Firm Size, Heterogeneous Strategic Complementarities, and Real Rigidity*

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Abstract

Recent research finds that only large firms exhibit strategic complementarities in price setting. Using firm survey data, we show that cost pass-through decreases significantly with firm size. To examine the implications for inflation, 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, such rigidity is much weaker in our model. Large firms that exhibit strategic complementarities align their goods prices with those of small firms that more fully pass through costs. Our findings challenge the notion of strategic complementarity as a source of real rigidity.

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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 goods 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 cost 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 goods. 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 goods, 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 substantially weakens real rigidity in relative prices in the DSGE model. We show this result by comparing the slope of the Phillips curve in our calibrated model (with heterogeneous complementarities) to that 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, the slope of the Phillips curve in our model is larger than that in the counterpart model. To put the magnitudes into context, we compare the impulse responses of output to a monetary policy shock obtained in our calibrated model and the counterpart model with the impulse response obtained in the case where all firms face a constant elasticity of demand (so there is no complementarity). Strategic complementarities increase the impulse response of output by about half as much in our model as in the counterpart model. Therefore, the concentration of strategic complementarities among large firms dampens the increase monetary non-neutrality substantially in our calibrated model.

Strategic complementarity and productivity have offsetting effects on the pass-through of large firms' 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 good. We show analytically that if productivity is homogeneous, heterogeneity in strategic complementarities increases the slope of the Phillips curve, thus generating less real rigidity than homogeneous strategic complementarity. Accounting also for differences in productivity across firms then further increases the slope in our calibrated model. In this way, heterogeneity in firm size and in strategic complementarities each lead to weaker real rigidity.

The model's equilibrium conditions provide an 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 goods 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.

Our results indicate that the real rigidity generated in standard DSGE models, which abstract from firm heterogeneity, is partly an artifact of homogeneity in strategic complementarity in price setting across firms. Once we account for the empirical heterogeneity in strategic complementarities by firm size, the real rigidity is greatly weakened, as noted above. Therefore, our findings challenge the notion of strategic complementarities 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 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 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

[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 multiple-product firms for equilibrium stability.

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

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 about their prices and costs. The high and volatile inflation observed in this period makes it an opportune time to study firms' cost 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

[6]For evidence on the role of strategic complementarity in cost 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.

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 j 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 j by taking the value one if the firm is small, medium, or 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

[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?*"

in the average markup during the sample period that saw a rise and fall in inflation. The coefficients β_i capture the cost 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 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 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 pass-through than small and medium firms.

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

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

[9] The six survey months are December 2020, April 2021, July 2021, November 2021, March 2022, and December 2022. With multiple-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.

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 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

[10]Specifically, $\hat{V} = \hat{Q}_{\tilde{X}\tilde{X}}^{-1} \hat{\Sigma} \hat{Q}_{\tilde{X}\tilde{X}}^{-1}$, 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).

[11]A plausible interpretation of our finding that large firms exhibit less cost pass-through than smaller firms would be that the price-setting behavior of large firms is subject to greater real rigidity but not greater

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 indicates 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 goods. 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.

3.1 Composite-good producers

The representative composite-good producer combines the outputs of a continuum of firms $j \in [0,1]$, each of which belongs to one of the k groups $\Omega_i = \{j \in [0,1] : z(j) = z_i, \epsilon(j) = \epsilon_i\}$,

nominal price rigidity. This is because Goldberg and Hellerstein (2011) use PPI micro data to show that large firms change their product prices more frequently (and by smaller amounts) than small firms. Consistently, Bhattarai and Schoenle (2014) find that firms that produce more goods adjust their prices more frequently (and by smaller amounts).

$i = 1, \ldots, k$, where $z(j)$ denotes firm-j-specific productivity relative to that of firms in group Ω_1 with the normalization of $z_1 = 1$ and the parameter $\epsilon(j)$ governs the superelasticity of demand for firm j's good. 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, $\int_{\Omega_i} dj = n_i$, so we have $\sum_{i=1}^{k} \int_{\Omega_i} dj = \sum_{i=1}^{k} n_i = 1$. The composite good Y_t is produced by combining individual differentiated goods $\{Y_t(j)\}$ with an aggregator of the sort proposed by Kimball (1995):

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

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

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

where $\gamma_i \equiv \theta(1 + \epsilon_i)$. A value of $\epsilon_i < 0$ gives rise to a positive superelasticity of demand for goods 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 $Y_t = [\int_0^1 (Y_t(j))^{(\theta-1)/\theta} dj]^{\theta/(\theta-1)}$, where $\theta > 1$ represents the elasticity of substitution between individual goods.

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

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

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

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

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

Eq. (3) is the demand curve for firm j's good, where d_t denotes the Lagrange multiplier on the aggregator (2). The multiplier describes an average relative price $d_{i,t}$ over goods of type-i firms according to (4). 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 $j \in [0, 1]$ produces an individual differentiated good $Y_t(j)$ using the Cobb-Douglas production technology

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

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 $K_t(j)$ and $l_t(j)$ are firm j's inputs of capital and labor.

Firm j minimizes cost $TC_t(j) = P_t r_{k,t}\, K_t(j) + P_t W_t\, l_t(j)$ 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 $K_{i,t} \equiv \frac{1}{n_i} \int_{\Omega_i} K_t(j)\, dj$ and $l_{i,t} \equiv \frac{1}{n_i} \int_{\Omega_i} l_t(j)\, dj$. 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

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

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

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 marginal cost can then be written as

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

Thus, this ratio is inversely proportional to the ratio of each firm type's relative productivity.

We turn next to firms' price setting. Firms set their goods prices on a staggered basis as in Calvo (1983). In each period, a fraction $\xi \in (0,1)$ of type-i firms (i.e., $j \in \Omega_i$) indexes their goods 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 $P_t(j)$, given the marginal cost (11), so as to maximize relevant profits

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

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 $t+j$. Assuming the same fraction ξ for all firm types i allows us to highlight the implications of heterogeneous strategic complementarities for inflation dynamics. 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

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

while the capital-service market clearing condition is

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

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

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

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 $u_{r,t} = \rho u_{r,t-1} + \varepsilon_{r,t}$ is a shock to the monetary policy rate with $|\rho| < 1$ and $\varepsilon_{r,t}$ is a normally distributed innovation, that is, $\varepsilon_{r,t} \sim i.i.d. N(0, \sigma^2)$. The monetary policy shock 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

$$\Gamma_i \equiv 1 + (-\epsilon_i)\left(\frac{p^*_i}{d}\right)^{\gamma_i}\mu_i \tag{28}$$

measures real rigidity 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 goods 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

$$\hat{\pi}_t = \frac{1-\xi}{\xi}\sum_{i=1}^{k}\omega_i\,\hat{p}^*_{i,t}, \tag{29}$$

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 (29) in (25) leads to

$$\hat{p}^*_{i,t} = \beta[\xi + (1-\xi)\omega_i]E_t\hat{p}^*_{i,t+1} + \beta(1-\xi)\sum_{j\neq i}\omega_j E_t\hat{p}^*_{j,t+1} + \frac{1-\beta\xi}{\Gamma_i}\,\hat{mc}_t. \tag{30}$$

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 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

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \kappa\,\hat{mc}_t = \beta E_t\hat{\pi}_{t+1} + \left(\sum_{i=1}^{k}\omega_i\kappa_i\right)\hat{mc}_t, \tag{31}$$

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 (31) and the following 10 equations:

$$\hat{mc}_t = (1-\alpha)\hat{w}_t + \alpha\,\hat{r}_{k,t}\,, \tag{32}$$

$$\hat{k}_{t-1} - l_t = \hat{w}_t - \hat{r}_{k,t}\,, \tag{33}$$

$$\hat{y}_t = (1-\alpha)\hat{l}_t + \alpha\,\hat{k}_{t-1}, \tag{34}$$

$$\hat{c}_t = E_t\hat{c}_{t+1} - \hat{r}_t + E_t\hat{\pi}_{t+1}, \tag{35}$$

$$\hat{w}_t = \frac{1}{\chi}\,\hat{l}_t + \hat{c}_t, \tag{36}$$

[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.

$$\hat{k}_t = \frac{1-\delta}{g}\,\hat{k}_{t-1} + \left(1 - \frac{1-\delta}{g}\right)\hat{\imath}_t, \tag{37}$$

$$\hat{q}_t = \zeta\left(\hat{\imath}_t - \hat{\imath}_{t-1}\right) - \beta\zeta\left(E_t\hat{\imath}_{t+1} - \hat{\imath}_t\right), \tag{38}$$

$$\hat{r}_t - E_t\hat{\pi}_{t+1} = \left[1 - \beta\left(\frac{1-\delta}{g}\right)\right] E_t\hat{r}_{k,t+1} + \beta\left(\frac{1-\delta}{g}\right) E_t\hat{q}_{t+1} - \hat{q}_t, \tag{39}$$

$$\hat{y}_t = \frac{c}{y}\,\hat{c}_t + \frac{i}{y}\,\hat{\imath}_t, \tag{40}$$

$$\hat{r}_t = \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + u_{r,t}\,. \tag{41}$$

The last 10 conditions (32)–(41) 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 goods 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 goods of type-i firms is derived as $\eta_i(Y_t(j)/Y_t) = \theta(1 + \epsilon_i - \epsilon_i(Y_t(j)/Y_t)^{-1})$. Then, given $\epsilon_i < 0$, the elasticity is smaller for a larger relative demand $Y_t(j)/Y_t$, which leads the desired markup $\eta_i(Y_t(j)/Y_t)/\left(\eta_i(Y_t(j)/Y_t) - 1\right)$ 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

[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 (40).

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 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., $Y_t(j)/Y_t = 1$. The superelasticity of demand for goods of type-i firms (i.e., the elasticity of the elasticity $\eta_i(Y_t(j)/Y_t)$) is derived as $\sigma_i(Y_t(j)/Y_t) = -\theta\epsilon_i/(Y_t(j)/Y_t)$. Hence, a smaller, non-positive value of ϵ_i or a smaller firm size in terms of relative demand $Y_t(j)/Y_t$ leads to a larger superelasticity of demand for the goods. 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:

$$\sigma = \sum_{i=1}^{k} \omega_i \left(-\theta\epsilon_i\right). \tag{42}$$

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 not optimizing its good's price is set at $\xi = 0.6$. The monetary policy responses to inflation and output are chosen respectively at $\phi_\pi = 1.5$ and $\phi_y = 0.5/4$, as in Taylor (1993), and the persistence of the monetary policy shock is set at $\rho = 0.8$.

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
ρ	Persistence of monetary policy shock	0.8

The firm heterogeneity introduces $3k$ new parameters: n_i, z_i, and ϵ_i for $i = 1, \ldots, k$. To select values for these parameters, we calibrate the model to 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. 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.[14]

[14]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

First, the measure n_i of firms of each size $i = 1, \ldots, k$ is set equal to the fraction of establishments in each firm-size group. In the model, every firm produces one good as in standard DSGE models. While this is a good approximation for small firms, actual large firms typically produce multiple goods (Broda and Weinstein, 2010; Bernard et al., 2010). We can account for this empirical fact by calibrating n_i to the number of products in each firm-size group.[15] Because the SUSB data do not provide information on the number of products per firm, we approximate that number with the number of establishments per firm assuming every establishment produces one good.[16]

Second, values of ϵ_i for all $i = 1, \ldots, k$ are obtained jointly with values of the steady-state variables d and p_i^* for $i = 1, \cdots, k$. 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 ϵ_i for $i = 2, \ldots, k$ and determine the relative prices, we rely on the SUSB data on payrolls and revenues.[17] 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 $S_i = wl_i/(p_i^* y \Delta_i) = (1-\alpha)/\mu_i$. Thus, we have $k-1$ conditions

$$S_i \mu_i - S_{i-1} \mu_{i-1} = 0, \quad i = 2, \ldots, k. \tag{43}$$

The steady-state composite-good producer's zero profit condition (6) involves the revenue share ω_i for $i = 1, \ldots, k$. We can target revenues of $k-1$ firm-size groups because the condition requires that the revenue shares across firm size groups sum to one. Thus, we match

and expand the second group to firms with 500–4,999 employees. Grouping firms based on the number of their production units or establishments, another metric of firm size, also leaves the results qualitatively unchanged.

[15] The model is observationally equivalent with one that distinguishes the number of firms and the number of products per firm. Suppose that m_i firms produce multiple goods using the production technology distinguished by z_i for $i = 1, \cdots, k$, so each firm belongs to only one firm-size group and the firms in group i produce a total of n_i goods. Then we can aggregate consecutively over the goods per firm and the firms in each group. The steady state and the equilibrium conditions of the model remain unchanged. Appendix A provides the details.

[16] Although empirical evidence about the mapping between a firm's establishments and its products is lacking, our assumption is in line with models of industrial organization (e.g., Cao et al., 2022).

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

the revenue shares $\omega_2, \ldots, \omega_k$ with their empirical counterparts using the $k-1$ conditions

$$\omega_i - R_i = n_i p_i^* \frac{\left(\frac{p_i^*}{d}\right)^{-\gamma_i} + \epsilon_i}{1+\epsilon_i} - R_i = 0, \quad i = 2, \ldots, k. \tag{44}$$

Solving the $2k-2$ conditions (43) and (44) and the following 2 steady-state conditions

$$1 = \sum_{i=1}^{k} \omega_i, \tag{45}$$

$$0 = \sum_{i=1}^{k} \frac{n_i}{\gamma_i - 1} \left[\left(\frac{p_i^*}{d}\right)^{1-\gamma_i} - 1 \right], \tag{46}$$

yields the $k-1$ values ϵ_i for $i = 2, \ldots, k$ and the $k+1$ values d and p_i^* for $i = 1, \ldots, k$.

Third, the relative productivity level of small firms is normalized to $z_1 = 1$ and the parameters z_i for $i = 2, \ldots, k$ are obtained from the ratio of real marginal costs (12) in the steady state, which can be written as

$$z_i = \frac{\mu_i \, p_1^*}{\mu_1 \, p_i^*}, \quad i = 2, \ldots, k. \tag{47}$$

Table 3 presents the values of the firm-size-specific parameters and steady-state variables. Recall that these values can affect inflation dynamics through the slope κ of the Phillips curve (31). The first row shows that the smallest-firm group makes up the vast majority of all establishments in the SUSB ($n_1 = 0.8504$), whereas the measure of the other firm-size groups $i > 1$ is small. However, revenue shares in the SUSB are more evenly distributed across firm size, as displayed in the second row. The largest-firm group actually has the largest revenue share. The third row 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 almost double that in the smallest-size group, as indicated by the value of z_3.[18]

The fourth row of Table 3 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

[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 $z_3/z_1 = 1.80$ in Table 3.

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 establishments (percent)	85.04	3.95	11.01
(2)	ω_i	Revenue share (percent)	40.03	14.44	45.54
(3)	z_i	Relative productivity level	1	1.46	1.80
(4)	$-\theta\epsilon_i$	Superelasticity of demand	0	5.63	7.65
(5)	p_i^*	Steady-state optimized relative price	1.14	0.85	0.78
(6)	μ_i	Steady-state average markup	1.11	1.21	1.36

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 ϵ_i and p_i^* are obtained as part of a solution to eqs. (43)–(46), by setting $\epsilon_1 = 0$ 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 z_i and μ_i are then calculated.

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 (42) is calculated as $\sigma = 4.30$, a value roughly 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 last two rows of Table 3. 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 a declining labor share by

[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 $d = 1.05$, thus raising the demand for all goods evenly.

firm size S_i in the SUSB data and the micro evidence in De Loecker et al. (2020) and Autor et al. (2020). Finally, firm size, measured as relative output $(\Delta_1, \Delta_2, \Delta_3) = (0.41, 4.28, 5.32)$ or labor input $(l_1, l_2, l_3) \propto (0.13, 0.96, 0.97)$, is increasing in productivity in the model.[20]

4.2 Homogeneous productivity

We begin our analysis of heterogeneous strategic complementarities by abstracting from differences in productivity across firms. The results obtained in this case will clarify the distinct roles of heterogeneity in firm size and in strategic complementarities in the next subsection, where we analyze the calibrated model with both features. If $z_i = 1$ for all i, then for arbitrary values of ϵ_i a solution to eqs. (45)–(47) is $p_i^* = d = 1$ for all i.[21] Thus, firm size has no effect on the slope of the Phillips curve (31).

The extent to which strategic complementarities induce real rigidity can be measured by their effect on the slope of the Phillips curve κ, an effect that is captured by the factor Γ_i described in (28). All else equal, larger values of Γ_i for any i induce more real rigidity and hence the model will display greater monetary non-neutrality. We then have the following result.

Proposition 1 *Suppose firm productivity is homogeneous, that is, $z_i = 1$ for all i, and consider the models with heterogeneous and homogeneous strategic complementarities that both have the same curvature $\sigma = -\theta \sum_{i=1}^k \omega_i \epsilon_i$. Then the slope coefficient $\kappa = \sum_{i=1}^k \omega_i \kappa_i$ of the Phillips curve (31) is larger in the model with heterogeneous strategic complementarities.* Proof: see Appendix B.

Proposition 1 states that heterogeneity in strategic complementarities weakens real rigidity. To illustrate this result, we use the values of ω_i and ϵ_i from Table 3. They imply that the slope coefficient of the Phillips curve is $\kappa = \sum_{i=1}^k \omega_i \kappa_i = 0.198$. The case of homogeneous strategic complementarity, in which the value of $\epsilon_i = \bar{\epsilon}$ for each i is chosen to achieve the same curvature $\sigma = 4.30$ as in the case of heterogeneous complementarities, implies a smaller slope coefficient of $\bar{\kappa} = 0.182$. Strategic complementarities reduce the slope of the

[20] These values can be obtained from Table 3 by noting that $\Delta_i = \omega_i/(n_i p_i^*)$ and $l_i \propto p_i^* \Delta_i / \mu_i$, for $i = 1, \cdots, k$.

[21] The solution implies that $\Delta_i = 1$ for all i and that eqs. (43) and (44) are not satisfied with the empirical number of establishments, labor share, and revenue share by firm-size group. Hence the model needs heterogeneity in firm productivity to determine values of the parameters ϵ_i that govern strategic complementarities in price setting.

Phillips curve less if the complementarities are concentrated in larger firms than if they are spread uniformly across firms, and thus real rigidity is weaker. We will find an even smaller effect of heterogeneous strategic complementarities once we account for firm size in the next subsection.

4.3 Main result

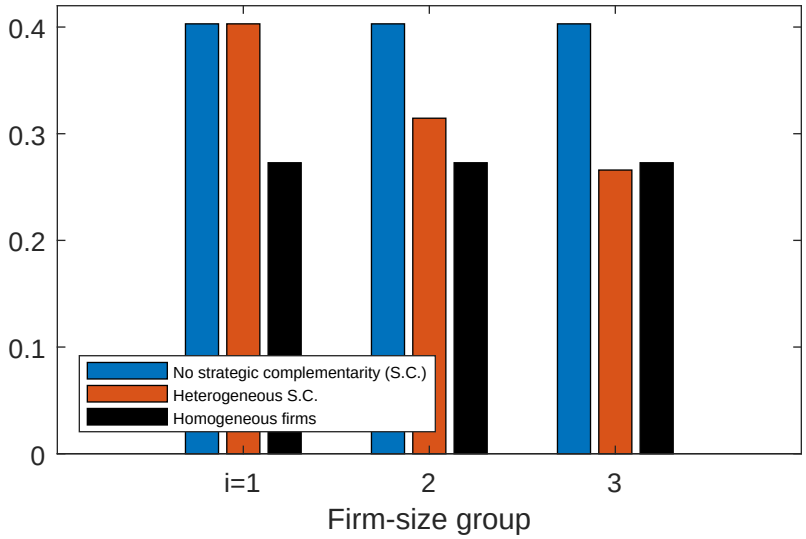
In this subsection, we use the calibrated model to show that heterogeneity in strategic complementarities in price setting by firm size substantially weakens real rigidity and monetary non-neutrality, compared to the case of homogeneous complementarity.

The calibration of model parameters summarized in Tables 2 and 3 makes the model consistent with the aggregate SUSB data and the empirical evidence on cost pass-through by firm size reported in Table 1. Figure 1 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. Heterogeneous strategic complementarities lower the marginal cost elasticities of larger firms, because they exhibit stronger strategic complementarities than smaller firms. In contrast, in the case of homogeneous firms, strategic complementarities reduce the elasticity of all firms evenly.

The slope of the Phillips curve in the calibrated model is again larger if strategic complementarities are concentrated in large firms. In our calibrated model, the slope coefficient is $\kappa = 0.219$, which exceeds the value $\bar{\kappa} = 0.182$ in the standard DSGE counterpart model with homogeneous firms. The slope κ is larger than in the case of homogeneous productivity analyzed in the previous subsection (where $\kappa = 0.198$). This is because the higher productivity of larger firms reduces the steady-state optimized price and hence the price elasticity of demand for the firms' goods, which mitigates the increase in real rigidity induced by the group's greater superelasticity. The latter effect, captured by $(p_i^*/d)^{\gamma_i} < 1$ in (28), is only partly offset by a larger steady-state markup $\mu_i > 1$ of larger firms that results from their lower price elasticity of demand.

The larger slope κ and thus weaker real rigidity due to heterogeneous strategic com-

Figure 1: Marginal cost elasticities.

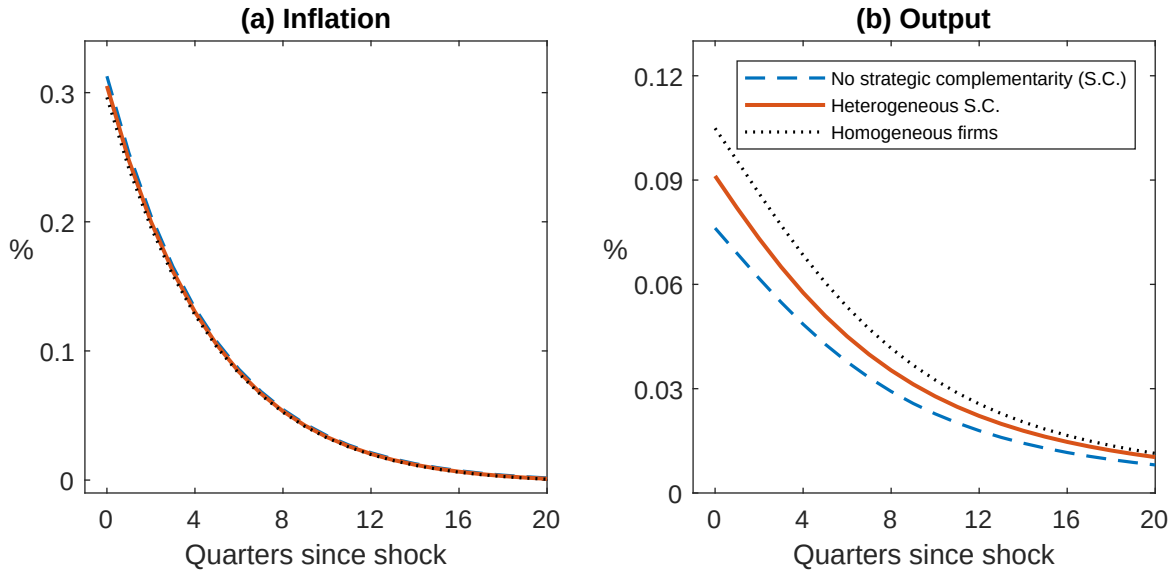


Notes: The figure displays the marginal cost elasticity of the optimized price $(1-\beta\xi)/\Gamma_i$ for each firm-size group $i = 1, 2, 3$. The results labeled "Heterogeneous S.C." are obtained under the calibration of model parameters reported in Tables 2 and 3, while those labeled "No strategic complementarity (S.C.)" represent the case of a constant elasticity of demand for each firm's good (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 $\sigma = 4.30$ as in the case of heterogeneous strategic complementarities.

plementarities reduces monetary non-neutrality in the calibrated model. Monetary non-neutrality can be gauged by its impulse responses to a monetary policy shock. Figure 2 plots the responses of inflation (panel a) and output (panel b) to a 1 percent expansionary shock to the annualized monetary policy rate under the calibration of model parameters reported in Tables 2 and 3 (solid 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 good (i.e., $\epsilon_i = 0$ for all i) in the calibration (dashed 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 panel, the impulse response in our calibrated model lies about midway between those in the cases of no complementarity and homogeneous complementarities. The response of output indicates that heterogeneous strategic complementarities dampen the increase in

monetary non-neutrality by about half.

Figure 2: Impulse responses to a monetary shock.

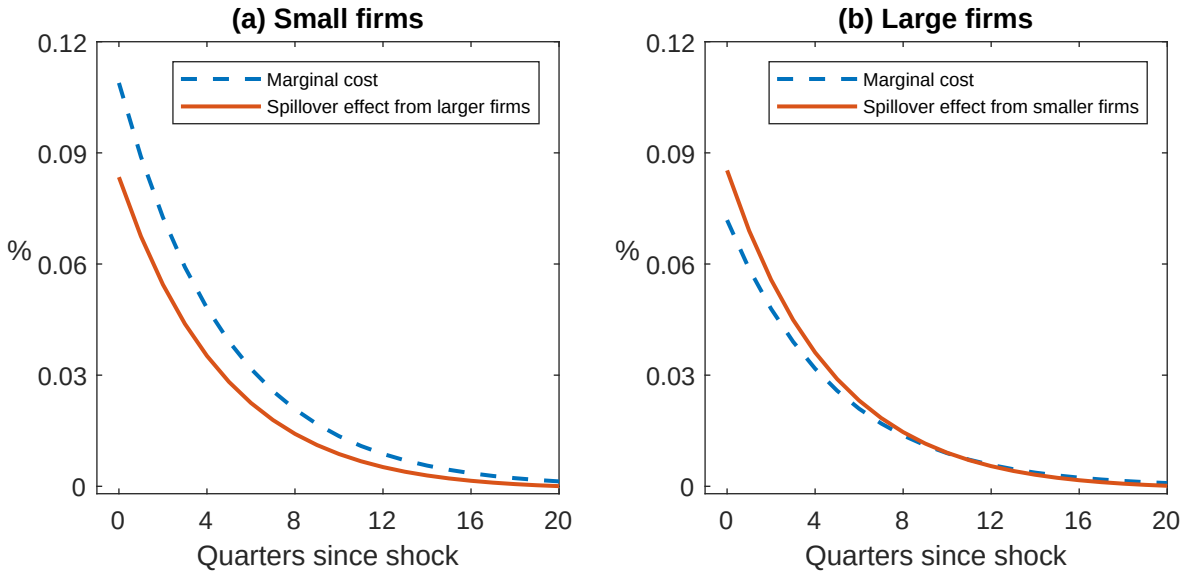


Notes: Panels (a) and (b) plot impulse responses of inflation and output, respectively, to a 1 percent expansionary shock to the annualized monetary policy rate in the model. The results labeled "Heterogeneous S.C." are obtained under the calibration of model parameters reported in Tables 2 and 3, while those labeled "No strategic complementarity (S.C.)" represent the case of a constant elasticity of demand for each firm's good (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 $\sigma = 4.30$ as in the case of heterogeneous strategic complementarities.

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 0.964, while the corresponding ratio of the cumulative response of output is 1.216. 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 0.936, whereas the corresponding ratio of the cumulative response of output is 1.402. This confirms that heterogeneous complementarities reduce the amplification of the output response by almost half and thus dampen the increase in monetary non-neutrality substantially.

An economic explanation for the weak real rigidity and subdued increase in monetary non-neutrality in our model is as follows. Since small firms adjust their goods prices facing a constant elasticity of demand, they more fully pass through changes in the real marginal cost

Figure 3: Contributions to the impulse responses of optimized goods prices.



Notes: Panels (a) and (b) plot contributions to the impulse response of the optimized price of small firms (i.e., $i = 1$) and large firms (i.e., $i = 3$), respectively, to a 1 percent expansionary shock to the annualized monetary policy rate. The contributions come from the external drivers of the optimized price described in Eq. (30): The real marginal cost, $(1 - \beta\xi)/\Gamma_i \, \hat{mc}_t$ and the spillover effect from the goods prices of other firm-size groups, $\beta(1 - \xi) \sum_{j \neq i} \omega_i E_t \, \hat{p}^*_{j,t+1}$.

to their prices. Large 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 large firms through their strategic complementarities. In this way, small and large firms all adjust their goods prices substantially after the policy shock, resulting in weak real rigidity. This explanation is supported by Figure 3, which displays the external drivers of the impulse responses of the optimized goods prices $\hat{p}^*_{i,t}$ of small and large firms to an expansionary monetary policy shock. The two external drivers are the real marginal cost and the spillover effect from the goods prices of other firm-size groups. The figure plots their contributions to the impulse response of the optimized goods price of the firm, which are the third and second terms on the right hand side of Eq. (30), respectively. Among the two drivers, the marginal cost is the primary one for small firms (those belonging to group $i = 1$), as shown by the dashed line. In contrast, the spillover effect from smaller firms form the primary driver for

large firms (those belonging to group $i = 3$), as the solid line shows.[22]

4.4 Robustness analysis

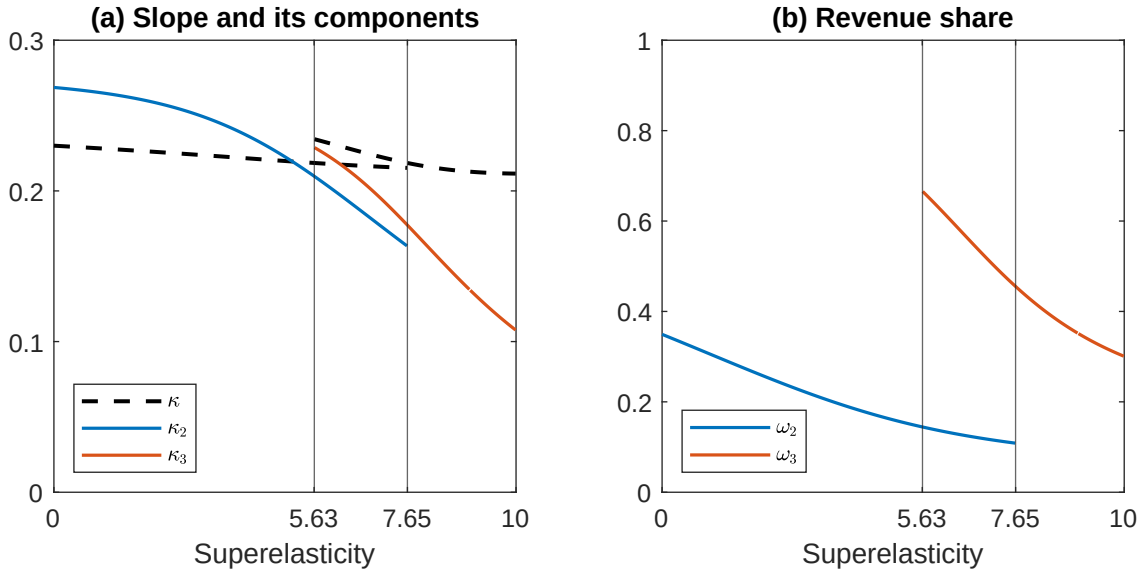
We have found that heterogeneity in strategic complementarity by firm size substantially weakens real rigidity and monetary non-neutrality. In this subsection, we confirm the robustness of the finding to alternative values of model parameters. We begin by varying the degree of strategic complementarity and subsequently consider the role of other structural parameters.

An increase in the superelasticity of demand for larger firms leads to a muted increase in real rigidity. Figure 4 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. The solid lines in panel (a) of the figure demonstrate that the slope components κ_i of larger-firm groups $i = 2, 3$ decrease for a larger superelasticity. The dashed line then traces the Phillips curve slope κ and shows that the slope remains relatively flat. One reason for the muted increase in real rigidity is that each slope component κ_i has a weight less than one given by the steady-state revenue share shown in panel (b). The revenue share of the middle-size group of firms, $i = 2$, is smaller than that of the large-size group, $i = 3$, and hence the slope is less sensitive to the superelasticity of demand for firms in the middle group than those in the large group.

A second reason why the slope κ remains relatively flat is that a greater superelasticity lowers each larger-firm group's steady-state revenue share in panel (b), thus reducing the effect of the smaller slope component κ_i on the slope κ. This is because 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. Thus, stronger strategic complementarity in the price-setting behavior of larger-firm groups

[22] The impulse response of the optimized price is not shown, but it increases less for large firms than for small ones, consistent with the evidence of Goldberg and Hellerstein (2011) that large firms change their prices on average by a smaller amount than small firms and of Bhattarai and Schoenle (2014) that firms selling more goods—a proxy for firm size—change their prices on average by a smaller amount.

Figure 4: 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. The values of other model parameters are reported in Tables 2 and 3.

is evident both in their smaller marginal cost elasticities and a larger spillover effect in the price-setting condition (30) because the revenue shares shift toward the other firm-size groups, in particular the smallest-firm group, which exhibits no complementarities.

As for the other structural 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, the amplification of the CIR of output to a monetary policy shock in the case of homogeneous firms is dampened substantially by heterogeneous complementarities. 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

Table 4: Cumulative impulse responses and their ratios.

	Inflation		Output	
Case	CIR	Ratio	CIR	Ratio
(a) *Baseline calibration of model parameters*				
No strategic complementarity (S.C.)	1.537	1	0.757	1
Heterogeneous S.C.	1.482	0.964	0.921	1.216
Homogeneous firms	1.438	0.936	1.061	1.402
(b) *More nominal price rigidity*: $\xi = 0.75$				
No S.C.	1.156	1	1.944	1
Heterogeneous S.C.	1.043	0.902	2.281	1.173
Homogeneous firms	0.966	0.836	2.544	1.309
(c) *Less elastic labor supply*: $\chi = 1/2$				
No S.C.	1.461	1	0.966	1
Heterogeneous S.C.	1.393	0.953	1.165	1.206
Homogeneous firms	1.339	0.916	1.334	1.381
(d) *Smaller elasticity of substitution between goods*: $\theta = 7$				
No S.C.	1.534	1	0.762	1
Heterogeneous S.C.	1.495	0.975	0.876	1.150
Homogeneous firms	1.448	0.944	1.026	1.345
(e) *Modest superelasticity for smallest-firm group*: $-\theta\epsilon_1 = 2$				
No S.C.	1.537	1	0.757	1
Heterogeneous S.C.	1.449	0.943	1.022	1.350
Homogeneous firms	1.427	0.929	1.096	1.448
(j) *Larger number of firm groups*: $k = 5$				
No S.C.	1.537	1	0.757	1
Heterogeneous S.C.	1.483	0.965	0.917	1.212
Homogeneous firms	1.440	0.937	1.056	1.395

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).

values influence the CIR quantitatively, their influence goes in the same direction in each of the cases of heterogeneous complementarities and no complementarity, so that the ratios of the CIR are less sensitive. 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 this makes the marginal cost elasticities across firm-size groups more similar, the increase in monetary non-neutrality is more substantial though still weaker than that in the case of perfectly homogeneous firms. Finally, panel (j) 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 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. The calibrated model generates substantially less real rigidity in relative prices and a substantially smaller increase in monetary non-neutrality than strategic complementarities achieve in standard DSGE models with homogeneous firms. Real rigidity is weakened 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 goods 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. A promising direction for future research using DSGE models is therefore to consider other sources of real rigidity. A shift in emphasis from so-called micro real rigidities including strategic complementarities in price setting toward macro real rigidities, such as real wage rigidity and the input-output structure of the economy, could put DSGE models on a more robust footing.

Appendix

A Multiple-product firms

This appendix outlines a version of the model in which firms produce multiple goods all within the same firm-size group.

There are k groups of firms, $\Omega_i = \{f \in [0,1] : z(f) = z_i, \epsilon(f) = \epsilon_i\}$, for $i = 1, \ldots, k$. The firm groups Ω_i are mutually exclusive, $\bigcup_{i=1}^{k} \Omega_i = [0,1]$, and the measure of firms in group Ω_i is $\int_{\Omega_i} df = m_i$, so $\sum_{i=1}^{k} \int_{\Omega_i} df = \sum_{i=1}^{k} m_i = 1$. Each firm may produce multiple goods and the number of goods per firm can differ by firm-size group. Denote the set of firm f's goods by $\Phi_f = \{j \in [0,1] \text{ produced by firm } f\}$, and assume $\bigcup_{f=0}^{1} \Phi_f = [0,1]$, and $\int_{\Phi_f} dj = n_i/m_i$. Then $\int_{\Omega_i} \int_{\Phi_f} dj\, df = n_i$ and $\sum_{i=1}^{k} \int_{\Omega_i} \int_{\Phi_f} dj\, df = \sum_{i=1}^{k} n_i = 1$.

All goods are now indexed by the good and firm numbers (j, f). The aggregator (2) of the composite-good producer becomes

$$1 = \int_0^1 F\left(\frac{Y_t(j,f)}{Y_t}\right) dj = \sum_{i=1}^{k} \int_{\Omega_i} \int_{\Phi_f} F\left(\frac{Y_t(j,f)}{Y_t}\right) dj\, df.$$

The average relative price (4) and the condition for zero profits (6) become, respectively,

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

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

As for the firms, the aggregate production function for firm-size group $i = 1, \ldots, k$ continues to be described by (8), where

$$l_{i,t} \equiv \frac{1}{m_i} \int_{\Omega_i} l_t(f) df, \qquad l_t(f) \equiv \frac{m_i}{n_i} \int_{\Phi_f} l_t(j,f) dj,$$

$$K_{i,t} \equiv \frac{1}{m_i} \int_{\Omega_i} K_t(f) df, \qquad K_t(f) \equiv \frac{m_i}{n_i} \int_{\Phi_f} K_t(j,f) dj,$$

and

$$s_{i,t} \equiv \frac{1}{m_i} \int_{\Omega_i} \frac{m_i}{n_i} \int_{\Phi_f} \left(\frac{P_t(j,f)}{P_t}\right)^{-\gamma_i} dj\, df.$$

B Proof of Proposition 1

Recall that the slope of the Phillips curve (31) is given by $\kappa = \sum_{i=1}^{k} \omega_i \kappa_i$ and curvature is measured as $\sigma = -\theta \sum_{i=1}^{k} \omega_i \epsilon_i$. Define $\bar{\epsilon} = \sum_{i=1}^{k} \omega_i \epsilon_i$ as the parameter value that induces the same curvature with homogeneous strategic complementarities as that under heterogeneous strategic complementarities and let $\bar{\kappa}$ be the slope of the Phillips curve associated with $\bar{\epsilon}$.

Suppose $z_i = 1$ for all i. Then for arbitrary values of ϵ_i we can verify that $p_i^* = d = 1$ for all i is a solution to eqs. (45)–(47). Because $p_i^* = d = 1$, the factor in (28) simplifies to $\Gamma_i = 1 - \epsilon_i \theta/(\theta - 1)$ in the i-th component of the slope $\kappa_i = (1 - \xi)(1 - \beta\xi)/(\xi \Gamma_i)$, for $i = 1, \ldots, k$.

Define the function

$$f(x) = \frac{(1 - \xi)(1 - \beta\xi)}{\xi[1 + x\theta/(\theta - 1)]}.$$

The function $f(\cdot)$ gives the value of any of the components of the slope coefficient in the Phillips curve as a function of $x = -\epsilon$. We can verify that $f'(x) < 0$ and $f''(x) > 0$ (convexity). Consider k values $\{\epsilon_i\}_{i=1}^{k}$ such that $0 \geq \epsilon_1 > \cdots > \epsilon_k$ and the components $\kappa_i = f(-\epsilon_i)$. By the convexity of $f(x)$, $\sum_{i=1}^{k} \omega_i \kappa_i = \sum_{i=1}^{k} \omega_i f(-\epsilon_i) > f\left(-\sum_{i=1}^{k} \omega_i \epsilon_i\right) = \bar{\kappa}$. ■

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