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Firm Size, Heterogeneous Strategic Complementarities, and Real Rigidity*

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Abstract

Recent research indicates substantial differences in price-setting behavior between small and large firms, as only large firms exhibit strategic complementarities in price setting. Using firm survey data, we present new evidence that the cost-price pass-through decreases with firm size. To examine the implications for inflation dynamics, we develop a DSGE model that features heterogeneous complementarities across firm size. While standard DSGE models with homogeneous firms generate real rigidity in relative prices, there is little such rigidity in our model. Heterogeneity in strategic complementarity by firm size weakens real rigidity because large firms that exhibit strategic complementarities bring their product prices in line with those of small firms that more fully pass through cost changes. Our findings challenge the notion of strategic complementarity as a source of real rigidity in DSGE models.

JEL Classification: E31, E52, L11

Keywords: Firm heterogeneity, Pass-through, Monetary non-neutrality

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1 Introduction

In the literature on dynamic stochastic general equilibrium (DSGE) models, including the seminal work of Smets and Wouters (2007), it is often assumed that all firms identically exhibit strategic complementarities in price setting under monopolistic competition. Such homogeneous complementarities generate real rigidity in relative prices, since price-adjusting firms respond more cautiously to changes in their real marginal costs in order to keep their product prices close to those of the other firms. Consequently, the complementarities allow DSGE models to reconcile micro evidence of moderate nominal price rigidity with macro evidence of substantial monetary non-neutrality.[1]

Recent research indicates that firm size matters for price-setting behavior. Amiti et al. (2019) present empirical evidence of substantial heterogeneity in strategic complementarity in price setting by firm size: "*Small firms exhibit no strategic complementarities in price setting, and fully pass through their marginal cost shocks into their domestic prices. The behavior of these small firms is well approximated by constant-markup pricing, in line with a standard model of monopolistic competition under CES demand. In contrast, large firms exhibit strong strategic complementarities and incomplete pass-through of own marginal cost shocks*" (p. 2357).[2] Complementing their research, our paper presents new empirical evidence using firm survey data on price changes and cost changes. Our panel regression analysis shows that the cost-price pass-through decreases significantly with firm size. The empirical evidence suggests that firm size could also matter for inflation dynamics.

We develop a DSGE model that features heterogeneous strategic complementarities in price setting across firm size. To describe this feature, we introduce firm heterogeneity in productivity in an otherwise standard DSGE model, as the size of firms in terms of output and labor input is associated with their productivity. We also assume that small firms face a constant elasticity of demand in line with the empirical evidence by Amiti et al. (2019), while larger firms confront a positive superelasticity (i.e., elasticity of the elasticity)

[1]This idea dates back at least to Ball and Romer (1990). Gopinath and Itskhoki (2011) review empirical evidence on real rigidity. For micro evidence on nominal price rigidity, see, e.g., Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), and Nakamura et al. (2018). A large literature documents monetary non-neutrality; see, e.g., Christiano et al. (2005) and Bu et al. (2021).

[2]Berman et al. (2012) and Amiti et al. (2014) study the price-setting behavior of exporters and find that their exchange rate pass-through decreases with their market shares.

of demand that arises from a non-CES aggregator of individual differentiated goods of the sort proposed by Kimball (1995).[3] This leads larger firms but not small firms to exhibit strategic complementarities in price setting. We then show that the log-linearized model is almost the same as its standard DSGE counterpart model with homogeneous firms, except for the slope (i.e., the real marginal cost elasticity of inflation) of the Phillips curve. In the presence of firm heterogeneity in the model, the slope reflects a steady-state revenue-weighted average of each firm's marginal cost elasticity of its optimized price.

An advantage of accounting for firm heterogeneity is that data can inform values of the productivity levels of larger firms (relative to that of small firms) and the superelasticity of demand for their products. We quantitatively examine the implications of heterogeneity in strategic complementarity in price setting by firm size for inflation dynamics, by calibrating the model to data from the Statistics of US Businesses (SUSB) of the US Census Bureau. The data provide the number of firms and their employment, payrolls, and revenues for firm-size categories ranging from firms with fewer than five employees to those with 5,000 or more employees. Because many of the firm-size categories represent only a small share of aggregate revenues, we consolidate the number of categories into three groups using statistical (k-means) clustering. After normalizing the productivity level of the smallest-firm group, for which the elasticity of demand is assumed to be constant, we obtain, for the remaining two groups of firm size, values of their relative productivity levels and the model parameters that govern the superelasticity of demand for their products, by targeting the empirical revenue shares and labor shares of each firm-size group. The resulting values imply that larger-firm groups feature not only higher productivity but also stronger strategic complementarity in line with the empirical evidence. Moreover, a steady-state revenue-weighted average of the superelasticity of demand over the three groups of firm size in our calibrated model implies an overall measure of curvature of demand that is consistent with micro evidence (Dossche et al., 2010; Beck and Lein, 2020).

Our main quantitative result is that heterogeneity in strategic complementarity in price

[3]Since Marshall (1890) argued that the elasticity of demand increases with price, a positive superelasticity of demand is often referred to as "Marshall's Second Law of Demand." Kimball (1995) introduced a non-CES aggregator as a source of real rigidity in relative prices. Smets and Wouters (2007) adopted it in their DSGE model, after which the aggregator has become mainstream in DSGE models. It is also used in other macroeconomic models with firm heterogeneity (e.g., Edmond et al., 2023) and in international economics (e.g., Gopinath and Itskhoki, 2010).

setting by firm size greatly weakens real rigidity in relative prices in the DSGE model. We show this result by comparing impulse responses of inflation and output to a monetary policy shock in our calibrated model (with heterogeneous complementarities) to those obtained in the case where all firms face a constant elasticity of demand (so there is no complementarity) and those obtained in the standard DSGE counterpart model with homogeneous firms (and hence homogeneous complementarities). Although our calibrated model captures an overall measure of demand curvature that is both consistent with micro evidence as noted above and identical to that in the counterpart model, each impulse response in our model is very similar to those in the case of no strategic complementarity or real rigidity but each displays a larger change in inflation and a smaller change in output than those in the counterpart model. Therefore, the strategic complementarities concentrated in larger firms do not materially increase monetary non-neutrality in our calibrated model.

Strategic complementarity and productivity have offsetting effects on larger firms' pass-through of their real marginal costs in the calibrated model. While stronger strategic complementarity lowers the pass-through, higher productivity raises it because a more productive firm's optimized price is lower, which reduces the price elasticity of demand for the firm's product. However, the offsetting effects do not fully explain the lack of real rigidity in the model. Stronger complementarity or a smaller difference in firm productivity reduces the pass-through of larger firms in the model, yet still fails to materially increase monetary non-neutrality.

The model's equilibrium conditions provide a full explanation. The model features a firm-size-specific condition for price setting. For each of the firm-size groups, the condition relates the optimized price of firms in the group to its expected future value, the real marginal cost, and the expected future inflation rate. Then, the inflation rate is based on a steady-state revenue-weighted average of all firms' optimized prices, and thus the optimized price of firms in each size group reflects the expected future optimized prices of firms in the other size groups. As a consequence, larger firms that exhibit strategic complementarities in price setting bring their product prices in line with those of small firms that more fully pass through changes in their real marginal costs. This spillover effect from small firms to larger firms is absent in standard DSGE models in which all firms behave identically. As noted above, inflation dynamics in the model can be represented as a standard form of the Phillips curve but with the slope that reflects a steady-state revenue-weighted average of each firm's marginal cost elasticity of its optimized price. Heterogeneous strategic complementarities concentrated solely in larger firms then have little influence on the slope of the Phillips curve in the calibrated model. This is because higher productivity of larger firms mitigates decreases in their marginal cost elasticities induced by the stronger complementarity and because the stronger complementarity reduces their steady-state revenue weights, which strengthens the spillover effect from small firms to larger firms.

Our results indicate that the real rigidity generated in standard DSGE models, which abstract from firm heterogeneity, is an artifact of homogeneity in strategic complementarity in price setting across firms. Once we account for the empirical heterogeneity in strategic complementarity by firm size, the real rigidity is greatly weakened, as noted above. Therefore, our findings challenge the notion of strategic complementarity as a source of real rigidity in DSGE models. Levin et al. (2008) demonstrate that the source of real rigidity in DSGE models can have implications for optimal monetary policy, which suggests that adopting an empirically plausible source is policy relevant.

The paper is related to different strands of the macroeconomic literature. Previous macroeconomic research on firm size is concerned with business fluctuations. Gertler and Gilchrist (1994) and Crouzet and Mehrotra (2020) document that small firms are more cyclically sensitive than large firms. While the former authors associate the greater cyclicality of small firms with financial frictions, the latter attribute it to a larger industry scope of large firms.[4] Research on the implications of firm heterogeneity for inflation dynamics focuses on sectoral heterogeneity in nominal price rigidity. Carvalho (2006) finds that homogeneous strategic complementarities in price setting lead firms with more flexible prices to behave similar to firms with stickier prices. Due to this spillover effect, the firms with stickier prices have a disproportionate influence on the aggregate price level, so heterogeneity in nominal price rigidity increases monetary non-neutrality.[5] Our model, in which all firms face the same nominal price rigidity, possesses a distinct spillover effect because firms that exhibit strategic complementarities in price setting behave similar to firms that more fully pass through

[4] Gilchrist et al. (2017) show that liquidity-constrained firms raised their product prices during the global financial crisis, while unconstrained firms lowered their prices. Haque et al. (2025) examine the implications of multi-product firms for equilibrium stability.

[5] See also Nakamura and Steinsson (2010), Pasten et al. (2020), and Carvalho et al. (2021).

changes in their real marginal costs, so heterogeneity in strategic complementarity across firms weakens monetary non-neutrality. In our model, a positive superelasticity of demand leads larger firms to display both strategic complementarity and a large desired markup. A recent strand of research endogenizes the link between market power and strategic price-setting by departing from the assumption of monopolistic competition (e.g., Mongey, 2021; Wang and Werning, 2022; Ueda, 2023). Wang and Werning (2022) then point out that the implications of oligopolistic competition for monetary non-neutrality are well approximated by introducing a Kimball-type non-CES aggregator in models with monopolistic competition. Our model retains monopolistic competition for tractability and employs a Kimball-type aggregator to highlight the spillover effect from small firms to larger firms that exhibit strategic complementarities in a DSGE setting. Our paper also contributes to research that challenges the use of strategic complementarity for generating monetary non-neutrality (e.g., Bils et al., 2012; Klenow and Willis, 2016).

The remainder of the paper proceeds as follows. Section 2 presents new empirical evidence supporting the notion that firm size matters for price setting. Section 3 develops a DSGE model that features heterogeneous strategic complementarities in price setting across firm size. Section 4 calibrates the model to US Census data and then quantitatively examines the implications of heterogeneity in strategic complementarity by firm size for inflation dynamics. Section 5 concludes.

2 Empirical Evidence

In this section, we empirically examine the role of firm size in price-setting behavior using firm survey data, and present new evidence that the pass-through from firms' costs to prices decreases with firm size.[6]

The data are taken from the Business Inflation Expectations survey of the Federal Reserve Bank of Atlanta, a monthly survey of firms in the Sixth Federal Reserve District.[7] In nine separate months during the period from February 2020 to February 2024, firms were asked

[6]For evidence on the role of strategic complementarity in cost-price pass-through, see Gopinath and Itskhoki (2010), Auer and Schoenle (2016), Dogra et al. (2023), and Gödl-Hanisch and Menkoff (2024).

[7]The Sixth District includes Alabama, Florida, Georgia, and portions of Louisiana, Mississippi, and Tennessee.

about their prices and costs. The high and volatile inflation observed in this period makes it an opportune time to study firms' cost-price pass-through. We begin by discussing the three variables used in the panel estimation: price growth, cost growth, and firm size.

First, the survey question on price growth was phrased in one of two slightly different ways across survey waves.[8] Given the minor differentiations between the two formulations, we merged firms' answers to the question into one variable, the 12-month percentage change in a firm's price, which provides a larger time series dimension of the panel.

Second, firms in the survey indicate how their current unit costs compare with those a year earlier, by selecting one of five categories: "down," "unchanged," "up somewhat," "up significantly," and "up very significantly." We treat the cost growth indicator as an interval variable by assuming that each category covers a similar range of values for cost growth. This assumption should be innocuous because our goal is to test whether the average association between price growth and cost growth—the sum of all the coefficients if we were to include one for each possible value of the ordinal variable in the panel regression—differs across firm-size groups. Hence, whether one interval is wider than the others should be less relevant to the extent that it is wider for each firm size. The benefit of treating the ordinal variable as if it had linear effects is greater parsimony.

Third, a firm-size variable in the survey sorts firms into one of three groups: small firms (with 1–99 employees), medium firms (with 100–499 employees), or large firms (with 500 or more employees). While a more precise employee count is available, we choose the three groups of firm size to ensure that each group contains a sufficient number of firms.

Using the three survey variables, we estimate the following panel regression:

$$\Delta Price_{f,t} = \mu + \beta_1 \Delta Cost_{f,t} \mathbb{I}_{f,t}(1) + \beta_2 \Delta Cost_{f,t} \mathbb{I}_{f,t}(2) + \beta_3 \Delta Cost_{f,t} \mathbb{I}_{f,t}(3) + \alpha_f + \gamma_t + \varepsilon_{f,t}, \quad (1)$$

where μ is a constant term, $\Delta Price_{f,t} \in \mathbb{R}$ is the price growth of firm f in month t, $\Delta Cost_{f,t} \in \{1, 2, 3, 4, 5\}$ denotes its cost growth, and $\mathbb{I}_{f,t}(i)$ is a dummy variable that indicates the size $i = 1, 2, 3$ of firm f by taking the value one if the firm is small, medium, or

[8] In six of the survey waves, the question was: "*In percentage terms, over the past 12 months, by how much did your firm increase [decrease] the price of the product or service responsible for the largest share of your revenue?*" In three of the survey waves, the question was instead: "*By roughly what percentage has your firm changed the price of the product/product line or service responsible for the largest share of your revenue of the last 12 months?*"

large, respectively, and zero otherwise. The regression model includes firm fixed effects α_f, which can absorb structural differences in price growth between firms, including differences in the responsiveness of own prices to competitors' prices, which could depend on firm size. Time fixed effects γ_t are also included to absorb aggregate drivers of price growth, such as changes in the average markup during the sample period that saw a rise and fall in inflation. The coefficients β_i capture the cost-price pass-through of firms. Although the ordinal regressor renders the magnitude of the estimated coefficients not economically meaningful, the estimates allow us to test whether the cost-price pass-through differs by firm size.

Before proceeding to the estimation, we balance the dataset. The full dataset is an unbalanced panel; we select the largest possible balanced subset of the panel for the estimation. The balanced sample retains $T = 6$ survey months and contains at least 31 firms in each size group.[9] If T is larger than six, the sample size and the number of firms in each size group become smaller; if T is less than six, time variation is reduced with no gain in the sample size.

Table 1 presents the estimation results. The first column of numbers reports the estimated cost-price pass-through coefficients for small firms (β_1), medium firms (β_2), and large firms (β_3) in the balanced sample with $T = 6$. The estimators are decreasing in firm size and are significantly different from zero for small and medium firms but not for large firms, suggesting that large firms exhibit smaller pass-through from costs to prices than small and medium firms. Some firms move between size groups in the sample, which could happen due to growth or downsizing. The second column shows the estimation results when the sample is limited to firms that remain in the same size group. Decreases in the point estimates across firm-size groups are slightly starker. The third column shows that larger time variation across firms in the sample, obtained by using the subsample with $T = 7$ survey months, somewhat increases the point estimates for each firm-size group, but leaves unchanged the result that large firms exhibit smaller cost-price pass-through than small and medium firms.

We test whether cost-price pass-through depends on firm size using a Wald test. Defining the coefficient vector $\beta = (\beta_1, \beta_2, \beta_3)'$, the asymptotic distribution $\sqrt{nT}(\hat{\beta} - \beta) \xrightarrow{d} N(0, V)$,

[9] The six survey months are December 2020, April 2021, July 2021, November 2021, March 2022, and December 2022. With multi-month time intervals between surveys, we did not attempt to balance the panel by imputing missing observations.

Table 1: Estimation results of panel regression.

Variables	(1) Main sample	(2) Same firm size	(3) Larger T
$\Delta Cost_{f,t} \times \mathbb{I}_{f,t}(1)$	3.093^{***}	3.192^{***}	3.781^{***}
	(1.069)	(1.104)	(0.842)
$\Delta Cost_{f,t} \times \mathbb{I}_{f,t}(2)$	2.965^{***}	2.823^{***}	3.214^{***}
	(0.752)	(0.930)	(0.589)
$\Delta Cost_{f,t} \times \mathbb{I}_{f,t}(3)$	0.891	0.859	1.042
	(0.740)	(0.762)	(0.809)
Firm fixed effects	yes	yes	yes
Time fixed effects	yes	yes	yes
Sample size	724	641	669
Wald test	6.843^{**}	6.016^{**}	7.781^{**}

Notes: *** and ** denote statistical significance at the 1 percent and 5 percent level, respectively. Column (1) presents the estimation results obtained with the main sample, a balanced panel in which firms are surveyed six times, i.e., $T = 6$. Column (2) shows the results obtained only with firms that remain in the same size group during the sample period. Column (3) displays the results obtained with the sample of firms that are surveyed seven times (i.e., $T = 7$), during the same six months as in the main sample and May 2023. The price growth variable is winsorized at the 5th and 95th percentiles. The within transformation of the panel regression model is estimated by OLS. Stock and Watson (2008) robust standard errors are reported in parentheses and critical values are based on the standard normal distribution.

where V is the variance matrix of β. Under the null hypothesis that firm size is irrelevant to pass-through, $\beta_1 = \beta_2 = \beta_3$. Thus, the null is a two-dimensional vector $R\beta$, where

$$R = \begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \end{bmatrix}.$$

It follows that $\sqrt{nT}(R\hat{\beta} - R\beta) \xrightarrow{d} N(0, RVR')$. The Wald test statistic is then

$$\xi_W = nT \left(R\hat{\beta}\right)' \left(R\hat{V}R\right)^{-1} \left(R\hat{\beta}\right),$$

where $\hat{V}$ is a consistent estimator for V that is obtained by following Stock and Watson (2008).[10] Under the null, the test statistic has a chi-square distribution with two degrees of freedom. The null hypothesis of no role of firm size in the pass-through is rejected in the main sample and in the two alternative samples. Thus, the results in Table 1 indicate

[10]Specifically, $\hat{V} = \hat{Q}^{-1}_{\tilde{X}\tilde{X}} \hat{\Sigma} \hat{Q}^{-1}_{\tilde{X}\tilde{X}}$, where $\hat{Q}_{\tilde{X}\tilde{X}} = (nT)^{-1} \sum_{f=1}^{N} \sum_{t=1}^{T} \tilde{X}_{f,t} \tilde{X}'_{f,t}$, $\tilde{X}$ is the matrix of within-transformed regressors, and $\hat{\Sigma}$ is the bias-adjusted heteroskedasticity robust covariance matrix estimator described by eq. (6) in Stock and Watson (2008).

that large firms exhibit significantly less pass-through from costs to prices than small and medium firms.

The evidence presented above complements existing evidence of heterogeneity in strategic complementarity in price setting by firm size.[11] Amiti et al. (2019) study the extent of strategic complementarity using micro data on domestic prices, marginal costs, and competitors' prices of manufacturing firms in Belgium. The data feature variation in firms' own marginal costs as the firms source intermediate inputs from different suppliers in different countries. The authors empirically decompose firms' price changes into their own cost pass-through and a response to their competitors' price changes, which reveals strong evidence of strategic complementarity. The elasticity of firms' own prices with respect to their competitors' prices is 0.4, while the elasticity with respect to their own costs is 0.6 on average. Moreover, they find substantial evidence of heterogeneity in strategic complementarity, as noted in the Introduction. Small firms exhibit no strategic complementarities, whereas large firms are characterized by a competitor price elasticity of slightly more than 0.5 and an own cost elasticity of slightly less than 0.5. This evidence clearly establishes that firm size matters for price-setting behavior and raises the question of whether it also matters for inflation dynamics, which we turn to next.

3 Model

We develop a DSGE model augmented with firm heterogeneity in productivity and in strategic complementarity in price setting to examine whether firm size matters for inflation dynamics. A novel feature of the model is the presence of multiple groups of individual-good-producing firms that are distinguishable by the productivity levels of their production technologies and the superelasticities of demand for their products. Then, a representative composite-good producer aggregates the outputs of the firms. The remaining part of the model is standard in the DSGE literature and consists of a representative household and a monetary authority.

[11] A plausible interpretation of our finding that large firms exhibit less cost-price pass-through than smaller firms would be that the price-setting behavior of large firms is subject to greater real rigidity but not greater nominal price rigidity. This is because Goldberg and Hellerstein (2011) use PPI micro data to show that the product prices of large firms change more frequently and have shorter durations than those of smaller firms.

3.1 Composite-good producers

The representative composite-good producer combines the outputs of a continuum of firms $f \in [0,1]$, each of which belongs to one of the k groups $\Omega_i = \{f \in [0,1] : z(f) = z_i, \epsilon(f) = \epsilon_i\}$, $i = 1, \ldots, k$, where $z(f)$ denotes firm-f-specific productivity relative to that of firms in group Ω_1 with the normalization of $z_1 = 1$ and the parameter $\epsilon(f)$ governs the superelasticity of demand for firm f's product. The firm groups Ω_i, $i = 1, \ldots, k$ are mutually exclusive and $\bigcup_{i=1}^k \Omega_i = [0,1]$. The measure of firms in group Ω_i (i.e., type-i firms) is $n_i \in (0,1)$, that is, $\int_{\Omega_i} df = n_i$, so we have $\sum_{i=1}^k \int_{\Omega_i} df = \sum_{i=1}^k n_i = 1$. The composite good Y_t is produced by combining individual differentiated goods $\{Y_t(f)\}$ with an aggregator of the sort proposed by Kimball (1995):

$$1 = \int_0^1 F\left(\frac{Y_t(f)}{Y_t}\right) df = \sum_{i=1}^k \int_{\Omega_i} F\left(\frac{Y_t(f)}{Y_t}\right) df. \tag{2}$$

Following Dotsey and King (2005) and Levin et al. (2008), the function $F(\cdot)$ is assumed to be of the form

$$F\left(\frac{Y_t(f)}{Y_t}\right) = \frac{\theta}{\gamma_i - 1}\left((1+\epsilon_i)\frac{Y_t(f)}{Y_t} - \epsilon_i\right)^{\frac{\gamma_i - 1}{\gamma_i}} + 1 - \frac{\theta}{\gamma_i - 1} \quad \forall f \in \Omega_i, \quad i = 1, \ldots, k,$$

where $\gamma_i \equiv \theta(1+\epsilon_i)$. A value of $\epsilon_i < 0$ gives rise to a positive superelasticity of demand for products of type-i firms and hence strategic complementarity in price setting. In the special case of $\epsilon_i = 0$ for all firm types i, the aggregator (2) is reduced to the CES one $Y_t = [\int_0^1 (Y_t(f))^{(\theta-1)/\theta} df]^{\theta/(\theta-1)}$, where $\theta > 1$ represents the elasticity of substitution between individual goods.

The composite-good producer maximizes profit $\Pi_t = P_t Y_t - \int_0^1 P_t(f) Y_t(f)\, df$ subject to the aggregator (2), given the composite good's price P_t and individual goods' prices $P_t(f)$. Combining the first-order conditions for profit maximization and the aggregator (2) leads to

$$\frac{Y_t(f)}{Y_t} = \frac{1}{1+\epsilon_i}\left[\left(\frac{P_t(f)}{P_t\, d_t}\right)^{-\gamma_i} + \epsilon_i\right] \quad \forall f \in \Omega_i, \quad i = 1, \ldots, k, \tag{3}$$

$$d_{i,t} = \left[\frac{1}{n_i}\int_{\Omega_i}\left(\frac{P_t(f)}{P_t}\right)^{1-\gamma_i} df\right]^{\frac{1}{1-\gamma_i}}, \quad i = 1, \ldots, k, \tag{4}$$

$$0 = \sum_{i=1}^{k} \frac{n_i}{\gamma_i - 1} \left[\left(\frac{d_{i,t}}{d_t} \right)^{1-\gamma_i} - 1 \right], \tag{5}$$

$$1 = \sum_{i=1}^{k} \frac{n_i}{1+\epsilon_i} \left[\left(\frac{d_{i,t}}{d_t} \right)^{-\gamma_i} d_{i,t} + \epsilon_i \left(\frac{1}{n_i} \int_{\Omega_i} \frac{P_t(f)}{P_t}\, df \right) \right]. \tag{6}$$

Eq. (3) is the demand curve for firm f's product, where d_t denotes the Lagrange multiplier on the aggregator (2). Eq. (4) describes an average relative price $d_{i,t}$ over products of type-i firms. The aggregator (2) and the condition for zero profits (i.e., $\Pi_t = 0$) are reduced to (5) and (6), respectively. Eq. (6) states that the sum of each firm's revenue share is one.

3.2 Firms

Each firm $f \in [0, 1]$ produces an individual differentiated good $Y_t(f)$ using the Cobb-Douglas production technology

$$Y_t(f) = A_t\, z(f)[K_t(f)]^{\alpha}[l_t(f)]^{1-\alpha},$$

where $\alpha \in (0, 1)$ is the capital elasticity of production, A_t represents economy-wide productivity and grows at a constant rate $A_t/A_{t-1} = g^{1-\alpha}$, and $K_t(f)$ and $l_t(f)$ are firm f's inputs of capital and labor.

Firm f minimizes cost $TC_t(f) = P_t r_{k,t}\, K_t(f) + P_t W_t\, l_t(f)$ subject to the Cobb-Douglas production technology, given the capital rental rate $P_t r_{k,t}$ and the wage rate $P_t W_t$. In the presence of economy-wide, perfectly competitive factor markets, combining the first-order conditions for cost minimization shows that all firms choose an identical capital–labor ratio, so that

$$\frac{K_{i,t}}{l_{i,t}} = \frac{\alpha}{1-\alpha} \frac{W_t}{r_{k,t}}, \quad i = 1, \ldots, k, \tag{7}$$

where $K_{i,t} \equiv \frac{1}{n_i} \int_{\Omega_i} K_t(f)\, df$ and $l_{i,t} \equiv \frac{1}{n_i} \int_{\Omega_i} l_t(f)\, df$. Aggregating the outputs of type-i firms leads to

$$Y_t \Delta_{i,t} = A_t z_i K_{i,t}^{\alpha}\, l_{i,t}^{1-\alpha}, \quad i = 1, \ldots, k, \tag{8}$$

where

$$\Delta_{i,t} \equiv \frac{s_{i,t} + \epsilon_i}{1+\epsilon_i}, \quad i = 1, \ldots, k, \tag{9}$$

$$s_{i,t} \equiv \frac{1}{n_i} \int_{\Omega_i} \left(\frac{P_t(f)}{P_t} \right)^{-\gamma_i} df, \quad i = 1, \ldots, k. \tag{10}$$

The aggregate output over firms of type i is their average output $Y_t \Delta_{i,t}$, where $\Delta_{i,t}$ is the average output over type-i firms relative to the composite good's output Y_t and may differ from one due to the effects of productivity z_i on relative prices, strategic complementarity in price setting on demand, and price dispersion across firms of type i in the presence of staggered price-setting. Moreover, each firm type i's real marginal cost of production varies inversely with its productivity level

$$mc_{i,t} = \frac{1}{A_t z_i} \left(\frac{r_{k,t}}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}, \quad i = 1, \ldots, k. \tag{11}$$

The ratio of each firm type's average labor productivity can then be written as

$$\frac{Y_t \Delta_{i,t}/l_{i,t}}{Y_t \Delta_{i-1,t}/l_{i-1,t}} = \frac{mc_{i-1,t}}{mc_{i,t}} = \frac{z_i}{z_{i-1}}, \; i = 2, \ldots, k. \tag{12}$$

Thus, this ratio is inversely proportional to the ratio of each firm type's real marginal cost.

We turn next to firms' price setting. Firms set their product prices on a staggered basis as in Calvo (1983). In each period, a fraction $\xi \in (0, 1)$ of type-i firms (i.e., $f \in \Omega_i$) indexes their product prices to the steady-state rate π of the composite good's price inflation $\pi_t \equiv P_t/P_{t-1}$, while the remaining fraction $1-\xi$ sets the price $P_t(f)$, given the marginal cost (11), so as to maximize relevant profits

$$E_t \sum_{j=0}^{\infty} \xi^j \, \Lambda_{t,t+j} \left(P_t(f)\pi^j - P_{t+j}\, mc_{i,t+j}\right) Y_t(f)$$

subject to the demand curve (3), where E_t denotes the expectation operator conditional on information available in period t and $\Lambda_{t,t+j}$ is the (nominal) stochastic discount factor between period t and period $t+j$. The first-order conditions for profit maximization can be written as

$$0 = E_t \sum_{j=0}^{\infty} (\beta\xi)^j \frac{Y_{t+j}}{C_{t+j}} \left[\left(\frac{p^*_{i,t}}{d_{t+j}}\right)^{-\gamma_i} \prod_{\tau=1}^{j} \left(\frac{\pi_{t+\tau}}{\pi}\right)^{\gamma_i} \left(p^*_{i,t} \prod_{\tau=1}^{j} \left(\frac{\pi_{t+\tau}}{\pi}\right)^{-1} - \frac{\gamma_i}{\gamma_i - 1} mc_{i,t+j} \right) \right.$$
$$\left. - \frac{\epsilon_i}{\gamma_i - 1} p^*_{i,t} \prod_{\tau=1}^{j} \left(\frac{\pi_{t+\tau}}{\pi}\right)^{-1} \right], \quad i = 1, \ldots, k, \tag{13}$$

where we use the equilibrium condition $\Lambda_{t,t+j} = \beta^j (C_t/C_{t+j})/(P_t/P_{t+j})$, which will be shown later, $\beta \in (0, 1)$ is the subjective discount factor, C_t denotes households' consumption of the composite good, $p^*_{i,t} \equiv P^*_{i,t}/P_t$, and $P^*_{i,t}$ is the price optimized by firms of type i in period t. Moreover, under staggered price-setting, eqs. (4) and (9) can be reduced to, respectively,

$$d_{i,t}^{1-\gamma_i} = \xi \left(\frac{\pi_t}{\pi}\right)^{\gamma_i - 1} d_{i,t-1}^{1-\gamma_i} + (1-\xi)\left(p^*_{i,t}\right)^{1-\gamma_i}, \quad i = 1, \ldots, k, \tag{14}$$

$$d_t^{-\gamma_i} s_{i,t} = \xi \left(\frac{\pi_t}{\pi}\right)^{\gamma_i} d_{t-1}^{-\gamma_i} s_{i,t-1} + (1-\xi)\left(p^*_{i,t}\right)^{-\gamma_i}, \quad i = 1, \ldots, k. \tag{15}$$

3.3 Households and monetary authority

The representative household consumes the composite good C_t, purchases one-period riskless bonds B_t, supplies labor l_t, and makes a capital investment I_t so as to maximize the utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \frac{l_t^{1+1/\chi}}{1+1/\chi}\right)$$

subject to the budget constraint

$$P_t C_t + P_t I_t + B_t = P_t W_t l_t + P_t r_{k,t} K_{t-1} + r_{t-1} B_{t-1} + J_t$$

and the capital accumulation equation

$$K_t = (1-\delta) K_{t-1} + \left(1 - S\left(\frac{I_t}{g I_{t-1}}\right)\right) I_t, \tag{16}$$

where $\chi > 0$ is the elasticity of labor supply, $\delta \in (0,1)$ is the depreciation rate of capital, r_t is the interest rate on the bonds and is assumed to coincide with the monetary policy rate, K_t is the capital stock, J_t represents firm profits received, and $S(\cdot)$ is an adjustment cost function that is assumed to be of the quadratic form

$$S\left(\frac{I_t}{g I_{t-1}}\right) = \frac{\zeta}{2}\left(\frac{I_t}{g I_{t-1}} - 1\right)^2,$$

where $\zeta \geq 0$.

Combining the first-order conditions for utility maximization with respect to consumption, bond holdings, labor supply, capital stock, and capital investment yields

$$1 = E_t \left[\frac{\beta C_t}{C_{t+1}} \frac{r_t}{\pi_{t+1}}\right], \tag{17}$$

$$W_t = l_t^{\frac{1}{\chi}} C_t, \tag{18}$$

$$1 = E_t \left[\frac{\beta C_t}{C_{t+1}} \frac{r_{k,t+1} + (1-\delta)\, q_{t+1}}{q_t} \right], \tag{19}$$

$$1 = q_t \left[1 - \frac{\zeta}{2} \left(\frac{I_t}{g I_{t-1}} - 1 \right)^2 - \zeta \left(\frac{I_t}{g I_{t-1}} - 1 \right) \frac{I_t}{g I_{t-1}} \right] + E_t \left[\frac{\beta C_t}{C_{t+1}} q_{t+1}\, \zeta \left(\frac{I_{t+1}}{g I_t} - 1 \right) \frac{I_{t+1}^2}{g I_t^2} \right], \tag{20}$$

where q_t denotes the real price of capital. Then, it follows that the stochastic discount factor $\Lambda_{t,t+j}$ meets the equilibrium condition $\Lambda_{t,t+j} = \beta^j \left(C_t/C_{t+j}\right) / \left(P_t/P_{t+j}\right)$.

The output of the composite good is equal to the sum of households' consumption and capital investment:

$$Y_t = C_t + I_t. \tag{21}$$

The labor market clearing condition is

$$l_t = \sum_{i=1}^{k} n_i\, l_{i,t} = \sum_{i=1}^{k} \int_{\Omega_i} l_t(f)\, df, \tag{22}$$

while the capital-service market clearing condition is

$$K_{t-1} = \sum_{i=1}^{k} n_i\, K_{i,t} = \sum_{i=1}^{k} \int_{\Omega_i} K_t(f)\, df. \tag{23}$$

The monetary authority conducts policy based on an interest-rate feedback rule of the sort proposed by Taylor (1993):

$$\log r_t = \log r + \phi_\pi \left(\log \pi_t - \log \pi\right) + \phi_y \left(\log y_t - \log y\right) + \varepsilon_{r,t}\,, \tag{24}$$

where ϕ_π and ϕ_y are the policy responses to inflation and output, respectively, $y_t \equiv Y_t / A_t^{1/(1-\alpha)}$ is detrended aggregate output, y is its steady-state value, and $\varepsilon_{r,t}$ is an i.i.d. shock to the monetary policy rate. The monetary policy shock $\varepsilon_{r,t}$ generates short-run responses in real economic activity due to the presence of nominal price rigidity in the model, i.e., $\xi > 0$.

3.4 Log-linearized equilibrium conditions

The equilibrium conditions of the model consist of eqs. (5)–(9), (11), and (13)–(24). After removing the balanced growth trend $\Upsilon_t \equiv A_t^{1/(1-\alpha)}$, we log-linearize the equilibrium conditions expressed in terms of stationary variables, such as $y_t = Y_t/\Upsilon_t$, $c_t = C_t/\Upsilon_t$, $w_t = W_t/\Upsilon_t$,

$i_t = I_t/\Upsilon_t$, and $k_t = K_t/\Upsilon_t$.

The following $2k+1$ log-linearized equilibrium conditions capture firm heterogeneity in inflation dynamics:

$$\hat{p}^*_{i,t} = \beta\xi\, E_t\hat{p}^*_{i,t+1} + \beta\xi\, E_t\hat{\pi}_{t+1} + \frac{1-\beta\xi}{\Gamma_i}\,\hat{mc}_t, \quad i = 1,\ldots,k, \tag{25}$$

$$\hat{d}_{i,t} = (1-\xi)\ \hat{p}^*_{i,t} + \xi\left(\hat{d}_{i,t-1} - \hat{\pi}_t\right), \quad i = 1,\ldots,k, \tag{26}$$

$$0 = \sum_{i=1}^{k}\omega_i\,\hat{d}_{i,t}\,, \tag{27}$$

where $\Gamma_i \equiv 1 - \epsilon_i\,(p^*_i/d)^{\gamma_i}\,\mu_i$ measures strategic complementarity in price setting of type-i firms, $\mu_i = \gamma_i/\left[\gamma_i - 1 - \epsilon_i\,(p^*_i/d)^{\gamma_i}\right]$ is their steady-state average markup, and $\omega_i = n_i p^*_i \Delta_i$ is their steady-state share of aggregate revenues. Eq. (25) represents the price-setting behavior of type-i firms that optimize their product prices in period t. In the real marginal cost term, the subscript i is dropped (i.e., $\hat{mc}_{i,t} = \hat{mc}_t$ for all i) in the presence of the economy-wide, perfectly competitive factor markets. The marginal cost elasticity of type-i firms' optimized price $(1-\beta\xi)/\Gamma_i$ depends not only on ϵ_i but also on z_i. A smaller, negative value of ϵ_i increases the value of Γ_i and thereby decreases the elasticity $(1-\beta\xi)/\Gamma_i$, so stronger strategic complementarity in price setting leads to less pass-through of changes in the real marginal cost. The firm-type-specific productivity z_i then influences the elasticity through its effects on the steady-state variables p^*_i and d. Higher productivity mitigates the decrease in the marginal cost elasticity induced by stronger strategic complementarity, as shown later.

Eq. (26) describes type-i firms' average relative price $\hat{d}_{i,t}$ that consists of the $1-\xi$ optimizing firms' relative price and the ξ remaining firms' average relative price, the latter of which erodes with higher inflation relative to steady-state inflation. Eq. (27) is the log-linearization of the composite-good producer's zero-profit condition (6) and requires that the steady-state revenue-weighted average of the average relative prices $\hat{d}_{i,t}$ over all firm types i is zero. Combining (26) and (27) yields

$$\hat{\pi}_t = \frac{1-\xi}{\xi}\,\sum_{i=1}^{k}\omega_i\,\hat{p}^*_{i,t}, \tag{28}$$

so the average relative prices are canceled out and thus the inflation rate $\hat{\pi}_t$ reflects only the steady-state revenue-weighted average of the optimized relative prices of all firm types.

Then, substituting (28) in (25) leads to

$$\hat{p}^*_{i,t} = \beta[\xi + (1-\xi)\omega_i] E_t \hat{p}^*_{i,t+1} + \beta(1-\xi) \sum_{j \neq i} \omega_j E_t \hat{p}^*_{j,t+1} + \frac{1-\beta\xi}{\Gamma_i} \hat{mc}_t. \tag{29}$$

In the presence of firm heterogeneity, type-i firms' optimized price $\hat{p}^*_{i,t}$ reflects the expected future optimized prices $E_t \hat{p}^*_{j,t+1}$ of the other firm types $j \neq i$. As a consequence, there is a spillover effect from firms that more fully pass through changes in the real marginal cost to those that exhibit strategic complementarities in price setting, with the larger revenue shares of the former firms increasing the magnitude of the effect. Moreover, from (25)–(27), it follows that the Phillips curve is of the standard form

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\, \hat{mc}_t = \beta E_t \hat{\pi}_{t+1} + \left(\sum_{i=1}^{k} \omega_i \kappa_i \right) \hat{mc}_t, \tag{30}$$

but with a slope that consists of the steady-state revenue-weighted average of each firm type's component $\kappa_i = (1-\xi)(1-\beta\xi)/(\xi\,\Gamma_i)$, a component that is proportional to the firm type's marginal cost elasticity of its optimized price $(1-\beta\xi)/\Gamma_i$. As with the marginal cost elasticities, the components κ_i of the Phillips curve slope are affected by ϵ_i and z_i. While a smaller, negative value of ϵ_i decreases the value of κ_i, higher productivity z_i mitigates the decrease in κ_i, as shown later.[12]

In sum, the log-linearized model consists of the Phillips curve (30) and the following 10 equations:

$$\hat{mc}_t = (1-\alpha)\hat{w}_t + \alpha\, \hat{r}_{k,t}\,, \tag{31}$$

$$\hat{k}_{t-1} - l_t = \hat{w}_t - \hat{r}_{k,t}\,, \tag{32}$$

$$\hat{y}_t = (1-\alpha)\hat{l}_t + \alpha\, \hat{k}_{t-1}, \tag{33}$$

$$\hat{c}_t = E_t \hat{c}_{t+1} - \hat{r}_t + E_t \hat{\pi}_{t+1}, \tag{34}$$

$$\hat{w}_t = \frac{1}{\chi} \hat{l}_t + \hat{c}_t, \tag{35}$$

$$\hat{k}_t = \frac{1-\delta}{g} \hat{k}_{t-1} + \left(1 - \frac{1-\delta}{g}\right) \hat{\imath}_t, \tag{36}$$

[12] A smaller, negative value of ϵ_i reduces the value of κ_i directly and indirectly through a larger steady-state markup μ_i. The latter effect is analogous to the finding of Wang and Werning (2022) that higher market concentration due to fewer firms in an oligopoly makes the Phillips curve flatter.

$$\hat{q}_t = \zeta\left(\hat{\iota}_t - \hat{\iota}_{t-1}\right) - \beta\zeta\left(E_t\hat{\iota}_{t+1} - \hat{\iota}_t\right), \tag{37}$$

$$\hat{r}_t - E_t\hat{\pi}_{t+1} = \left[1 - \beta\left(\frac{1-\delta}{g}\right)\right] E_t\hat{r}_{k,t+1} + \beta\left(\frac{1-\delta}{g}\right) E_t\hat{q}_{t+1} - \hat{q}_t, \tag{38}$$

$$\hat{y}_t = \frac{c}{y}\,\hat{c}_t + \frac{i}{y}\,\hat{\iota}_t, \tag{39}$$

$$\hat{r}_t = \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + \varepsilon_{r,t}\,. \tag{40}$$

The last 10 conditions (31)–(40) are the same as in the standard DSGE counterpart model with homogeneous firms, so the firm heterogeneity alters the slope of the Phillips curve.[13]

3.5 Firm size and demand curvature

Thus far firms differ by their productivity, as indexed by $i = 1, \ldots, k$. Empirically, there is a well-documented relationship between labor productivity and firm size (e.g., Leung et al., 2008). We now explore the relationship in the steady state of the model.

In the special case of a constant elasticity of demand for products of each firm type i (i.e., $\epsilon_i = 0$ for all i), we have that $p_i^* = \theta/(\theta-1)\,mc_i$, and thus the real marginal cost ratios (12) imply that $p_i^* = p_1^*/z_i$. It follows that output per firm $y\Delta_i = (z_i/p_1^*)^\theta$ is increasing in z_i, where Δ_i is the steady-state value of type-i firms' average output relative to the composite-good producer's output. Likewise, given that all firms face the same real wage rate, more productive firms demand more labor. As a consequence, the labor input per firm is also increasing in z_i.

In the case of empirical interest, larger firms with higher productivity exhibit stronger strategic complementarity. In the model, the price elasticity of demand for products of type-i firms is derived as $\eta_i(Y_t(f)/Y_t) = \theta(1 + \epsilon_i - \epsilon_i(Y_t(f)/Y_t)^{-1})$. Then, given $\epsilon_i < 0$, the elasticity is smaller for a larger relative demand $Y_t(f)/Y_t$, which leads the desired markup $\eta_i(Y_t(f)/Y_t)/\left(\eta_i(Y_t(f)/Y_t) - 1\right)$ to be larger. The larger markup mitigates the relative price differential caused by the productivity differential between firms. In the next section we will confirm numerically that productivity is higher and strategic complementarity is stronger for larger firms in terms of steady-state output and labor input in the calibrated model. Thus, in the remainder of the paper we will refer to the firm group $i = 1, \ldots, k$ as indexing firm

[13]The firm heterogeneity also has a very small effect on the steady-state output shares of consumption and investment c/y and i/y in the log-linearized composite-good market clearing condition (39).

size.

The degree of strategic complementarity can be summarized by the curvature of demand, which we define as the mean superelasticity of demand evaluated at a relative demand of one, i.e., $Y_t(f)/Y_t = 1$. The superelasticity of demand for products of type-i firms (i.e., the elasticity of the elasticity $\eta_i(Y_t(f)/Y_t)$) is derived as $\sigma_i(Y_t(f)/Y_t) = -\theta\epsilon_i/(Y_t(f)/Y_t)$. Hence, a smaller, non-positive value of ϵ_i or a larger firm size in terms of relative demand $Y_t(f)/Y_t$ leads to a larger superelasticity of demand for the products. Evaluating the superelasticity at a relative demand of one prevents firm size from directly affecting the curvature of demand and is consistent with the approaches used in previous studies (e.g., Dossche et al., 2010; Klenow and Willis, 2016; Beck and Lein, 2020). Aggregating each firm's superelasticity evaluated at a relative demand of one using its steady-state revenue share as its weight yields a mean curvature of demand:

$$\sigma = \sum_{i=1}^{k} \omega_i \left(-\theta\epsilon_i\right). \tag{41}$$

In the next section, we will compare the cases of heterogeneous versus homogeneous strategic complementarities in price setting across firm size in which the mean curvature of demand has the same value.

4 Quantitative Investigation

In this section, we explain the method to calibrate the parameters of the model and demonstrate the main result: accounting for firm size weakens the link between strategic complementarity and real rigidity.

4.1 Calibration of model parameters

For the parameters that are not related to firm size, we adopt values that are commonly used in the macroeconomic literature. Table 2 presents the quarterly calibration of the parameters. We set the subjective discount factor at $\beta = 0.995$, the elasticity of labor supply at $\chi = 1$, the depreciation rate of capital at $\delta = 0.025$, and the capital elasticity of production at $\alpha = 0.33$. The rate of balanced growth is chosen at $g = 1.005$, that is, 2 percent annually. The parameter governing investment adjustment costs is set at $\zeta = 2.5$, the estimate of

Christiano et al. (2005). The parameter governing the elasticity of substitution between individual goods is chosen at $\theta = 10$ to target a desired markup of about 11 percent for firms that face a constant elasticity of demand; firms that exhibit strategic complementarities will have a larger desired markup. The probability of each firm's not optimizing its product price is set at $\xi = 0.6$. The monetary policy responses to inflation and output are chosen at $\phi_\pi = 1.5$ and $\phi_y = 0.5/4$, respectively, as in Taylor (1993).

Table 2: Quarterly calibration of model parameters.

Parameter	Description	Value
β	Subjective discount factor	0.995
χ	Elasticity of labor supply	1
δ	Depreciation rate of capital	0.025
α	Capital elasticity of production	0.33
g	Gross rate of balanced growth	1.005
ζ	Parameter governing investment adjustment costs	2.5
θ	Parameter governing elasticity of substitution between goods	10
ξ	Probability of not optimizing price	0.6
ϕ_π	Monetary policy response to inflation	1.5
ϕ_y	Monetary policy response to output	0.5/4

The firm heterogeneity introduces $3k$ new parameters: n_i, z_i, and ϵ_i for $i = 1, \ldots, k$. The measure n_i of firms of each size $i = 1, \ldots, k$ is based on data from the SUSB of the US Census Bureau. Although the SUSB provides summary statistics for 23 firm-size categories, many of them represent only a small share of aggregate revenues.[14] This indicates that the model can capture the role of firm size by choosing a smaller number of groups k than the 23 available categories. Thus we select $k = 3$ in the baseline calibration and use k-means clustering to combine the 23 categories into three clusters or groups. The first group consists of firms with fewer than 1,000 employees, which can be characterized as small and medium-sized enterprises. The second and third groups consist of firms with 1,000–4,999 employees and with 5,000 or more employees, respectively.[15]

[14]We consider firms as business units under the assumption that price-setting decisions are more often made at the firm level than at the establishment level. A firm in the data is a business unit that consists of one or more domestic establishments in the same geographic area and industry. Considering establishments as business units would substantially reduce the dispersion in firm size, since the largest establishments are much smaller than the largest firms.

[15]A common definition of a small business is having fewer than 500 employees. The results presented in this section remain qualitatively unchanged if we limit the first group to firms with fewer than 500 employees

Values of z_i and ϵ_i for all $i = 1, \ldots, k$ are obtained as follows. We have already set $z_1 = 1$ as a normalization. We assume $\epsilon_1 = 0$, in line with the micro evidence in Amiti et al. (2019) that small firms exhibit no strategic complementarities. To calibrate the remaining parameters z_i and ϵ_i for $i = 2, \ldots, k$, we use the SUSB data. For each firm-size category, the survey provides not only the number of firms and their employment but also their payrolls and revenues.[16] Specifically, we target the empirical labor share S_i and revenue share R_i by firm size i. Firms' labor demand conditions imply the steady-state labor share $S_i = wl_i/(p_i^* y \Delta_i) = (1-\alpha)mc/p_i^*$. The $k-1$ real marginal cost equalities (12) can then be written as

$$S_i p_i^* z_i - S_{i-1} p_{i-1}^* z_{i-1} = 0, \quad i = 2, \ldots, k. \tag{42}$$

The log-linearization of the composite-good producer's zero profit condition (27) involves the steady-state revenue share ω_i for $i = 1, \ldots, k$. We can target revenues of only $k-1$ firm-size groups because the log-linearized condition requires that the revenue shares across firm size groups sum to one. Thus, we match the revenue shares $\omega_2, \ldots, \omega_k$ with their empirical counterparts using the $k-1$ conditions

$$\omega_i - R_i = n_i p_i^* \frac{\left(\frac{p_i^*}{d}\right)^{-\gamma_i} + \epsilon_i}{1 + \epsilon_i} - R_i = 0, \quad i = 2, \ldots, k. \tag{43}$$

Solving the $2k-2$ conditions (42) and (43) and the following $k+1$ steady-state conditions gives rise to the $2k-2$ values z_i and ϵ_i for $i = 2, \ldots, k$ and the $k+1$ values d and p_i^* for $i = 1, \ldots, k$:

$$1 = \sum_{i=1}^{k} \omega_i, \tag{44}$$

$$0 = \sum_{i=1}^{k} \frac{n_i}{\gamma_i - 1} \left[\left(\frac{p_i^*}{d} \right)^{1-\gamma_i} - 1 \right], \tag{45}$$

$$0 = \mu_1 \, p_i^* z_i - \mu_i \, p_1^*, \quad i = 2, \ldots, k. \tag{46}$$

Table 3 presents the values of the firm-size-specific parameters and steady-state vari-

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and expand the second group to firms with 500–4,999 employees.

[16] The data on revenues are provided every five years. We use the latest pre-COVID-19 data in 2017, but our results are virtually unchanged using the latest available data in 2022.

ables.[17] Recall that these values can affect inflation dynamics through the slope κ of the Phillips curve (30). The data reported in the top panel of the table are taken from the SUSB. The first row shows that the smallest-firm group makes up the vast majority of all firms ($n_1 = 0.9983$), whereas the measure of the other firm-size groups $i > 1$ is very small. However, revenue shares are more evenly distributed across firm size, as displayed in the second row. The largest-firm group actually has the largest revenue share.

Table 3: Values of firm-size-specific model parameters and steady-state variables.

	Parameter or variable	Description	Value for firm group i 1	2	3
(1)	n_i	Share of firms (percent)	99.83	0.13	0.04
(2)	ω_i	Revenue share (percent)	40.93	13.89	45.19
(3)	z_i	Relative productivity level	1	2.96	15.66
(4)	$-\theta\epsilon_i$	Superelasticity of demand	0	4.51	6.52
(5)	p_i^*	Steady-state optimized relative price	1.27	0.47	0.10
(6)	μ_i	Steady-state average markup	1.11	1.22	1.40

Source: US Census Bureau and authors' calculations.
Notes: The table presents the values of the firm-size-specific model parameters n_i, ω_i, z_i, and ϵ_i (multiplied by $-\theta$) and steady-state variables p_i^* and μ_i for all firm groups i. The values of n_i and ω_i are taken from the SUSB of the US Census Bureau. The values of z_i, ϵ_i, and p_i^* are obtained as part of a solution to eqs. (42)–(46), by setting $z_1 = 1$ and $\epsilon_1 = 0$ and using the data on the firm-size measure n_i, the revenue shares R_i, and the labor shares $S_{i,t}$ as well as the calibration of model parameters reported in Table 2. The values of μ_i are then calculated.

The parameter values shown in the middle panel and the steady-state values in the bottom panel are obtained by substituting the SUSB data, the parameter values reported in Table 2, and the assumptions $z_1 = 1$ and $\epsilon_1 = 0$ in eqs. (42)–(46).

The third row of Table 3 presents the relative productivity level of each firm group. The productivity level increases with firm size, such that the productivity of firms in the largest-size group is an order of magnitude greater than that in the smallest-size group, as indicated by the value of z_3.[18]

[17] Note that heterogeneity in firm productivity in the model is needed to determine values of the parameters ϵ_i that govern strategic complementarities in price setting. If firm productivity is homogeneous, that is, $z_i = 1$ for all i, then for arbitrary values of ϵ_i a solution to eqs. (44)–(46) is $p_i^* = d = 1$ for all i. The solution implies that $\Delta_i = 1$ for all i and that eqs. (42) and (43) are not satisfied with the empirical number of firms, labor share, and revenue share by firm-size group.

[18] Cunningham et al. (2023) present micro evidence on dispersion in establishment-level productivity. Across detailed manufacturing industries, total factor productivity of establishments at the 99th percentile is 2.38 times larger than that at the 90th percentile. This differential is similar to the productivity differential

The fourth row of the table displays the superelasticity of demand $-\theta\epsilon_i$ by firm size. Two points are worth noting. First, the superelasticity rises with firm size. The stronger superelasticity for larger-firm groups coincides with the micro evidence that the price-setting behavior of small firms is consistent with a constant elasticity of demand, while that of larger firms exhibits strategic complementarities, as discussed in Section 2. While the model is agnostic about the source of heterogeneity in the superelasticity by firm size, a possible interpretation is that customers are less loyal to the goods produced by larger firms, leading their demand elasticity to increase for higher prices. Holmes and Stevens (2014) suggest that small firms create specialty goods and large firms produce standardized goods. Thus, less customer loyalty to standard goods than to custom goods could rationalize the heterogeneity in strategic complementarity by firm size presented in our calibrated model. Second, given the firm-size-specific values reported in the table, the curvature defined as (41) is calculated as $\sigma = 3.57$, a value in line with the micro evidence in Dossche et al. (2010) and Beck and Lein (2020), who indicate that values in the range of 2–4 are empirically plausible.

The steady-state optimized relative prices and average markups are shown in the bottom panel of Table 3. Given the firm-size-specific model parameter values, the optimized price p_i^* decreases with firm size.[19] In addition, the steady-state average markups μ_i increase with firm size, consistent with the micro evidence in De Loecker et al. (2020) and Autor et al. (2020).[20] The latter authors refer to the largest firms, which have the largest markups and the smallest labor shares, as superstar firms.

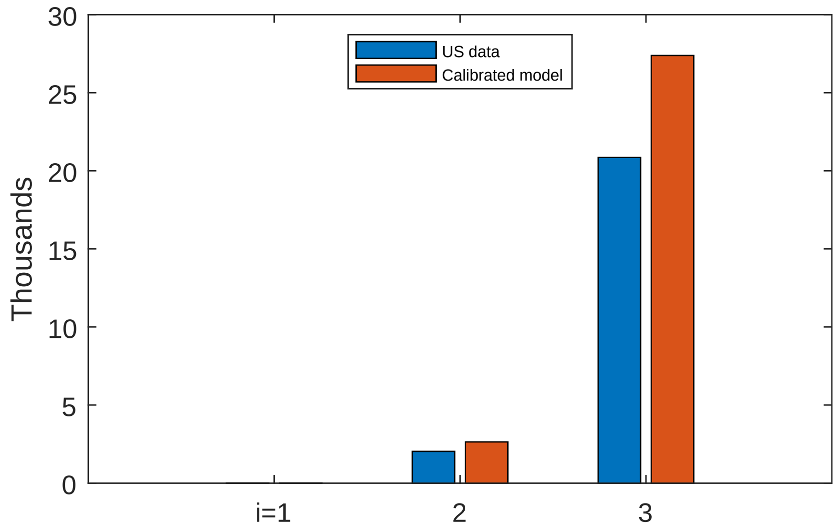
As for the relationship between firm productivity and firm size in the calibrated model, Figure 1 illustrates average employment per firm in the SUSB data (left bars) and labor input in the steady state of the calibrated model (right bars) for each of the three firm-size groups. The firm size measured as steady-state labor input in the model increases with the

$z_2/z_1 = 2.96$ in Table 3. We are not aware of micro evidence on productivity dispersion within the top 1 percentile of firms.

[19]A lower optimized relative price for larger firms implies that revenue productivity is less dispersed than physical productivity, consistent with the establishment-level evidence in Foster et al. (2008). The steady-state real marginal cost of producing the composite good is calculated as $d = 1.13$, thus raising the demand for all products evenly.

[20]We calculate a cost-weighted arithmetic average markup, which coincides with a sales-weighted harmonic average markup. De Loecker et al. (2020) employ a sales-weighted arithmetic average markup, which leads firms with higher markups to have higher sales weights relative to their cost weights. Edmond et al. (2023) point out that the cost-weighted arithmetic average markup is the relevant statistic that summarizes the distortions to employment and investment decisions.

Figure 1: Labor input by firm group.



Source: US Census Bureau and authors' calculations.
Notes: For each of the three firm groups, the figure presents average employment per firm in the SUSB data of the US Census Bureau (left bars) and labor input in the steady state of the model (i.e., l_i, right bars) under the calibration of parameters reported in Tables 2 and 3. Steady-state aggregate output y is normalized so that l_1 coincides with its empirical counterpart.

firm group index i as average employment per firm in the data does, although the dispersion in firm size is somewhat larger in the model.[21] Since the data on average employment per firm are not targeted in the calibration, the distribution provides an additional check on the model. The figure confirms that the size of firms increases with their productivity in the calibrated model.

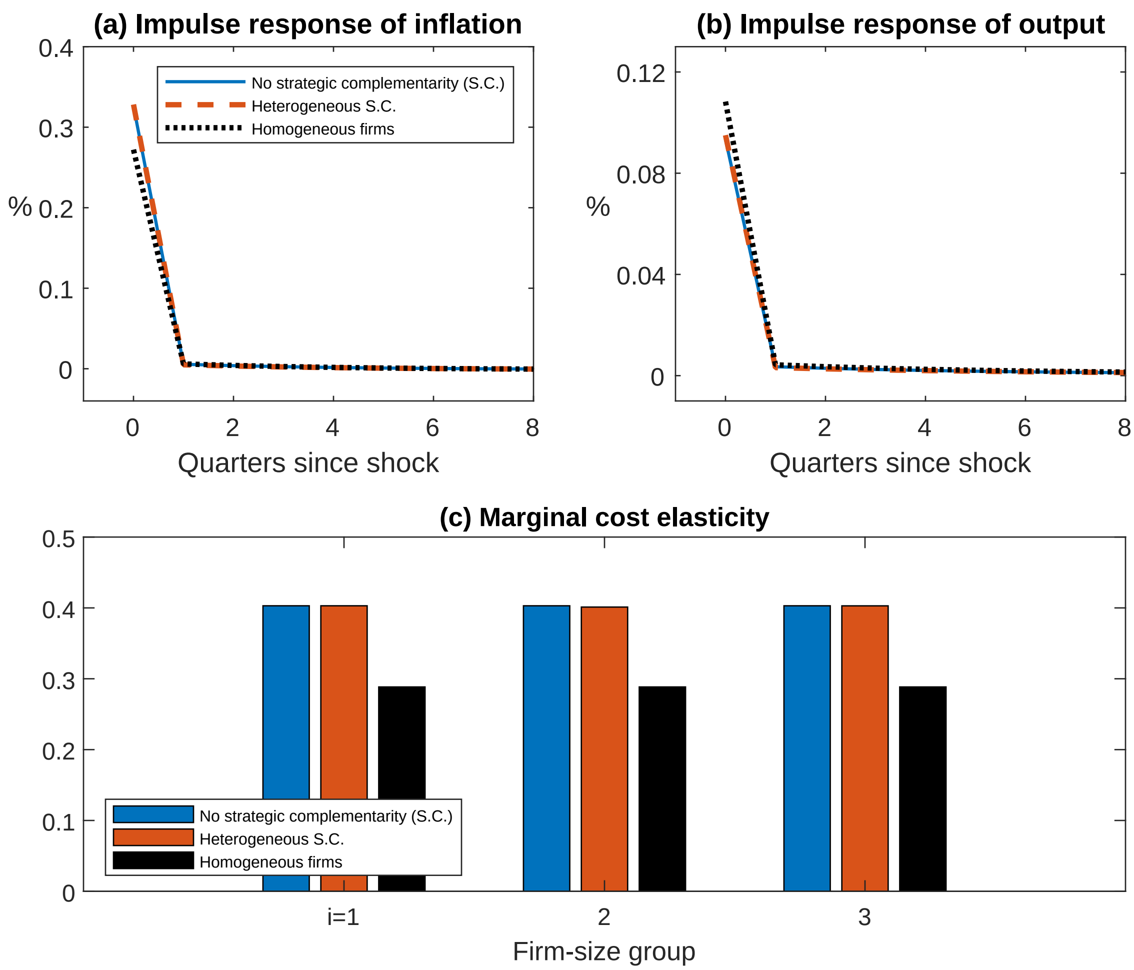
4.2 Main result

In this subsection, we use the calibrated model to show that heterogeneity in strategic complementarity in price setting by firm size does not materially increase monetary non-neutrality, compared to the cases of no complementarities and homogeneous complementarities, which suggests that heterogeneous complementarities generate little real rigidity in relative prices.

Monetary non-neutrality in the calibrated model can be gauged by its impulse responses to a monetary policy shock. Panels (a) and (b) of Figure 2 plot the responses of inflation and

[21] In the model the firm size measured as steady-state relative output Δ_i also rises with the firm group index i.

Figure 2: Strategic complementarity and monetary non-neutrality.



Notes: Panels (a) and (b) plot impulse responses of inflation and output, respectively, to a 1 percent expansionary shock to the annualized monetary policy rate in the model. Panel (c) displays the marginal cost elasticity of the optimized price $(1-\beta\xi)/\Gamma_i$ for each firm-size group $i = 1, 2, 3$. The results labeled "Heterogeneous S.C." are obtained under the calibration of model parameters reported in Tables 2 and 3, while those labeled "No strategic complementarity (S.C.)" represent the case of a constant elasticity of demand for each firm's product (i.e., $\epsilon_i = 0$ for all i) in the calibration and those labeled "Homogeneous firms" are obtained in the standard DSGE counterpart model with homogeneous firms in which the value of $\epsilon_i = \bar{\epsilon}$ for each i is chosen to achieve the same curvature $\sigma = 3.57$ as in the case of heterogeneous strategic complementarities.

output, respectively, to a 1 percent expansionary shock to the annualized monetary policy rate under the calibration of model parameters reported in Tables 2 and 3 (dashed lines), and compares the responses with those obtained in the case of no strategic complementarity, that is, a constant elasticity of demand for each firm's product (i.e., $\epsilon_i = 0$ for all i) in the calibration (solid lines) and those obtained in the standard DSGE counterpart model with homogeneous firms and hence homogeneous strategic complementarities (dotted lines). Both inflation and output increase on impact as the shock raises consumption and the real marginal cost, before returning to their steady-state values. In each of the top two panels, the impulse response in our calibrated model is practically identical to that in the case of no complementarity. In contrast, in the case of homogeneous complementarities, the response of inflation is smaller and that of output is larger. For a more quantitative assessment of strategic complementarity, we compare the cumulative impulse responses. The ratio of the cumulative response of inflation in our calibrated model to that in the case of no complementarity is 0.997, while the corresponding ratio of the cumulative response of output is 1.016. Seeing both ratios near one indicates that heterogeneous complementarities dampen the inflation response and amplify the output response only slightly. In contrast, the ratio of the cumulative response of inflation in the standard DSGE counterpart model to that in the case of no complementarity is 0.820, whereas the corresponding ratio of the cumulative response of output is 1.167. This shows that homogeneous complementarities dampen the inflation response and amplify the output response more and thus increase monetary non-neutrality substantially. Therefore, heterogeneous strategic complementarities concentrated in larger firms generate little increase in monetary non-neutrality.

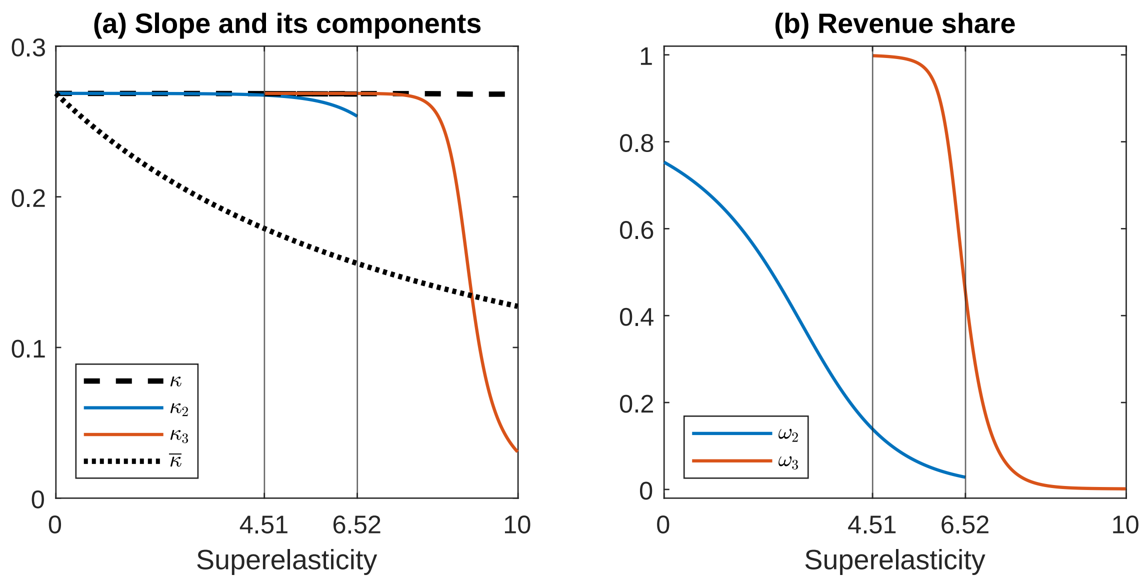
To better understand the result, panel (c) of Figure 2 displays the marginal cost elasticity of the optimized price for each firm-size group i. The middle bars illustrate the elasticity $(1 - \beta\xi)/\Gamma_i$ in eq. (25) in the model with heterogeneous strategic complementarities under the baseline calibration of parameters. As a reference, the left bars show the corresponding elasticity $1 - \beta\xi$ in the case of no complementarity, i.e., $\epsilon_i = 0$ for all i (so $\Gamma_i = 1$ for all i), while the right bars display the one $(1 - \beta\xi)/[1 - \bar{\epsilon}\theta/(\theta - 1)]$ in the case of homogeneous firms in which the value of $\epsilon_i = \bar{\epsilon}$ for each i is chosen to achieve the same curvature $\sigma = 3.57$ as in the case of heterogeneous complementarities. The elasticity of each firm-size group in the case of heterogeneous complementarities is almost the same as that in the case of no complementarity and is larger than that in the case of homogeneous firms and hence homogeneous complementarities, and thus so is the slope of the Phillips curve (30). In the case of heterogeneous complementarities, the elasticity of each larger-firm group declines through a smaller, negative value of ϵ_i and hence a larger steady-state markup μ_i, but it rises through higher productivity and hence a lower steady-state optimized price p_i^* because the lower price leads to a smaller steady-state price elasticity of demand for products of larger firms, which makes their optimized price more sensitive to the marginal cost. By these offsetting effects, the marginal cost elasticity varies little across firm size in the calibrated model.

The invariance of the marginal cost elasticity to firm size does not sit well with the empirical evidence presented in Table 1. Strengthening the effect of strategic complementarity on the price-setting behavior relative to that of firm size can reduce the elasticity in larger-firm groups and reconcile the model with the empirical evidence. Figure 3 plots the Phillips curve slope $\kappa = \sum_{i=1}^{k} \omega_i \kappa_i$, its components $\kappa_i = (1-\xi)(1-\beta\xi)/(\xi\,\Gamma_i)$, and their weights ω_i, or equivalently, the revenue shares of larger-firm groups $i = 2, 3$, as the superelasticity of demand of each larger-firm group in turn increases while those of the other firm-size groups are held fixed at their calibrated values reported in Table 3. In panel (a), the dotted line displays the Phillips curve slope $\bar{\kappa} = (1-\xi)(1-\beta\xi)/\{\xi[1-\bar{\epsilon}\theta/(\theta-1)]\}$ in the standard DSGE counterpart model with homogeneous firms, as the superelasticity $-\theta\bar{\epsilon}$ rises. This line shows that a greater value of the superelasticity decreases the slope $\bar{\kappa}$. Compared to the slope in the standard DSGE counterpart model, the solid lines demonstrate that the decreases in the slope components κ_i of larger-firm groups $i = 2, 3$ caused by a greater superelasticity are mitigated. The dashed line then traces the Phillips curve slope $\kappa = \sum_{i=1}^{k} \omega_i \kappa_i$ and shows that the slope remains near the level $(1-\xi)(1-\beta\xi)/\xi$ associated with no strategic complementarities (i.e., $\epsilon_i = 0$ for all i), indicating little or no increase in monetary non-neutrality. This is because a greater superelasticity for each larger-firm group reduces the steady-state price elasticity of demand for the products of firms in the group and thereby mitigates the decrease in the group's slope component κ_i induced by the greater superelasticity, as displayed by the solid lines in panel (a).[22] It is also because a greater superelasticity lowers each

[22]This is consistent with the result shown in panel (c) of Figure 2 that each firm-size group's marginal cost elasticity of its optimized price is largely unaffected by heterogeneity in strategic complementarity under the

larger-firm group's steady-state revenue share ω_i as detected in panel (b), thus giving the decreasing slope component κ_i a smaller weight ω_i in the slope κ. For each larger-firm group, a greater superelasticity implies a higher steady-state average markup and thus raises the steady-state optimized relative price, which induces decelerating demand and lower revenue in the steady state by increasing the steady-state price elasticity of demand.

Figure 3: Phillips curve slope, its components, and revenue shares for various degrees of strategic complementarity of larger firm-size groups.



Notes: Panel (a) displays the Phillips curve slope $\kappa = \sum_{i=1}^{k} \omega_i \kappa_i$ (dashed line) and its components $\kappa_i = (1-\xi)(1-\beta\xi)/(\xi\,\Gamma_i)$ for larger-firm groups $i = 2, 3$ (solid lines), while panel (b) shows the slope components' weights, or equivalently, their revenue shares ω_2 and ω_3. The slope component κ_i and its weight ω_i are calculated by increasing the superelasticity of each larger-firm group $i = 2, 3$ while keeping the superelasticities of the other firm-size groups at their calibrated values presented in Table 3. Panel (a) also plots the Phillips curve slope $\bar{\kappa} = (1-\xi)(1-\beta\xi)/\{\xi[1-\bar{\epsilon}\theta/(\theta-1)]\}$ in the standard DSGE counterpart model with homogeneous firms (dotted line). The values of other model parameters are reported in Tables 2 and 3.

Stronger strategic complementarity in the price-setting behavior of larger-firm groups is evident both in their smaller marginal cost elasticities and a larger spillover effect in the price-setting condition (29) because the revenue shares shift toward the other firm-size groups, in particular the smallest-firm group, which exhibits no complementarities. Thus, Figure 3 reinforces the finding that strategic complementarity is no longer a substantial source of real

calibration of model parameters reported in Tables 2 and 3.

rigidity once heterogeneity in complementarity by firm size is taken into account.[23]

4.3 Roles of strategic complementarity and firm size

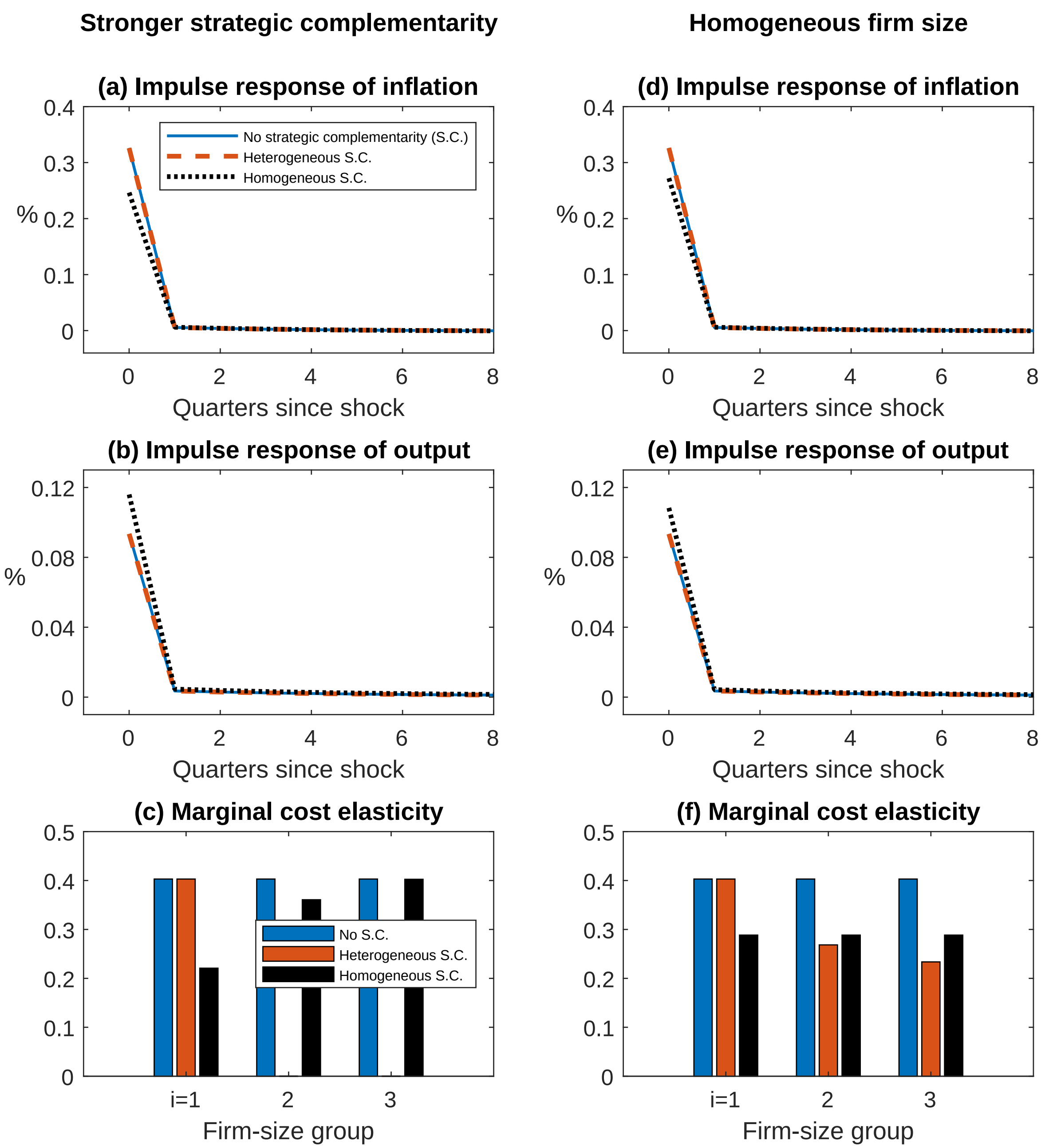
In this subsection, we examine other changes in parameter values that increase strategic complementarities of larger-firm groups or reduce their size in turn, and show that these changes preserve the result on monetary non-neutrality obtained in the previous subsection.

First, we consider stronger strategic complementarity in the price-setting behavior of larger-firm groups once more by scaling up the values of each parameter ϵ_i reported in Table 3 to double the mean curvature to $\sigma = 7.14$. Panels (a) and (b) of Figure 4 display the resulting impulse responses of inflation and output, respectively (dashed lines). Despite the stronger complementarity, the impulse responses remain almost the same as those obtained in the case of no strategic complementarity, i.e., $\epsilon_i = 0$ for all i (solid lines). The ratios of cumulative impulse responses for inflation and output are 0.999 and 1.001, respectively. The panels also include impulse responses in the case of homogeneous complementarities (dotted lines), obtained by choosing the value of the parameters $\epsilon_i = \bar{\epsilon}$ for all i (including $i = 1$) to achieve the same curvature $\sigma = -\theta\bar{\epsilon} = 7.14$ as that under heterogeneous complementarities. If all firms identically exhibit strategic complementarities, the response of inflation to a monetary policy shock is dampened while that of output is amplified. The ratios of cumulative impulse responses for inflation and output are 0.731 and 1.253, respectively. Thus, homogeneous complementarities generate a substantial increase in monetary non-neutrality.

Panel (c) of the figure displays the marginal cost elasticity of the optimized price for each firm-size group. In contrast to the case of no strategic complementarity (i.e., $\epsilon_i = 0$ for all i) displayed by the left bars, the middle bars representing the case of heterogeneous complementarities show that the marginal cost elasticity for larger-firm groups is almost zero, indicating that firms in these groups influence inflation dynamics mostly by adjusting their optimized prices to the expected future optimized price of the smallest-firm group, which

[23] Changing the firm-size-specific parameter values that govern strategic complementarity leads the revenue shares in the calibrated model to deviate from the SUSB data. Thus, the quantitative model faces a tension between replicating the empirical evidence on firms' price-setting behavior presented in Table 1 and matching the data by firm size. Figure 3 indicates that heterogeneity in strategic complementarity by firm size has little effect on monetary non-neutrality, regardless of which evidence or data are prioritized in calibrating model parameters. Hence, we leave the task of considering model enhancements that reconcile replicating the empirical evidence and matching the data for future research.

Figure 4: Strategic complementarity and monetary non-neutrality in the cases of stronger strategic complementarity and homogeneous firm size.



Notes: Panels (a)–(c) present results obtained by scaling up the parameters ϵ_i for each i to reach $\sigma = 7.14$ from $\sigma = 3.57$ (dashed lines and middle bars), those for the case of homogeneous strategic complementarities in which the value of $\epsilon_i = \bar{\epsilon}$ for all i is chosen to achieve the same curvature $\sigma = 7.14$ (dotted lines and right bars), and those for the case of no strategic complementarity, i.e., $\epsilon_i = 0$ for all i (solid lines and left bars), respectively. Panels (d)–(f) present analogous results for the case of homogeneous firm size that is obtained by setting $z_i = 1$ for all i. The values of model parameters other than those indicated just above are reported in Tables 2 and 3.

has a larger marginal cost elasticity. The right bars show the case of homogeneous complementarities and demonstrate that if all firms identically exhibit strategic complementarities, the elasticity increases with firm size, because a lower steady-state optimized price of each larger-firm group leads to a smaller steady-state price elasticity of demand for the products of firms in the group.

Another change in the calibration of model parameters is reducing differences in firm size to mitigate the effect of size on the marginal cost elasticities of larger-firm groups. Arguably, the model accounts primarily for heterogeneity in firm size to pin down the values of the parameters ϵ_i using the SUSB data of the US Census Bureau. By considering values of the productivity parameters of $z_i = 1$ for all i while holding the parameters ϵ_i at the values reported in Table 3, the dynamics of the model abstract from firm size.

For the case of homogeneous firm size, panels (d) and (e) of Figure 4 plot impulse responses of inflation and output, respectively. The impulse responses obtained in the presence of heterogeneous strategic complementarities (dashed lines) are similar to those obtained in the case of no complementarity (solid lines). The ratios of the cumulative impulse responses for inflation and output are 0.999 and 1.000, respectively, indicating that heterogeneous complementarities generate almost no increase in monetary non-neutrality. The results with homogeneous complementarities (dotted lines) are obtained by choosing the value of the parameters $\epsilon_i = \bar{\epsilon}$ for each i to achieve the curvature $\sigma = 3.57$. If all firms identically exhibit strategic complementarities, the ratios of cumulative impulse responses for inflation and output are 0.820 and 1.167, respectively, indicating a substantial increase in monetary non-neutrality in line with the standard DSGE counterpart model with homogeneous firms that abstracts from heterogeneity in firm size and in strategic complementarity.

Panel (f) of the figure displays the marginal cost elasticity of the optimized price for each firm-size group i in the case of homogeneous firm size, i.e., $z_i = 1$ for all i. If strategic complementarity is also homogeneous (right bars), the parameter value $\bar{\epsilon} < 0$ reduces the elasticity equally for each firm-size group, compared to the case of no strategic complementarity (left bars). In contrast, heterogeneity in strategic complementarity using the parameter values ϵ_i reported in Table 3 reduces the elasticity for larger-firm groups $i = 2, 3$ (middle bars).

In the cases of stronger strategic complementarity and homogeneous firm size, homogeneous complementarities generate a substantial increase in monetary non-neutrality. Once strategic complementarity is concentrated in larger-firm groups in line with the empirical evidence on the cost-price pass-through by firm size presented in Table 1, the model fails to materially increase monetary non-neutrality, indicating that heterogeneous complementarities generate little real rigidity. An explanation is as follows. Since small firms adjust their product prices facing a constant elasticity of demand, they more fully pass through changes in the real marginal cost to their prices. Larger firms, however, exhibit strategic complementarities in price setting. Then, an expansionary monetary policy shock raises the real marginal cost and hence the optimized relative price of small firms, which in turn increases the optimized relative prices of larger firms through their strategic complementarities. In this way, small and larger firms all adjust their product prices substantially after the policy shock, resulting in weak real rigidity.

4.4 Other robustness analysis

We have found that heterogeneity in strategic complementarity by firm size weakens monetary non-neutrality. In this subsection, we confirm the robustness of the finding to alternative values of model parameters.

Table 4 reports the cumulative impulse responses (CIR) in the case of heterogeneous strategic complementarities and that of homogeneous firms, both of which share the same curvature σ, and the ratios of the CIR with the corresponding ones in the case of no complementarity. Panel (a) summarizes the numbers obtained under the baseline calibration of model parameters reported in Table 2 and the firm-size-specific parameter values presented in Table 3. As observed previously, heterogeneous complementarities do little to dampen the CIR of inflation or amplify the CIR of output to a monetary policy shock, in contrast to the case of homogeneous firms. Panels (b), (c), and (d) consider more nominal price rigidity ($\xi = 0.75$), less elastic labor supply ($\chi = 1/2$), and a smaller elasticity of substitution between goods ($\theta = 7$), respectively. Although the alternative parameter values influence the CIR quantitatively, their influence is similar in each of the cases of heterogeneous complementarities and no complementarity, so that the ratios of the CIR all remain close to one in the table. Panel (e) relaxes the assumption of a constant elasticity of demand in the smallest-firm group by selecting a modest positive value of the superelasticity of $-\theta\epsilon_1 = 2$. Because the steady-state optimized price in this group is high, the marginal cost elasticity

Table 4: Cumulative impulse responses and their ratios.

Case	Inflation		Output	
	CIR	Ratio	CIR	Ratio
(a) *Baseline calibration of model parameters*				
No strategic complementarity (S.C.)	0.317	1	0.127	1
Heterogeneous S.C.	0.315	0.997	0.129	1.016
Homogeneous firms	0.259	0.820	0.148	1.167
(b) *More nominal price rigidity*: $\xi = 0.75$				
No S.C.	0.135	1	0.195	1
Heterogeneous S.C.	0.132	0.980	0.198	1.015
Homogeneous firms	0.095	0.703	0.210	1.079
(c) *Less elastic labor supply*: $\chi = 1/2$				
No S.C.	0.268	1	0.144	1
Heterogeneous S.C.	0.266	0.993	0.147	1.017
Homogeneous firms	0.212	0.793	0.165	1.141
(d) *Smaller elasticity of substitution between goods*: $\theta = 7$				
No S.C.	0.316	1	0.128	1
Heterogeneous S.C.	0.315	0.997	0.129	1.015
Homogeneous firms	0.265	0.837	0.147	1.150
(e) *Modest superelasticity for smallest-firm group*: $-\theta\epsilon_1 = 2$				
No S.C.	0.317	1	0.127	1
Heterogeneous S.C.	0.292	0.922	0.137	1.082
Homogeneous firms	0.252	0.797	0.151	1.189
(f) *Larger number of firm groups*: $k = 5$				
No S.C.	0.317	1	0.127	1
Heterogeneous S.C.	0.315	0.996	0.129	1.017
Homogeneous firms	0.256	0.810	0.149	1.176

Notes: The table presents the cumulative impulse responses (CIR) of inflation and output to a 1 percent expansionary shock to the annualized monetary policy rate obtained with the values of ϵ_i reported in Table 3 ("Heterogeneous S.C."), those obtained with the values $\epsilon_i = \bar{\epsilon}$ for each i that achieve the same curvature in the standard DSGE counterpart model ("Homogeneous firms"), and their ratios with the corresponding CIR in the case of "No strategic complementarity (S.C.)," i.e., $\epsilon_i = 0$ for all i. The other model parameter values are reported in Tables 2 and 3, except for the alternative parameter values used in panels (b)–(e).

is smaller than that for the larger-firm groups, leading to a modest increase in monetary non-neutrality. Finally, panel (f) increases the number of firm groups to $k = 5$ and detects almost no change from the results under the baseline calibration reported in panel (a).

5 Concluding Remarks

This paper has presented new empirical evidence based on firm survey data that compared to small firms, larger firms exhibit significantly less cost-price pass-through. The evidence complements the empirical result of previous research that only large firms exhibit strategic complementarities in price setting. To examine the implications of firm size for inflation dynamics, the paper has developed a DSGE model with the twin features that firm heterogeneity in productivity generates heterogeneity in firm size and that strategic complementarity in price setting arising from a non-CES aggregator of differentiated goods is heterogeneous across firm size. The model is calibrated to the SUSB data of the US Census Bureau and the calibration implies that larger firms with higher productivity exhibit stronger strategic complementarities. Heterogeneous complementarities generate almost no increase in monetary non-neutrality or little real rigidity in relative prices in the calibrated model. This result arises because small firms more fully pass through changes in the real marginal cost, which leads larger firms that exhibit strategic complementarities in price setting to bring their product prices in line with those of small firms.

Monetary policymakers gain insights from results based on DSGE models that often assume homogeneous strategic complementarities in price setting across firms to generate real rigidity in relative prices and hence plausible monetary non-neutrality along with moderate nominal price rigidity. The paper has shown that the link between strategic complementarity and real rigidity is a fragile one that depends on the unrealistic simplifying assumption that firm size is irrelevant for price-setting behavior. Therefore, our results recommend that future research using DSGE models consider other sources of real rigidity. A shift in emphasis from so-called micro real rigidity including strategic complementarity in price setting toward macro real rigidity, such as real wage rigidity and the input-output structure of the economy, could put DSGE models on a more robust footing.[24]

[24] Rubbo (2023) examines implications of input-output linkages for the Phillips curve.

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