quantitative slider from 0-100 about the business uncertainty in the next six months. Source: ifo Institute's business survey.

Table A.1: Pass-through until 10/2022 and return on sales in 2019 and 2022

	(1)	(2)	(3)	(4)
Return on Sales 2019	-0.80**	-0.68**	-0.84***	-0.69**
	(0.32)	(0.32)	(0.31)	(0.32)
Return on Sales 2022	1.25***	1.21***	1.20***	1.15***
	(0.30)	(0.30)	(0.29)	(0.30)
Log Employees			2.76***	2.36***
			(0.74)	(0.77)
Constant	47.1***	46.8***	34.9***	36.4***
	(1.33)	(1.33)	(3.59)	(3.74)
Observations	1078	1078	1078	1078
R^2	0.018	0.089	0.030	0.097
Sector FE	No	Yes	No	Yes

Notes: The table reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices until 10/2022 on the return on sales (ROS) in 2019 and 2022. The ROS of the current year is elicited in September in the survey. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ifo Institute's business survey.

Table A.2: Pass-through until 10/2022 and uncertainty at industry level

	(1)	(2)
Uncertainty	1.28***	1.33***
	(0.27)	(0.37)
Business State		1.22***
		(0.39)
Business Expectations		-1.17**
		(0.45)
Constant	-61.2***	-79.6
	(18.8)	(48.1)
Observations	49	49
R^2	0.267	0.476

Notes: The table reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices until 10/2022 on uncertainty aggregated at 2-digit industries (at least 20 obs. per industry). Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ifo Institute's business survey.

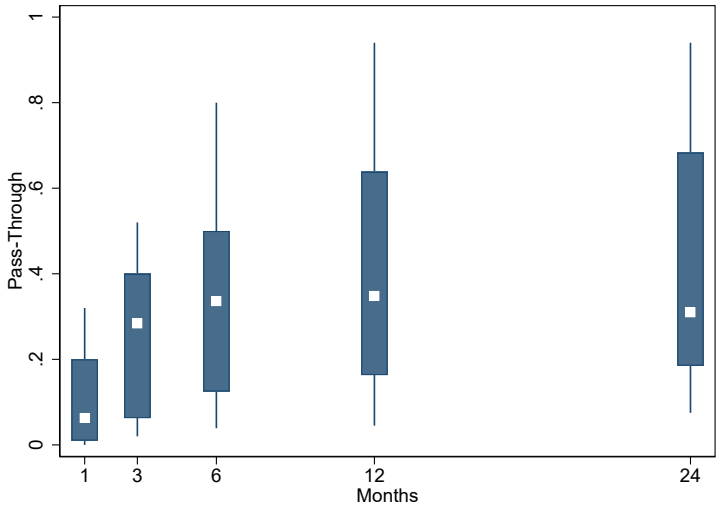
Table A.3: Pass-through until 10/2022 and uncertainty at firm level

	(1)	(2)	(3)	(4)
Uncertainty	0.18***	0.19***	0.093***	0.10***
	(0.023)	(0.025)	(0.023)	(0.023)
Business State		0.26***	0.22***	0.19***
		(0.025)	(0.023)	(0.023)
Business Expectations		-0.20***	-0.083***	-0.058**
		(0.030)	(0.028)	(0.028)
Constant	20.7***	15.3***	19.8***	19.4***
	(1.71)	(2.65)	(2.46)	(2.46)
Observations	4689	4689	4689	4689
R^2	0.014	0.039	0.235	0.316
Industry FE	No	No	2-Digit	4-Digit

Notes: The table reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices until 10/2022 on uncertainty. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ifo Institute's business survey.

B Pass-Through Estimates in the Literature

Figure B.1: Box plots of pass-through estimates in the literature



Notes: Comparison of pass-through estimates of selected papers in the literature, listed in Table B.1.

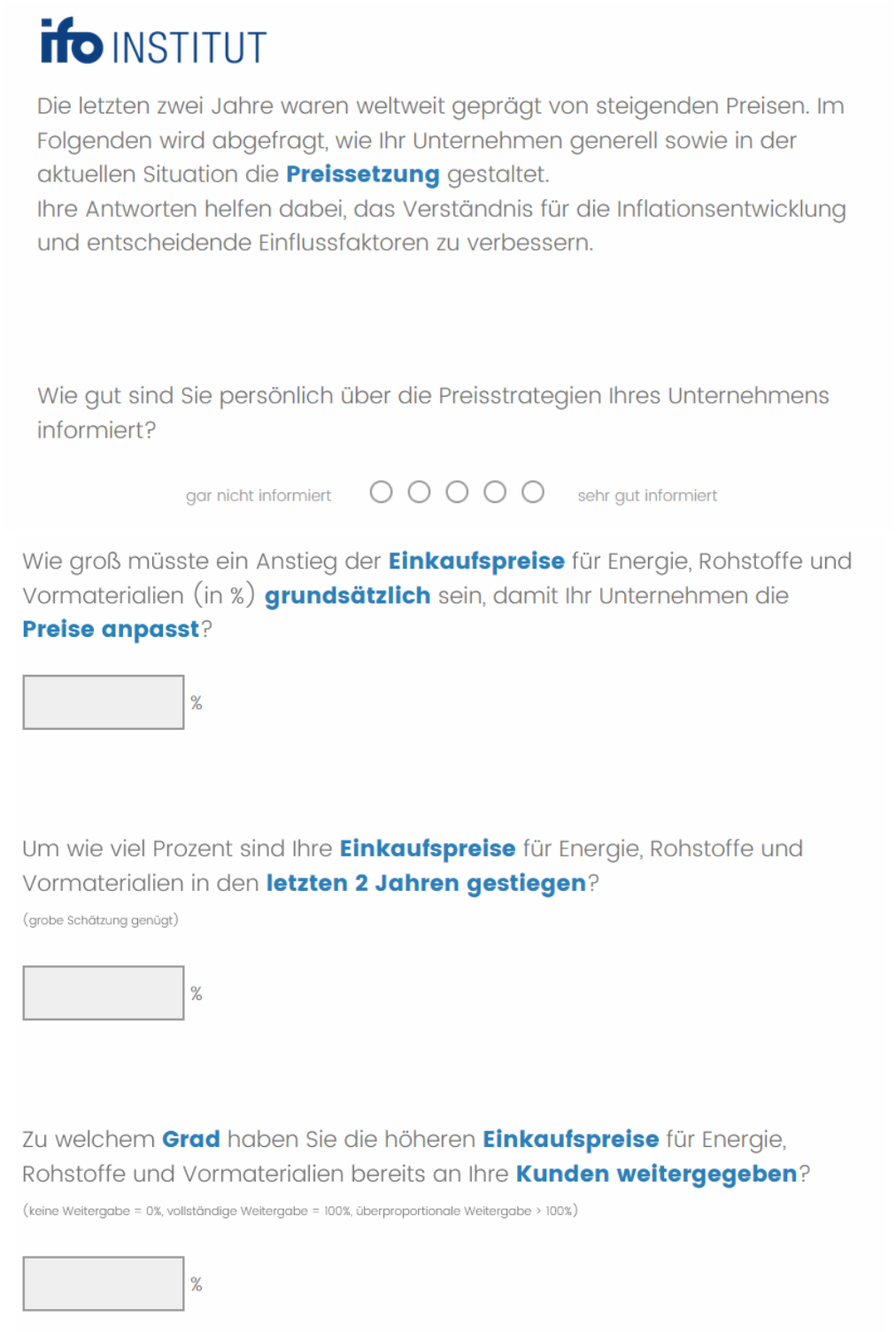
Table B.1: Pass-through estimates across studies

Paper	Specification	0	1	2	3	4	5	6	12	24
Dedola et al. (2021)	energy cost	0,04	0.03	0.13	0.18	0.27	0.26	0.34	0.64	0.68
	import cost shock	0.28	0.34	0.35	0.40	0.41	0.39	0.38	0.35	0.21
Yagi et al. (2022)	material cost, JPN	0.20			0.40			0.55	0.70	0.81
	material cost pass-through USA	0.32			0.52			0.80	1.06	1.15
	exchange-rate pass-through JPN	0.01			0.02			0.03	0.05	0.05
Nakamura and Zerom (2010)	commodity cost to retail prices	0.06			0.17			0.18	0.26	0.25
	commodity cost to wholesale prices	0.12			0.28			0.27	0.27	0.26
Gopinath and Itskhoki (2010)	all countries, high freq. adjustments		0.00	0.04	0.06	0.11	0.11	0.13	0.16	0.16
	all countries, low freq. adjustments		0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.08
	high-income OECD high freq		0.04	0.10	0.11	0.16	0.19	0.21	0.35	0.44
	high-income OECD low freq		0.00	0.02	0.04	0.07	0.07	0.07	0.13	0.19
Gopinath et al. (2010)	goods priced in non-dollars		0.96	0.92	0.95	0.95	0.98	0.98	0.94	0.94
	aggregate		0.22	0.22	0.25	0.26	0.27	0.27	0.28	0.31
	goods priced in dollars		0.03	0.04	0.06	0.07	0.08	0.09	0.12	0.15
Neiman (2010)	intrafirm		0.00				0.04			
	arm´s length		0.00				0.04			
Ahlander et al. (2023)	OLS	0.25	0.29	0.33	0.33	0.29	0.20	0.35		
	IV	-0.03	0.05	0.30	0.30	0.30	0.20	0.35	0.40	0.45

Notes: Comparison of pass-through estimates across selected papers in the literature. Horizon from zero to 24 months. Full title and author details on the individual papers are deferred to references. For papers with more than one baseline pass-through estimate, the specification is specified.

C ifo Management-Survey

C.1 Original Questionnaire



ifo INSTITUT

Die letzten zwei Jahre waren weltweit geprägt von steigenden Preisen. Im Folgenden wird abgefragt, wie Ihr Unternehmen generell sowie in der aktuellen Situation die **Preissetzung** gestaltet.
Ihre Antworten helfen dabei, das Verständnis für die Inflationsentwicklung und entscheidende Einflussfaktoren zu verbessern.

Wie gut sind Sie persönlich über die Preisstrategien Ihres Unternehmens informiert?

gar nicht informiert ○ ○ ○ ○ ○ sehr gut informiert

Wie groß müsste ein Anstieg der **Einkaufspreise** für Energie, Rohstoffe und Vormaterialien (in %) **grundsätzlich** sein, damit Ihr Unternehmen die **Preise anpasst**?

[ ] %

Um wie viel Prozent sind Ihre **Einkaufspreise** für Energie, Rohstoffe und Vormaterialien in den **letzten 2 Jahren gestiegen**?

(grobe Schätzung genügt)

[ ] %

Zu welchem **Grad** haben Sie die höheren **Einkaufspreise** für Energie, Rohstoffe und Vormaterialien bereits an Ihre **Kunden weitergegeben**?

(keine Weitergabe = 0%, vollständige Weitergabe = 100%, überproportionale Weitergabe > 100%)

[ ] %

Welche wesentlichen **Faktoren begrenzen den Preissetzungsspielraum** Ihres Unternehmens?

Bitte priorisieren Sie.

wichtigster Faktor	
zweitwichtigster Faktor	
drittwichtigster Faktor	

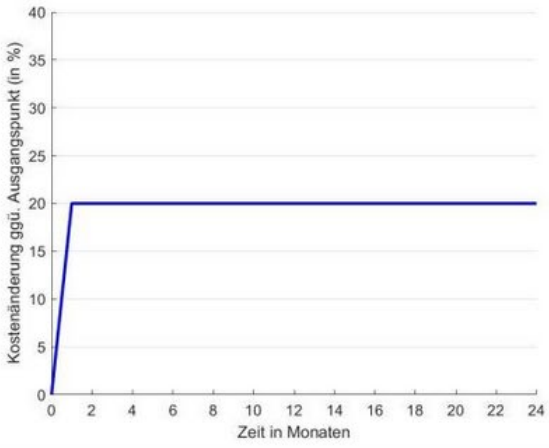
Wie hoch war der **Jahresüberschuss nach Steuern bzw. Verlust** Ihres Unternehmens in **% des Nettoumsatzes** in den Jahren 2018 und 2022?

(grobe Schätzung genügt)

2018:		%
2022:		%

Versetzen Sie sich bitte nun in die folgenden **hypothetischen Szenarien**.

Stellen Sie sich vor, dass die **Einkaufspreise** für Sie und Ihre Konkurrenten in der Branche **dauerhaft um 20%** steigen aufgrund eines globalen Angebotsschocks (siehe Abbildung). Alle weiteren Faktoren, wie beispielsweise die Zinsentwicklung und fiskalpolitische Maßnahmen, bleiben unverändert. Nehmen Sie als Ausgangspunkt eine **gute wirtschaftliche Lage mit normaler Auslastung** für Ihr Unternehmen und die Gesamtwirtschaft an.



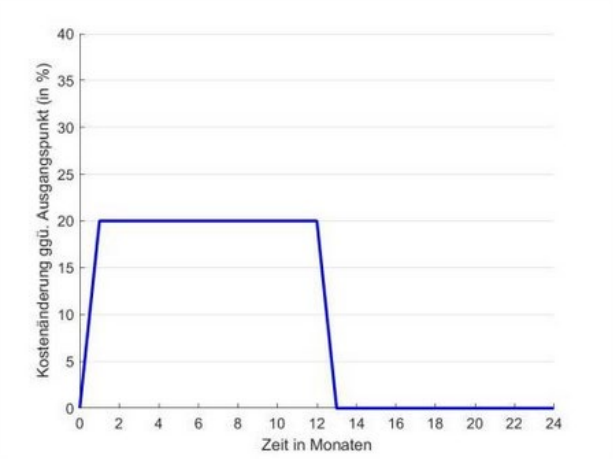
Zu welchem Grad würden Sie die Kostenanstiege in diesem Szenario an Ihre Kunden weitergeben?

(keine Weitergabe = 0%, vollständige Weitergabe = 100%, überproportionale Weitergabe > 100%)

Geben Sie an, wie hoch die Weitergabe zu dem jeweiligen Zeitpunkt ist.

	4 Wochen	3 Monate	6 Monate	12 Monate	24 Monate
Weitergabe in % innerhalb der nächsten...					

Stellen Sie sich nun die gleichen Gegebenheiten vor wie in der vorhergehenden Frage, mit dem einzigen Unterschied, dass der Kostenanstieg nicht dauerhaft ist, sondern **temporär für 12 Monate** (siehe Abbildung).



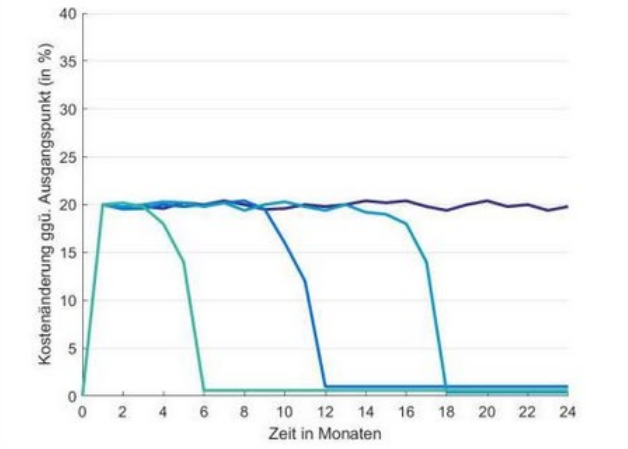
Zu welchem Grad würden Sie die Kostenanstiege in diesem Szenario an Ihre Kunden weitergeben?

(keine Weitergabe = 0%, vollständige Weitergabe = 100%, überproportionale Weitergabe > 100%)

Geben Sie an, wie hoch die Weitergabe zu dem jeweiligen Zeitpunkt ist.

	4 Wochen	3 Monate	6 Monate	12 Monate
Weitergabe in % innerhalb der nächsten...				

Stellen Sie sich nun die gleichen Gegebenheiten vor wie in der vorhergehenden Frage, mit dem einzigen Unterschied, dass der Angebotsschock nicht dauerhaft sein muss, sondern die **Dauer** der Kostenerhöhung **ungewiss** ist (siehe Abbildung mit Beispielen für mögliche Preispfade).
Mit gleicher Wahrscheinlichkeit (~10 %) kann die Kostenerhöhung jeden Monat wieder zurückgehen.



Zu welchem Grad würden Sie die Kostenanstiege in diesem Szenario an Ihre Kunden weitergeben?
Nehmen Sie an, dass zu dem jeweiligen Zeitpunkt die Kostenerhöhung noch vorhanden ist.

(keine Weitergabe = 0%, vollständige Weitergabe = 100%, überproportionale Weitergabe > 100%)

	4 Wochen	3 Monate	6 Monate	12 Monate	24 Monate
Weitergabe in % innerhalb der nächsten...					

Zu welchem Grad würden Sie die Kostenanstiege weitergeben, wenn **nur Ihr Unternehmen** und **nicht die gesamte Branche** betroffen ist? Gehen Sie von den gleichen Rahmenbedingen wie in den vorhergehenden Fragen aus. Bitte geben Sie die Preisweitergabe **nach 6 Monaten** in diesen Szenarien an.

Permanenter Kostenanstieg (bei dem branchenweiten Kostenanstieg haben Sie % angegeben):

Temporärer Kostenanstieg (bei dem branchenweiten Kostenanstieg haben Sie % angegeben):

Unsichere Dauer (bei dem branchenweiten Kostenanstieg haben Sie % angegeben):

Anmerkungen:

Wurde aufgrund von starken Kostenerhöhungen das Produktangebot umstrukturiert?

- ○ ja
- ○ nein
- ○ nicht zutreffend

C.2 English translation

The last two years have been globally marked by rising prices. The following survey asks how your company approaches price setting generally as well as in the current situation. Your answers will help improve understanding of inflation dynamics and crucial decision-making factors.

1. How well-informed are you personally about your company's pricing strategies?

   uninformed ○ ○ ○ ○ ○ well informed

2. What would be the minimum cost increase for energy, raw materials, and intermediate input goods (in %) for your company to adjust prices?
   _____ %

3. By how much (in %) have input prices for energy, raw materials, and intermediate input goods increased in the last two years?
   _____ %

   (Rough estimate is sufficient)

4. To what extent have you already passed through the higher input prices for energy, raw materials, and intermediate input goods to your customers?
   _____ %

   (No pass-through = 0%, full pass-through= 100%, disproportionate pass-through> 100%)

5. What key factors limit your company's pricing flexibility? Please prioritize them.
   Most important factor: _____
   Second most important factor: _____
   Third most important factor: _____

6. What was your company's annual net profit or loss as a percentage of net sales in 2018 and 2022?
   _____ %

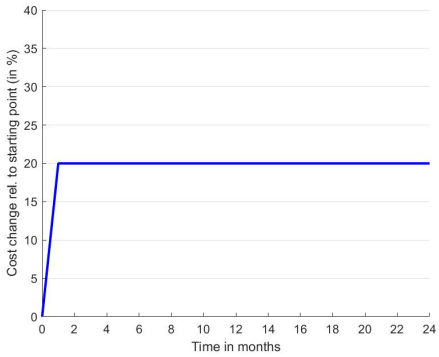
   (Rough estimate is sufficient)

---

7. Please now imagine the following hypothetical scenarios.

   Suppose that purchase prices for you and your competitors in the industry permanently increase by 20% due to a global supply shock (see figure). All other factors,

such as interest rates and fiscal policy measures, remain unchanged. Assume [good economic conditions][28] with normal capacity utilization for your company and the overall economy.

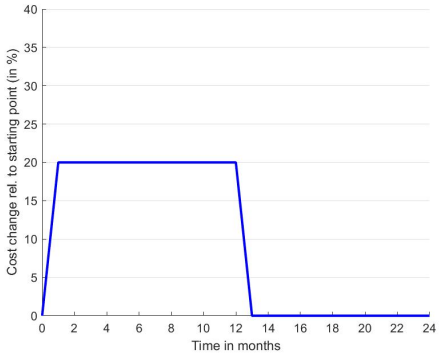


To what extent would you pass through the cost increase to your customers in this scenario? Indicate the level of pass-through at the respective point in time.

	4 weeks	3 months	6 months	12 months	24 months
Pass-through in % after ...	☐	☐	☐	☐	☐

(No pass-through = 0%, full pass-through= 100%, disproportionate pass-through> 100%)

8. Now, imagine the same circumstances as in the previous question, with the only difference that the cost increase is not permanent but temporary for 12 months (see figure).



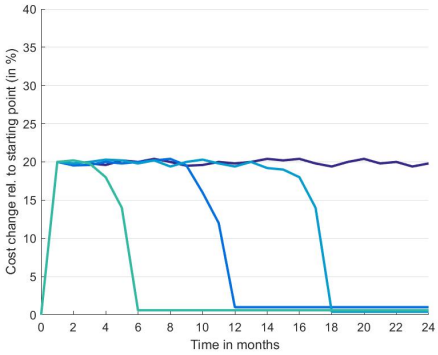
To what extent would you pass through the cost increase to your customers in this scenario? Indicate the level of pass-through at the respective point in time.

[28] Economic conditions vary across participants: good economic conditions vs. bad economic conditions.

	4 weeks	3 months	6 months	12 months
Pass-through in % after ...	☐	☐	☐	☐

(No pass-through = 0%, full pass-through= 100%, disproportionate pass-through> 100%)

9. Now, imagine the same circumstances as in the previous question, with the only difference that the cost increase is not necessarily permanent, but the duration of the cost increase is uncertain (see figure with examples of possible price paths). There is an equal probability (10%) that the cost increase could peak off every month.



To what extent would you pass through the cost increase to your customers in this scenario? Indicate the level of pass-through at the respective point in time. Assuming that at each respective point in time, the cost increase is still present.

	4 weeks	3 months	6 months	12 months	24 months
Pass-through in % after ...	☐	☐	☐	☐	☐

(No pass-through = 0%, full pass-through= 100%, disproportionate pass-through> 100%)

10. To what extent would you pass through cost increases if only your company, and not the entire industry, is affected? Assuming the same conditions as in the previous questions, please indicate the degree of price pass-on after 6 months in these scenarios.

- Permanent cost increase (for the industry-wide increase you stated ☐%): _____%
- Temporary cost increase (for the industry-wide increase you stated ☐%): _____%
- Uncertain duration (for the industry-wide increase you stated ☐%): _____%

11. Has your product portfolio been restructured due to significant cost increases?
    Yes ☐
    No ☐
    Not applicable ☐

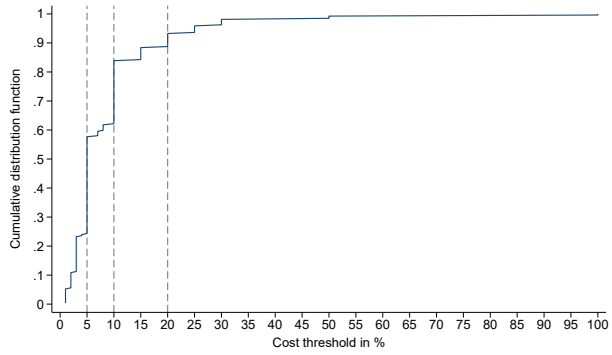
12. If yes, in what manner?

    _____

    Thank you for your participation!

C.3 Additional results

Figure C.1: Threshold of cost increases for pass-through

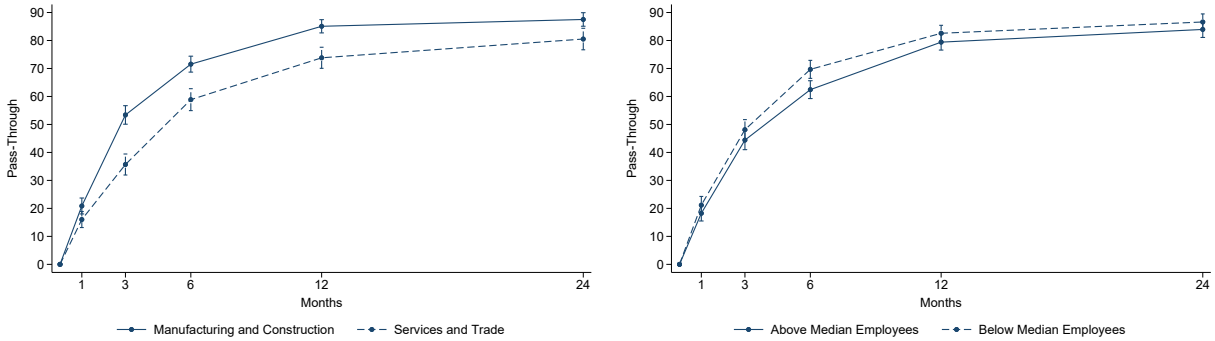


Notes: The figure plots the cumulative density function of the minimum required cost increase (in %) for a firm to change prices. 5%, 10%, and 20% cost threshold levels are highlighted by the dashed lines. Source: ifo Institute's Management-Survey.

Figure C.2: Heterogeneity of pass-through across sectors and firm size

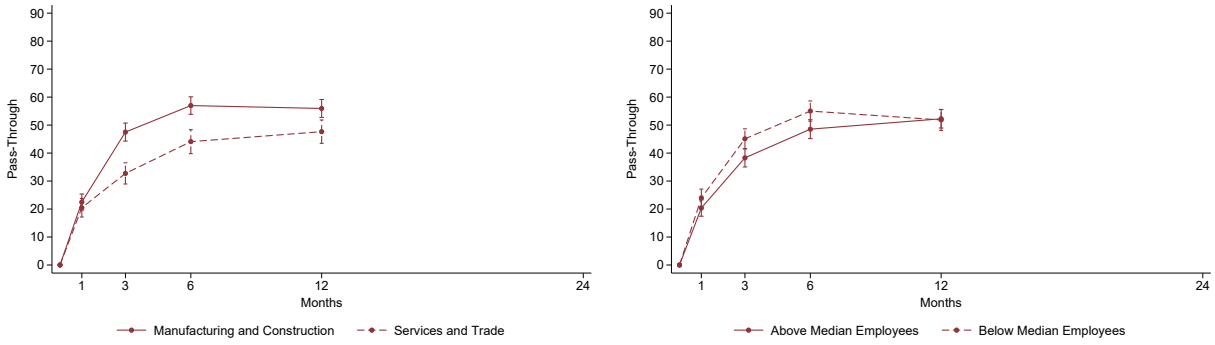
(a) Permanent shock by sector

(b) Permanent shock by size



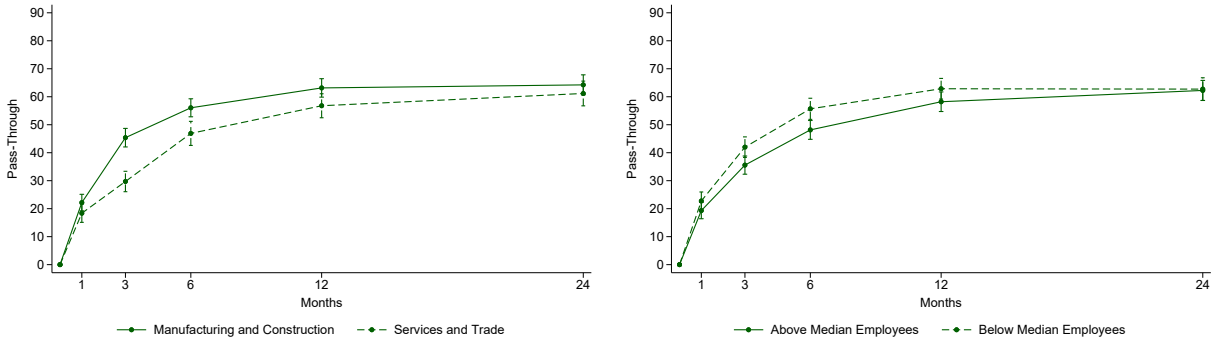
(c) Transitory shock by sector

(d) Transitory shock by size



(e) Uncertain shock by sector

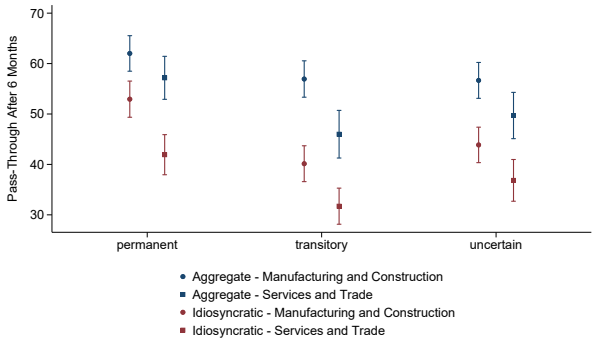
(f) Uncertain shock by size



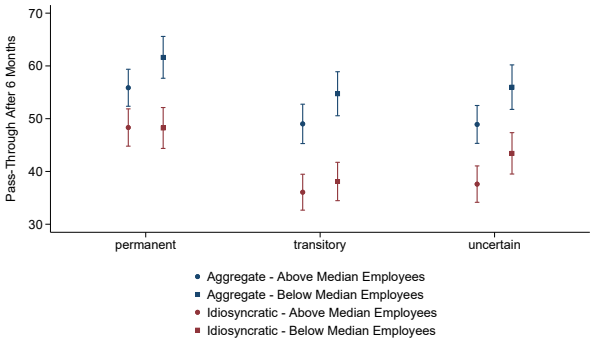
Notes: The figure plots the pass-through of cost-push shocks across horizons, split by sector (left column) and size (right column). The rows refer to the nature of the shock, differing between permanent, transitory, and uncertain duration shocks, in blue, green, and red colors, respectively. The whiskers reflect the 68% confidence interval (one standard deviation). Source: ifo Institute's Management-Survey.

Figure C.3: Aggregate vs idiosyncratic pass-through across sectors and firm size

(a) Heterogeneity by sector



(b) Heterogeneity by size



Notes: The figure shows the pass-through of permanent vs. idiosyncratic cost-push shocks after six months, depending on the nature of the shock, differing between permanent, transitory, and uncertain duration shocks. The left column splits firms by sector, and the right column by firm size. The whiskers reflect the 68% confidence interval (one standard deviation). Source: ifo Institute's Management-Survey.

Table C.1: Factors limiting firm's price setting (open-ended question)

Factor	%
Competition	41
Customers	16
Market	10
Contracts	9
Demand	3
Regulation	2
Fixed prices	2
Energy	2
Input prices	2
Employees	2
Others	11

Notes: The table presents the share of respondents (in %), stating that the above factor limits the firm's price setting. The results are based on an open-ended survey question, see Appendix C.2 for the exact wording (question 5). We focus on the "most important factor", the first out of three text boxes. The ten categories group similar answers. *Others* summarizes all factors stated once and cannot be assigned to the other categories. Source: ifo Institute's Management-Survey.

Table C.2: Expected duration of the shock and pass-through in April 2022

	(1)	(2)	(3)	(4)	(5)	(6)
Duration Supply (Oct. 21)	0.68***	0.72**	0.83***			
	(0.22)	(0.28)	(0.31)			
Duration Supply (June 22)				0.38***	0.51***	0.56**
				(0.12)	(0.17)	(0.22)
Range of Orders (April 22)		-0.97**	-0.94**		-0.97***	-1.09***
		(0.39)	(0.47)		(0.28)	(0.39)
Capacity Utilization (April 22)		0.49***	0.65***		0.13	0.39***
		(0.11)	(0.14)		(0.087)	(0.13)
Change in Revenues (April 22)		2.90	3.81		4.72**	5.55**
		(2.28)	(2.70)		(1.95)	(2.65)
Change in Orders (April 22)		2.05	-1.21		2.49	0.25
		(2.11)	(2.74)		(2.01)	(2.88)
Production Expectations (April 22)		-1.02	-1.56		3.55	-0.71
		(2.50)	(2.84)		(2.27)	(3.08)
Log Employees		0.61	-0.26		1.54*	2.36*
		(0.97)	(1.25)		(0.88)	(1.24)
Cost Changes (March-May 21)			0.11**			0.16*
			(0.054)			(0.079)
Energy Intensity 21			-0.93***			-0.59**
			(0.25)			(0.27)
Constant	45.1***	5.05	-1.16	44.7***	29.7***	6.96
	(1.75)	(9.62)	(11.7)	(1.26)	(7.51)	(12.3)
Observations	951	732	561	1095	878	511
R^2	0.202	0.262	0.287	0.179	0.221	0.265

Notes: The table reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices in April 2022 on the expected duration of supply shortages in months (elicited in October 2021 and June 2022) in the manufacturing sector. Columns 2 and 5 control for the range of orders in months, capacity utilization in percent, the qualitative change in revenues, qualitative change in orders, qualitative production expectations, and log employees. Columns 3 and 6 additionally control for the energy intensity (measured as the share of energy costs in terms of revenues) and cost changes between March and May 2021. All specifications control for 4-digit industry fixed effects. Appendix A provides the wording of the specific questions. Clustered standard errors at the 4-digit industry level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ifo Institute's business survey.

Discussion of other variables in Table C.2 The coefficients of the control variables in Table C.2 are also of interest to itself. For instance, the negative coefficient on the range of orders in months indicates the existence of nominal rigidities. Firms with an extended range of orders cannot pass through increased costs due to existing contracts with fixed prices. In addition, a more significant cost increase is associated with a higher pass-through. Intuitively, large cost increases imply large adjustment gains relative to the fixed costs of

adjusting prices. Lastly, there is a negative effect of energy exposure on pass-through. This may be attributed to two potential factors: first, energy costs are part of firms' fixed costs and are therefore to a first order irrelevant for pricing off marginal costs; second, firms' energy costs are very volatile and hence, as just discussed, firms have a lower incentive to respond to transitory shocks.

Table C.3: Change in expected duration of the shock and pass-through until April 2023

	(1)	(2)	(3)	(4)	(5)	(6)
Δ Duration Supply	0.48**	0.56**	0.59**			
	(0.21)	(0.24)	(0.26)			
Δ Duration Supply (winsorized)				0.70**	0.69**	0.74**
				(0.30)	(0.31)	(0.33)
Pass-Through (April 22)	0.40***	0.42***	0.45***	0.40***	0.42***	0.45***
	(0.049)	(0.055)	(0.060)	(0.048)	(0.055)	(0.059)
Range of Orders (April 22)		1.21***	1.18**		1.22***	1.19**
		(0.45)	(0.46)		(0.45)	(0.46)
Capacity Utilization (April 22)		0.11	0.061		0.11	0.063
		(0.13)	(0.16)		(0.13)	(0.16)
Change in Revenues (April 22)		-1.18	-1.54		-1.13	-1.49
		(2.37)	(2.42)		(2.36)	(2.41)
Change in Orders (April 22)		1.50	0.52		1.55	0.54
		(2.94)	(3.02)		(2.93)	(2.99)
Production Expectations (April 22)		-6.17**	-4.93		-6.04**	-4.77
		(2.93)	(3.43)		(2.93)	(3.44)
Log Employees		0.95	0.68		0.91	0.63
		(1.20)	(1.48)		(1.21)	(1.49)
Energy Intensity 21			-0.59**			-0.58**
			(0.26)			(0.26)
Cost Changes (March-May 21)			0.020			0.013
			(0.100)			(0.10)
Constant	44.9***	25.2**	31.9**	44.3***	25.0**	31.7**
	(2.54)	(11.5)	(14.9)	(2.52)	(11.5)	(14.9)
Observations	592	467	379	592	467	379
R^2	0.341	0.387	0.413	0.342	0.388	0.414

Notes: The table reports estimates from linear regressions of the firm-level pass-through of cost changes to sales prices until April 2023 on the change of expected duration of supply shortages in months from October 2021 to June 2022 in the manufacturing sector. In Columns 4-6, the change in the duration of supply shortages is winsorized at the 5th and 95th percentiles. Columns 2 and 5 control for the range of orders in months, capacity utilization in percent, the qualitative change in revenues, qualitative change in orders, qualitative production expectations, and log employees. Columns 3 and 6 additionally control for the energy intensity (measured as the share of energy costs in terms of revenues) and cost changes between March and May 2021. All specifications control for 4-digit industry fixed effects. Appendix A provides the wording of the specific questions. Clustered standard errors at the 4-digit industry level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ifo Institute's business survey.

Table C.4: Estimates of **K** in the literature

	ARRS (2023)			RW (1997)	Gali (2008)	NS (2014)	HHNS (2023)
	GL	NS	Calvo				
K	1.71	0.47	0.08	0.0095	0.0425	0.00385	0.0031

Notes: The table summarizes estimates in the literature. ARRS: Auclert et al. (2023) with calibration to GL (Golosov and Lucas, 2007), NS (Nakamura and Steinsson, 2014), and a Calvo setting; RW: Woodford and Rotemberg (1997); Gali (2008); NS: Nakamura and Steinsson (2014); HHNS: Hazell et al. (2022).

D Additional Model Details and Results

D.1 Calibration

Table D.1: Calibration for the menu-cost model with micro real rigidities

Parameter	Description	Value
β	Discount factor	$0.96^{1/12}$
γ	Relative risk aversion	1.5
ϕ	Inverse of Frisch elasticity of labor supply	1
L^*	Steady-state labor share	1/3
sm	Material input share	0.7
$\bar{\theta}$	Elasticity of demand	4
μ	Trend inflation (monthly)	0.0015906
σ_S	St. dev. of nominal demand shock	0.0015883
σ_A	St. dev. of productivity shock	0.046
ρ_A	Persistence of productivity shock	0.7
ρ_S	Persistence of nominal demand shock	1

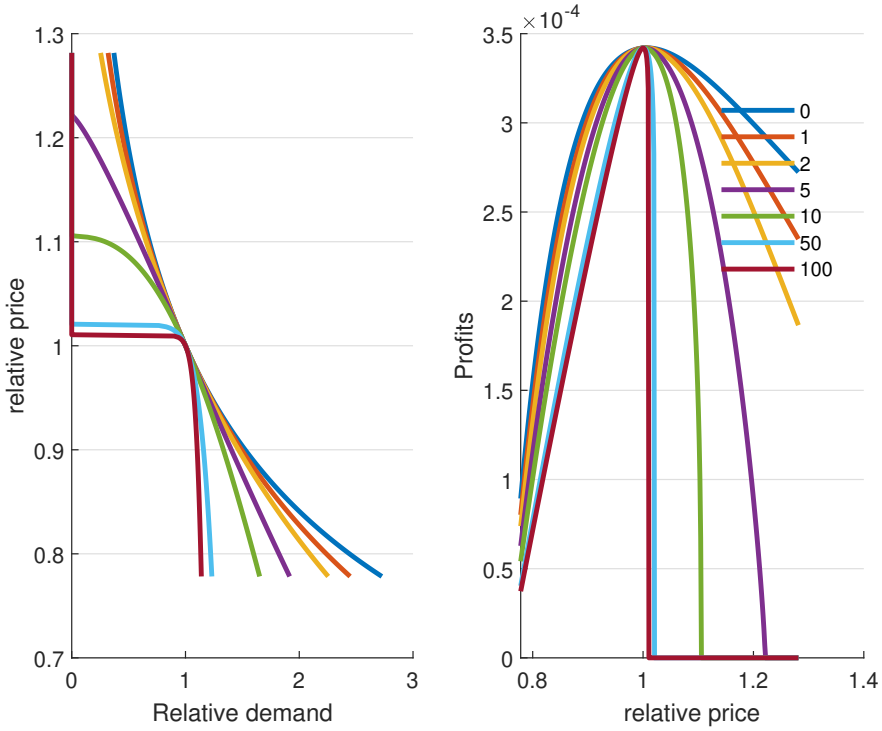
The trend inflation rate μ and standard deviation of the nominal demand σ_S are calculated as the average and standard deviation of the German Harmonised Index of Consumer Prices (HICP) for 1997 to 2023.

D.2 Simulated method of moments

We simulate data for a broad range of menu cost values and real rigidities, estimate the pass-through dynamics and frequency of price changes for each parameter combination, and calculate the weighted value function for each pair correspondingly. We weight both moments —the frequency of price changes $freq^{data}$ and the level of the impulse response function to the aggregate shock $IRF_h^{data} \ \forall \ h \ \in \ (1, 3, 6, 12, 24)$—according to their relative squared deviations from the target and equally to minimize the target function: $\frac{1}{(1+\sum^H IRF_h^{data})^2} \sum_h^H (IRF_h^{model} - IRF_h^{data})^2 + \frac{1}{(1+freq^{data})^2}(freq^{model} - freq^{data})^2$, where h reflects the respective horizon.

D.3 Shape of the demand and profit functions

Figure D.1: Relative demand and profit functions varying extent of micro real rigidities

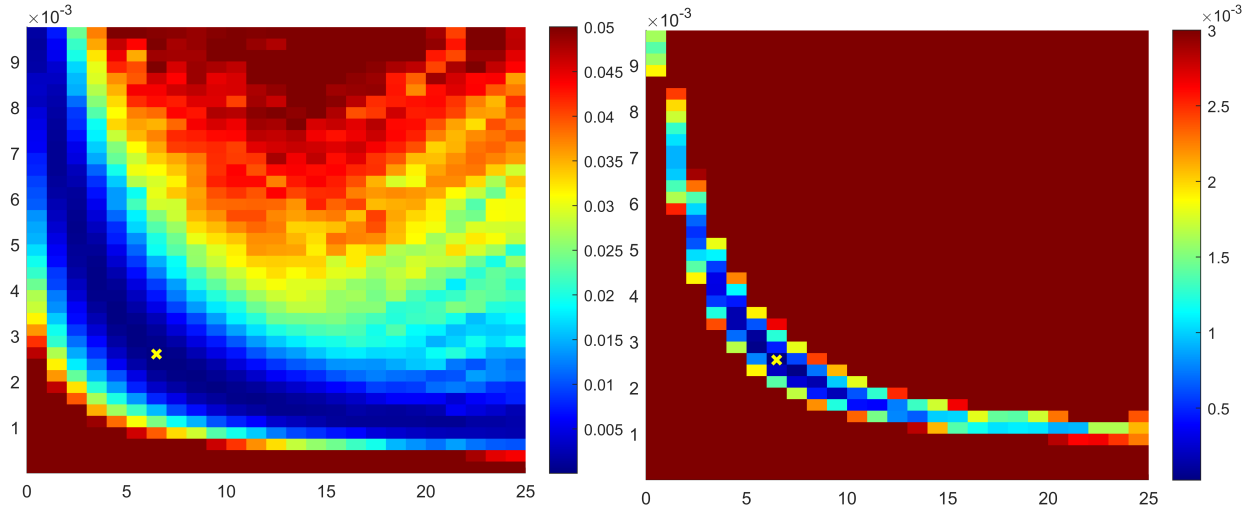


Notes: The figure shows the relative demand and profit functions for different values of the super-elasticity parameter $\bar{\epsilon}$.

D.4 Results of estimation

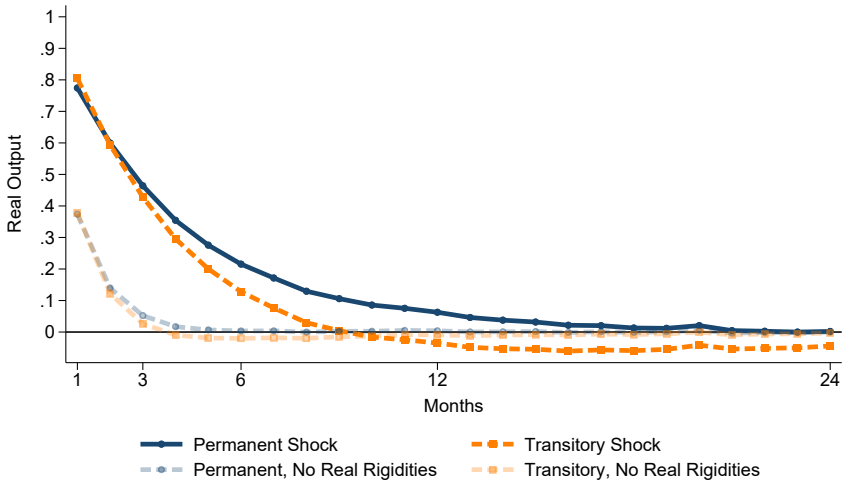
Figure D.2: Values of the weighted function

(a) Full range (b) Focus on minimum



Notes: The figure shows the values of the weighted function on the vertical axis depending on the degree of real rigidities (0-25) and menu costs (0.001-0.01). The right panel focuses on the area around the minimum. The minimum is marked by the yellow cross. The values of the weighted function above 0.05 and 0.003 are winsorized in the left and right panels, respectively.

Figure D.3: Effect of Nominal Demand Shock on Output



Notes: The solid dark-blue line reflects the model-implied impulse response of real output to a permanent aggregate shock with the estimated degree of real rigidities. The solid orange line is the model-implied impulse response of real output to a transitory aggregate shock with the estimated degree of real rigidities. The dashed light-blue line is the model-implied counterfactual impulse response of real output to a permanent aggregate shock with no real rigidities. The dashed light-orange line is the model-implied counterfactual impulse response of real output to a transitory aggregate shock with no real rigidities.