Asymmetric Firms and Monetary Policy

Gregory Auclair*

October 2023

[Latest Version Here]

Abstract

This paper links the market position of individual firms within an industry to aggregate price dynamics, using a general equilibrium framework. Market structure is relevant for several reasons. First, growing concentration may explain the observed flattening of the Phillips curve over recent decades. Second, monetary policy generates first-order effects on efficiency and welfare when it acts on market distortions. On this point, there are strong indications the leading firm in an industry charges significantly higher markups compared to other firms. At the same time, market position affects pricing behavior. In particular, large firms may limit the pass through of cost shocks and respond in-kind to price changes by competitors. The consequences are explored through the lens of a simple New Keynesian framework with asymmetric firms. It matches observed price dynamics closely and yields a rich set of results. It aligns with empirical evidence suggesting small firms are more sensitive to the business cycle and explains observed fluctuations in price and markup dispersion following economic shocks. It also provides a basis to evaluate the dynamic welfare costs of market distortions. The efficient reallocation of demand across firms following a shock crucially depends on how firms exercise market power, in particular, the strength of strategic complementarity.

1 Introduction

Markets are difficult to generalize. Still, a few key facts should be considered. First, a limited number of firms participate in an industry and the top two or three firms usually control most market share.[1] In other words, a mix of small and large firms compete. At the same time, evidence suggests market position influences pricing behavior.[2] Small firms tend to have lower markups and adjust prices in line with their costs. Large firms have higher markups and act strategically – they limit the pass-through of cost shocks and react to price changes by rival firms. In this case, a simple market structure cannot fully account for price dynamics and a more elaborate structure can help evaluate the aggregate welfare and efficiency cost of economic shocks and monetary policy actions. The analysis here incorporates nested CES demand solves for firms with heterogeneous productivity levels. As a consequence of their market position, firms face different demand schedules and adjust their markup accordingly.

Quasi-kinked demand, e.g. Kimball (1995), assumes large price changes are more costly than small ones. In other words, the second derivative of demand is negative with respect to the firm's *own* price. This

*PhD Candidate in Macroeconomics, International Economics Department, IHEID. My thanks to my advisor Cédric Tille and many others. Author's email: allan.auclair@graduateinstitute.ch

[1] As will be discussed in section 2.1.2, more than 60 percent of market share is controlled by the top two firms on average when looking within narrowly defined markets for consumer goods. This result appears consistent across studies. An analysis of EU antitrust data indicates the market leader is twice as large as the next largest firm on average.

[2] See Amiti et al. (2019) for example.

can explain why firms limit the pass-through of cost shocks. Strategic effects also adjust this curvature. With strategic complementarity, firms match the price movements of their competitors and the cross-price second derivative is positive. Given a realistic market structure with finite firms, both effects are present. In addition to the demand schedule, two additional margins likely explain variation in pricing behavior across firms: heterogeneity in (i) price adjustments frictions and (ii) marginal costs following a shock. Their interaction is not straightforward, but a growing body of research on market structure and pricing behavior provides guidance, as will be discussed.

This analysis is motivated by concern market concentration in the United States and Europe has increased. Market concentration has two distinct dimensions (i) the number of market participants and (ii) control of markets by leading firms. This paper emphasizes the second.[3] Even if market participation is stable or increasing, a few firms may consolidate substantial market power. An analysis of Nielsen retail scanner data in Hottman et al. (2016) finds the top three or four firms explain most market share. The leading firm within each product group accounts for 22 percent of sales on average while the next largest firm accounts for less than 13 percent. Related estimates indicate the leading firm typically charges a markup 24 to 100 percent higher than the sector average.[4]

In terms of the analytical focus, this paper is probably closest to Baqaee et al. (2021), which identifies a link between allocative efficiency and monetary policy. If high-markup firms have a lower pass-through than low-markup firms, monetary easing will reduce markup dispersion.[5] Evidence from Meier and Reinelt (2022) supports this: markup dispersion in the United States appears to rise given monetary tightening and fall with easing. The model presented later replicates this outcome. It implies monetary policy can have a direct effect on productivity through the markup channel. There are also some similarities between this paper and Guimaraes and Sheedy (2011) as well as Sheremirov (2020). Both explain pricing behavior across retailers, while this paper is more concerned with market power among producers.

The paper is organized as follows. Section 2 presents a set of stylized facts motivating the analysis. It has two parts. Subsection 2.1 looks at market structure and subsection 2.2 looks at firm pricing behavior. The framework is presented in section 3 along with a cursory overview of the solution method. The calibration and results are discussed in section 4. This section includes an analysis of changes in the Phillips curve, the dynamic response of the economy to monetary policy and productivity shocks, and dynamic allocative efficiency. The results are followed by a discussion of the policy implications and future directions for research in section 5.

2 Empirical Evidence on Market Structure and Firm Behavior

2.1 Concentration Trends and Industry Structure

This section provides a set of stylized facts on market structure within an industry. Along with the distribution of market share, differences in markups are of particular interest. Markups generate distortions from two different perspectives. On the supply side, they act as a 'tax' on the factors of production. This depresses

[3]It also emphasizes within-industry differences across firms. Baqaee and Farhi (2019) notes dispersion in markups is much higher within (rather than across) sectors.

[4]Depending on the approach. Hottman et al. also attempts a structural decomposition of the drivers of firm-level demand into four components: cost, markups product scope, and taste. The results indicate taste explains 50 to 75 percent of variation in firm size, while cost accounts for less than 20 percent of total variation. Therefore, a more realistic specification might add different tastes within the household consumption bundle.

[5]Monetary easing raises marginal costs in the the New Keynesian model and high-markup firms will absorb some of the cost increase if their pass-through is low.

aggregate output. On the demand side, markup dispersion reduces the allocative efficiency of the economy. In an efficient economy, prices reflect the preferences of households along with the supply of different goods. If markups are uniform across goods, the consumption basket is close to the optimal one. Markup dispersion affects the allocation of consumption since households will favor goods with low markups, even if they are inefficiently produced.[6]

2.1.1 National Concentration, Rising Markups, and 'Superstar' Firms

There is substantial evidence markets in the United States have become more concentrated and that markups have increased, developments which negatively affect aggregate welfare.[7] The increase in the national Herfindahl–Hirschman index (HHI), the principal measure of product market and industry concentration, is well documented and multiple studies link it to the expansion of 'superstar' firms (Autor et al., 2020; Grullon et al., 2019).[8] Kwon et al. (2023) finds in the late 1970s, the top 0.1 percent of corporations accounted for less than 70 percent of total business assets in the United States. This share increased to almost 90 percent by the end of the 2010s. Similarly, the top 0.1 percent share of sales increased 10-15 percentage points and now accounts for almost two-thirds of the total.

Since superstar firms tend to be highly efficient, the increase in market share is desirable as long as competition remains strong and there is no corresponding increase in pricing power. However, there are indications this has not been the case. Covarrubias et al. (2019) finds concentration in the United States was efficient in the 1990s, but was associated with rising market power in the 2000s. Over this period, estimated markups appear to grow disproportionately for firms at the top of the markup distribution; meanwhile, the market share of high-markup firms also expanded (Baqaee & Farhi, 2019; Barkai, 2020; Cunningham et al., 2023; De Loecker et al., 2020).[9] The factors explaining rising markups are not well-understood and perhaps multiple. Most current markup estimates rely on a production function approach, yet assuming the same functional form across industries obfuscates potential differences. Production in mining (e.g.) has vastly different labor and capital inputs compared to telemarketing – a major limitation.[10] Given these ambiguities, the literature has offered a variety of explanations for rising markups.

What are the possible drivers? To start, network effects could be more prominent than in the past, particularly on digital platforms (OECD, 2022).[11] Top managers may be increasingly adept as exploiting market power (Bao et al., 2022). The increase in markups may equally reflect a decline in real wages. Unionization rates in the United States are historically low and workers may have less bargaining power. A large body of research shows concentration among employers is associated with lower wages (Azar et al., 2022; Mertens & Mottironi, 2023). Globalization may be adding pressure as well. Top firms have access to global supply chains and low-cost inputs abroad. They can achieve better economies of scale, diversify

[6] Of course, some level of markup is probably needed for the economy to function properly. They include compensation for entrepreneurial activity and risk, along with rents. The analysis here does not take a view on what level is correct.

[7] There is some evidence for increased concentration in Europe as well (Bajgar et al., 2023), but the trend is less pronounced.

[8] The HHI is a common measure of concentration, calculated as the sum of the squared market shares of all firms in a given industry. If firms are identical and atomistic, this gives an HHI of 0. If one firm controls 100 percent of the market, this gives an HHI of 10,000.

[9] Most modern studies use the 'production function' approach to measure markups, which assumes functional form and relies on financial accounts to estimate firm-level markups. Examples include De Loecker et al. and Hall (2018). As highlighted in Basu (2019), these estimates lack granularity and can only capture aggregate trends.

[10] Different assumptions on inputs can influence the results when using the production function approach. There is ongoing debate on whether aggregate outcomes are driven by assumptions on the relative mix of inputs (Raval, 2023).

[11] It is clear some platforms form natural monopolies – for example a small number of firms dominate social media and online search. Large firms may benefit from digitization as well. They can better realize economies of scale and scope, conduct market research and build customers profiles, and invest in online marketing and logistical infrastructure. Online price discrimination is common in many industries, including airlines, entertainment, and retail.

into international markets, and may gain tax advantages from opaque international accounts and transfer mispricing. Markups increase in firm age, which is rising in the United States (Hopenhayn et al., 2018; Peters, 2020). Related to this, a number of studies look at rising barriers to entry, regulatory capture, and rent seeking. For example, Covarrubias et al. (2019) attributes the decline in competition to stronger barriers to entry and the entrenchment of market leaders. Similarly, Zingales (2017) and Faccio and McConnell (2020) link regulatory capture and political connections to the lack of business dynamism.

Measurement issues are present and the rise in markups could stem from relatively benign causes or prove illusory. The correlation between markups and firm size could simply reflect fixed costs are high for large firms while marginal costs are low. Crouzet and Eberly (2019) attributes weakness in physical investment to intangible capital. Tambe et al. (2020) finds superstar firms accumulated substantial digital capital, which explains much of their apparent productivity advantage. At the same time, markups may result from changes in household preferences. Rising purchasing power may increase the weight of luxury goods in the consumption basket (Döpper et al., 2022). The shift in consumption from manufacturing to services is important in this context as well. Markups are generally higher in service sectors, due in part to the prevalence of owner-employees and pass-through income (Cooper et al., 2015). Similarly, variable costs and other indirect costs of production (e.g. marketing, payments to management) are often excluded from markup estimates. Traina (2018) finds markups have been relatively flat since the mid-1980s when these are included. Still, accounting profits appear to have grown over recent decades and the bulk of the evidence suggests markups have increased as well.[12]

2.1.2 Declining Local Product Market Concentration

There is an ongoing debate on whether concentration in local product markets increased. Most spending is local and retail data may better reflect the choices faced by consumers.[13] A divergence between local and national concentration trends is not implausible. The United States is geographically large and many markets remain regionally segmented. Economies of scope may explain why national firms have expanded into new product lines.[14] National concentration could also reflect consumers in different markets are now buying from the same firms, a positive development if local consumers have more choice.[15] For now, the trend in the United States is unclear and the studies in circulation present conflicting results. Two recent papers using Census product-level data find local sales concentration rose in tandem with national measures, namely Autor et al. (2023) and Smith and Ocampo (2022). The underlying data in these studies remain fairly aggregated. Analyses of alternative, more granular commercial data sources in Rossi-Hansberg et al. (2018) and Benkard et al. (2021) suggest local product market concentration decreased as top national firms expanded.

Despite ambiguity on the trends, the study by Benkard et al. notes the level of local product market concentration appears higher than commonly appreciated. Using a market research firm survey covering around 25,000 consumers per year between 1994 and 2019, the authors extract all questions relating to brands purchased and sort these into economically relevant units, i.e. goods that are closely substitutable. On this

[12] The appendix provides an overview of the evolution of corporate profitability since the 1980s (see section A.1). There is some ambiguity about the overall trend, in large part because wages and profits are not cleanly separated. The analysis adds officer compensation to profits, which aids comparability over time. On this basis, profits increased by around 4 percentage points of GDP when comparing the 2010s with the 1980s.

[13] Many services, intermediate goods, and major durable purchases are absent from retail data. This extends to healthcare, car purchases, private education, and other significant outlays.

[14] In addition, internet retail has significantly increased the product space available to consumers, made it easier to compare prices and product quality, and generated economies of scale that might not otherwise exist.

[15] On this topic, Shimomura and Thisse (2012) analyses the welfare effect of the expansion of large firms.

basis, they find 44 percent of industries have an HHI above 2500 over the sample period.[16] This estimate is much higher than most circulating in the literature and meets the U.S. Horizontal Merger Guidelines criterion for "highly concentrated." Furthermore, the average market share of the top two firms was around 55-60 percent. Along with the findings of Benkard et al., other studies indicate markets are highly concentrated.[17] Looking at IRI retail scanner data, Mongey (2017) finds the median number of effective firms in a product category is around 3.7 and the revenue share of the top two firms is 66 percent. Affeldt et al. (2021) looks at concentration in Europe through the lens of antitrust markets, which are defined by the European Commission as part of its merger review process. Looking at cases between 1995 and 2014, the study finds the average post-merger HHI for an antitrust market was around 2200 points with 4 firms competing on average. Additional summary statistics are provided in the appendix (see section A.2). While less has been said about the relative size of firms in an industry, the data from Affeldt et al. indicate market leaders are much larger than their rivals.

2.1.3 The Distribution of Market Share: An Analysis of the EU Merger Control Database

The data from Affeldt et al. are publicly available, which allows for a more granular analysis of firm characteristics across well-defined market segments. The published *EU Merger Control Database* covers the period between 1990 and 2014 and includes information on more than 5000 cases reviewed by the European Commission as part of its antitrust enforcement. Each case contains the name of the target firm and its potential acquirer, their market shares across different geographies, and whether the merger was approved. Competing firms are identified for a large number of these markets along with the Commission's assessment of their market share. Nearly 31,000 markets are identified, over 23,000 of these observations contain information on the merging entities' market shares, and around 10,000 observations contain information on competing firms and their market shares.

The left-hand panel in figure 1 shows how market share is distributed in the overall sample.[18] The market share of the largest firm exceeds 30 percent in more than one-half of antitrust markets and exceeds 50 percent in almost one-quarter. Also, market followers tend to be significantly smaller than market leaders, as suggested by the right-hand panel in figure 1. The panel shows the market share of the market leader and top trailing firm when both are available. Within an observation, the ratio of the market shares for the leading firm and top trailing firm gives a median value of 1.6x with the mean around 1.9x.[19] In addition, the top two firms control around 63 percent of the market on average and the median is similar at 61 percent. This cannot be fully generalized to the United States; still, the findings are consistent with Mongey (2017) and Benkard et al. (2021).

2.2 Firm Size and Pricing Behavior

This section provides context for the modelization. This paper builds on three recent additions to the literature featuring firm heterogeneity: Mongey (2017), Wang and Werning (2022), and Ueda (2023). The consolidation of market share by a few large, strategic firms likely affects monetary policy transmission,

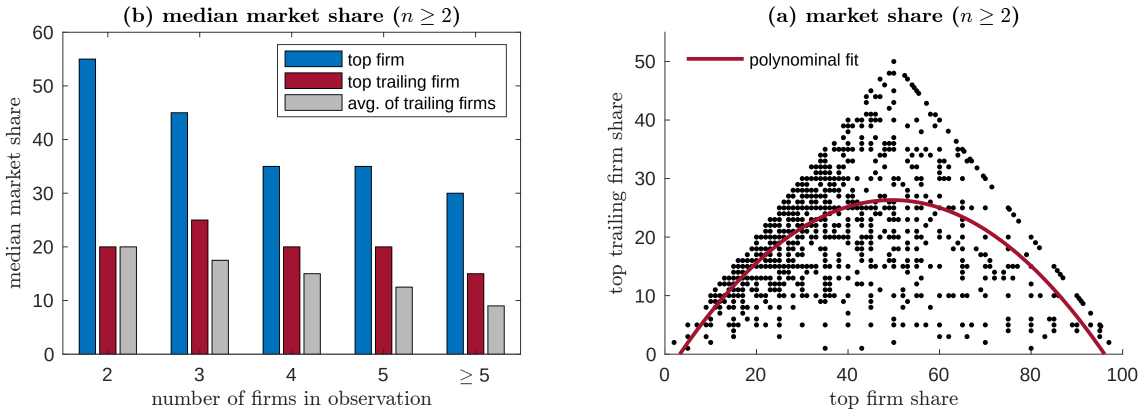
[16] It is also worth noting the 75th and 90th percentiles were at 3600 and 4600 respectively in 2019, where the threshold for monopoly is commonly defined around 6000.

[17] As mentioned before, Hottman et al. (2016) finds the leading firm within each product group accounts for 22 percent of sales on average, compared to for 12.7 percent for the top trailing firm. Also, the leading firm typically charges a markup 24 to 100 percent higher than the sector average.

[18] The market share of the post-merger entity is used if the merger was approved.

[19] These calculations are limited to cases where both the leader and follower report market shares above 10 percent. The unconditional median is 1.7x.

Figure 1: European Commission Antitrust Markets



The left-hand panel separates observations in Affeldt et al. (2018) by the number of firms reported. The median across observations is calculated for the top observed market share, the second largest share, and the average share across all trailing firms. The first set of bars where $n = 2$ makes clear there is usually some residual market share. Usually around 15 percent is unexplained and a more complete set of tabulations is in section A.2 of the appendix. The right-hand panel shows the joint distribution of market shares for the top and top trailing firms when both are reported. The top reported market share by observation is on the x-axis and the next largest market share is on the y-axis. A second-order polynominal gives the conditional expectation. The prediction ($y = -0.012x^2 + 1.213x - 3.788$) is very close to what smoothing methods return. The conditional expectation indicates the top firm typically controls a significantly larger market share than the top trailing firm.

the main focus of Wang and Werning (2022). Mongey (2017) develops a menu-cost model where strategic complementarity increases aggregate price rigidity while firms maintain price flexibility in response to idiosyncratic shocks.[20] The solution method used here follows Ueda (2023). While all these studies feature strategic complementarity, it plays a relatively minor role in this paper. Rotemberg adjustment costs lead to smooth and relatively small price adjustments. Strategic complementarity only becomes a significant force when shocks are firm-specific. This informs the analysis on dynamic reallocation (see section 4.4). As mentioned in the introduction, market position may influence pricing behavior in three different ways: the demand schedule, price adjustments frictions, and changes in marginal costs following a shock. Much of the following discussion focuses on differences between small and large firms across these dimensions. This motivates the modeling approach.

2.2.1 Market Position and the Price Elasticity of Demand

Early interest in the relationship between market position and price dynamics stemmed from antitrust cases. Markham (1951) discusses how rational market behavior could resemble collusion whenever price 'leaders' anticipate the prices of their rivals. While the industrial organization literature has much to offer, most models for aggregate price dynamics use a relatively simple market structure. General equilibrium requires a coherent relationship between individual prices, changes in the demand schedule, and aggregate dynamics. This greatly limits the toolkit available to researchers. The CES specification is popular because it meets these criteria while incorporating some realism in term of pricing power. The markup distortion is not particularly interesting by itself – the CES specification assumes all firms have equal pricing power and face the same demand curve – but the interaction of market power and price staggering proves more interesting.

Exploring price dynamics with heterogeneous firms requires a more complicated functional form. Following Dornbusch (1987), Atkeson and Burstein (2008) propose the nested CES specification used here. As the name suggests, it 'nests' a discrete CES aggregator, representing an industry, and within a continuous

[20]Firms respond to rival markups. Since aggregate shocks reduce these markups, firms adjust their prices by less.

CES aggregator, representing the overall economy. Accordingly, there is strategic interaction between firms within an industry, but not across industries. Since consumers substitute between varieties (i.e. the products of firms within the same industry) more easily than across goods, there is a positive association between market share and pricing power. Two further extensions of the baseline nested CES specification are of interest. Shimomura and Thisse (2012) captures the interaction between large and small firms. Hottman et al. (2016) develops a system where firms produce a number of closely substitutable varieties, which leads to the cannibalization of own sales – another example of how feedback effects can influence the price elasticity of demand. The authors suggest small firms are less likely to cannibalize sales compared to large firms, all else equal.

Several papers test if nested CES demand describes firm behavior accurately. The prediction is simple – large and small firms face different demand curves. As a result, they should behave differently. Unfortunately, the data requirements are intensive. At a minimum, information on prices over time, market shares, and input costs are needed, meaning both firm- and industry-level data are needed. Still, the empirical evidence seems to align, at least when studies separate strategic and own-price effects. An analysis of French exporters by Berman et al. (2012) finds large firms generally absorb a large part of exchange rate movements in their markups. A later paper by Auer and Schoenle (2016) looks specifically at whether firms react to own-cost shocks or price changes by competitors using BLS micro-price data. The results indicate the strength of strategic complementarity is hump-shaped in market share while the pass-through of exchange rate shocks is U-shaped. Amiti et al. (2019) uses Belgian manufacturing data. The study has the advantage of a more representative sample and also a research design that better controls for potential endogeneity issues, in particular, the possibility firms anticipate price changes by rivals. The results suggest small firms fully pass through marginal cost shocks while large firms have a much lower pass-through.[21] Furthermore, large firms behave strategically while small firms do not.[22] Bruin et al. (2023) reports similar results. All three studies are consistent with the predictions of nested CES demand, although some caution is due given potential reporting bias.[23]

2.2.2 Price Adjustment Frictions

Price adjustment frictions can arise from a wide variety of sources. These include (i) explicit and implicit contracts, (ii) strategic interaction and price coordination failures, (iii) menu and information costs, (iv) managerial inattention and misalignment of incentives, (v) fear of alienating customers, and (vi) uncertainty around the duration of shocks.[24] Firm size appears relevant in all these cases. For example, price increases by large firms might receive wider media attention.[25] Equally, managers at small firms have to balance multiple tasks, leading to managerial inattention. Studies looking at price adjustment frequency and firm

[21] This pattern is also observed in Dedola et al. (2021). Similarly, a survey on price setting practices in Europe by Marques et al. (2011) finds large firms are less responsive to cost shocks than small firms. In response to a positive cost shock, 91 percent of small firms reported adjusting their prices compared to 86 percent of large firms. A corresponding probit estimate also indicates size is correlated with a longer price duration at high confidence.

[22] Rival prices are based on a price index of all firms in the same industry, at the lowest level of aggregation.

[23] The finding in Auer and Schoenle the pass-through and slope of the best response price are respectively U- and hump-shaped follows the transition from negligible market share to near monopoly. The analysis in this paper focuses on oligopoly – the downward part of the 'U' and upward part of the 'hump,' meaning firms limit their pass-through and become more strategic as market share increases. Monopoly levels of concentration are never considered.

[24] The role of sales in price movements is well documented (Klenow & Malin, 2010; Kryvtsov & Vincent, 2021). On the other hand, Kehoe and Midrigan (2015) argues aggregate prices are sticky even if prices change frequently at the consumer level. Since prices usually return to the exact same level, the 'regular' price is fairly consistent over time. Still, the micro-evidence indicates retailers maintain substantial price flexibility and casual observation, along with empirical evidence, suggests large firms are more adept at price discrimination through sales (Katz, 2019).

[25] For example, when McDonald's increases 'dollar' menu prices, national media often report the price change.

size usually find size is relevant. Still, a limited number are in circulation and they use a variety of data sources and methodologies, making it difficult to draw general conclusions about the direction. Other factors correlated with firm size, such as market power, could be latent as well.

Most studies find large firms adjust prices more frequently than small firms. An analysis of US producer prices by Goldberg and Hellerstein (2009) indicates large firms change prices two to three times more frequently than small firms.[26] Among good-producing industries, the implied price duration of 4.3 months for large firms and 8.5 months for small firms. While large firms appear to change prices more often, the average price change is smaller. Results from Amirault et al. (2006) are similar when looking at the frequency of price adjustments for large and small firms in Canada, as are those from Stokman and Hoeberichts (2006) for the Netherlands. The latter also finds weaker competition is associated with greater price rigidity. Other relevant studies include Álvarez and Hernando (2005), Coleman and Silverstone (2007), and Copaciu et al. (2010). In all cases, results are generally consistent.[27] Not all studies control for differences in firm size across industries, a confounding factor which could influence adjustment costs. On this point, Gopinath and Itskhoki (2010) suggests most variation in price adjustment costs occurs within rather than across sectors. In other words, it takes place at highly disaggregated levels, i.e. individual industries.

Price leadership likely plays a role as well. When thinking about oligopoly competition and price setting, Stackleberg games provide a natural starting point. A comparison of experimental evidence on Stackelberg and Cournot competition in Hildenbrand (2010) suggests Stackelberg better fits observed outcomes under price competition, but not under quantity competition. Weber and Wasner (2023) argues price leaders only engage in price hikes if they expect their competitors to do the same. Coordination of price increases therefore requires a sector-wide cost shock. Of course, not all sectors have a clear price leader and other aspects of market structure play a role. For example, Levy et al. (1998) relates the high frequency of price changes among grocery stores to the intensity of competition, low margins on each good sold, and the price sensitivity of consumers. In sectors with high transaction volumes, the price serves as an active feedback mechanism and firms can accurately gauge consumer demand and rival prices. In sectors with few sellers and buyers, firms have less information on the price sensitivity of demand, leading to coordination failures (Pennerstorfer et al., 2020).[28]

2.2.3 Firm-Specific Marginal Costs and Aggregate Shocks

Since the publication of Gertler and Gilchrist (1994), studies looking at the financial cycle have paid close attention to firm size, which can serve as a proxy for the presence of financial constraints. Since the study's publication, the general view has been that small firms are more sensitive to monetary policy than large firms. Still, it is notable the result in Gertler and Gilchrist is state dependent and the effects of monetary tightening only appear when growth is weak. Largely because of data limitations, both the basic facts on the financial

[26] Using product-level data across a number of retailers, Nakamura (2008) suggests most price variation arises at the retail level rather than manufacturer level. At the same time, the analysis of producer prices in Goldberg and Hellerstein suggests a high degree of flexibility, equal to that of consumer goods.

[27] Not all evidence suggests large firms have greater price flexibility. For example, DellaVigna and Gentzkow (2019) finds most mass retailers charge uniform prices across stores. This is not because the demand schedule is uniform. Estimates show substantial variation in the price elasticity of demand across geographic regions. Similarly, online and offline prices are often the same within retailers (Cavallo, 2017).

[28] While the analysis here focuses on price dynamics within an industry, there is a long-standing literature looking at how difference in price adjustment speeds across industries affects the propagation of shocks. Basu (1995) shows a roundabout production structure amplifies initial price differences because they affect marginal costs. A subsequent paper by Nakamura and Steinsson (2010) constructs a menu cost model with different price adjustment frictions across sectors. This increases monetary non-neutrality three-fold compared to a model where price frictions are uniform. The model can generate persistent real effects from nominal shocks, even when price stickiness is low.

accelerator and their interpretation remain subject to debate. For example, Ottonello and Winberry (2020) identifies firms with low default risk as those most responsive to monetary shocks. Meanwhile, Pérez-Orive and Timmer (2023) finds firms in financial distress respond most strongly to monetary tightening in terms of investment and employment. Durante et al. (2022) finds young firms are more sensitive to monetary policy shocks, particularly when they are highly leveraged. Financial strength does not appear to explain differences in firm performance over the business cycle at all in Crouzet and Mehrotra (2020).

Turning to the business cycle more generally, Crouzet and Mehrotra (2020) finds large firms are less affected by economic fluctuations than small firms due to differences in export exposure. This is intuitive since large firms tend to be more diversified, both across different product categories and geographic markets. Hong (2018) similarly reports the markup for small firms fluctuates 45 percent more than for large firms over the business cycle.[29] This may also reflect large and small firms have different wage structures. Bargaining power among workers and employers likely varies over the business cycle, as highlighted in Lombardi et al. (2023) and large firms may exercise more power over labor markets (Azar et al., 2022). Notably, Mertens and Mottironi (2023) links growth in the markups of large firms to wage compression.[30] It is possible wages are more flexible within large firms. For example, they may reduce wages and working hours in a downturn, as opposed to firing employees (Babecký et al., 2009). Miklian and Hoelscher (2022) provides a useful literature review on why small firms appear more exposed to shocks.[31]

3 A Simple New Keynesian Model with Asymmetric Competition

The literature supports the following points: First, there is significant variation in productivity levels within an industry.[32] Second, a few firms usually explain most market share. The leading firm in an industry is usually more profitable than its competitors and 1.5x to 2x larger. The framework here matches these features, but otherwise follows the same general template used throughout the New Keynesian literature. It solves for aggregate price dynamics. It is forward looking and assumes rational expectations. It incorporates the standard demand- and supply-side relationships: the investment-saving decision of households, the Phillips curve, and the Taylor rule. While the household side is mostly standard, the firm side has two distinct elaborations. The first and most important is a nested CES demand system with asymmetric firms. Large firms are strategic and respond to rival's prices. The second results from the addition of firm-specific pricing frictions and marginal cost shocks. These are not explored in the baseline results but are relevant in some of the subsequent analysis of dynamic reallocation. As a final note, the model uses Rotemberg costs, which saves a great deal of computational expense. For example, the results establish a relation between market concentration and Phillips curve very close to Wang and Werning (2022), which uses a more complicated Calvo setup. At the same time, it matches observed levels of price and markup dispersion following shocks.

[29] It is unclear if this due to differences across industries. Small firms may be clustered sectors more sensitive to business conditions for example.

[30] Large firms usually offer a wage premium, even when controlling for skills (Gibson & Stillman, 2009). This might be one reason workers are more willing to accept cuts over downturns.

[31] A number of recent studies compare large and small firms over the financial and business cycles. Recent examples include Begenau and Salomao (2018), Crane and Decker (2019), Dinlersoz et al. (2018), Fort et al. (2013), Kudlyak and Sánchez (2017), and Zetlin-Jones and Shourideh (2017).

[32] On this point, Cunningham et al. (2023) notes large and persistent differences in productivity across firms within an industry.

3.1 Households and Firms

Household preferences are given by[33]

$$\max_{\{C_t,\, L_t,\, B_t,\, K_{t+1}\}} \quad U_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\log(C_t) - L_t\right] \tag{1}$$

subject to

$$P_t C_t + B_t + Q_t\big(K_{t+1} - K_t\big) \leq W_t L_t + R^n_{t-1} B_{t-1} + Z_t K_t + P_t\,\Pi_t + T_t \tag{2}$$

where P is the aggregate price index, B bonds, R^n the nominal return on bonds, K capital, Q its price, W wages, Π profits, and T a lump sum transfer that accounts for price adjustment costs net of a capital subsidy paid by household. The optimality condition for labor implies

$$P_t C_t = W_t \tag{3}$$

The trade-off between consumption and investment is

$$1 = \mathbb{E}_t \left[\beta \frac{P_t C_t}{P_{t+1} C_{t+1}} \frac{Z_{t+1} + Q_{t+1}}{Q_t}\right] \tag{4}$$

The trade-off between saving and consumption gives the normal Euler condition

$$1 = \mathbb{E}_t \left[\beta \frac{P_t C_t}{P_{t+1} C_{t+1}} R^n_t\right] \tag{5}$$

Aggregate capital is fixed and price adjustment costs are rebated to households. The resource constraint becomes

$$Y_t = C_t \tag{6}$$

Monetary policy follows a Taylor rule

$$R^n_t = e^{m_t} R^n \left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} \tag{7}$$

where ϕ_π and ϕ_y determine the strength of the monetary policy response to deviations in inflation and the output. The persistence of monetary policy shocks follows

$$m_t = \rho_m m_{t-1} + \varepsilon_t \quad \text{where} \quad \varepsilon_t \sim \mathcal{N}(0, \sigma_m) \tag{8}$$

Firms, indexed by s, produce a variety of an intermediate good j. They have a Cobb-Douglas production function

$$y_{st} = e^{a_t} \bar{a}_s (k_{st-1})^{\alpha} (\ell_{st})^{1-\alpha} \tag{9}$$

[33] Demand shocks are omitted. Due to the simple nature of the model, they are isomorphic to a monetary policy shock.

where k is the firm's capital, ℓ labor, and $\bar{a}$ is a firm-specific productivity level. The parameter α represents the capital share in production. The persistence of aggregate productivity shocks follows

$$a_t = \rho_a a_{t-1} + \xi_t \quad \text{where} \quad \xi_t \sim \mathcal{N}(0, \sigma_a) \tag{10}$$

The firm's budget constraint includes a subsidy that offsets the price distortion to capital

$$\Pi_{st} = (1+\tau_t) p_{st} y_{st} - w_t \ell_{st} - z_t k_{st} \quad \text{where} \quad z_t = \frac{Z_t}{P_t} \quad \text{and} \quad w_t = \frac{W_t}{P_t} \quad \text{and} \quad 1+\tau_t = P_t^{\alpha} \tag{11}$$

where the relative price of the firm is denoted by p. The marginal cost $\boldsymbol{\mathcal{C}}$ includes all factors exogenous to the firm

$$\boldsymbol{\mathcal{C}}_{st} = \frac{1}{e^{a_t} \bar{a}_s P_t^{\alpha}} \left(\frac{z_t}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha} \tag{12}$$

In equilibrium, the market share of firms relates closely to their relative efficiency ($\bar{a}$). This lowers their marginal costs and gives them a price advantage over rival firms.

3.2 Nested CES Demand

Moving to production and price setting, the nested-CES case combines industry j and firm-level s output.[34] This specification was first proposed by Atkeson and Burstein (2008). Shimomura and Thisse (2012) develop a similar structure with a mix of large and small firms. It is a specific case of nested CES demand, so the general case is discussed first.

3.2.1 General Case

The general nested CES case has the following structure. Final output bundles together a continuum of goods, each produced by an industry. In turn, industries bundle a finite number of varieties of a good, each produced by an individual firm.

$$(i) \quad Y_t = \left[\int_0^1 y_{jt}^{\frac{\sigma-1}{\sigma}} dj\right]^{\frac{\sigma}{\sigma-1}} \quad \text{where for each industry} \quad (ii) \quad y_{jt} = \left[\sum_{s=1}^{n} y_{sjt}^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}} \tag{13}$$

where $n \geq 2$. The elasticity of substitution across goods is given by σ while φ is the elasticity of substitution across varieties. The corresponding price indices are given by

$$(i) \quad P_t = \left[\int_0^1 P_{jt}^{1-\sigma} dj\right]^{\frac{1}{1-\sigma}} \quad \text{where for each industry} \quad (ii) \quad P_{jt} = \left[\sum_{s=1}^{n} P_{sjt}^{1-\varphi}\right]^{\frac{1}{1-\varphi}} \tag{14}$$

[34] There is an implicit assumption in this paper, general in macroeconomics, that an individual firm cannot change the aggregate price index. Hence the measure of industries is zero.

where P_t is the aggregate price index and P_{jt} gives the price index for each industry. The allocation of demand across goods and varieties becomes

$$(i) \quad y_{jt} = \left(\frac{P_{jt}}{P_t}\right)^{-\sigma} Y_t \quad \text{and} \quad (ii) \quad y_{sjt} = \left(\frac{P_{sjt}}{P_{jt}}\right)^{-\varphi} y_{jt} \tag{15}$$

$$\implies \quad y_{sjt} = \left(\frac{P_{sjt}}{P_{jt}}\right)^{-\varphi} \left(\frac{P_{jt}}{P_t}\right)^{-\sigma} Y_t \tag{16}$$

Using relative prices, the demand schedule for each firm can be written as

$$y_{sjt} = p_{sjt}^{-\varphi} \left[\sum_{s=1}^{n} p_{sjt}^{1-\varphi}\right]^{\frac{\varphi-\sigma}{1-\varphi}} Y_t \tag{17}$$

The price elasticity of demand is therefore

$$\Psi_{sjt} \equiv \frac{\partial \log(y_{sjt})}{\partial \log(p_{sjt})} = (\varphi - \sigma)x_{sjt} - \varphi \quad \text{where} \quad x_{sjt} = \left(\frac{p_{sjt}}{p_{jt}}\right)^{1-\varphi} \equiv \frac{p_{sjt}y_{sjt}}{\sum_{s=1}^{n} p_{sjt}y_{sjt}} \tag{18}$$

$$= \frac{\varphi - \sigma}{n} - \varphi \quad \text{(if firms are identical)} \tag{19}$$

The price elasticity of demand is affected by a firm's market share x. Normally, the elasticity of substitution within an industry is greater than substitution across industries, i.e. $\varphi > \sigma$. In other words, it is easier to substitute across relatively homogeneous varieties of a good than different goods.[35] When the firm's market share is negligible, it only considers substitution across varieties, i.e.

$$\lim_{x_s \to 0} \Psi_s = -\varphi \tag{20}$$

As a firm's market share increases, demand becomes less sensitive to prices. At the limit, the firm controls the entire market and is only sensitive to substitution across goods

$$\lim_{x_s \to 1} \Psi_s = -\sigma \tag{21}$$

When there are multiple firms, the price elasticity of demand falls between the limit cases.

3.2.2 Nested CES with Asymmetric Firms

Following Shimomura and Thisse (2012), an asymmetric setup is specified where a sector has a mix of large and small firms. To simplify the case, firms are divided by size $s \in \{L, S\}$ into large (L) and small (S). Within each category, they are identical. The industry-level price index becomes

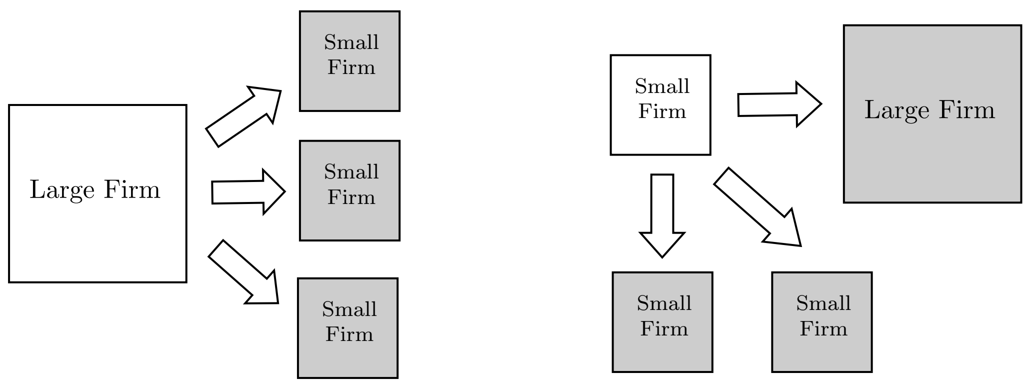
$$p_{jt} = \Big[\underbrace{(p_{sjt}^{i})^{1-\varphi}}_{\text{own price}} + \underbrace{(n_s - 1)(p_{sjt}^{\text{-}i})^{1-\varphi} + n_{\text{-}s}(p_{\text{-}sjt}^{\text{-}i})^{1-\varphi}}_{\text{rival prices}}\Big]^{\frac{1}{1-\varphi}} \tag{22}$$

where $i \in \{d, r\}$ denotes the firm making the pricing decision (d) and rival firms (r). This specification adheres to the general nested CES case. Since all small and large firms are otherwise identical, they are

[35] For example, a household may buy a different type of toothpaste if their preferred variety becomes too expensive. They could also use baking soda, but might resist this change since the goods are not perfect substitutes.

summed together. This entails solving for cross-price effects. Generally, just one large firm (or 'leader') is assumed so that $n_L = 1$. The leader faces multiple smaller rivals where $n_S > 1$.[36] Figure 2 shows the market structure for an industry where one large and three small firms compete. The large firm dominates the market and views the small firms as rivals. Meanwhile, each small firm views the other small firms and the large firm as rivals. In the latter case, cross-price effects include both the large firm and the other small firms. This enters into each firm's optimization problem through the price elasticity of demand, as evident in expression 18.

Figure 2: Competition within an Industry from the Firm's Perspective



This figure helps clarify the competition structure in the model and the intuition behind expression 22. When $n_L = 1$, the large firm only faces smaller rivals and solves for prices accordingly (as on the left). When a small firm sets prices considers both the actions of other small firms and the large firm (as on the right).

3.2.3 Linking the Price Elasticity of Demand to Firm Behavior

Key aspects of firm behavior – markups, the pass-through of marginal costs, and the best response price – relate to the slope and curvature of the price elasticity of demand. Among specifications allowing for a non-linear relationship between relative prices and relative demand, Kimball (1995) is probably the most common. The observation that consumers react differently to a large price increase compared to a small one is a marginal effect, in other words, the curvature of the price elasticity of demand. In this case, the 'superelasticity' or second-derivative, is negative and results from the firm's own price. When this is introduced into the firm's problem, it will reduce its markup and limit the pass-through of marginal costs in order to maintain sales. The presence of a finite number of firms introduces strategic behavior, which is not an inherent feature of Kimball demand. Firms adjust prices in response to price changes by other firms. This is described by the cross-price superelasticity of demand. Prices are strategic complements if the cross-price superelasticity is positive, meaning firms raise prices in response to a price hike by a rival firm. It is also possible they are substitutes. The cross-price are typically omitted when firms are identical, but are important when asymmetries are present.

3.2.3.1 Finding the Curvature of Demand

[36]The total number of firms in an industry $n = n_L + n_S$.

The following definitions should be clear, recalling the ratio of logarithmic derivatives give an elasticity. Since

$$\partial \log(x) = \frac{\partial x}{x} \tag{23}$$

the price elasticity of demand is defined as

$$\Psi_t^i \equiv \frac{\partial \log(y_t^i)}{\partial \log(p_t^i)} \equiv \frac{\partial y_t^i / y_t^i}{\partial p_t^i / p_t^i} \tag{24}$$

This expression is related to markups in a simple way, as explained in Ueda (2023). Take a one-period profit maximation problem where the budget constraint for firm is

$$\Pi_t^i = \left(p_t^i - \boldsymbol{\mathcal{C}}_t^i\right) y_t^i \tag{25}$$

where Π_t^i represents real profits, p_t^i is the relative price of the firm, $\boldsymbol{\mathcal{C}}^i$ is the marginal cost, y_t^i is demand (which is a function of p_t^i and the prices of rival firms p_t^{-i}). Taking the logarithmic derivative with respect to p_t^i gives

$$\frac{\partial \log(\Pi_t^i)}{\partial \log(p_t^i)} = 0 \quad \Longrightarrow \quad \Psi_t^i \left(1 - \frac{\boldsymbol{\mathcal{C}}_t^i}{p_t^i}\right) = -1 \tag{26}$$

Defining the markup μ_t^i as price over marginal cost, the expression above can be rearranged so that

$$p_t^i = \frac{\Psi_t^i}{\Psi_t^i + 1} \boldsymbol{\mathcal{C}}_t^i \quad \Longleftrightarrow \quad \mu_t^i = \frac{\Psi_t^i}{\Psi_t^i + 1} \tag{27}$$

Next, we can define the own-price superelasticity

$$\Psi_t^{i,i} \equiv \frac{\Psi_t^i}{\partial \log(p_t^i)} \tag{28}$$

Generally this term is negative, which implies large price adjustments are more costly for firms than small adjustments. The co-movement of markups and prices describes the pass-through of marginal costs. The elasticity of the markup to the price is

$$\Psi_t^{\mu_i} \equiv \frac{\partial \log(\mu_t^i)}{\partial \log(p_t^i)} = \frac{\Psi_t^{i,i}}{\Psi_t^i(\Psi_t^i + 1)} \tag{29}$$

Following Amiti et al. (2019), the pass-through $\boldsymbol{\mathcal{P}}_t^i$ is defined as

$$\boldsymbol{\mathcal{P}}_t^i \equiv \frac{1}{1 + \Psi_t^{\mu_i}} \tag{30}$$

Turning to strategic interaction, the cross-price superelasticity is given by

$$\Psi_t^{i,-i} \equiv \frac{\Psi_t^i}{\partial \log(p_t^{-i})} \tag{31}$$

and the slope of the best response price $\boldsymbol{\mathcal{B}}_t^i$ is given by

$$\boldsymbol{\mathcal{B}}_t^i \equiv \frac{\partial \log(p_t^i)}{\partial \log(p_t^{-i})} = \frac{\Psi_t^{i,-i}}{\Psi_t^i(\Psi_t^i + 1)} \tag{32}$$

Both the pass-through $\boldsymbol{\mathcal{P}}$ and the slope of the best response $\boldsymbol{\mathcal{B}}$ serve as target values in the baseline calibration.

3.2.3.2 Asymmetric Nested CES Case

Given asymmetric firms, where the industry-level price index follows expression 22, the price elasticity of demand becomes

$$\Psi_{st}^i = (\varphi - \sigma)\left(\frac{p_{sjt}^i}{p_{jt}}\right)^{1-\varphi} - \varphi \tag{33}$$

Taking second derivatives, the firm's own-price superelasticity $\Psi^{i,i}$ is

$$\Psi_{st}^{i,i} = (\varphi - \sigma)(1-\varphi)\left[\left(\frac{p_{sjt}^i}{p_{jt}}\right)^{1-\varphi} - \left(\frac{(p_{sjt}^i)^2}{p_{jt}^2}\right)^{1-\varphi}\right] \tag{34}$$

$$= (\varphi - \sigma)(1-\varphi)\frac{(n_s - 1)(p_{1jt}^i p_{1jt}^{-i})^{1-\varphi} + n_{-s}(p_{1jt}^i p_{2jt}^{-i})^{1-\varphi}}{p_{jt}^2} \tag{35}$$

and the cross-price superelasticity $\Psi^{i,-i}$ is

$$\Psi_{st}^{i,-i} = -(\varphi - \sigma)(1-\varphi)\frac{(n_s - 1)(p_{1jt}^i p_{1jt}^{-i})^{1-\varphi} + n_{-s}(p_{1jt}^i p_{2jt}^{-i})^{1-\varphi}}{p_{jt}^2} \tag{36}$$

This can be divided into two components.

$$\Psi_{st}'^{\,i,-i} = -(\varphi - \sigma)(1-\varphi)\frac{(n_s - 1)(p_{sjt}^i p_{sjt}^{-i})^{1-\varphi}}{p_{jt}^2} \tag{37}$$

$$\Psi_{st}''^{\,i,-i} = -(\varphi - \sigma)(1-\varphi)\frac{n_{-s}(p_{sjt}^i p_{-sjt}^{-i})^{1-\varphi}}{p_{jt}^2} \tag{38}$$

The first component ($\Psi'^{\,i,-i}$) represents the cross-price elasticity of other firms that are the same size. Since these firms will choose the exact same price, separating this term simplifies some of the subsequent analysis. The second term ($\Psi''^{\,i,-i}$) is the cross-price elasticity of firms that are a different size. It also happens the own- and cross-price elasticities perfectly offset with nested CES demand

$$\Psi_{st}^{i,i} = -\Psi_{st}^{i,-i}$$

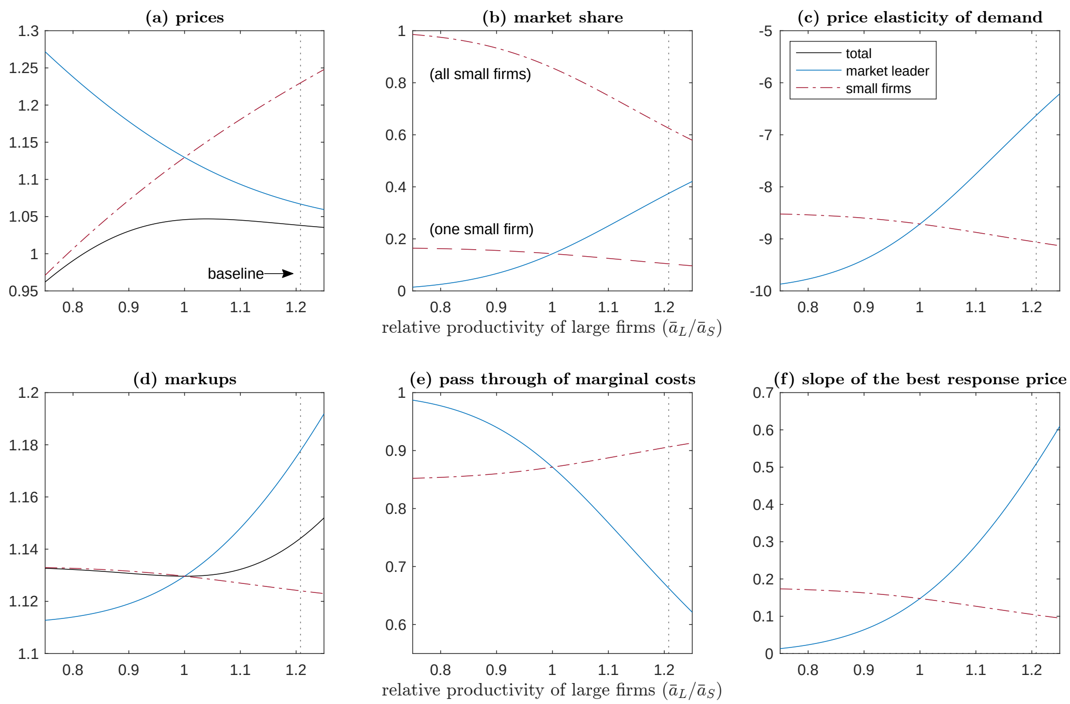
If these forces are equal – e.g. if firms are identical – the price elasticity of demand becomes linear. In other words, asymmetry is needed for a nested CES specification to meaningfully differ from the standard CES specification.[37]

Figure 3 shows the market structure resulting from nested CES demand when firms are asymmetric. The vertical lines show the baseline calibration. The market structure is determined by the parameters φ and

[37] Still, Nested CES with identical firms can be useful to target markup levels and the effects of firm entry and exit.

σ along with the relative marginal costs of firms, set by $\bar{a}$. The x-axis displays the relative productivity of the market leader. Moving from left to right in each plot, the market leader becomes more efficient and its production costs go down. It sets a lower price and gains market share, which increases its markup. Because there are multiple trailing firms within each industry, they remain relatively small. In the baseline calibration $n_S = 6$ and the market share of each small firm is constrained to a maximum of 16.7 percent.[38] Therefore, customers remain price sensitive and small firms cannot raise their markups by much. In addition, small firms do not respond to price adjustments by other firms and fully pass through cost shocks. The opposite is true of large firms (i.e. the 'market leader'). In the baseline calibration, the market leader passes through around 65 percent of marginal cost increases to consumers, as opposed to 90 percent for small firms. Also, the leader matches around 50 percent of price increases by its rivals.

Figure 3: Market Structure under Flexible Prices



The x-axis gives the relative productivity advantage of large firms over small firms, which is increasing from left to right. When large firms have a productivity advantage, they set a lower relative price. In turn, this increases demand for their variety and their market share increases. As market share increases, demand becomes less sensitive to price changes, which allows large firms to increase their markups. Due to the number of small firms ($n_s = 6$), their market share is constrained. Even if they have a productivity advantage, they cannot exercise significant market power. Given the curvature of demand, large firms limit the pass through of marginal cost shocks and respond to competitors prices when their productivity advantage grows.

Quasi-kinked demand (Kimball, 1995) is an example of where the demand curve is adjusted by the firm's own-price superelasticity. While cross-price effects are omitted, Kimball demand can mimic strategic behavior if the curvature is adjusted appropriately, as suggested in Wang and Werning (2022). However, cross-price effects are present whenever the number of firms is finite. The following sections will show price dynamics remain highly tractable given the setup. In fact, own- and cross-price superelasticities serve as direct inputs when using the method of undetermined coefficients and the solution method can readily accommodate other demand functions. Section A.3.1 in the appendix includes some further discussion the price elasticity of demand given strategic interaction.

[38]Small firms are generally treated as less efficient than the market leader. The instance where they have a cost advantage is included for illustration only.

3.3 Solving the Flexible Price Equilibrium

This section gives the solution method for the flexible price equilibrium. Figure 3 already gives a preview of the results. The flexible price equilibrium is also equivalent to the zero-inflation steady state in the dynamic problem. This section also sets the stage for solving for general equilibrium the presence of cross-price effects. Log-linearization and the method of undetermined coefficients greatly simplify the task.[39] The dynamic problem is more complicated, but follows the exact same approach. In the absence of price adjustment costs or rigidities, firms optimize their profits as follows

$$\max_{p_{st}^i} \quad \Pi_{st}^i = \left(p_{st}^i - \boldsymbol{\mathcal{C}}_{st}^i\right) y_{st}^i \tag{39}$$

where demand depends on the prices set by the firm and the prices set by its rivals. With identical firms, the solution for prices is straightforward. Asymmetric firms requires the best reply. The two cases are discussed separately.

3.3.1 Identical firms

When firms and industries are identical, demand follows expression 19 and the solution to the maximisation problem becomes

$$\frac{\partial \Pi_t}{\partial p_t} = 0 \quad \Longrightarrow \quad \left(1 - \frac{\boldsymbol{\mathcal{C}}_t}{p_t}\right)\left(\frac{\varphi - \sigma}{n} - \varphi\right) = -1 \tag{40}$$

Solving for the price is simple in this case

$$p_t^* = \frac{(n-1)\varphi + \sigma}{(n-1)\varphi + \sigma - n}\boldsymbol{\mathcal{C}}_t^* \tag{41}$$

This indicates the price is a direct function of marginal costs. Also notice that setting $n = 1$ leads to the standard CES case. It is relatively straightforward to determine how the number of firms in an industry affects the markup

$$\frac{\partial \mu^*}{\partial n} = \frac{\sigma - \varphi}{[(n-1)\varphi + \sigma - n]^2} \quad < 0 \quad \text{given} \quad \varphi > \sigma \tag{42}$$

This indicates greater concentration is associated with rising markups.

3.3.2 Asymmetric firms

The solution to the firm's optimization problem under asymmetric oligopoly ($n \geq 2$) proceeds as follows.[40] Going back to the maximization problem faced by the firm

$$\frac{\partial \Pi_{st}}{\partial p_{st}^i} = 0 \quad \Longrightarrow \quad \left(1 - \frac{\boldsymbol{\mathcal{C}}_{st}}{p_{st}^i}\right) \underbrace{\left[(\varphi - \sigma)\left(\frac{p_{st}^i}{p_{jt}}\right)^{1-\varphi} - \varphi\right]}_{\Psi_{st}^i} = -1 \tag{43}$$

[39]The solution is only locally accurate, but useful for illustrative purposes. The error becomes larger as prices move further from their starting point and numerical methods are usually more precise.

[40]Industries are identical and the index is reduced to s whenever possible to lighten the notation.

Solving prices requires inverting the demand function

$$p^i_{st} = \frac{\Psi^i_{st}}{\Psi^i_{st}+1}\boldsymbol{\mathcal{C}}_{st} \tag{44}$$

The optimal price can be solved numerically or approximated using the method of undetermined coefficients. Log-linearizing around the symmetric equilibrium and taking a first-order Taylor expansion gives the following relationship

$$\tilde{p}^i_{st} = \underbrace{\frac{\Psi^i_s(\Psi^i_s+1)\boldsymbol{\mathcal{C}}_s}{p^i_s(\Psi^i_s+1)^2-(\Psi^{i,i}+\Psi'^{\,i,\text{-}i}_s)\boldsymbol{\mathcal{C}}_s/p^i_s}}_{1+\Omega'_s}\widetilde{\boldsymbol{\mathcal{C}}}_{st} + \underbrace{\frac{\Psi''^{\,i,\text{-}i}\boldsymbol{\mathcal{C}}_s}{p^{\text{-}i}_s[p^i_s(\Psi^i_s+1)^2-(\Psi^{i,i}+\Psi'^{\,i,\text{-}i}_s)\boldsymbol{\mathcal{C}}_s/p^i_s]}}_{\Omega^*_s}\tilde{p}^{\text{-}i}_{\text{-}st} \tag{45}$$

For brevity of notation, the term for similar-size rivals ($\tilde{p}^{\text{-}i}_{st}$) is already incorporated on the left-hand side (since $\tilde{p}^i_{st}=\tilde{p}^{\text{-}i}_{st}$). Prices are a function of the firm's marginal costs and rival prices. The decision rule can be summarized as

$$\tilde{p}^i_{st} = (1+\Omega'_s)\,\widetilde{\boldsymbol{\mathcal{C}}}_{st} + \Omega^*_s\,\tilde{p}^{\text{-}i}_{\text{-}st} \tag{46}$$

Using the decision rule of rival firms allows the problem to be solved as a function of marginal costs alone

$$\tilde{p}^i_{st} = \frac{1+\Omega'_s}{1-\Omega^*_s\Omega^*_{\text{-}s}}\widetilde{\boldsymbol{\mathcal{C}}}_{st} + \frac{\Omega^*_s(1+\Omega'_{\text{-}s})}{1-\Omega^*_s\Omega^*_{\text{-}s}}\widetilde{\boldsymbol{\mathcal{C}}}_{\text{-}st} \tag{47}$$

While the method of undetermined coefficients is accurate around the initial point (e.g. p^*), it is a linear approximation. The nested CES specification leads to a non-linear system and a numerical solution is generally preferable (away from p^*).[41] Finally, the derivation of other outcomes, such as markups, should be clear. Market share is determined using expression 18. The following section lays out the dynamic problem.

3.4 Solving the Dynamic Problem under Sticky Prices

Price adjustment frictions are specified using quadratic costs, as in Rotemberg (1982). In his seminal paper, Rotemberg speculated price adjustment costs were non-linear, i.e. large price adjustments were more costly than small ones. Given imperfect information, consumers preferred firms that maintained stable price paths. Rotemberg pricing gives the same first-order solution as Calvo pricing if trend inflation is zero and the system is linear. When higher-order approximations are needed, there has been some debate about which specification better describes aggregate price dynamics. There are only a few comparative studies in the literature, but the evidence supporting Rotemberg pricing is generally favorable. Richter and Throckmorton (2016) finds a baseline New Keynesian model using Rotemberg pricing better fits observed price dynamics compared to an equivalent specification with Calvo pricing. The model incorporates a zero-lower bound (or ZLB) constraint, which introduces a non-linear element into the system. Similarly, Oh (2020) finds Rotemberg pricing better fits the data when looking at uncertainty shocks.

The model assumes firms set prices using a first-order approximation of demand and rivals' decision rules. The model is log-linearized around the steady state. Since trend inflation is omitted, this is analogous to the flexible price equilibrium. Agents are rational and correctly infer the persistence of the shock. The solution involves several different steps and they covered as follows. The first part of this section explains how the

[41] See figure 12 in the appendix and corresponding discussion.

decision rule for each firm's price is derived. Next, changes in firm-specific marginal costs are related to aggregates shocks. The final part derives the Phillips curve. The outline focuses more on intuition and steps are omitted if not particularly informative. Section A.3 in the appendix provides a more comprehensive overview of the solution.

3.4.1 Firm Optimization

As mentioned, pricing frictions take the form of Rotemberg adjustment costs in the dynamic model, which are rebated to households

$$\frac{\Theta_s}{2}\left(\frac{P^i_{st}}{P^i_{st-1}}-1\right)^2 Y_t \quad \text{where} \quad \Theta_s=\gamma_s x_s \Theta \tag{48}$$

The price adjustment costs Θ are specified so they are proportional across firms. Accordingly, Θ is multiplied by the steady state market share of each firm. This ensures the 'weight' firms put on their markup is equal to the weight they put on the price friction.[42] To examine how differences in adjustment costs affect outcomes, a firm-specific shifter for the price adjustment cost γ is included as well. With this in mind, the profit maximization problem becomes

$$\mathcal{L}=\mathbb{E}_t\sum_{k=0}^{\infty}\Lambda_{t+k}\left[\left(p_{st+k}-\boldsymbol{\mathcal{C}}_{st+k}\right)y_{st+k}-\frac{\Theta_s}{2}\left(\pi_{t+k}\frac{p_{st+k}}{p_{st+k-1}}-1\right)^2 P_{t+k}Y_{t+k}\right] \tag{49}$$

When Rotemberg costs are written using relative prices, aggregate inflation appears as an additional term. This is exogenous to the firm and represents a negative externality. Stochastic discounting follows from the household Euler condition

$$\Lambda_{t+k}=\beta^k\frac{P_t}{P_{t+k}}\frac{C_t}{C_{t+k}} \tag{50}$$

where $C_t=Y_t$ given the resource constraint. After some cancellations, the FOC with respect to p^i_{st} yields[43]

$$0=p^i_{st}y^i_{st}+\left(p^i_{st}-\boldsymbol{\mathcal{C}}^i_{st}\right)y^i_{st}\Psi^i_{st}-\Theta_s Y_t\left\{\left(\pi_t\frac{p^i_{st}}{p^i_{st-1}}-1\right)\pi_t\frac{p^i_{st}}{p^i_{st-1}}+\beta\mathbb{E}_t\left[\left(\pi_{t+1}\frac{p^i_{st+1}}{p^i_{st}}-1\right)\pi_{t+1}\frac{p^i_{st+1}}{p^i_{st}}\right]\right\} \tag{51}$$

Since demand can be written as a function of prices, the log-linearized decision rule for each firm is assumed to follow[44]

$$\tilde{p}^i_{st}=\Gamma_s\,\tilde{p}^i_{st-1}+\,(1+\Gamma'_s)\,\widetilde{\boldsymbol{\mathcal{C}}}^i_{st}+\,\Gamma^*_s\,\tilde{p}^{-i}_{-st}+\widehat{\Gamma}_s\,\tilde{\pi}_t \tag{52}$$

This expression is solved through the method of undetermined coefficients. Rotemberg pricing is forward looking, but embeds past prices as state variable and they appear in the decision rule. Future prices are solved in expectation. The term for similar-size rivals is already incorporated on the left-hand side (since

[42]A specification using Θ would result in large firms putting more 'weight' on their markup since they account for a greater share of output.
[43]The problem is fully described in section A.3.2 in the appendix.
[44]This is defined as $\tilde{x}=\log\left(\frac{x_t}{\bar{x}}\right)$ where $\bar{x}$ is the steady state value. The notation for the steady state drops the time subscript.

$\tilde{p}^{i}_{st} = \tilde{p}^{\text{-}i}_{st}$). Following Ueda (2023), the rival's decision rule gives the best reply. Together they give

$$\tilde{p}^{i}_{st} = \underbrace{\frac{\Gamma_s}{1-\Gamma^*_s\Gamma^*_{\text{-}s}}}_{\Upsilon_s}\tilde{p}^{i}_{st-1} + \underbrace{\frac{\Gamma^*_s\Gamma_{\text{-}s}}{1-\Gamma^*_s\Gamma^*_{\text{-}s}}}_{\Upsilon^*_s}\tilde{p}^{\text{-}i}_{\text{-}st-1} + \underbrace{\frac{1+\Gamma'_s}{1-\Gamma^*_s\Gamma^*_{\text{-}s}}}_{\Upsilon'_s}\widetilde{\mathcal{C}}^{i}_{st} + \underbrace{\frac{\Gamma^*_s(1+\Gamma'_{\text{-}s})}{1-\Gamma^*_s\Gamma^*_{\text{-}s}}}_{\Upsilon''_s}\widetilde{\mathcal{C}}^{\text{-}i}_{\text{-}st} + \underbrace{\frac{\widehat{\Gamma}_s+\Gamma^*_s\widehat{\Gamma}_{\text{-}s}}{1-\Gamma^*_s\Gamma^*_{\text{-}s}}}_{\Upsilon^{\pi}_s}\tilde{\pi}_t \quad (53)$$

The final decision rule reflects price inertia and marginal costs, both for the deciding firm and its rivals, and aggregate inflation. The corresponding terms are collected into the Υ's for convenience. Marginal costs are also related to aggregate output using the method of undetermined coefficients. For the monetary policy shock

$$(i) \quad \tilde{\pi}_t = \Gamma^{\pi} m_t \qquad\qquad (ii) \quad \widetilde{Y}_t = \Gamma^{y} m_t \qquad (54)$$

where Γ^{π} and Γ^{y} capture the overall response of inflation and output to the shock. The persistence of the shock implies

$$(i) \quad \mathbb{E}_t[\tilde{\pi}_{t+1}] = \rho_m\Gamma^{\pi} m_t \qquad\qquad (ii) \quad \mathbb{E}_t[\widetilde{Y}_{t+1}] = \rho_m\Gamma^{y} m_t \qquad (55)$$

The exact same relation holds for the productivity shock, which is omitted for brevity. After log-linearizing expression 51 and collecting coefficients, the coefficients are given by

$$\Upsilon_s = \frac{(\psi_s+\beta\Theta_s\Upsilon^*_s)\Upsilon^*_{\text{-}s}+\Theta_s}{\kappa_s-\beta\Theta_s\Upsilon_s} \qquad \text{(own past price)} \qquad (56)$$

$$\Upsilon^*_s = \frac{(\psi_s+\beta\Theta_s\Upsilon^*_s)\Upsilon_{\text{-}s}}{\kappa_s-\beta\Theta_s\Upsilon_s} \qquad \text{(rival past price)} \qquad (57)$$

$$\Upsilon'_s = \frac{(\psi_s+\beta\Theta_s\Upsilon^*_s)\Upsilon''_{\text{-}s}-(p^i_s)^{-\varphi}p_j^{\varphi-\sigma}\Psi^i_s\mathcal{C}^i_s}{\kappa_s-\beta\Theta_s(\Upsilon_s+\rho)} \qquad \text{(own marginal cost)} \qquad (58)$$

$$\Upsilon''_s = \frac{(\psi_s+\beta\Theta_s\Upsilon^*_s)\Upsilon'_{\text{-}s}}{\kappa_s-\beta\Theta_s(\Upsilon_s+\rho)} \qquad \text{(rival marginal cost)} \qquad (59)$$

$$\Upsilon^{\pi}_s = \frac{(\psi_s+\beta\Theta_s\Upsilon^*_s)\Upsilon^{\pi}_{\text{-}s}-\Theta_s(1-\rho\beta)}{\kappa_s-\beta\Theta_s(\Upsilon_s+\rho)} \qquad \text{(inflation)} \qquad (60)$$

where the convenience terms κ and ψ are defined as

$$\kappa_s = \Theta_s+\beta\Theta_s-(p^i_s)^{1-\varphi}p_j^{\varphi-\sigma}\left[\left(1-\frac{\mathcal{C}_s}{p^i_s}\right)\frac{\Psi^{i,i}_s+\Psi'^{\,i,\text{-}i}_s}{p^i_s}+\Psi^i_s\frac{\mathcal{C}_s}{p^i_s}\right] \qquad (61)$$

$$\psi_s = (p^i_s)^{1-\varphi}p_j^{\varphi-\sigma}\left(1-\frac{\mathcal{C}_s}{p^i_s}\right)\frac{\Psi''^{\,i,\text{-}i}_s}{p^{\text{-}i}_{\text{-}s}} \qquad (62)$$

In the solution for the Υ's above, the term ρ may refer to the persistence of the monetary or productivity shock, depending on the case. It embeds expectations for future prices along with the best reply by rival firms. The steps behind the derivation are included in the appendix (section A.3.2). There are ten unknowns and ten equations, which are solved numerically.

3.4.2 Aggregate Output and Firm-Specific Marginal Costs

The link between marginal costs and aggregate output still needs to be clarified. This is not completely straightforward. While wages and output share a simple relationship, capital rental costs depend on the marginal product of capital. Section A.3.3 in the appendix explains the asset market clearing and the link between capital rental costs and the aggregate shocks. The resulting capital rental price corresponds to nominal output

$$\tilde{z}_t = \widetilde{P}_t + \widetilde{Y}_t \tag{63}$$

Real wages are given by the household labor-leisure trade-off

$$w_t = C_t \quad \Longrightarrow \quad \widetilde{w}_t = \widetilde{Y}_t \tag{64}$$

where wages are proportional to real output since $C_t = Y_t$. The log-linear marginal cost for each firm becomes

$$\widetilde{\boldsymbol{\mathcal{C}}}_{st} = \alpha \tilde{z}_t + (1-\alpha)\widetilde{w}_t - a_{st} - \alpha \widetilde{P}_t \tag{65}$$

Substituting in capital rental costs and wages

$$\widetilde{\boldsymbol{\mathcal{C}}}_{st} = \widetilde{Y}_t - a_t \tag{66}$$

This gives the final expression for marginal costs, which are a function of aggregate output and productivity. Firm-specific changes in marginal costs are discussed in the appendix in section A.5. Also note the capital subsidy eliminates the price distortion to capital.

3.4.3 Aggregate Shocks and the Phillips Curve

Another application of the method of undetermined coefficients connects aggregate shocks to changes in output and inflation. In the case of the monetary policy shock, the Phillips curve is described by the ratio of Γ^π and Γ^y while the sacrifice ratio is the inverse. Monetary policy is solved first, followed by productivity in section 3.4.3.2. Both cases assume identical firms. The case with asymmetric firms requires a recursive solution, which is described in the appendix in section A.4.

3.4.3.1 Monetary Policy Shocks with Identical Firms

Firms take both costs and aggregate demand as given. The monetary policy shock acts on demand through the household Euler equation. Combining expressions 5 and 6 and log-linearizing yields

$$\widetilde{Y}_t = \mathbb{E}_t \left[\widetilde{Y}_{t+1} + \widetilde{P}_{t+1}\right] - \widetilde{P}_t - \widetilde{R}^n_t \tag{67}$$

the interest rate follows a Taylor rule. In log-linear form this becomes

$$\widetilde{R}^n_t = m_t + \phi_\pi \tilde{\pi}_t + \phi_y \widetilde{Y}_t \tag{68}$$

Using this expression, the household Euler equation can be written

$$\widetilde{Y}_t = \mathbb{E}_t \left[\widetilde{Y}_{t+1} + \tilde{\pi}_{t+1}\right] - m_t - \phi_\pi \tilde{\pi}_t - \phi_y \widetilde{Y}_t \tag{69}$$

Replacing $\widetilde{Y}$ and $\tilde{\pi}$, the problem now gives aggregate demand

$$\Gamma^y m_t = \rho_m(\Gamma^y + \Gamma^\pi)m_t - m_t - \phi_\pi \Gamma^\pi m_t - \phi_y \Gamma^y m_t \tag{70}$$

$$\implies \Gamma^\pi = \frac{(1 + \phi_y - \rho_m)\Gamma^y + 1}{\rho_m - \phi_\pi} \tag{71}$$

When firms are identical, there is no variation in relative prices and the decision rule boils down to aggregate supply

$$-\Upsilon^\pi \tilde{\pi}_t = \Upsilon' \widetilde{\mathcal{C}}_t^* \tag{72}$$

where

$$(i) \quad \Upsilon^\pi = \frac{\Theta}{n}(\rho_m \beta - 1) \quad \text{and} \quad (ii) \quad \Upsilon' = n^{\frac{\varphi-\sigma}{1-\varphi}} (p^*)^{1-\sigma} \left(\varphi - \frac{\varphi - \sigma}{n}\right) \frac{\mathcal{C}^*}{p^*} \tag{73}$$

Replacing the terms $\tilde{\pi}$ and $\widetilde{Y}$ again, the monetary policy shock enters as

$$-\Upsilon^\pi \Gamma^\pi m_t = \Upsilon' \Gamma^y m_t \tag{74}$$

$$\implies \quad \Gamma^y = \frac{-\Upsilon^\pi}{\Upsilon'} \Gamma^\pi \tag{75}$$

Along with expression 71 there are now two equations (describing aggregate supply and demand) where the Γ^π and Γ^y are the unknowns. Solving gives the reaction of output and inflation to a monetary policy shock.

3.4.3.2 Aggregate Productivity Shocks with Identical Firms

For productivity, the relation between the shock and aggregate output and inflation is given by

$$(i) \quad \widetilde{Y}_t = \Omega^y a_t \qquad\qquad (ii) \quad \tilde{\pi}_t = \Omega^\pi a_t \tag{76}$$

The resulting aggregate supply curve is

$$\Omega^y = \frac{-\Upsilon^\pi}{\Upsilon'} \Omega^\pi + 1 \tag{77}$$

The result is similar to expression 75. As before, the household Euler equation and the Taylor rule can be combined so that

$$\Omega^\pi = \frac{(1 + \phi_y - \rho_a)}{\rho_a - \phi_\pi} \Omega^y \tag{78}$$

There are two equations and two unknowns, which gives the solution for the elasticity output and inflation to a productivity shock. Again, the asymmetric case is described in the appendix in section A.4.

4 The Response of Firms to Aggregate Shocks

The model uses Rotemberg pricing where firms can reset their prices every period. As a consequence, dispersion arises solely from the cross-section of firms. This contrasts with most models incorporating Calvo price frictions, which only generate dispersion through price staggering. This section has four parts. First, it explains the calibration and target values for the model. Next, it looks at how concentration affects the slope of the Phillips curve. The third part describes the dynamic response to a monetary policy and productivity shocks across firms. The final part covers dynamic reallocation and how shocks can amplify steady state distortions.

4.1 Model Calibration

The model is solved at a quarterly frequency. The baseline calibration is given in table 1.

Table 1: Baseline Parameter Values

Parameter	Value	Description
β	0.99	Household time discount
α	0.30	Capital share
σ	1	Elasticity of substitution across goods
φ	10	Elasticity of substitution across varieties
Θ	125	Rotemberg price adjustment costs
γ_s	1	Relative price adjustment costs
n_L	1	Number of large firms in an industry
n_S	6	Number of small firms in an industry
$\bar{a}_L$	0.91	Productivity of large firms
$\bar{a}_S$	1.09	Productivity of small firms
ϕ_π	1.50	Monetary policy inflation reaction
ϕ_y	0.125	Monetary policy output gap reaction
ρ_m	0.85	Persistence of monetary policy shocks
ρ_a	0.90	Persistence of productivity shocks

The time discount factor and the capital share of income use standard values.[45] The Taylor rule coefficients match the values originally proposed in Taylor (1993). The parameters describing the elasticity of substitution across varieties and goods follow Atkeson and Burstein (2008). The number of firms and their relative productivity are based on several target moments, described in tables 2 and 3. Targets include the distribution of market share across large and small firms, the pass-through, and the best response price. Additional outcomes of interest include the industry HHI, the aggregate markup, and price dispersion. Generally, steady state values align closely with the desired results, excepting the pass-through and best response price of small firms. In practice, the impact of this mismatch is minimal. Finally, the parameter for the price adjustment cost Θ is equivalent to a 35 percent reset probability under Calvo pricing.[46] This appears consistent with the data, although the average price duration can be measured in different ways. Large and small firms are assumed to have the same price adjustment costs in the baseline.

The market shares in table 2 are based on an analysis of the EU Merger Control database (Affeldt et al., 2018). The large firm target is the average across all observations of the largest market share reported in

[45] The persistence of monetary policy shocks matches table 1 column 5 in Coibion and Gorodnichenko (2012). The persistence of productivity shocks follows table 1 column 3 in Pancrazi and Vukotić (2013).

[46] The corresponding parameter under Calvo pricing θ is the probability a firm keeps the same price. The average price elasticity of demand in an industry is around 8.1 and setting $\Theta = 125$ matches a benchmark model using Calvo pricing where $\theta \approx 0.65$, which implies the average duration is 8.6 months. This matches the mean duration for the regular price reported in Klenow and Kryvtsov (2008).

Table 2: Industry-Level Targets

Description	Large firms Target	Large firms Value	Small firms Target	Small firms Value	Source
Targeted					
Market share	0.35	0.37	0.12	0.10	Affeldt et al. (2018)
Pass-through	0.65	0.66	0.97	0.91	Amiti et al. (2019)
Slope of best response price	0.48	0.51	0.00	0.10	Ibid.
Markup ($\mu - 1$)	0.24	0.18	0.16	0.12	Hottman et al. (2016)
Implied					
Log price	–	0.06	–	0.21	–

each. The small firm share is based on the average share of all trailing firms in a market, when reported.[47] The slope of the best response price and the pass-through are from Amiti et al. (2019).[48] The model does fully not match the level of markups reported in Hottman et al. (2016), but the relative gap is the same.[49] Moving to table 3, the HHI estimated by Benkard et al. (2021) provides an alternative target for the distribution of market share. The study finds the median HHI in local product markets decreased from 2360 to 2045 between the years 1994 and 2019. The value generated by the model is at the lower end of this range. The aggregate markup is based on the long-term average of corporate accounting profits. The underlying tabulations are discussed in the appendix (see section A.1). A meta-study by Tetlow (2022) finds the sacrifice ratio usually falls between 2 and 3 and this informs the target for the Phillips curve.

Table 3: Aggregate Targets

Description	Target (range)	Value	Source
Targeted			
Median Industry HHI	2045 - 2360	2060	Benkard et al. (2021)
Aggregate Markup ($\mu - 1$)	0.13 - 0.16	0.14	See appendix[50]
Slope of the Phillips curve	0.33 - 0.50	0.36	Tetlow (2022)
Implied			
Price dispersion (std. dev.)	–	0.07	–
Markup dispersion (std. dev.)	–	0.02	–

Due to the presence of asymmetries, the model generates dispersion in prices and markups across the cross-section of firms. This is measured using the standard deviation of log prices and markups, weighted by market share. Using Compustat data, Meier and Reinelt (2022) documents an increase in the variance of markups over time. Towards the end of the sample period, the variance of log markups within a 4-digit industry is around 0.08 – an order of magnitude higher than what the model implies.[51] This does not mean the model performs poorly. The data in Meier and Reinelt are not fully disaggregated to the level of

[47] Only observations with four or more firms are included (meaning there are at least three trailing firms). Both the mean and median market share align for small firms (12 percent) and around 85 percent of market share is explained on average. The restriction on the number of firms per observation has no effect on the market share of the largest firm. It remains 35 percent.

[48] The pass-through is taken from table 1 column 4 while table 2 column 1 gives the pass-through costs for small firms.

[49] See the top decile and median firm in table 8 in Hottman et al. (2016). The markup estimates assume monopolistic competition and use product-level elasticities.

[50] Section A.1. Note that the relation between markups and aggregate profits is $\frac{Y_t}{Y_t - \Pi_t} = \mu_t$

[51] At least in the case of an aggregate shock. Firm-specific shocks generate much higher levels of dispersion.

individual markets. Idiosyncratic shocks may increase the variance of markups in an industry Furthermore, markups are not directly observed and measurement issues could affect the variance estimate.[52] For these reasons, markup dispersions is not targeted.

There are many estimates of price dispersion in the literature, but few apply directly to the model. Abbott (1989) is the only example looking at producer prices. The study finds variation in prices is around 16 percent for the median industry when dividing the interquartile range for prices by the median. The model returns 15 percent by the same calculation. There are a fairly large set of studies looking at price dispersion across retailers. Even for identical goods, the variation across retailers can be fairly large. Sheremirov (2020) finds the standard deviation is around 6.6 log points for homogeneous products in IRI retail scanner data. Kaplan and Menzio (2015) finds the standard deviation of normalized prices for identical goods is 0.19 while this rises to 0.25 for closely substitutable goods.[53] Yet even when studies include near substitutes, it is unclear whether price dispersion arises from differences in producer prices or those set by retailers. The slope of the Phillips curve, another key outcome, is discussed in the following section.

4.2 Concentration and the Slope of the Phillips Curve

When firms are identical, the relationship between markups and the flattening of the Phillips curve is clear (figure 4). As discussed in section 3.4.3, the slope is given by

$$\frac{\Gamma^\pi}{\Gamma^y} = \frac{n^{\frac{1-\sigma}{1-\varphi}}(p^*)^{-\sigma}\left(\varphi - (\varphi-\sigma)/n\right)\boldsymbol{\mathcal{C}}^*}{\Theta(1-\rho_m\beta)} \tag{79}$$

It is easy to take the limit case. Setting $n = 1$ gives

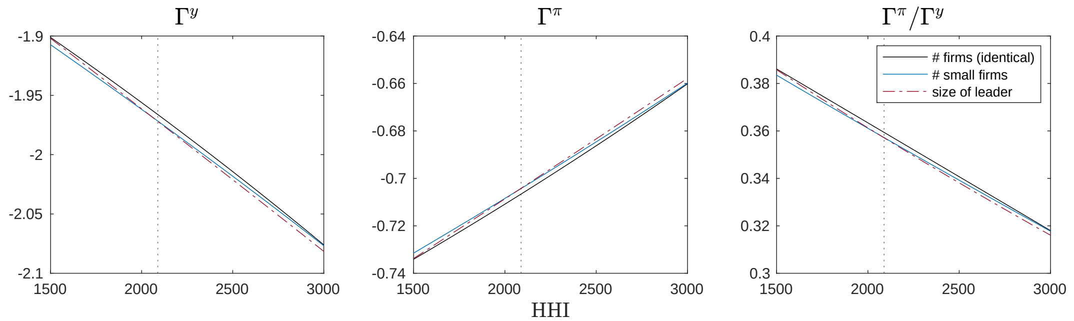
$$\frac{\Gamma^\pi}{\Gamma^y} = \frac{\sigma(p^*)^{-\sigma}\boldsymbol{\mathcal{C}}^*}{\Theta(1-\rho_m\beta)} \quad \text{where} \quad p^* = \frac{\sigma}{\sigma-1}\boldsymbol{\mathcal{C}}^* \tag{80}$$

Since the elasticity of substitution $\sigma = 1$, the markup becomes infinite and Phillips curve goes to zero. Other factors influence the slope as well. Lower Rotemberg adjustment costs steepen the slope of the Phillips curve. When prices are fully flexible, i.e. $\Theta = 0$, the Phillips curve is vertical and monetary policy has no real effects. The same applies for the expected persistence of monetary policy shocks. As ρ_m increases, the slope of the Phillips curve steepens.

Wang and Werning (2022) looks at the impact of higher concentration on the Phillips curve. Figure 4 presents a similar set of results. The panel on the left of the figure gives the responsiveness of output to a monetary policy shock (Γ^y). The center panel gives the responsiveness of inflation (Γ^π). Their ratio gives the slope of the Phillips curve, which is presented on the right. Moving from left to right along the x-axis corresponds to an increase in concentration. The vertical dotted line shows the HHI implied by the baseline calibration. An HHI of 5000 represents a symmetric duopoly. The results here are close to those presented in Wang and Werning. In the their study, a naïve oliogopoly model matches a more sophisticated model with strategic complementarity closely. The same could be said here. When looking at a range of plausible values for the HHI, a specification with asymmetry yields results very close to a specification with identical firms. While it is tempting to link higher concentration to the flattening of the Philips Curve, even modest change requires a large increase in concentration.[54] In part, this is a consequence of the parameterization.

[52] Ridder et al. (2021) demonstrates assumptions on the production function can have a large impact on results.
[53] Similarly, Böheim et al. (2021) finds a coefficient of variation around 0.12 comparing online prices across retailers in Austria
[54] A decrease in the slope of the Philips curve by 0.01 implies an increase in the HHI of more than 200 points.

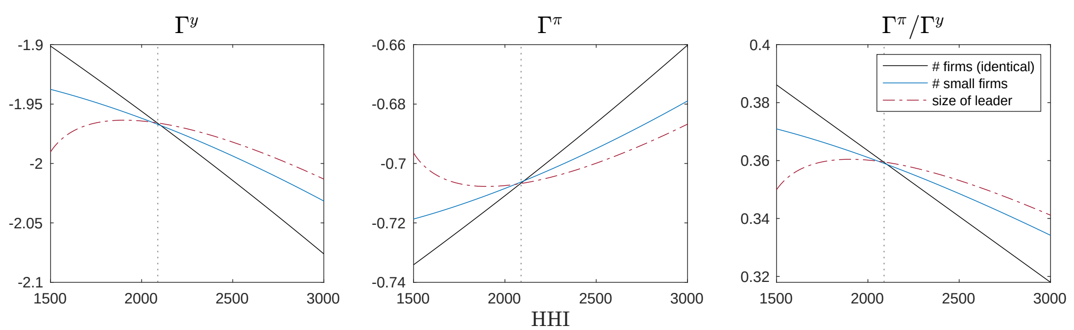
Figure 4: Concentration and the Aggregate Response to a Monetary Policy Shock (Baseline)



The x-axis displays the HHI and a move from left to right corresponds to an increase in concentration. An increase due to firm exit is comparable to an increase from the consolidation of market share by one firm. The left-hand panel shows the response of aggregate output to a monetary policy shock, while the center panel gives the response of inflation. The right-hand panel gives their ratio, i.e. the slope of the Phillips curve. The vertical dotted line gives the HHI corresponding to the baseline calibration. It is evident a positive monetary policy shock decreases both output and inflation. An increase in the HHI corresponds to a flattening of the Phillips curve. The three lines give (i) identical firms where n decreases, (ii) the baseline calibration where n_S decreases, and (iii) the baseline calibration where the productivity of the leader improves and it gains market share.

The apparent similarity between specifications breaks down in several ways. The calibration plays a role and setting the parameter for the elasticity of substitution across goods σ differently can have a large effect. With a higher σ, the slope of the Phillips curve is less sensitive to growing asymmetry, but more sensitive to concentration when firms are identical. Differences in price adjustment costs between firms affect outcomes as well. Goldberg and Hellerstein (2009) suggests large firms have greater price flexibility than small firms. The the price adjustment costs are adjusted so that γ_L and γ_S are 0.6 and 1.3 respectively, which corresponds to a price duration for large firms around one-half that of small firms. As figure 5 shows, the slope of the Phillips curve is much less sensitive to growing asymmetry in this case. The interpretation is simple. As large firms expand, the degree of aggregate price flexibility increases, which offsets the change in markup resulting from higher concentration.

Figure 5: Concentration and the Aggregate Response to a Monetary Policy Shock ($\gamma_L = 0.6$ and $\gamma_S = 1.3$)



The underlying exercise and interpretation is the same as figure 4, except the price adjustment costs of small and large firms are modified. Large firms are assumed to have a significantly lower price adjustment cost where $\gamma_L = 0.6$ and $\gamma_S = 1.3$. This scenario indicates the change in the Phillips curve from the expansion of large firms is ambiguous if their prices are more flexibile.

4.3 Dynamic Responses

This section looks at price dynamics following a shock. The impulse response functions (IRFs) give the log of the steady state deviation of a variable.[55] The monetary policy shock is discussed first. Given the simplicity

[55]This is defined as $\tilde{x} = \log\left(\frac{x_t}{\bar{x}}\right)$

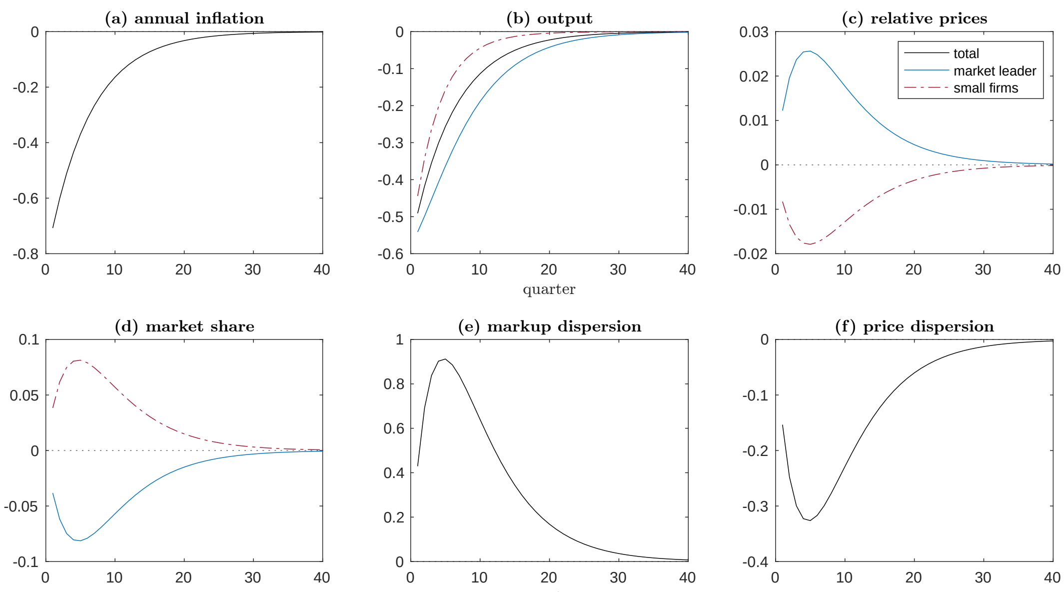
of the model, monetary tightening is also analogous to a negative demand shock.

4.3.1 Monetary Policy Shock

The dynamic response to a one percentage point increase in the annualized interest rate is presented in figure 6. Both aggregate inflation and output decline in response to the shock, as they would using a standard model, e.g. Galí (2015). Due to differences in the price elasticity of demand, the effect of the shock on prices and output is not symmetric across firms. Large firms have a larger response. This relates to the pass-through. When monetary policy tightens, marginal costs fall in line with output. Large firms do not fully pass these cost savings through to consumers and they cut prices by less than small firms. Demand for the variety produced by the large firm drops since its relative price is higher, which leads to a decline in market share.

Since small firms set a higher price in the steady state, changes in relative prices following monetary tightening lead to price compression.[56] Meanwhile, markup dispersion rises. Both small and large firms increase their markups, but the increase for large firms is more pronounced. Large firms already charge a higher markup in equilibrium, so this amplifies the steady state distortion. This outcome is consistent with the findings in Meier and Reinelt (2022) where a contractionary monetary shock increases markup dispersion while easing lowers it. The implied change in the level of the variance from a 1 percentage point increase in the interest rate is 0.001, which matches what Meier and Reinelt report.

Figure 6: Baseline Impulse Response to Monetary Tightening ($\varepsilon_0 = 0.25$)



The monetary policy shock is equivalent to a one percentage point increase in the nominal interest rate. The x-axis gives the quarter following the shock. The y-axis is scaled to give the deviation from the steady state. Inflation drops by around 0.7 percent in the first period e.g. $1 * \exp(-0.007)$. The response of aggregate inflation and output are standard. The change in the relative price of small and large firms results from differences in pricing behavior. Marginal costs fall. Large firms do not fully pass through savings and set a higher relative price following the shock. As a consequence, they lose market share. Because large firms increase their markup by more than small firms, this amplifies markup dispersion.

Given monetary easing, the results are fully symmetric. Large firms set a lower relative price since they absorb part of the increase in marginal costs. Small firms have higher relative prices and face lower demand,

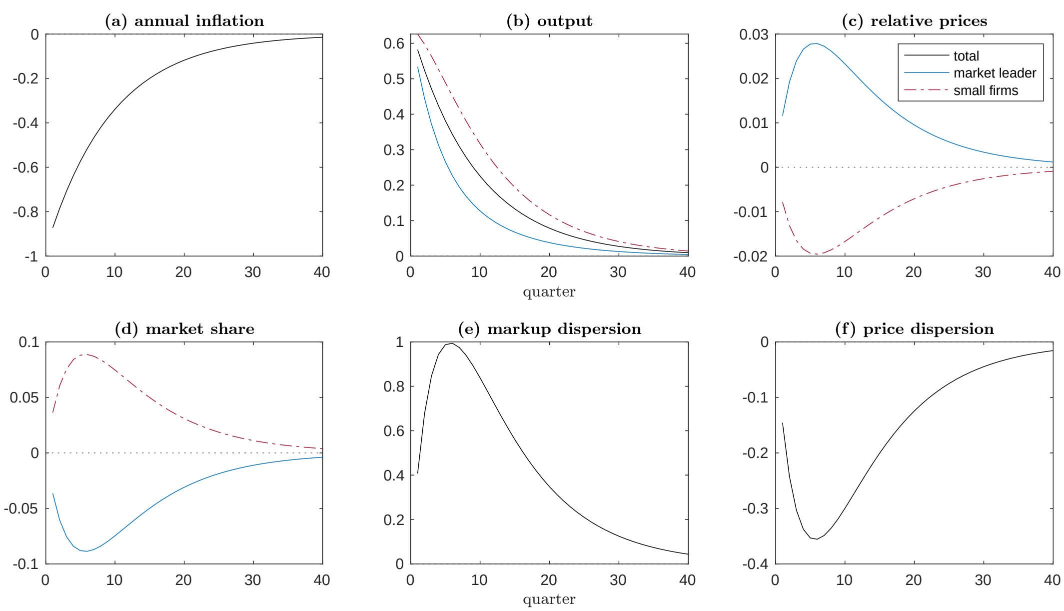
[56] Price dispersion is measured using the weighted standard deviation of log prices in each time period, where the market share of each firm gives the weight. Log markups are similarly used to measure markup dispersion.

accordingly they lose market share following the shock. Altogether, large firms are less sensitive to monetary policy than small firms. This differs from the conventional view, where small firms are more sensitive to monetary tightening due to the financial accelerator. When looking at detailed firm-level microdata from the US Census Bureau's Quarterly Financial Report survey, Crouzet and Mehrotra (2020) do not find a statistically significant difference in the response across large and small firms to monetary policy.[57] It is possible differences in the price elasticity of demand across firms are confounded by other factors. When price adjustment cost for large firms is set lower than the cost for small firms (i.e. $\gamma_L < \gamma_S$), this significantly dampens the response.

4.3.2 Aggregate Productivity Shock

Figure 7 gives the dynamic response to a one percent productivity shock. As expected, the productivity shock increases aggregate output. While this raises the cost of labor and capital inputs for firms, the shock also improves their efficiency and prices drop. Because prices demonstrate significant inertia compared to costs, markups increase, particularly for large firms. This amplifies the steady state distortion and markup dispersion rises. As with the monetary shock, the gap in relative prices relates to differences in the pass-through. Large firms only pass through part of the cost saving to households and they cut their prices by less compared to small firms. Since the price level of large firms is below the level set by small firms in the steady state, the shock leads to price compression. Differences in the the evolution of relative prices also explain the reallocation of market share towards small firms.

Figure 7: Baseline Impulse Response to a Productivity Shock ($\xi_0 = 1$)



The initial shock increases aggregate productivity by one percent. Inflation drops and output expands. These outcomes are standard for a New Keynesian model. While wages and capital rental costs increase, efficiency is also higher. The latter effect dominates and firms reduce their marginal costs. Small firms pass their savings to consumers and cut their relative prices more than large firms. This reduces price dispersion. Large firms increase their markup by more than small firms. This increases markup dispersion.

The results relate to two empirical studies. First, Sheremirov (2020) observes a positive co-movement

[57] The authors suggest economies of scope may play an important role in explaining why small firms are more sensitive to aggregate shocks. Large firms often operate in multiple industries and are more likely to experience the 'average' shock whereas small firms are more exposed to industry-specific conditions – this is beyond the scope of the model, but could inform an extension.

between dispersion in regular prices and inflation.[58] For a 1 percentage point increase in inflation, dispersion in the log of regular prices increases 0.026 percent. The model implies a value of 0.027 percent and aligns closely with the empirical estimate. The results also indicate small firms are more sensitive to the business cycle, which is consistent with Crouzet and Mehrotra (2020). There, the authors find a differential in the response of sales to a change in GDP. The estimated elasticity of sales to GDP is 2.5 for the top 1 percent of firms (by size) and 3.1 for the bottom 99 percent.[59] Looking at output, the model implies small firms around around 35 percent more sensitive to the business cycle than large firms, whereas the corresponding figure from Crouzet and Mehrotra is 24 percent ($= 3.1/2.5 - 1$).

4.4 Allocative Efficiency and Strategic Complementarity

The allocation of demand influences the overall efficiency of the economy since large and small firms have different productivity levels. This is relatively simple to analyze. Given identical sectors, the change in aggregate productivity $\mathcal{A}$ has two main components: the change from dynamic reallocation $\mathcal{A}^d$ and the within or 'static' component of the shock $\mathcal{A}^s$ that holds market share constant[60]

$$(i) \quad \frac{\mathcal{A}_t^d}{\mathcal{A}} = \frac{y_{St} n_S \bar{a}_S + y_{Lt} n_L \bar{a}_L}{y_S n_S \bar{a}_S + y_L n_L \bar{a}_L} \qquad (ii) \quad \frac{\mathcal{A}_t^s}{\mathcal{A}} = e^{a_t} \quad \text{where} \quad \mathcal{A} = y_S n_S \bar{a}_S + y_L n_L \bar{a}_L \tag{81}$$

Both the monetary policy and productivity shocks lead to efficiency losses from dynamic reallocation.[61] While the change in efficiency from dynamic reallocation is minuscule in any given period, the cumulative effect is non-trivial. For the monetary policy shock, the cumulative loss amounts to around 0.1 percentage points of potential output. The productivity shock is more persistent and the cumulative loss is 0.2 percentage points of potential output.[62]

Shocks may affect firms unequally. In this case, the role of dynamic reallocation becomes more prominent. Figures 8 and 9 give the response of markups, prices, and productivity to firm-specific shocks. In figure 8, a negative productivity shock is only applied to large firms. Nonetheless, it has general equilibrium effects. It lowers marginal costs for small firms and is inflationary. Large firms both raise prices and cut their markups in response to the shock. Small firms are slow to react and lower their prices very gradually in response – the markup remains relatively constant. With a higher relative prices, large firms lose market share. Since they are the most efficient producers, this reallocation further diminishes the overall efficiency of the economy. This amplifies 'static' losses from the shock, i.e. losses before changes in market share are taken into account. The cumulative static losses are around 4 percentage points of potential output. Meanwhile, the losses from dynamic reallocation are around 1 percentage points of potential output, accounting for 21 percent of the total.

If small firms receive a negative productivity shock, the static loss outweighs the dynamic gain from reallocation. Following the shock, small firms are forced to raise their prices and reduce their markups, whereas large firms perceive competition as weaker and raise their markups by a significant margin. This highlights the role of strategic complementarity. Given a comparable negative shock to large firms, small firms raise their markup by much less. This leads to a key result: without strategic complementarity, i.e. if large

[58] Sheremirov (2020) also observes the Calvo model overstates the comovement of price dispersion with inflation by a factor of 15 and a similar analysis is included in the appendix in section A.6.

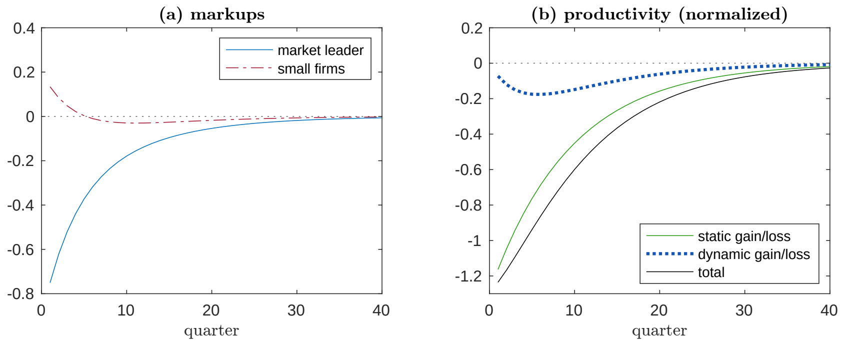
[59] While there are no industry controls in the baseline, estimates are similar when using NAICS 3-digit controls.

[60] The interaction of the change in productivity and the change in output is small and therefore omitted.

[61] It is evident large firms lose market share in figures 6 and 7, which lowers overall efficiency.

[62] To give a sense of magnitude, the cumulative increase in potential output is around 4 percentage points following the productivity shock. The reallocation of demand to less-efficient firms reduces this to 3.8 percentage points (i.e. by 4 percent).

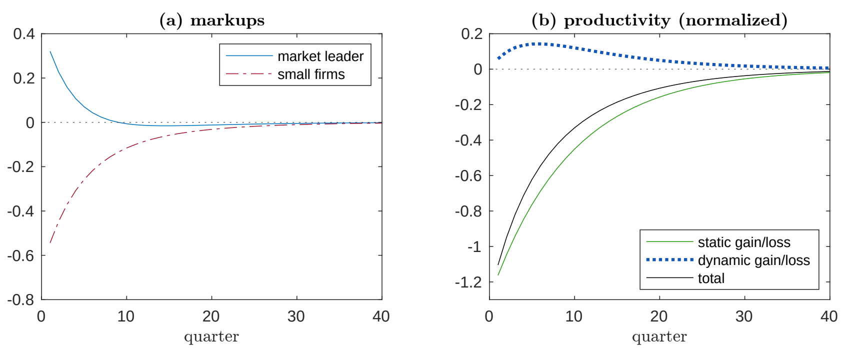
Figure 8: Impulse Response Given a Positive Negative Shock to Large Firms ($\xi_0 = 1$)



A one percent productivity shock is applied to large firms. Although large firms raise their markup, they also cut relative prices. The change in efficiency is divided between two components. The first is the effect of the productivity shock holding the allocation of demand constant. The second is productivity gain resulting from the reallocation of demand to high productivity firms. The outcomes for productivity in figures 8 and 9 are normalized to reflect an equally-sized shock given the respective weight of large and small firms in the economy.

firms were monopolistic, the dynamic gain would be around 35 percent larger.[63] Given this counterfactual, the cumulative loss from the shock would be 4.2 percentage points of potential output compared to 4.6 percentage points. The difference, 0.4 percentage points, is largely explained by strategic complementarity.

Figure 9: Impulse Response Given a Positive Negative Shock to Small Firms ($\xi_0 = 1$)



A one percent productivity shock is applied to small firms. The interpretation is the same as figure 8 but the outcomes are different. First, small firms raise their markup by less than large firms when facing a comparable shock; meanwhile, large firms cut their markups more. Despite the shift in markups, the relative price of small firms increases by more and this leads demand to shift towards large firms. This reallocation partially offsets the static losses resulting from the shock.

5 Policy Implications

There are three main takeaways from the previous set of exercises. First, rising concentration could explain the flattening of the Phillips curve over the 1990s and 2000s. Second, small firms are more sensitive to the business cycle due to lower pricing power. Finally, strategic complementarity plays a strong role when shocks are firm-specific. Under a specific set of circumstances, they can lead to noticeable efficiency losses. The following section will cover these points, along with considerations on household welfare and firm exit.

[63] In the baseline, the cumulative dynamic gain is 1.2 percentage points. To find the counterfactual, the number of firms is increased while targeting the same equilibrium allocation of market share between large and small firms. In practice, the alternative setting is $n_L = 200$ and $n_S = 1900$. This eliminates both own-price effects and strategic complementarity since each firm's market share is negligible, but there is still a gap in terms of the productivity level across firms. In this case, the cumulative dynamic gain is 1.7 percentage points. Compared to the baseline, the gap is around 0.4 percentage points.

On the first point, it seems unlikely higher concentration explains the flattening of the Phillips curve. A measurable increase would require a change in the HHI over 500 points and it is not clear the HHI increased at all. Furthermore, if large firms set prices more flexibly than small firms, this might offset the effect of growing market power. Given a flat Phillips curve, the model suggests increasing the expected persistence of monetary policy shocks can steepen the slope. There is a long-standing literature on this topic, for example Eggertsson and Woodford (2003). However, the model also implies a trade-off. Increasing the expected persistence of shocks widens the gap between large and small firms. For example, raising ρ_m from 0.8 to 0.9 increases markup dispersion by 30 percent following a shock.

The results suggest that large firms disproportionately benefit from monetary easing. This contributes to a large literature showing low interest rates over the 2010s likely exacerbated the concentration trend. One obvious channel is M&A activity, which favors established firms (Blonigen & Pierce, 2016; Chatterjee & Eyigungor, 2023; Stiebale & Szücs, 2022). Kroen et al. (2021) finds a decline in interest rates disproportionately lowers borrowing costs for industry leaders, who use their cost advantage to invest and pursue acquisitions. Low interest rates likely affected R&D as well, allowing market leaders to pull ahead. While the model here focuses on short- and medium-run dynamics, an extension with endogenous growth could be useful. There are a number of examples in the literature. Liu et al. (2019) argues low rates have widened the gap between firms at the innovation frontier and those behind, discouraging competition and market entry.[64] That is, once market leaders pull sufficiently far ahead of their rivals, innovation may decline. Cunningham et al. (2021) documents the presence of 'killer' acquisitions where incumbents acquire rival firms solely to disrupt innovation within their industry. Others point to the slowdown in productivity growth along with demographic changes and declining entrepreneurship as potential culprits behind the decline in business dynamism (Hopenhayn et al., 2018; Karahan et al., 2019; Olmstead-Rumsey, 2019).

The presence of strategic complementarity in model relates to so-called 'greedflation' – the idea large corporates exploited inflation to exercise market power (Weber & Wasner, 2023). As highlighted in the section on dynamic reallocation, strategic complementarity is a source of inefficiency when small firms are more exposed to cost/productivity shocks, which might have been the case following the Covid pandemic. This is much less the case with aggregate shocks. Given a negative shock, large firms will in fact absorb cost increases to some extent. Of course, the model cannot capture all salient features of the recent crisis. It is not clear if producers can easily increase supply given global disruptions. Also, the problem of 'greedflation' raises a normative question: should companies raise prices if they are already highly profitable? In a time of crisis, the answer is not completely clear. The analysis here establishes the economic costs are potentially large when shocks are firm-specific.

To raise another concern, changes in efficiency may not correlate with household welfare. With CES preferences, households gain utility from the presence of multiple varieties. Therefore, households might prefer to allocate their income across varieties despite the efficiency costs. Even if households are indifferent between varieties, the model highlights another tension. The most efficient producer should supply the entire market, but this increases their market power (Minner, 2003; Rysman, 2009). Static and dynamic trade-offs are important in this context. For example, the vertical integration of firms and their suppliers appears to benefit consumers since there is no 'double markup' (Bellucci & Rungi, 2022). At the same, vertical integration may increase the rigidity of supply chains, lowering dynamic efficiency. Realism on household preferences as well a more complex interlinkages between sectors are needed to fully evaluate these trade-offs.

As a final point, a large shock could lead firms to exit, as in Hopenhayn (1992). A VAR analysis in

[64] The authors further argue this regime is not fully passive, rather leading firms use innovation to realize a strategic advantage.

Hamano and Zanetti (2022) indicates monetary policy tightening both reduces firm entry and increases firm exit. Due to low rates of market entry, the short-term impact on productivity is negative – incumbent firms are insulated from competition and increase their markups. These dynamics seems simple to replicate and could explain market hysteresis following shocks. If the change is markups is asymmetric across firms, this channel could further reduce the allocative efficiency of the economy. This is left for a future extension, but one that appears straightforward to implement.

6 Conclusion

This paper embeds an industry structure featuring strategic interaction between firms within a standard New Keynesian framework. It aligns with three key empirical findings: first, industry leaders usually control a significant share of the market; second, they charge higher markups; and third, firm size affects pricing behavior. It shows the degree of industry concentration in an economy can affect the slope of the Phillips curve. It also adds the caveat that differences in price adjustment costs across firms may weaken this relationship. When looking at economic shocks, the framework demonstrates differences in pricing behavior have a significant effect on the allocation of demand and may explain why small firms appear more sensitive to the business cycle. Finally, the framework is used to evaluate whether aspects of large firm price setting behavior – in particular strategic complementarity – are economically relevant given an aggregate shock. Under specific circumstances, for example a widespread negative shock to small firms, such behavior may further aggravate existing market distortions and generate sizable efficiency losses.

References

Abbott, T. A. (1989). *Price Dispersion in U.S. Manufacturing* (Working Papers No. 89-7). Center for Economic Studies, U.S. Census Bureau. https://ideas.repec.org/p/cen/wpaper/89-7.html

Adjemian, S., Bastani, H., Juillard, M., Karamé, F., Maih, J., Mihoubi, F., Mutschler, W., Perendia, G., Pfeifer, J., Ratto, M., & Villemot, S. (2021). *Dynare: Reference manual version 4* (Dynare Working Papers No. 1). CEPREMAP. https://EconPapers.repec.org/RePEc:cpm:dynare:001

Affeldt, P., Duso, T., Gugler, K., & Piechucka, J. (2021). *Market Concentration in Europe: Evidence from Antitrust Markets* (Discussion Papers of DIW Berlin No. 1930). DIW Berlin, German Institute for Economic Research. https://ideas.repec.org/p/diw/diwwpp/dp1930.html

Affeldt, P., Duso, T., & Szücs, F. (2018). *EU Merger Control Database: 1990-2014* (tech. rep.). DIW Berlin, German Institute for Economic Research. https://ideas.repec.org/p/diw/diwddc/dd95.html

Álvarez, L. J., & Hernando, I. (2005). *The price setting behaviour of Spanish firms: evidence from survey data* (Working Papers No. 0537). Banco de España. https://ideas.repec.org/p/bde/wpaper/0537.html

Amirault, D., Kwan, C., & Wilkinson, G. (2006). *Survey of Price-Setting Behaviour of Canadian Companies* (Staff Working Papers No. 06-35). Bank of Canada. https://ideas.repec.org/p/bca/bocawp/06-35.html

Amiti, M., Itskhoki, O., & Konings, J. (2019). International Shocks, Variable Markups, and Domestic Prices. *The Review of Economic Studies*, *86*(6), 2356–2402. https://doi.org/10.1093/restud/rdz005

Atkeson, A., & Burstein, A. (2008). Pricing-to-Market, Trade Costs, and International Relative Prices. *American Economic Review*, *98*(5), 1998–2031. https://doi.org/10.1257/aer.98.5.1998

Auer, R. A., & Schoenle, R. S. (2016). Market structure and exchange rate pass-through. *Journal of International Economics*, *98*, 60–77. https://doi.org/10.1016/j.jinteco.2015.10.003

Autor, D., Dorn, D., Katz, L. F., Patterson, C., & Van Reenen, J. (2020). The Fall of the Labor Share and the Rise of Superstar Firms. *The Quarterly Journal of Economics*, *135*(2), 645–709. https://doi.org/10.1093/qje/qjaa004

Autor, D., Patterson, C., & Van Reenen, J. (2023). *Local and National Concentration Trends in Jobs and Sales: The Role of Structural Transformation* (Working Paper No. 31130). National Bureau of Economic Research. https://doi.org/10.3386/w31130

Azar, J., Marinescu, I., & Steinbaum, M. (2022). Labor Market Concentration. *Journal of Human Resources*, *57*(S), S167–S199. https://doi.org/10.3368/jhr.monopsony.1218-9914R1

Babecký, J., Du Caju, P., Kosma, T., Lawless, M., Messina, J., & Room, T. (2009). *The margins of labour cost adjustment: survey evidence from European firms* (Working Paper Series No. 1106). European Central Bank. https://EconPapers.repec.org/RePEc:ecb:ecbwps:20091106

Bajgar, M., Berlingieri, G., Calligaris, S., Criscuolo, C., & Timmis, J. (2023). Industry Concentration in Europe and North America. *Industrial and Corporate Change*. https://doi.org/10.1093/icc/dtac059

Bao, R., De Loecker, J., & Eeckhout, J. (2022). *Are Managers Paid for Market Power?* (Working Paper No. 29918). National Bureau of Economic Research. https://doi.org/10.3386/w29918

Baqaee, D., & Farhi, E. (2019). Productivity and Misallocation in General Equilibrium. *The Quarterly Journal of Economics*, *135*(1), 105–163. https://doi.org/10.1093/qje/qjz030

Baqaee, D., Farhi, E., & Sangani, K. (2021). *The Supply-Side Effects of Monetary Policy* (Working Paper No. 28345). National Bureau of Economic Research. https://doi.org/10.3386/w28345

Barkai, S. (2020). Declining Labor and Capital Shares. *The Journal of Finance*, *75*(5), 2421–2463. https://doi.org/10.1111/jofi.12909

Basu, S. (1995). Intermediate goods and business cycles: Implications for productivity and welfare. *The American Economic Review*, *85*(3), 512–531. Retrieved September 21, 2023, from http://www.jstor.org/stable/2118185

Basu, S. (2019). Are Price-Cost Markups Rising in the United States? A Discussion of the Evidence. *Journal of Economic Perspectives*, *33*(3), 3–22. https://doi.org/10.1257/jep.33.3.3

Begenau, J., & Salomao, J. (2018). Firm Financing over the Business Cycle. *The Review of Financial Studies*, *32*(4), 1235–1274. https://doi.org/10.1093/rfs/hhy099

Bellucci, C., & Rungi, A. (2022). Supply Chains, Takeovers, and Market Power. https://www.aeaweb.org/conference/2023/program/paper/46DBDzR4

Benkard, C. L., Yurukoglu, A., & Zhang, A. L. (2021). *Concentration in Product Markets* (Working Paper No. 28745). National Bureau of Economic Research. https://doi.org/10.3386/w28745

Berman, N., Martin, P., & Mayer, T. (2012). How do different exporters react to exchange rate changes? *The Quarterly Journal of Economics*, *127*(1), 437–492. http://www.jstor.org/stable/41337214

Blonigen, B. A., & Pierce, J. R. (2016). *Evidence for the Effects of Mergers on Market Power and Efficiency* (Working Paper No. 22750). National Bureau of Economic Research. https://doi.org/10.3386/w22750

Böheim, R., Hackl, F., & Hölzl-Leitner, M. (2021). The impact of price adjustment costs on price dispersion in e-commerce. *International Journal of Industrial Organization*, *77*, 102743. https://doi.org/10.1016/j.ijindorg.2021.102743

Bruin, W. B. D., Dogra, K., Heise, S., Knotek, E. S., Meyer, B., Rich, R. W., Schoenle, R., Topa, G., & der Klaauw, W. V. (2023). *Estimates of Cost-Price Passthrough from Business Survey Data* (FRB Atlanta Working Paper No. 2023-5). Federal Reserve Bank of Atlanta. https://doi.org/10.29338/wp2023-05

Cavallo, A. (2017). Are Online and Offline Prices Similar? Evidence from Large Multi-channel Retailers. *American Economic Review*, *107*(1), 283–303. https://doi.org/10.1257/aer.20160542

Chatterjee, S., & Eyigungor, B. (2023). The Firm Size-Leverage Relationship and Its Implications for Entry and Business Concentration. *Review of Economic Dynamics*, *48*, 132–157. https://doi.org/10.1016/j.red.2022.04.002

Cheng, S. F., Vyas, D., Wittenberg Moerman, R., & Zhao, W. (2023). Exposure to Superstar Firms and Financial Distress. *Available at SSRN 4506218*. https://doi.org/10.2139/ssrn.4506218

Coibion, O., & Gorodnichenko, Y. (2012). Why Are Target Interest Rate Changes So Persistent? *American Economic Journal: Macroeconomics*, *4*(4), 126–62. https://doi.org/10.1257/mac.4.4.126

Coleman, A., & Silverstone, B. (2007). Price changes by firms in New Zealand - some evidence from the Quarterly Survey of Business Opinion. *Reserve Bank of New Zealand Bulletin*, *70*. https://ideas.repec.org/a/nzb/nzbbul/september20074.html

Cooper, M., McClelland, J., Pearce, J., Prisinzano, R., Sullivan, J., Yagan, D., Zidar, O., & Zwick, E. (2015). *Business in the United States: Who Owns it and How Much Tax Do They Pay?* (Working Paper No. 21651). National Bureau of Economic Research. https://doi.org/10.3386/w21651

Copaciu, M., Neagu, F., & Braun-Erdei, H. (2010). Survey evidence on price-setting patterns of romanian firms. *Managerial and Decision Economics*, *31*(2/3), 235–247. Retrieved September 29, 2023, from http://www.jstor.org/stable/40606991

Covarrubias, M., Gutiérrez, G., & Philippon, T. (2019). *From Good to Bad Concentration? U.S. Industries over the Past 30 Years* (Working Paper No. 25983). National Bureau of Economic Research. https://doi.org/10.3386/w25983

Crane, L. D., & Decker, R. A. (2019). *Business Dynamics in the National Establishment Time Series (NETS)/Leland Crane, Ryan Decker* (Finance and Economics Discussion Series No. 2019-034). Board of Governors of the Federal Reserve System (U.S.) https://doi.org/10.17016/FEDS.2019.034

Crouzet, N., & Eberly, J. C. (2019). *Understanding Weak Capital Investment: the Role of Market Concentration and Intangibles* (Working Paper No. 25869). National Bureau of Economic Research. https://doi.org/10.3386/w25869

Crouzet, N., & Mehrotra, N. R. (2020). Small and Large Firms over the Business Cycle. *American Economic Review*, *110*(11), 3549–3601. https://doi.org/10.1257/aer.20181499

Cunningham, C., Foster, L., Grim, C., Haltiwanger, J., Pabilonia, S. W., Stewart, J., & Wolf, Z. (2023). Dispersion in dispersion: Measuring establishment-level differences in productivity. *Review of Income and Wealth*. https://doi.org/10.1111/roiw.12616

Cunningham, C., Ederer, F., & Ma, S. (2021). Killer Acquisitions. *Journal of Political Economy*, *129*(3), 649–702. https://doi.org/10.1086/712506

De Loecker, J., Eeckhout, J., & Unger, G. (2020). The Rise of Market Power and the Macroeconomic Implications. *The Quarterly Journal of Economics*, *135*(2), 561–644. https://doi.org/10.1093/qje/qjz041

Decker, R. A., Haltiwanger, J., Jarmin, R. S., & Miranda, J. (2020). Changing business dynamism and productivity: Shocks versus responsiveness. *American Economic Review*, *110*(12), 3952–90. https://doi.org/10.1257/aer.20190680

Dedola, L., Kristoffersen, M. S., & Zullig, G. (2021). The extensive and intensive margin of price adjustment to cost shocks: Evidence from danish multiproduct firms. *Working Paper*. https://gabrielzuellig.ch/research/

DellaVigna, S., & Gentzkow, M. (2019). Uniform Pricing in U.S. Retail Chains. *The Quarterly Journal of Economics*, *134*(4), 2011–2084. https://doi.org/10.1093/qje/qjz019

Dinlersoz, E., Kalemli-Ozcan, S., Hyatt, H., & Penciakova, V. (2018). *Leverage over the life cycle and implications for firm growth and shock responsiveness* (Working Paper No. 25226). National Bureau of Economic Research. https://doi.org/10.3386/w25226

Döpper, H., MacKay, A., Miller, N., & Stiebale, J. (2022). Rising markups and the role of consumer preferences. *Harvard Business School Strategy Unit Working Paper*, (22-025).

Dornbusch, R. (1987). Exchange Rates and Prices. *The American Economic Review*, *77*(1), 93–106. Retrieved August 8, 2023, from http://www.jstor.org/stable/1806731

Durante, E., Ferrando, A., & Vermeulen, P. (2022). Monetary policy, investment and firm heterogeneity. *European Economic Review*, *148*, 104251. https://doi.org/10.1016/j.euroecorev.2022.104251

Eggertsson, G. B., & Woodford, M. (2003). The zero bound on interest rates and optimal monetary policy. *Brookings Papers on Economic Activity*, *2003*(1), 139–211. Retrieved September 28, 2023, from http://www.jstor.org/stable/1209148

Faccio, M., & McConnell, J. J. (2020). *Impediments to the Schumpeterian Process in the Replacement of Large Firms* (Working Paper No. 27871). National Bureau of Economic Research. https://doi.org/10.3386/w27871

Fort, T., Haltiwanger, J., Jarmin, R., & Miranda, J. (2013). How firms respond to business cycles: The role of firm age and firm size. *IMF Economic Review*, *61*(3), 520–559. Retrieved September 29, 2023, from http://www.jstor.org/stable/43297800

Galí, J. (2015). *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications Second edition*. Princeton University Press. https://ideas.repec.org/b/pup/pbooks/10495.html

Gertler, M., & Gilchrist, S. (1994). Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms. *The Quarterly Journal of Economics*, *109*(2), 309–340. https://doi.org/10.2307/2118465

Gibson, J., & Stillman, S. (2009). Why do big firms pay higher wages? evidence from an international database. *The Review of Economics and Statistics*, *91*(1), 213–218. Retrieved September 22, 2023, from http://www.jstor.org/stable/25651329

Goldberg, P. K., & Hellerstein, R. (2009). *How rigid are producer prices?* (Staff Reports No. 407). Federal Reserve Bank of New York. https://ideas.repec.org/p/fip/fednsr/407.html

Gopinath, G., & Itskhoki, O. (2010). Frequency of price adjustment and pass-through. *The Quarterly Journal of Economics*, *125*(2), 675–727. Retrieved September 29, 2023, from http://www.jstor.org/stable/27867493

Grullon, G., Larkin, Y., & Michaely, R. (2019). Are US Industries Becoming More Concentrated? *Review of Finance*, *23*(4), 697–743. https://doi.org/10.1093/rof/rfz007

Guimaraes, B., & Sheedy, K. D. (2011). Sales and monetary policy. *American Economic Review*, *101*(2), 844–76. https://doi.org/10.1257/aer.101.2.844

Hall, R. E. (2018). *New Evidence on the Markup of Prices over Marginal Costs and the Role of Mega-Firms in the US Economy* (Working Paper No. 24574). National Bureau of Economic Research. https://doi.org/10.3386/w24574

Hamano, M., & Zanetti, F. (2022). Monetary policy, firm heterogeneity, and product variety. *European Economic Review*, *144*, 104089. https://doi.org/10.1016/j.euroecorev.2022.104089

Hildenbrand, A. (2010). *Cournot or Stackelberg competition? A survey on experimental evidence* (MPRA Paper No. 24468). University Library of Munich, Germany. https://ideas.repec.org/p/pra/mprapa/24468.html

Hong, S. (2018). Price Markups for Small and Large Firms Over the Business Cycle. *Economic Synopses*, (17), 1–3. https://doi.org/10.20955/es.2018.17

Hopenhayn, H. (1992). Entry, exit, and firm dynamics in long run equilibrium. *Econometrica*, *60*(5), 1127–1150. Retrieved September 28, 2023, from http://www.jstor.org/stable/2951541

Hopenhayn, H., Neira, J., & Singhania, R. (2018). *From Population Growth to Firm Demographics: Implications for Concentration, Entrepreneurship and the Labor Share* (Working Paper No. 25382). National Bureau of Economic Research. https://doi.org/10.3386/w25382

Hottman, C. J., Redding, S. J., & Weinstein, D. E. (2016). Quantifying the Sources of Firm Heterogeneity. *The Quarterly Journal of Economics*, *131*(3), 1291–1364. https://doi.org/10.1093/qje/qjw012

Kaplan, G., & Menzio, G. (2015). The morphology of price dispersion. *International Economic Review*, *56*(4), 1165–1206. https://doi.org/10.1111/iere.12134

Karahan, F., Pugsley, B., & Şahin, A. (2019). *Demographic Origins of the Startup Deficit* (Working Paper No. 25874). National Bureau of Economic Research. https://doi.org/10.3386/w25874

Katz, M. L. (2019). Multisided platforms, big data, and a little antitrust policy. *Review of Industrial Organization*, *54*(4), pp. 695–716. Retrieved September 22, 2023, from https://www.jstor.org/stable/48702971

Kehoe, P., & Midrigan, V. (2015). Prices are sticky after all. *Journal of Monetary Economics*, *75*, 35–53. https://doi.org/10.1016/j.jmoneco.2014.12.004

Kimball, M. S. (1995). The Quantitative Analytics of the Basic Neomonetarist Model. *Journal of Money, Credit and Banking*, *27*(4), 1241–1277. Retrieved August 7, 2023, from http://www.jstor.org/stable/2078048

Klenow, P. J., & Kryvtsov, O. (2008). State-Dependent or Time-Dependent Pricing: Does it Matter for Recent U.S. Inflation? *The Quarterly Journal of Economics*, *123*(3), 863–904. https://doi.org/10.1162/qjec.2008.123.3.863

Klenow, P. J., & Malin, B. A. (2010). *Microeconomic Evidence on Price-Setting* (Working Paper No. 15826). National Bureau of Economic Research. https://doi.org/10.3386/w15826

Kroen, T., Liu, E., Mian, A. R., & Sufi, A. (2021). *Falling Rates and Rising Superstars* (Working Paper No. 29368). National Bureau of Economic Research. https://doi.org/10.3386/w29368

Kryvtsov, O., & Vincent, N. (2021). The Cyclicality of Sales and Aggregate Price Flexibility. *Review of Economic Studies*, *88*(1), 334–377. https://ideas.repec.org/a/oup/restud/v88y2021i1p334-377..html

Kudlyak, M., & Sánchez, J. M. (2017). Revisiting the behavior of small and large firms during the 2008 financial crisis. *Journal of Economic Dynamics and Control*, *77*, 48–69. https://doi.org/10.1016/j.jedc.2017.01.017

Kwon, S. Y., Ma, Y., & Zimmermann, K. (2023). 100 Years of Rising Corporate Concentration. *SAFE Working Paper*, (359). https://doi.org/10.2139/ssrn.3936799

Levy, D., Dutta, S., Bergen, M., & Venable, R. (1998). Price adjustment at multiproduct retailers. *Managerial and Decision Economics*, *19*(2), 81–120. Retrieved September 22, 2023, from http://www.jstor.org/stable/3108151

Liu, E., Mian, A., & Sufi, A. (2019). *Low Interest Rates, Market Power, and Productivity Growth* (Working Paper No. 25505). National Bureau of Economic Research. https://doi.org/10.3386/w25505

Lombardi, M. J., Riggi, M., & Viviano, E. (2023). Workers' Bargaining Power and the Phillips Curve: A Micro–Macro Analysis. *Journal of the European Economic Association*, jvad016. https://doi.org/10.1093/jeea/jvad016

Markham, J. W. (1951). The Nature and Significance of Price Leadership. *The American Economic Review*, *41*(5), 891–905. Retrieved August 2, 2023, from http://www.jstor.org/stable/1809090

Marques, C. R., Martins, F., Dias, D., & Silva, J. (2011). *Why Are Some Prices Stickier Than Others? Firm-Data Evidence on Price Adjustment Lags* (Working Papers w201107). Banco de Portugal, Economics and Research Department. https://ideas.repec.org/p/ptu/wpaper/w201107.html

Meier, M., & Reinelt, T. (2022). Monetary Policy, Markup Dispersion, and Aggregate TFP. *The Review of Economics and Statistics*, 1–45. https://doi.org/10.1162/rest_a_01226

Mertens, M., & Mottironi, B. (2023). *Do larger firms have higher markups?* (IWH-CompNet Discussion Papers No. 1/2023). Halle Institute for Economic Research (IWH). https://ideas.repec.org/p/zbw/iwhcom/12023.html

Miklian, J., & Hoelscher, K. (2022). Smes and exogenous shocks: A conceptual literature review and forward research agenda. *International Small Business Journal*, *40*(2), 178–204. https://doi.org/10.1177/02662426211050796

Minner, S. (2003). Multiple-supplier inventory models in supply chain management: A review [Proceedings of the Eleventh International Symposium on Inventories]. *International Journal of Production Economics*, *81-82*, 265–279. https://doi.org/10.1016/S0925-5273(02)00288-8

Mongey, S. (2017). *Market Structure and Monetary Non-neutrality* (Staff Report No. 558). Federal Reserve Bank of Minneapolis. https://doi.org/10.21034/sr.558

Nakamura, E. (2008). *Pass-Through in Retail and Wholesale* (Working Paper No. 13965). National Bureau of Economic Research. https://doi.org/10.3386/w13965

Nakamura, E., & Steinsson, J. (2010). Monetary Non-neutrality in a Multisector Menu Cost Model. *The Quarterly Journal of Economics*, *125*(3), 961–1013. https://doi.org/10.1162/qjec.2010.125.3.961

OECD. (2022). *The Evolving Concept of Market Power in the Digital Economy* (Competition Policy Roundtable Background Note). OECD. www.oecd.org/daf/competition/the-evolving-concept-ofmarket-power-in-the-digital-economy-2022.pdf

Oh, J. (2020). The Propagartion of Uncertainty Shocks: Rotemberg Versus Calvo. *International Economic Review*, *61*(3), 1097–1113. https://doi.org/10.1111/iere.12450

Olmstead-Rumsey, J. (2019). *Market Concentration and the Productivity Slowdown* (MPRA Paper No. 93260). University Library of Munich, Germany. https://ideas.repec.org/p/pra/mprapa/93260.html

Ottonello, P., & Winberry, T. (2020). Financial Heterogeneity and the Investment Channel of Monetary Policy. *Econometrica*, *88*(6), 2473–2502. https://doi.org/10.3982/ECTA15949

Pancrazi, R., & Vukotić, M. (2013). *Technology persistence and monetary policy* (Working Paper). Coventry, UK, University of Warwick, Department of Economics. https://wrap.warwick.ac.uk/56596/

Pennerstorfer, D., Schmidt-Dengler, P., Schutz, N., Weiss, C., & Yontcheva, B. (2020). Information and price dispersion: Theory and evidence. *International Economic Review*, *61*(2), 871–899. https://doi.org/10.1111/iere.12443

Pérez-Orive, A., & Timmer, Y. (2023). *Distressed Firms and the Large Effects of Monetary Policy Tightenings* (FEDS Notes No. 2023-06-23-1). Board of Governors of the Federal Reserve System (U.S.) https://doi.org/10.17016/2380-7172.3279

Peters, M. (2020). Heterogeneous markups, growth, and endogenous misallocation. *Econometrica*, *88*(5), 2037–2073. https://doi.org/10.3982/ECTA15565

Raval, D. (2023). Testing the Production Approach to Markup Estimation. *The Review of Economic Studies*, rdad002. https://doi.org/10.1093/restud/rdad002

Richter, A. W., & Throckmorton, N. A. (2016). Is Rotemberg pricing justified by macro data? *Economics Letters*, *149*, 44–48. https://doi.org/10.1016/j.econlet.2016.10.011

Ridder, M. D., Grassi, B., & Morzenti, G. (2021). *The Hitchhiker's Guide to Markup Estimation* (Working Papers No. 677). IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University. https://ideas.repec.org/p/igi/igierp/677.html

Rossi-Hansberg, E., Sarte, P.-D., & Trachter, N. (2018). *Diverging Trends in National and Local Concentration* (Working Paper No. 25066). National Bureau of Economic Research. https://doi.org/10.3386/w25066

Rotemberg, J. J. (1982). Sticky Prices in the United States. *Journal of Political Economy*, *90*(6), 1187–1211. Retrieved August 27, 2023, from http://www.jstor.org/stable/1830944

Rysman, M. (2009). The economics of two-sided markets. *Journal of Economic Perspectives*, *23*(3), 125–43. https://doi.org/10.1257/jep.23.3.125

Sheremirov, V. (2020). Price dispersion and inflation: New facts and theoretical implications. *Journal of Monetary Economics*, *114*, 59–70. https://doi.org/10.1016/j.jmoneco.2019.03.007

Shimomura, K.-I., & Thisse, J.-F. (2012). Competition among the big and the small. *The RAND Journal of Economics*, *43*(2), 329–347. https://doi.org/10.1111/j.1756-2171.2012.00168.x

Smith, D. A., & Ocampo, S. (2022). *The Evolution of U.S. Retail Concentration* (Working Papers No. 22-07). Center for Economic Studies, U.S. Census Bureau. https://ideas.repec.org/p/cen/wpaper/22-07.html

Stiebale, J., & Szücs, F. (2022). Mergers and market power: evidence from rivals' responses in European markets. *The RAND Journal of Economics*, *53*(4), 678–702. https://doi.org/10.1111/1756-2171.12427

Stokman, A., & Hoeberichts, M. (2006). *Price setting behaviour in the Netherlands: results of a survey* (Working Paper Series No. 607). European Central Bank. https://ideas.repec.org/p/ecb/ecbwps/2006607.html

Tambe, P., Hitt, L., Rock, D., & Brynjolfsson, E. (2020). *Digital Capital and Superstar Firms* (Working Paper No. 28285). National Bureau of Economic Research. https://doi.org/10.3386/w28285

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, *39*, 195–214. https://doi.org/10.1016/0167-2231(93)90009-L

Tetlow, R. J. (2022). *How Large is the Output Cost of Disinflation?* (Finance and Economics Discussion Series No. 2022-079). Board of Governors of the Federal Reserve System (U.S.) https://doi.org/10.17016/FEDS.2022.079

Traina, J. (2018). *Is Aggregate Market Power Increasing? Production Trends Using Financial Statements* (Working Papers No. 272). The University of Chicago Booth School of Business, George J. Stigler Center for the Study of the Economy and the State. https://ideas.repec.org/p/zbw/cbscwp/272.html

Ueda, K. (2023). Duopolistic Competition and Monetary Policy. *Journal of Monetary Economics*, *135*, 70–85. https://doi.org/10.1016/j.jmoneco.2023.01.003

Wang, O., & Werning, I. (2022). Dynamic Oligopoly and Price Stickiness. *American Economic Review*, *112*(8), 2815–49. https://doi.org/10.1257/aer.20201739

Weber, I., & Wasner, E. (2023). Sellers' Inflation, Profits and Conflict: Why Can Large Firms Hike Prices in an Emergency? *Review of Keynesian Economics*, *11*, 183–213. https://doi.org/10.4337/roke.2023.02.05

Zetlin-Jones, A., & Shourideh, A. (2017). External financing and the role of financial frictions over the business cycle: Measurement and theory. *Journal of Monetary Economics*, *92*, 1–15. https://doi.org/10.1016/j.jmoneco.2017.08.001

Zingales, L. (2017). Towards a Political Theory of the Firm. *Journal of Economic Perspectives*, *31*(3), 113–30. https://doi.org/10.1257/jep.31.3.113

A Appendix

A.1 The Evolution of Accounting Profits by Form of Incorporation

The headline profits of US corporations have risen over the past 40 years, but there are several caveats. The separation of wages and profits typical for C-corporations is less well defined for other forms of incorporation. Most growth in registered businesses has been from partnerships and S-corporations.[65] With both, profits are 'passed through' directly to owners, who report the income on their individual tax returns. This blurs the normal separation of wages and profits. For pass-through business owners, there is no large tax advantage to reporting either form of income, at least for upper tax brackets.[66] In addition, many partnerships and S-corporations are set up as investment vehicles. Returns on other investments are reported as 'profits' and applicable taxes are paid accordingly. Therefore, headline profits should be adjusted for both officer compensation and portfolio income to ensure they are measured consistently over time.

Officer compensation (i.e. payments to owner employees) is large relative to net income in the corporate sector. For S-corporations, officer compensation averaged 70 percent of net income 1992-2016 while it was around 40 percent of net income for C-corporations. Notably, this ratio declined over time for both S- and C-corporations due to stricter enforcement of 'reasonable pay' clauses. A decline in the effective tax rate on corporate profits probably motivated this shift as well. While payments to owner-employees for their labor cannot be easily distinguished from profits, it is possible to add officer compensation and profits together as an alternative measure. This leads to a 50 percent upward revision for overall business profitability in the 1980s. Business activity was dominated by C-corporations during this period and officer compensation was relatively high. The same adjustment increases profitability by only 20 percent in the 2010s. As mentioned, a second source of bias comes from the inclusion of portfolio income in the net income of S-corporations and partnerships. Many are set up purely as investment vehicles and the share of portfolio income in net income has grown over time. This leads to a potential double-counting problem for profits. To mitigate this, a second adjustment takes only business (or 'ordinary') income earned by S-corporations and partnerships into account.

For internal consistency, the results for Table 4 are given in terms of net receipts rather than GDP. The growth in total net income (before adjustment) between 1981-89 and 2010-16 is equal to 7 percentage points of GDP − a significant increase. Including officer compensation lowers this slightly to 6 percentage points of GDP. Further excluding portfolio income reduces the change to 4 percentage points of GDP. By this meaasure, profits went from around 11 percent of GDP in the 1980s to 15 percent in the 2010s.[67] A shift-share decomposition indicates the majority of the change in overall profitability is explained by S-corporations and partnerships. The decomposition takes the following form

$$\Delta X_{it} = \underbrace{\sum_i (\Delta X_{ijt})\omega_{it-1}}_{within} + \underbrace{\sum_i (\Delta \omega_{it}) X_{it-1}}_{between} + \underbrace{\sum_i (\Delta X_{it})(\Delta \omega_{it})}_{dynamic\, reallocation}$$

[65]These tend to be smaller businesses, or at least closely held. The growth of pass-through entities is also consistent with growing service consumption since firms in the service sector tend to be smaller than in manufacturing.

[66]Cooper et al. (2015) finds that the effective tax rate on partnerships and S-corporations is lower than C-corporations, which may explain their rapid growth.

[67]As a rule of thumb, net receipts are around 2.2x GDP. CBO data for households indicate a corresponding increase around 4.8 percentage points for business income (including dividends) over the same period. Gross net income for the pass-through sector is larger in the IRS data than what CBO reports as household business income (e.g. $1.64 trillion compared to $1.01 trillion in 2016). There are several explanations for the discrepancy. First, there is a well-known mismatch between personal tax records and business income. Second, some share of net income reported to the IRS may go towards net lending by firms. Finally, some share of profits may go to foreign nationals.

where X is total income over a time period, subdivided by type of entity i weighted by their share of total receipts ω_i. The decomposition accounts for changes 'within' a category, holding weights constant. Notably, the within component is positive across all types of incorporation. The 'between' component describes the change in weights, which is negative for C-corporations and sole proprietorships. While large public companies are more profitable than in the past, they explain a smaller share of total activity. This is relevant to the debate on superstar firms and markups. Most of the overall increase in profitability is explained by S-corporation and partnerships. Because ownership is concentrated (with 2-3 owners for the median S-corporation) and potentially less diversified, investors may demand higher returns to offset higher idiosyncratic risk.

Table 4: Corporate Profitability by Business Type, Period Averages

(a) Share of Total Receipts

	1981-89	1990-99	2000-9	2010-16
C-corporation	0.833	0.742	0.665	0.625
S-corporation	0.068	0.149	0.175	0.192
Partnership	0.041	0.058	0.119	0.146
Sole proprietorship	0.058	0.051	0.041	0.038

(b) Net Income to Receipts

	1981-89	1990-99	2000-9	2010-16
Total	0.035	0.051	0.056	0.069
C-corporation	0.027	0.036	0.035	0.046
S-corporation	0.021	0.042	0.056	0.064
Partnership[a]	0.059	0.114	0.119	0.134
Sole proprietorship	0.152	0.209	0.213	0.228

(c) Shift-Share Decomposition

Δ Within	Between	Dynamic	Total
0.026	0.000	0.008	0.034
0.016	-0.006	-0.004	0.006
0.003	0.003	0.005	0.011
0.003	0.006	0.008	0.017
0.004	-0.003	-0.002	0.000

(d) Net Income and Officer Compensation to Receipts

	1981-89	1990-99	2000-9	2010-16
Total	0.053	0.068	0.072	0.082
C-corporation	0.046	0.053	0.048	0.056
S-corporation	0.039	0.078	0.094	0.101
Partnership[a]	0.059	0.114	0.119	0.134
Sole proprietorship	0.152	0.209	0.213	0.228

(e) Shift-Share Decomposition

Δ Within	Between	Dynamic	Total
0.020	-0.002	0.012	0.029
0.008	-0.010	-0.002	-0.004
0.004	0.005	0.008	0.017
0.003	0.006	0.008	0.017
0.004	-0.003	-0.002	0.000

(f) Net Ordinary Income and Officer Compensation to Receipts

	1981-89	1990-99	2000-9	2010-16
Total	0.051	0.064	0.062	0.071
C-corporation	0.046	0.053	0.048	0.056
S-corporation	0.035	0.069	0.083	0.095
Partnership[a]	0.031	0.069	0.058	0.067
Sole proprietorship	0.152	0.209	0.213	0.228

(g) Shift-Share Decomposition

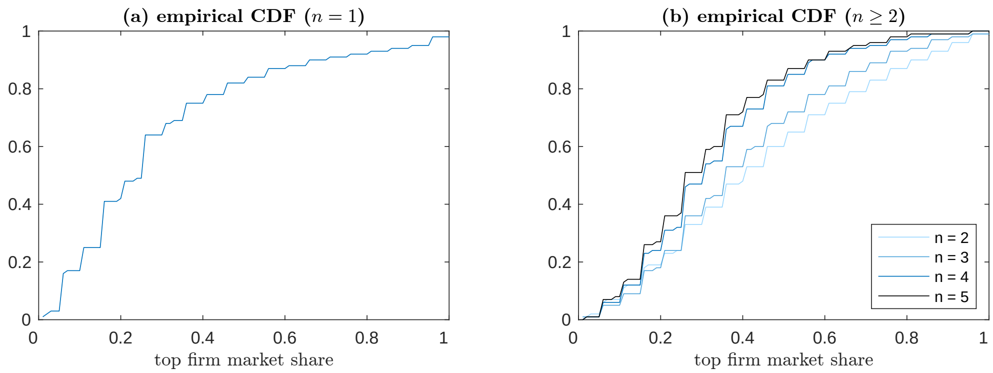
Δ Within	Between	Dynamic	Total
0.018	-0.005	0.008	0.020
0.008	-0.010	-0.002	-0.004
0.004	0.004	0.007	0.016
0.001	0.003	0.004	0.009
0.004	-0.003	-0.002	0.000

Notes: The shift-share decomposition compares the periods 1981-9 and 2010-16. The needed series are not available for 1980. All tabulations are in terms of net receipts. Net receipts are roughly 2.2x GDP on average, although is varies over time.
[a]Partnerships exclude capital gains and real estate and rental income from net income for all years.
Source: IRS Statistics of Income.

A.2 Evidence from Antitrust Markets

Figure 10 shows the CDF of market share reported in Affeldt et al. (2018). The left-hand panel shows the CDF for observations where only the market share of the post-merger entity is reported. The right-hand panel shows the CDF of the top market share when observations include competing firms. Each line is based on the number of competitors. The results suggest there is a strong correlation between the number of firms reported and the market share of the leading firm. This might be a feature of the data or a sign of upward bias when reporting is incomplete.

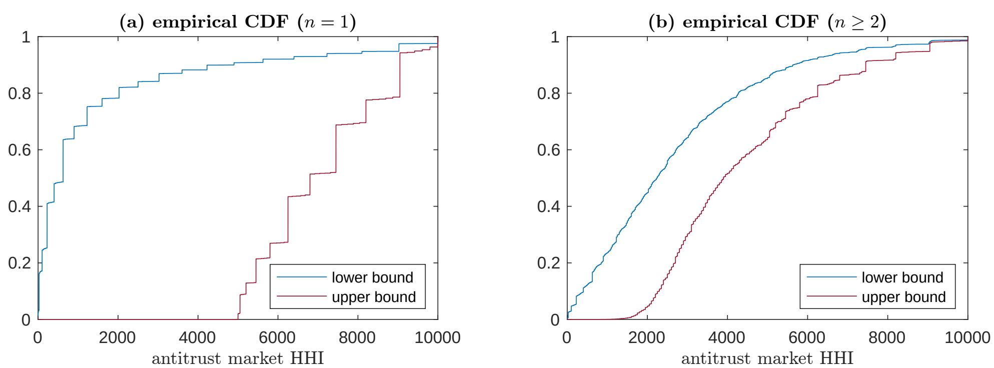
Figure 10: Cumulative Distribution of Top Market Shares across Antitrust Markets



Source: Affeldt et al. (2018)

Affeldt et al. calculate HHIs for each market.[68] The lower bound HHI is calculated in the normal way, except all unattributed market share is treated as a zero – equivalent to perfect competition between firms. The upper bound for the post-merger HHI adds the square of the residual market share. In other words, the residual market share is treated as one missing competitor. The corresponding CDFs are given in figure 11.

Figure 11: Distribution of HHIs across Antitrust Markets



Source: Affeldt et al. (2018)

Looking at the difference between the lower and upper bound in the left-hand panel of figure 11, most market share is treated as a residual and the resulting gap is large. The lower bound estimate in the right-hand panel is more interesting. It suggest the HHI is above 2000 in the median antitrust market, at least when market share was evaluated as part of the merger review.[69] This threshold is significant since the

[68]The calculation uses the post-merger market share if applicable and the market shares of competing firms.

[69]While it is likely more detailed information was collected on markets that are concentrated, the majority of cases (51 percent) include information on competitors. For cases where information on competitors is omitted, the post-merger entity is only marginally smaller than cases including such information: 30 versus 34 percent.

EU guidelines on horizontal mergers flag potential competition concerns for higher levels of concentration. Furthermore, almost one-quarter of market are assessed to have an HHI of 3000 or higher. As with Benkard et al. (2021), this suggests the prevailing level of concentration in most markets is higher than commonly appreciated.

Table 5: Descriptive Statistics for Antitrust Markets by Number of Firms ($n \geq 2$)

		Top Firm Market Share		
# Firms	Count	Mean	Median	Std. Dev.
2	1940	52.8	55.0	22.3
3	2523	46.0	45.0	18.8
4	2766	38.2	35.0	16.4
5	1411	36.1	35.0	15.7
> 5	1288	33.5	30.0	14.9
Total	**9928**	**42.1**	**40.0**	**19.3**

		Avg. Share of Trailing Firms		
# Firms	Count	Mean	Median	Std. Dev.
2	1940	22.1	20.0	12.4
3	2523	17.5	17.5	7.0
4	2766	13.8	15.0	4.7
5	1411	11.8	12.5	3.7
> 5	1288	9.0	9.0	3.0
Total	**9928**	**15.5**	**15.0**	**8.3**

		Share of Leader vs. Follower		
# Firms	Count	Mean	Median	Std. Dev.
2	1441	2.17	1.75	1.24
3	2172	1.97	1.57	1.11
4	2400	1.78	1.50	0.88
5	1228	1.80	1.50	0.89
> 5	1075	1.73	1.50	0.81
Total	**8316**	**1.90**	**1.59**	**1.02**

		Residual Market Share		
# Firms	Count	Mean	Median	Std. Dev.
2	1940	25.4	20.0	24.9
3	2523	19.8	15.0	20.2
4	2766	21.1	19.0	19.6
5	1411	17.7	15.0	18.2
> 5	1288	16.2	10.0	17.2
Total	**9928**	**20.5**	**15.0**	**20.6**

Source: Affeldt et al. (2018).

Table 5 provides a set of descriptive statistics from Affeldt et al. (2018), tabulated by the number of firms within an observation (including the post-merger entity). Outcomes of interest include the top firm's market share, the average market share of trailing firms, the ratio of market shares for the leader and top trailing firm, and the market share not attributed to any firm. The ratio of the leader and top follower is restricted to observations where both have a market share greater than 10 percent.

A.3 Nested CES Demand

A.3.1 Solving the Flexible Price Equilibrium

The method of undetermined coefficients is solved around the point where all firms are identical. As figure 12 makes clear, it is only locally accurate around p^*. Since small firms set prices monopolistically, the curvature is minimal and the method of undetermined coefficients works well. This is less the case for large firms, since the pricing behavior is non-linear. A higher-order Taylor approximation is not straightforward to implement when incorporating the best reply of rival firms. One option is that firms may solve for their own price using a second-order approximation while using a first-order approximation for rival prices.

Figure 12: Comparison of Solution Methods in the Flexible Price Equilibrium

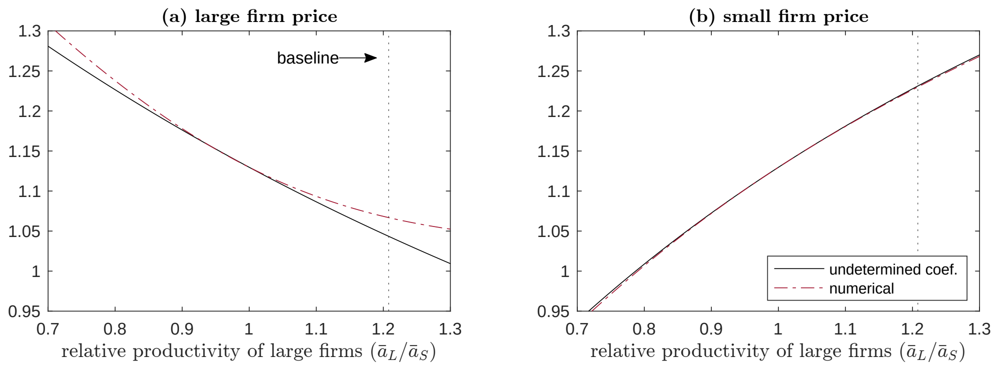


Table 6 gives the pricing rules when firms are identical. The Ω's are the same as in expression 47. The Υ's collect the coefficients for the firm's own marginal cost (Υ') and the marginal cost of its rival (Υ'').

Table 6: Estimated Decision Rules at p^*

	Ω'	Ω^*	Υ'	Υ''
Large firms	-0.116	0.116	0.897	0.103
Small firms	-0.0213	0.0213	0.979	0.021

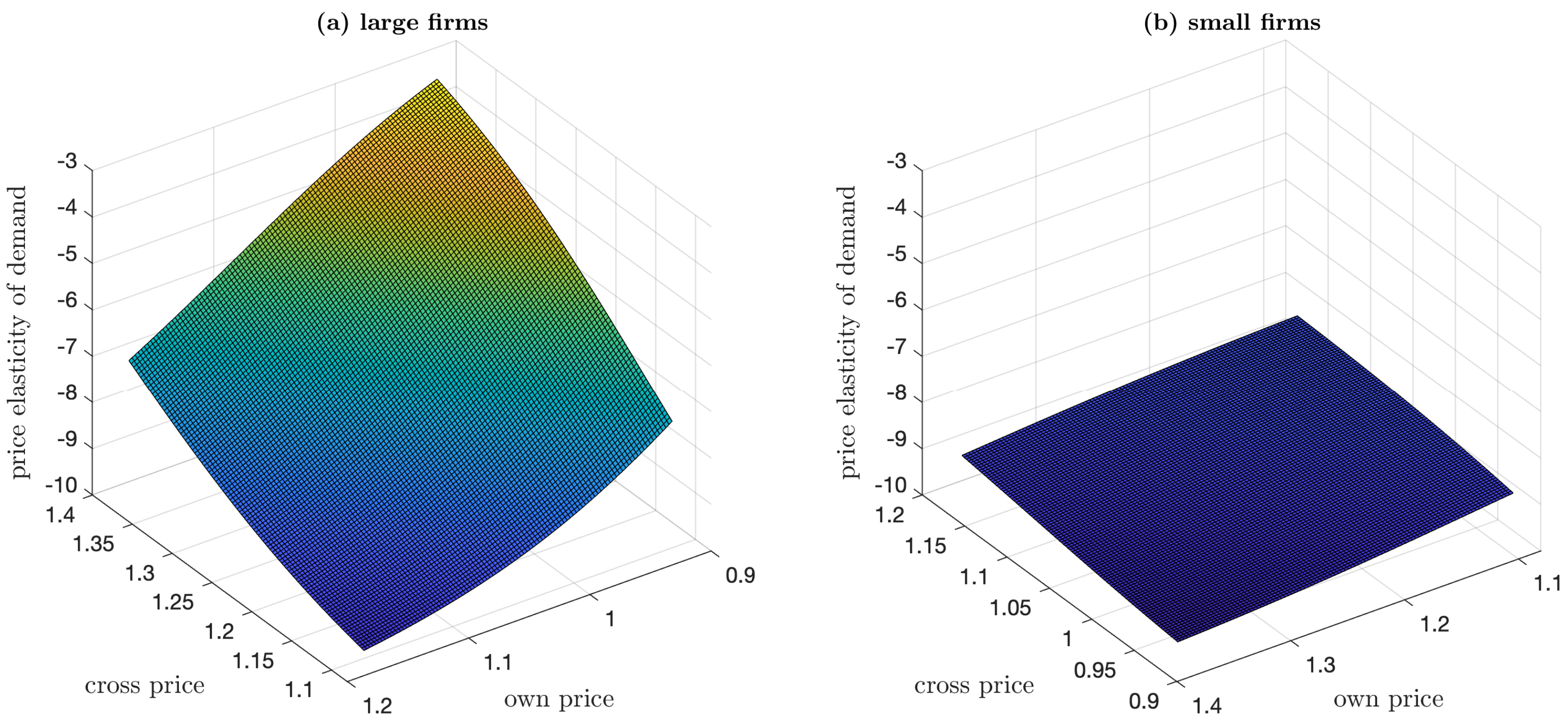
The difference between large and small firms in terms of pricing behavior is already apparent. Large firms put most weight on their own marginal costs, but also consider the marginal costs of their rivals to some degree. Meanwhile, small firms do not consider the costs of rival firms. With asymmetry between firms, the decision rule becomes

Table 7: Estimated Decision Rules for Baseline Productivity Gap

	Ω'	Ω^*	Υ'	Υ''
Large firms	-0.323	0.280	0.735	0.206
Small firms	-0.034	0.039	0.968	0.038

Here, the strength of strategic complementarity becomes more evident. The weight of rival marginal costs in the decision rule of large firms grows (see the values for Υ' and Υ'' in table 8). Figure 13 shows how the price elasticity of demand changes over different relative prices

Figure 13: The Price Elasticity of Demand Across Relative Prices



Each surface displays the price elasticity of demand for large and small firms across price combinations. Demand depends both on the firm's price and that of differently-sized rivals. The center of each surface is the steady state price elasticity of demand. In the case of large firms, this value is highly sensitive to changes in own- or cross-prices. An increase in the firm's own price lowers demand, as does a decrease in rival prices. The surface is flat for small firms, meaning they are not sensitive own- or cross-price effects.

A.3.2 Solving the Dynamic Problem

With Rotemberg adjustment costs, the profit maximization problem becomes

$$\mathbb{E}_t \sum_{k=0}^{\infty} \Lambda_{t+k} \left[\left(p_{sjt+k} - \boldsymbol{\mathcal{C}}_{sjt+k}\right) y_{sjt+k} - \frac{\Theta_s}{2} \left(\pi_{t+k} \frac{p_{sjt+k}}{p_{sjt+k-1}} - 1 \right)^2 P_{t+k} Y_{t+k} \right] \tag{82}$$

The FOC with respect to p_{sjt} gives

$$\begin{aligned} 0 &= p_{sjt} y_{sjt} \left[1 + \Psi^i_{st} \left(1 - \frac{\boldsymbol{\mathcal{C}}_{sjt}}{p_{sjt}} \right) \right] - \Theta_s \left(\pi_t \frac{p_{sjt}}{p_{sjt-1}} - 1 \right) \pi_t \frac{p_{sjt}}{p_{sjt-1}} Y_t \ldots \\ &+ \beta \Theta_s \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \left(\pi_{t+1} \frac{p_{sjt+1}}{p_{sjt}} - 1 \right) \pi_{t+1} \frac{p_{sjt+1}}{p_{sjt}} Y_{t+1} \right] \end{aligned} \tag{83}$$

The solutions for identical and asymmetric firms follow. In both cases, any unnecessary index is dropped from the notation.

A.3.2.1 Identical Firms

Using expression 16 and noting that

$$p_{jt} = n^{\frac{1}{1-\varphi}} p_{sjt} \tag{84}$$

where the solution for p_{sjt} is given by expression 41. The FOC of the pricing equation (49) becomes

$$0 = p_{st}^{1-\varphi} p_{jt}^{\varphi-\sigma} Y_t \left[1 + \left(\frac{\varphi - \sigma}{n} - \varphi \right) \left(1 - \frac{\boldsymbol{\mathcal{C}}_{st}}{p_{st}} \right) \right] - \frac{\Theta}{n} \left(\pi_t \frac{p_{st}}{p_{st-1}} - 1 \right) \pi_t \frac{p_{st}}{p_{st-1}} Y_t \ldots \tag{85}$$

$$\begin{aligned} &+ \beta \Theta_s \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \left(\pi_{t+1} \frac{p_{st+1}}{p_{st}} - 1 \right) \pi_{t+1} \frac{p_{st+1}}{p_{st}} Y_{t+1} \right] \\ &= n^{\frac{\varphi-\sigma}{1-\varphi}} p_s^{1-\sigma} \left[1 + \left(\frac{\varphi - \sigma}{n} - \varphi \right) \left(1 - \frac{\boldsymbol{\mathcal{C}}_{st}}{p_{st}} \right) \right] - \frac{\Theta}{n} \left(\pi_t - 1 \right) \pi_t + \frac{\beta \Theta}{n} \mathbb{E}_t \left[\Lambda_{t+1} \left(\pi_{t+1} - 1 \right) \pi_{t+1} \right] \end{aligned} \tag{86}$$

given $C_t = Y_t$. Log-linearizing the pricing equation

$$0 = n^{\frac{\varphi-\sigma}{1-\varphi}} p_s^{1-\sigma} \left(\varphi - \frac{\varphi - \sigma}{n} \right) \frac{\boldsymbol{\mathcal{C}}_s}{p_s} \widetilde{\boldsymbol{\mathcal{C}}}_{st} - \frac{\Theta}{n} \tilde{\pi}_t + \frac{\beta \Theta}{n} \tilde{\pi}_{t+1} \quad \text{where} \quad p_s = \frac{(n-1)\varphi + \sigma}{(n-1)\varphi + \sigma - n} \boldsymbol{\mathcal{C}}_s \tag{87}$$

Monopolistic competition is a special case of nested CES demand where $n = 1$. The elasticity of inflation to the monetary shock is

$$\Gamma^y = \frac{\Theta(1 - \rho_m \beta)/n}{n^{\frac{\varphi-\sigma}{1-\varphi}} p_s^{1-\sigma} \left(\varphi - (\varphi - \sigma)/n \right) \boldsymbol{\mathcal{C}}_s / p_s} \Gamma^\pi \tag{88}$$

where expression 71 gives the second equation. The elasticity of inflation to the productivity shock is similarly

$$\Omega^y = \frac{\Theta(1 - \rho_m \beta)/n}{n^{\frac{\varphi-\sigma}{1-\varphi}} p_s^{1-\sigma} \left(\varphi - (\varphi - \sigma)/n \right) \boldsymbol{\mathcal{C}}_s / p_s} \Omega^\pi + 1 \tag{89}$$

where expression 78 gives the second equation.

A.3.2.2 Asymmetric Firms

The FOC with respect to p^i_{st} gives

$$0 = p^i_{st} y^i_{st} \left[1 + \left((\varphi - \sigma) \left(\frac{p^i_{st}}{p_{jt}} \right)^{1-\varphi} - \varphi \right) \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_{st}}{p^i_{st}} \right) \right] \ldots$$
$$- \Theta_s \left(\pi_t \frac{p^i_{st}}{p^i_{st-1}} - 1 \right) \pi_t \frac{p^i_{st}}{p^i_{st-1}} Y_t + \beta \Theta_s \mathbb{E}_t \left[\frac{C_t}{C_{t+1}} \left(\pi_{t+1} \frac{p^i_{st+1}}{p^i_{st}} - 1 \right) \pi_{t+1} \frac{p^i_{st+1}}{p^i_{st}} Y_{t+1} \right] \tag{90}$$

Using expression 16 and dividing through by Y_t this becomes

$$0 = (p^i_{st})^{1-\varphi} p^{\varphi-\sigma}_{jt} \left[1 + \Psi^i_{st} \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_{st}}{p^i_{st}} \right) \right] - \Theta_s \left(\pi_t \frac{p^i_{st}}{p^i_{st-1}} - 1 \right) \pi_t \frac{p^i_{st}}{p^i_{st-1}} \ldots$$
$$+ \beta \Theta_s \mathbb{E}_t \left[\left(\pi_{t+1} \frac{p^i_{st+1}}{p^i_{st}} - 1 \right) \pi_{t+1} \frac{p^i_{st+1}}{p^i_{st}} \right] \tag{91}$$

Log-linearizing and taking a first-order Taylor expansion, noting that $\tilde{p}^i_{st} = \tilde{p}^{\text{-}i}_{st}$

$$0 = (1-\varphi)(p^i_s)^{-\varphi} p^{\varphi-\sigma}_j \left[1 + \Psi^i_s \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_s}{p^i_s} \right) \right] \tilde{p}^i_s \ldots$$
$$+ (\varphi - \sigma)(p^i_s)^{1-\varphi} p^{2\varphi-\sigma-1}_j \left[1 + \Psi^i_s \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_s}{p^i_s} \right) \right] \left[n_s (p^i_s)^{-\varphi} \tilde{p}^i_{st} + n_{\text{-}s} (p^{\text{-}i}_{\text{-}s})^{-\varphi} \tilde{p}^{\text{-}i}_{\text{-}st} \right] \ldots$$
$$+ (p^i_s)^{1-\varphi} p^{\varphi-\sigma}_j \left[\left(1 - \frac{\boldsymbol{\mathcal{C}}^i_j}{p^i_s} \right) \left[\frac{\Psi^{i,i}_s + \Psi'^{\,i,\text{-}i}_s}{p^i_s} \tilde{p}^i_{st} + \frac{\Psi''^{\,i,\text{-}i}_s}{p^{\text{-}i}_{\text{-}s}} \tilde{p}^{\text{-}i}_{\text{-}st} \right] - \Psi^i_s \frac{\boldsymbol{\mathcal{C}}^i_j}{p^i_s} (\widetilde{\boldsymbol{\mathcal{C}}}^i_{st} - \tilde{p}^i_{st}) \right] \ldots$$
$$- \Theta_s (\tilde{\pi}^i_t + \tilde{p}^i_{st} - \tilde{p}^i_{st-1}) + \beta \Theta_s \mathbb{E}_t \left[\tilde{\pi}^i_{t+1} + \tilde{p}^i_{st+1} - \tilde{p}^i_{st} \right] \tag{92}$$

In the steady state

$$\Psi^i_s = - \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_s}{p^i_s} \right)^{-1} \quad \Longrightarrow \quad 1 + \Psi^i_s \left(1 - \frac{\boldsymbol{\mathcal{C}}^i_s}{p^i_s} \right) = 0 \tag{93}$$

so the first part of expression 92 can be ignored

$$0 = (p^i_s)^{1-\varphi} p^{\varphi-\sigma}_j \left[\left(1 - \frac{\boldsymbol{\mathcal{C}}^i_j}{p^i_s} \right) \left[\frac{\Psi^{i,i}_s + \Psi'^{\,i,\text{-}i}_s}{p^i_s} \tilde{p}^i_{st} + \frac{\Psi''^{\,i,\text{-}i}_s}{p^{\text{-}i}_{\text{-}s}} \tilde{p}^{\text{-}i}_{\text{-}st} \right] - \Psi^i_s \frac{\boldsymbol{\mathcal{C}}^i_j}{p^i_s} (\widetilde{\boldsymbol{\mathcal{C}}}^i_{st} - \tilde{p}^i_{st}) \right] \ldots$$
$$- \Theta_s (\tilde{\pi}^i_t + \tilde{p}^i_{st} - \tilde{p}^i_{st-1}) + \beta \Theta_s \mathbb{E}_t \left[\tilde{\pi}^i_{t+1} + \tilde{p}^i_{st+1} - \tilde{p}^i_{st} \right] \tag{94}$$

Expression 94 shows the role of the superelastiticies in a clear way. Given a log-linear approximation around the steady state, they adjust the slope of the price elasticity of demand. They also perfectly offset if firms are identical. The decision rule is characterized as

$$\tilde{p}^i_{st} = \Upsilon_s \, \tilde{p}^i_{st-1} + \Upsilon^*_s \, \tilde{p}^{\text{-}i}_{\text{-}st-1} + \Upsilon'_s \, \widetilde{\boldsymbol{\mathcal{C}}}^i_{st} + \Upsilon''_s \, \widetilde{\boldsymbol{\mathcal{C}}}^{\text{-}i}_{\text{-}st} + \Upsilon^{\pi}_s \tilde{\pi}_t \tag{95}$$

Rival firms follow

$$\tilde{p}^{\text{-}i}_{\text{-}st} = \Upsilon_{\text{-}s} \, \tilde{p}^{\text{-}i}_{\text{-}st-1} + \Upsilon^*_{\text{-}s} \, \tilde{p}^i_{st-1} + \Upsilon'_{\text{-}s} \, \widetilde{\boldsymbol{\mathcal{C}}}^{\text{-}i}_{\text{-}st} + \Upsilon''_{\text{-}s} \, \widetilde{\boldsymbol{\mathcal{C}}}^i_{\text{-}st} + \Upsilon^{\pi}_{\text{-}s} \tilde{\pi}_t \tag{96}$$

Given some aggregate shock, expected prices in the next period are

$$\mathbb{E}_t\left[\tilde{p}^i_{st+1}\right] = \Upsilon_s\,\tilde{p}^i_{st} + \Upsilon^*_s(\Upsilon_{\text{-}s}\,\tilde{p}^{\text{-}i}_{\text{-}st-1} + \Upsilon^*_{\text{-}s}\,\tilde{p}^i_{st-1} + \Upsilon'_{\text{-}s}\,\widetilde{\mathcal{C}}^{\text{-}i}_{\text{-}st} + \Upsilon''_s\,\widetilde{\mathcal{C}}^{i}_{st} + \Upsilon^\pi_s\tilde{\pi}_t)\ ...$$
$$+\,\rho\left[\Upsilon'_s\,\widetilde{\mathcal{C}}^{i}_{st} + \Upsilon''_s\,\widetilde{\mathcal{C}}^{\text{-}i}_{\text{-}st} + \Upsilon^\pi_s\tilde{\pi}_t\right] \tag{97}$$

where ρ is the persistence of the shock. This suggests

$$\Upsilon_s = \frac{(\psi_s + \beta\Theta_s\Upsilon^*_s)\Upsilon^*_{\text{-}s} + \Theta_s}{\kappa_s - \beta\Theta_s\Upsilon_s} \tag{98}$$
$$\Upsilon^*_s = \frac{(\psi_s + \beta\Theta_s\Upsilon^*_s)\Upsilon_{\text{-}s}}{\kappa_s - \beta\Theta_s\Upsilon_s} \tag{99}$$
$$\Upsilon'_s = \frac{(\psi_s + \beta\Theta_s\Upsilon^*_s)\Upsilon''_{\text{-}s} - (p^i_s)^{-\varphi}p_j^{\varphi-\sigma}\Psi^i_s\mathcal{C}^i_s}{\kappa_s - \beta\Theta_s(\Upsilon_s + \rho)} \tag{100}$$
$$\Upsilon''_s = \frac{(\psi_s + \beta\Theta_s\Upsilon^*_s)\Upsilon'_{\text{-}s}}{\kappa_s - \beta\Theta_s(\Upsilon_s + \rho)} \tag{101}$$
$$\Upsilon^\pi_s = \frac{(\psi_s + \beta\Theta_s\Upsilon^*_s)\Upsilon^\pi_{\text{-}s} - \Theta_s(1-\rho\beta)}{\kappa_s - \beta\Theta_s(\Upsilon_s + \rho)} \tag{102}$$

where

$$\kappa_s = \Theta_s + \beta\Theta_s - (p^i_s)^{1-\varphi}p_j^{\varphi-\sigma}\left[\left(1 - \frac{\mathcal{C}_s}{p^i_s}\right)\frac{\Psi^{i,i} + {\Psi'}^{i,\text{-}i}_s}{p^i_s} + \Psi^i\frac{\mathcal{C}_s}{p^i_s}\right] \tag{103}$$
$$\psi_s = (p^i_s)^{1-\varphi}p_j^{\varphi-\sigma}\left(1 - \frac{\mathcal{C}_s}{p^i_s}\right)\frac{{\Psi''}^{i,\text{-}i}_s}{p^{\text{-}i}_{\text{-}s}} \tag{104}$$

Once relative prices are known, the change in the market share of each firm is given by

$$\tilde{x}^i_{st} = \frac{\Psi^{i,i}_s + {\Psi'}^{i,\text{-}i}_s}{(\varphi-\sigma)p^i_s}\tilde{p}^i_{st} + \frac{{\Psi''}^{i,\text{-}i}_s}{(\varphi-\sigma)p^{\text{-}i}_{\text{-}s}}\tilde{p}^{\text{-}i}_{\text{-}st} \tag{105}$$

As suggested before, output for each firm is equal to

$$\tilde{y}^i_{st} = \tilde{x}^i_{st} + \widetilde{Y}_t + \widetilde{P}_t - \tilde{p}^i_{st} \tag{106}$$

Table 8: Estimated Decision Rules (Baseline Calibration)

	Υ	Υ^*	Υ'	Υ''	Υ^π
Large firms	0.777	0.028	0.101	0.015	-0.392
Small firms	0.776	0.004	0.145	0.002	-0.360

A.3.3 Capital Rental Costs and Aggregate Output

The capital rental price is equal to the marginal product of capital. To simplify dynamics, aggregate capital is held fixed and the capital share of total income is

$$z_tK = (1+\tau_t)\frac{\alpha}{\mu_t}Y_t \tag{107}$$

where μ_t is the aggregate markup and τ is an offsetting subsidy paid to firms. Although aggregate capital is fixed, firms may trade capital so that its marginal product is equalized

$$\frac{p_{st}y_{st}}{k_{st}} = \frac{p_{\text{-}st}y_{\text{-}st}}{k_{\text{-}st}} \quad \Longrightarrow \quad \frac{k_{st}}{k_j - n_s k_{st}} = \frac{x_{st}}{1 - n_s x_{st}} \quad \text{given} \quad \frac{p_{st}y_{st}}{n_{\text{-}s}p_{\text{-}st}y_{\text{-}st}} \equiv \frac{x_{st}}{1 - n_s x_{st}} \tag{108}$$

where capital in each industry $k_j = n_s k_{st} + n_{\text{-}s}k_{\text{-}st}$. Payments on capital within an industry must equal the sum of payments by firms

$$z_t = \frac{n_s z_t k_{st} + n_{\text{-}s} z_t k_{\text{-}st}}{k_j} \tag{109}$$

where k_j is proportional to K given identical industries. In log-linear form, this expression becomes

$$\tilde{z}_t = \frac{n_s k_s}{k_j}(\tilde{k}_{st} + \tilde{z}_t) + \frac{n_{\text{-}s}k_{\text{-}s}}{k_j}(\tilde{k}_{\text{-}st} + \tilde{z}_t) \tag{110}$$

noting that k_j is fixed since K is fixed. As before, the rental rate on capital equals its marginal product. This can be related to market share, using expressions 15 and 18

$$\tilde{k}_{st} = \tilde{p}_{st} + \tilde{y}_{st} - \tilde{z}_t \quad \Longrightarrow \quad \tilde{k}_{st} = \tilde{x}_{st} + \widetilde{P}_t + \widetilde{Y}_t - \tilde{z}_t \quad \text{given} \quad \tilde{p}_{st} + \tilde{y}_{st} = \tilde{x}_{st} + \widetilde{P}_t + \widetilde{Y}_t \tag{111}$$

noting p_{jt} and y_{jt} are proportional to P_t and Y_t given identical industries. This implies

$$\tilde{z}_t = \frac{n_s k_s}{k_j}(\tilde{x}_{st} + \widetilde{P}_t) + \widetilde{Y}_t + \frac{n_{\text{-}s}k_{\text{-}s}}{k_j}(\tilde{x}_{\text{-}st} + \widetilde{P}_t + \widetilde{Y}_t) \tag{112}$$

By expression 108

$$\frac{k_s}{k_j} \equiv x_s \tag{113}$$

Movements in market share perfectly offset

$$n_s x_s \tilde{x}_{st} + n_{\text{-}s} x_{\text{-}s} \tilde{x}_{\text{-}st} = 0 \tag{114}$$

The resulting capital rental price is

$$\tilde{z}_t = \widetilde{P}_t + \widetilde{Y}_t \tag{115}$$

A.4 Aggregate Shocks with Asymmetric Firms

A.4.1 Monetary Policy

As before, the elasticity of output and inflation to the monetary policy shock is

$$\widetilde{Y}_t = \Gamma^y m_t \tag{116}$$

$$\tilde{\pi}_t = \Gamma^\pi m_t \tag{117}$$

The decision rule for each firm can be written

$$\widetilde{P}_{st} - \widetilde{P}_t = \Upsilon_s^{\pi}\Gamma^{\pi} m_t + \Upsilon_s \left(\widetilde{P}_{st-1} - \widetilde{P}_{t-1}\right) + \Upsilon_s^{*} \left(\widetilde{P}_{\text{-}st-1} - \widetilde{P}_{t-1}\right) + \left(\Upsilon_s' + \Upsilon_s''\right) \Gamma^{y} m_t \tag{118}$$

The log-linearized price index is

$$\widetilde{P}_t = \frac{n_s (P_s)^{-\varphi}\widetilde{P}_{st} + n_{\text{-}s}(P_{\text{-}s})^{-\varphi}\widetilde{P}_{\text{-}st}}{P^{-\varphi}} \tag{119}$$

while expression 71 gives the relation between Γ^y and Γ^π. The price index is a restriction. If all small firms set their relative price above it, then the relative price of all large firms must set their price below. Recalling Γ^π solves

$$\Gamma^{\pi} = \frac{\widetilde{P}_t - \widetilde{P}_{t-1}}{m_t} \tag{120}$$

the decision rule can be restated as

$$\widetilde{P}_{st} - \widetilde{P}_t - \Upsilon_s(\widetilde{P}_{st-1} - \widetilde{P}_{t-1}) - \Upsilon_s^{*}(\widetilde{P}_{\text{-}st-1} - \widetilde{P}_{t-1}) = \left[\Upsilon_s^{\pi}\Gamma^{\pi} + (\Upsilon_s' + \Upsilon_s'')\Gamma^{y}\right] m_t \tag{121}$$

In the first period of the monetary policy shock, this reduces to

$$\frac{\widetilde{P}_{st} - \widetilde{P}_t}{m_t} = \Gamma_s^m \quad \text{where} \quad \Gamma_s^m = \Upsilon_s^{\pi}\Gamma^{\pi} + (\Upsilon_s' + \Upsilon_s'')\Gamma^{y} \tag{122}$$

Recognizing the recursive nature of the problem

$$\mathbb{E}_t\left[\frac{\widetilde{P}_{st+1} - \widetilde{P}_{t+1}}{m_t}\right] = \Upsilon_s\Gamma_s^m + \rho_m\Gamma_s^m + \Upsilon_s^{*}\Gamma_{\text{-}s}^m \tag{123}$$

This implies

$$\mathbb{E}_t\left[\frac{\widetilde{P}_{st+1} - \widetilde{P}_{st}}{m_t}\right] = \mathbb{E}_t\left[\frac{\widetilde{P}_{t+1} - \widetilde{P}_{t}}{m_t}\right] + (\Upsilon_s - 1)\Gamma_s^m + \rho_m\Gamma_s^m + \Upsilon_i^{*}\Gamma_{\text{-}s}^m \tag{124}$$

Using expression 120

$$\mathbb{E}_t\left[\widetilde{P}_{st+1}\right] - \widetilde{P}_{st} = \left[\rho_m\,\Gamma^{\pi} + (\Upsilon_s - 1)\Gamma_i^m + \rho_m\Gamma_i^m + \Upsilon_s^{*}\Gamma_{\text{-}s}^m\right] m_t \tag{125}$$

Accordingly, Γ^π solves the following identity (using expressions 71, 120, and 125 and the definitions of Γ_i^m above)

$$\mathbb{E}_t\left[\widetilde{P}_{t+1}\right] - \widetilde{P}_t = \mathbb{E}_t\left[\frac{n^i(P_s)^{-\varphi}(\widetilde{P}_{st+1} - \widetilde{P}_{st}) + n^{\text{-}i}(P_{\text{-}s})^{-\varphi}(\widetilde{P}_{\text{-}st+1} - \widetilde{P}_{\text{-}st})}{P^{-\varphi}}\right] \tag{126}$$

A.4.2 Aggregate Productivity

The decision rule for each firm can be written in terms of relative prices

$$\widetilde{P}_t^i - \widetilde{P}_t = \Upsilon_s^\pi \, \Omega^\pi a_t + \Upsilon_s \, (\widetilde{P}_{t-1}^i - \widetilde{P}_{t-1}) + \Upsilon_s^* \, (\widetilde{P}_{t-1}^{-i} - \widetilde{P}_{t-1}) + (\Upsilon_s' + \Upsilon_s'') \, (\Omega^y a_t - a_t) \tag{127}$$

where

$$\Omega^\pi = \frac{\widetilde{P}_t - \widetilde{P}_{t-1}}{a_t} \tag{128}$$

the decision rule can be restated as

$$\widetilde{P}_t^i - \widetilde{P}_t - \Upsilon_i(\widetilde{P}_{t-1}^i - \widetilde{P}_{t-1}) - \Upsilon_s^*(\widetilde{P}_{t-1}^{-i} - \widetilde{P}_{t-1}) = [\Upsilon_s^\pi \Omega^\pi + (\Upsilon_s' + \Upsilon_s'')(\Omega^y - 1)] \, a_t \tag{129}$$

In the first period of the monetary policy shock, this reduces to

$$\frac{\widetilde{P}_t^i - \widetilde{P}_t}{a_t} = \Omega_s^a \quad \text{where} \quad \Omega_s^a = \Upsilon_s^\pi \Omega^\pi + (\Upsilon_s' + \Upsilon_s'')(\Omega^y + 1) \tag{130}$$

Solving recursively

$$\mathbb{E}_t \left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_{t+1}}{a_t} \right] = (\Upsilon_i + \rho_a)\Omega_s^a + \Upsilon_s^* \Omega_{-s}^a \tag{131}$$

This implies

$$\mathbb{E}_t \left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_t^i}{a_t} \right] = \mathbb{E}_t \left[\frac{\widetilde{P}_{t+1} - \widetilde{P}_t}{a_t} \right] + (\Upsilon_s + \rho_a - 1)\Omega_s^a + \Upsilon_s^* \Omega_{-s}^a \tag{132}$$

Using expression 128

$$\mathbb{E}_t \left[\widetilde{P}_{t+1}^i \right] - \widetilde{P}_t^i = [\rho \, \Omega^\pi + (\Upsilon_s + \rho_a - 1)\Omega_s^a + \Upsilon_s^* \Omega_{-s}^a] \, a_t \tag{133}$$

Finally, Ω^π solves the following identity (using expressions 128 and 146 and the definitions of Ω_s^a above)

$$\mathbb{E}_t \left[\widetilde{P}_{t+1} \right] - \widetilde{P}_t = \mathbb{E}_t \left[\frac{n^i (P^i)^{-\varphi} (\widetilde{P}_{t+1}^i - \widetilde{P}_t^i) + n^{-i} (P^{-i})^{-\varphi} (\widetilde{P}_{t+1}^{-i} - \widetilde{P}_t^{-i})}{P^{-\varphi}} \right] \tag{134}$$

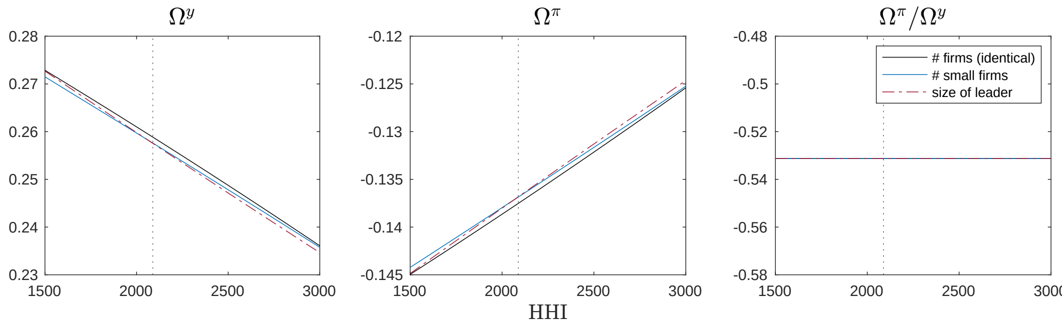
where

$$\Omega^y = \frac{(\rho - \phi_\pi)\Omega^\pi}{1 + \phi_y - \rho_a} \tag{135}$$

Looking at the left-hand panel in figure 14, the responsiveness of output to productivity shocks is declining as concentration increases.[70] The center panel indicates productivity shocks are also deflationary, which is a normal result in a New Keynesian setup. Looking at expression 78, it is clear the slope of the Phillips curve is only a function of parameters, as reflected in the right-hand panel of the figure.

[70] The results are consistent with Decker et al. (2020), which finds firms are becoming less responsive to the economic cycle.

Figure 14: Concentration and the Response to an Aggregate Productivity Shock



The x-axis displays the HHI and a move from left to right corresponds to an increase in concentration. The interpretation is analogous to figure 4. As concentration increases, firms less response to economic shocks. The ratio of the inflation and output reponse are a constant.

A.5 Firm-Specific Shocks

A.5.1 Productivity of Large Firms

Technology shocks may affect small and large firms differently. Market leaders invest more in R&D and employee training and are often the first to benefit from new technologies. Some technology improvements could be general across sectors but specific to large firms, such as IT infrastructure. To explore this aspect, it is necessary to relate changes in marginal costs across large firms to aggregate output. First take that productivity shocks are different across firms

$$\boldsymbol{\mathcal{C}}_{st} = \frac{1}{e^{a_{st}} \bar{a}_s P_t^{\alpha}} \left(\frac{z_t}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha} \tag{136}$$

For simplicity, shocks to the small firm are set to zero ($a_{St} = 0$). Meanwhile, shocks to the large firm follow

$$a_{Lt} = \rho_a a_{Lt-1} + \xi_t \tag{137}$$

Accordingly, the prices of large firms are given by

$$\widetilde{P}_t^L - \widetilde{P}_t = \Upsilon_L^{\pi}\, \Omega'^{\,\pi} a_{Lt} + \Upsilon_L\, (\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) + \Upsilon_L^*\, (\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) + \Upsilon_L'(\Omega'^{\,y} a_{Lt} - a_{Lt}) + \Upsilon_L''\Omega'^{\,y} a_{Lt} \tag{138}$$

while for small firms

$$\widetilde{P}_t^S - \widetilde{P}_t = \Upsilon_S^{\pi}\, \Omega'^{\,\pi} a_{St} + \Upsilon_S\, (\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) + \Upsilon_S^*\, (\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) + \Upsilon_S'\, \Omega'^{\,y} a_{Lt} + \Upsilon_S''(\Omega'^{\,y} a_{Lt} - a_{Lt}) \tag{139}$$

As before, each expression can be rearranged so that

$$\widetilde{P}_t^L - \widetilde{P}_t - \Upsilon_L(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) - \Upsilon_L^*(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) = [\Upsilon_L^{\pi}\Omega'^{\,\pi} + \Upsilon_L'(\Omega'^{\,y} - 1) + \Upsilon_L''\Omega'^{\,y}]\, a_{Lt} \tag{140}$$

$$\widetilde{P}_t^S - \widetilde{P}_t - \Upsilon_S(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) - \Upsilon_S^*(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) = [\Upsilon_S^{\pi}\Omega'^{\,\pi} + \Upsilon_S'\Omega'^{\,y} + \Upsilon_S''(\Omega'^{\,y} - 1)]\, a_{Lt} \tag{141}$$

Meaning in the first period, the shock is given by

$$\widetilde{P}_t^L - \widetilde{P}_t = \Omega_L^a a_{Lt} \quad \text{where} \quad \Omega_L^a = \Upsilon_L^\pi \Omega'^{\,\pi} + \Upsilon_L'(\Omega'^{\,y} - 1) + \Upsilon_L'' \Omega'^{\,y} \tag{142}$$

$$\widetilde{P}_t^S - \widetilde{P}_t = \Omega_S^a a_{Lt} \quad \text{where} \quad \Omega_S^a = \Upsilon_S^\pi \Omega'^{\,\pi} + \Upsilon_S' \Omega'^{\,y} + \Upsilon_S''(\Omega'^{\,y} - 1) \tag{143}$$

Solving recursively

$$\mathbb{E}_t \left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_{t+1}}{a_{Lt}} \right] = (\Upsilon_i + \rho_a)\Omega_i^a + \Upsilon_i^* \Omega_{\text{-}i}^a \tag{144}$$

This implies

$$\mathbb{E}_t \left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_t^i}{a_{Lt}} \right] = \mathbb{E}_t \left[\frac{\widetilde{P}_{t+1} - \widetilde{P}_t}{a_{Lt}} \right] + (\Upsilon_i + \rho_a - 1)\Omega_i^a + \Upsilon_i^* \Omega_{\text{-}i}^a \tag{145}$$

Using expression 128

$$\mathbb{E}_t \left[\widetilde{P}_{t+1}^i \right] - \widetilde{P}_t^i = \left[\rho_a \, \Omega'^{\,\pi} + (\Upsilon_i + \rho_a - 1)\Omega_i^a + \Upsilon_i^* \Omega_{\text{-}i}^a \right] a_{Lt} \tag{146}$$

Finally, Ω^π solves the following identity (using expressions 128 and 146 and the definitions of Ω_i^a above)

$$\mathbb{E}_t \left[\widetilde{P}_{t+1} \right] - \widetilde{P}_t = \mathbb{E}_t \left[\frac{n^i (P^i)^{-\varphi} (\widetilde{P}_{t+1}^i - \widetilde{P}_t^i) + n^{\text{-}i} (P^{\text{-}i})^{-\varphi} (\widetilde{P}_{t+1}^{\text{-}i} - \widetilde{P}_t^{\text{-}i})}{P^{-\varphi}} \right] \tag{147}$$

Figure 15 shows the impulse response following a productivity shock to large firms. There are general equilibrium effects – the shock is deflationary and increases aggregate output. This raises marginal costs for small firms. Also, the shock has a large effect on relative prices and markups. Therefore, there are noticable changes in market share and markup dispersion rises by around 30 percent. The shock also increases price dispersion, but the effect is much smaller.

A.5.2 Capital Costs of Small Firms

Cheng et al. (2023) finds firms exposed to 'superstars' exhibit weaker financial performance, greater riskiness, and are more likely to file for bankruptcy. This risk may translate into higher capital rental costs for small firms. The shock is described as follows. The firm's budget constraint is written

$$\Pi_{st} = (1 + \tau_t) p_{st} y_{st} - w_t \ell_{st} - e^{v_t} z_t k_{st} \tag{148}$$

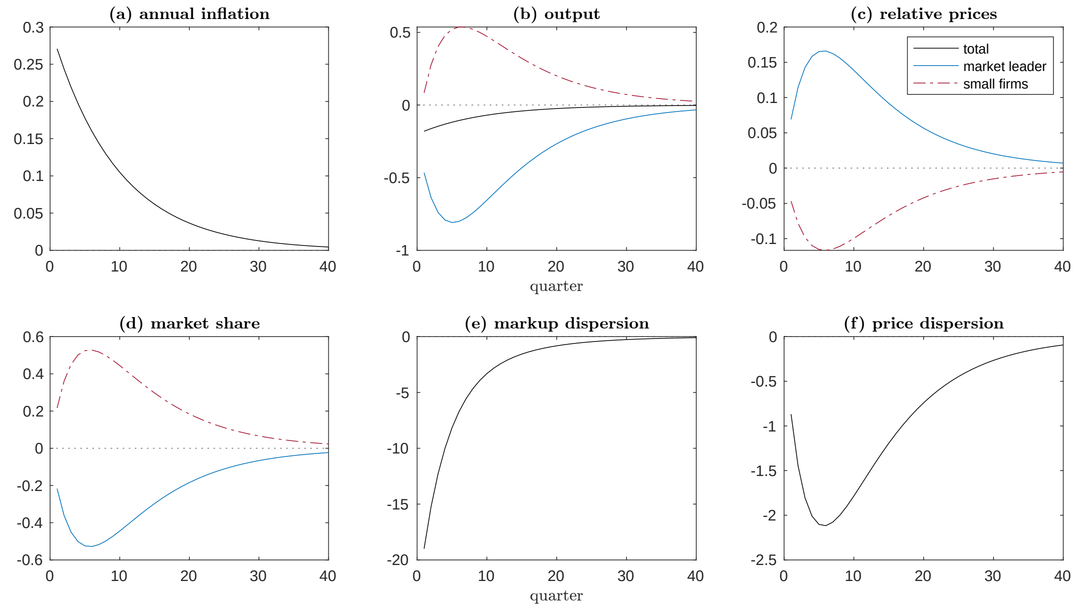
where v_t is a shock on capital rental costs. This implies

$$\boldsymbol{\mathcal{C}}_{st} = \frac{1}{\bar{a}_s P_t^\alpha} \left(\frac{e^{v_{st}} z_t}{\alpha} \right)^\alpha \left(\frac{w_t}{1 - \alpha} \right)^{1-\alpha} \tag{149}$$

For simplicity, shocks to large firms are set to zero ($v_{Lt} = 0$). Meanwhile, shocks to small firms follow

$$v_{St} = \rho_v v_{St-1} + \zeta_t \quad \text{where} \quad \zeta_t \sim \mathcal{N}(0, \sigma_v) \tag{150}$$

Figure 15: Impulse Response to a Large Firm Productivity Shock ($\xi_0 = -1$)



A negative 1 percent productivity shock is applied to large firms. This has general equilibrium effects and there is an increase in inflation and decline in output. Becuase the shock is asymmetric, there is a large impact on relative prices and market share. Compression in the markups of large firms is particularly large and markup dispersion significantly falls. Given a positive shock to large firms, the opposite would hold.

The premium reduces the capital demanded by small firms

$$\tilde{k}_{Lt} = \tilde{p}_{St} + \tilde{y}_{St} - \tilde{z}_t - v_{St} \tag{151}$$

In turn, this affects overall capital demand

$$\tilde{z}_t = \widetilde{Y}_t + \widetilde{P}_t - n_S x_S v_{St} \tag{152}$$

For large firms, log-linear marginal costs become

$$\widetilde{\mathcal{C}}_{St} = \alpha \tilde{z}_t + (1-\alpha)\widetilde{w}_t - \alpha \widetilde{P}_t \tag{153}$$
$$= \widetilde{Y}_t - \alpha n_S x_S v_{St} \tag{154}$$

while for small firms

$$\widetilde{\mathcal{C}}_{Lt} = \alpha(\tilde{z}_t + v_t) + (1-\alpha)\widetilde{w}_t - \alpha \widetilde{P}_t \tag{155}$$
$$= \widetilde{Y}_t + \alpha(1 - n_S x_S) v_{St} \tag{156}$$

Aggregate output and inflation are assumed to have some elasticity to the shock

$$\widetilde{Y}_t = \Gamma'^y v_{St} \tag{157}$$
$$\tilde{\pi}_t = \Gamma'^\pi v_{St} \tag{158}$$

Noting that

$$\Gamma'^{\pi} = \frac{\widetilde{P}_t - \widetilde{P}_{t-1}}{v_{St}} \tag{159}$$

Accordingly, the prices of large firms are given by

$$\widetilde{P}_t^L - \widetilde{P}_t = \Upsilon_L\,(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) + \Upsilon_L^*\,(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) + \Upsilon'_L\,\widetilde{\boldsymbol{\mathcal{C}}}_{Lt} + \Upsilon''_L\,\widetilde{\boldsymbol{\mathcal{C}}}_{St} + \Upsilon_L^{\pi}\,\Omega^{\pi} v_{St} \tag{160}$$

where

$$\widetilde{\boldsymbol{\mathcal{C}}}_{Lt} = (\Gamma'^y - \alpha n_S x_S) v_{St} \tag{161}$$

$$\widetilde{\boldsymbol{\mathcal{C}}}_{St} = [\Gamma'^y + \alpha(1 - n_S x_S)] v_{St} \tag{162}$$

while for small firms

$$\widetilde{P}_t^S - \widetilde{P}_t = \Upsilon_S\,(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) + \Upsilon_S^*\,(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) + \Upsilon'_S\,\widetilde{\boldsymbol{\mathcal{C}}}_{St} + \Upsilon''_S\,\widetilde{\boldsymbol{\mathcal{C}}}_{Lt} + \Upsilon_S^{\pi}\,\Gamma'^{\pi} v_{St} \tag{163}$$

As before, each expression can be rearranged so that

$$\widetilde{P}_t^L - \widetilde{P}_t - \Upsilon_L(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) - \Upsilon_L^*(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) = [\Upsilon_L^{\pi}\Gamma'^{\pi} + (\Upsilon'_L + \Upsilon''_L)(\Gamma'^y - \alpha n_L x_L) + \alpha\Upsilon''_L]\, v_{St} \tag{164}$$

$$\widetilde{P}_t^S - \widetilde{P}_t - \Upsilon_S(\widetilde{P}_{t-1}^S - \widetilde{P}_{t-1}) - \Upsilon_S^*(\widetilde{P}_{t-1}^L - \widetilde{P}_{t-1}) = [\Upsilon_S^{\pi}\Gamma'^{\pi} + (\Upsilon'_S + \Upsilon''_S)(\Gamma'^y - \alpha n_L x_L) + \alpha\Upsilon'_S]\, v_{St} \tag{165}$$

Meaning in the first period, the shock is given by

$$\widetilde{P}_t^L - \widetilde{P}_t = \Gamma_L^v v_t \quad \text{where} \quad \Gamma_L^v = \Upsilon_L^{\pi}\Gamma'^{\pi} + (\Upsilon'_L + \Upsilon''_L)\Gamma'^y + \alpha\Upsilon''_L \tag{166}$$

$$\widetilde{P}_t^S - \widetilde{P}_t = \Gamma_S^v v_t \quad \text{where} \quad \Gamma_S^v = \Upsilon_S^{\pi}\Gamma'^{\pi} + (\Upsilon'_S + \Upsilon''_S)\Gamma'^y + \alpha\Upsilon'_S \tag{167}$$

Solving recursively

$$\mathbb{E}_t\left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_{t+1}}{v_t}\right] = (\Upsilon_i + \rho_v)\Gamma_i^v + \Upsilon_i^*\Gamma_{\text{-}i}^v \tag{168}$$

This implies

$$\mathbb{E}_t\left[\frac{\widetilde{P}_{t+1}^i - \widetilde{P}_t^i}{v_t}\right] = \mathbb{E}_t\left[\frac{\widetilde{P}_{t+1} - \widetilde{P}_t}{v_t}\right] + (\Upsilon_i + \rho_v - 1)\Gamma_i^v + \Upsilon_i^*\Gamma_{\text{-}i}^v \tag{169}$$

Using expression 159

$$\mathbb{E}_t\left[\widetilde{P}_{t+1}^i\right] - \widetilde{P}_t^i = [\rho_v\Gamma'^{\pi} + (\Upsilon_i + \rho_v - 1)\Gamma_i^v + \Upsilon_i^*\Gamma_{\text{-}i}^v]\, v_t \tag{170}$$

Finally, Γ'^{π} solves the identity (using expressions 159 and 170 and the definitions of Γ_i^v above)

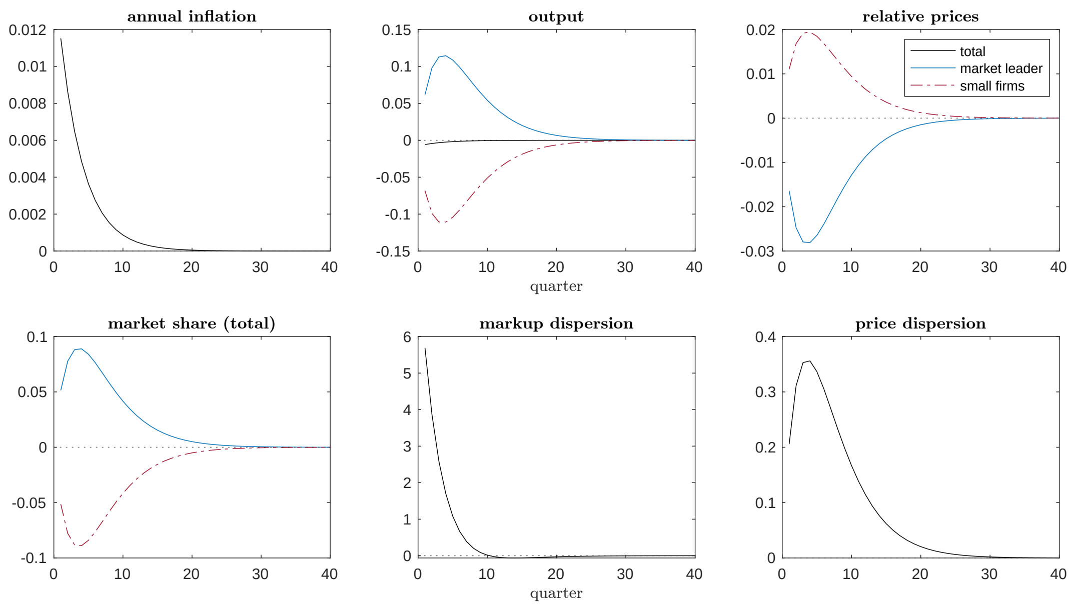
$$\mathbb{E}_t\left[\widetilde{P}_{t+1}\right] - \widetilde{P}_t = \mathbb{E}_t\left[\frac{n^i(P^i)^{-\varphi}(\widetilde{P}_{t+1}^i - \widetilde{P}_t^i) + n^{\text{-}i}(P^{\text{-}i})^{-\varphi}(\widetilde{P}_{t+1}^{\text{-}i} - \widetilde{P}_t^{\text{-}i})}{P^{-\varphi}}\right] \tag{171}$$

where

$$\Gamma'^{y} = \frac{(\rho - \phi_\pi)\Gamma'^{\pi}}{1 + \phi_y - \rho_v} \tag{172}$$

The response to the shock is given in figure 16. While the shock does not impact inflation and aggregate output, it has a meaningful impact on market share and markup dispersion.

Figure 16: Impulse Response to a Small Firm Capital Cost Shock ($\zeta_0 = 1$)



There is a 1 percent shock to the capital rental costs of small firms. Unlike most other shocks, this capital cost shock does not have a significant impact on aggregate inflation or output. Since general equilibrium effects are weak, the efficiency of large firms is not impeded and they benefit from a relative price advantage. Since large firms match the price increase of small firms to some degree, this leads to higher markup dispersion.

A.6 Comparing the Standard NK Model with Price Staggering

How do the results for markup and price dispersion presented earlier compare to the standard New Keynesian model with price staggering? The model is implemented using Dynare modifying the replication package for Galí (2015) chapter 3.[71] The implementation proposed in Galí matches the main outcomes from the baseline model. The settings in table 9 give the same equilibrium markup (0.14) and slope for the Phillips curve (0.36). All other values are identical to table 1.

Table 9: Alternative Parameter Values

Parameter	Value	Description
σ	8.1	Elasticity of substitution across goods
θ	0.65	Probability firm keeps the same price

The standard deviation of log prices can be determined as follows. In each period of the shock, some

[71] Refer to Galí (2015) for details on how Calvo pricing is implemented. Dynare is a software program designed to solve dynamic stochastic general equilibrium models (Adjemian et al., 2021).

fraction $1-\theta$ of firms can reset their price. This means in period t a share θ^t of firms will never reset their price. For all prices $\boldsymbol{P}_t^* = \{\widetilde{P}_0, \widetilde{P}_1^*, \widetilde{P}_2^*, ..., \widetilde{P}_t^*\}$, indexed by k, their respective weights are given by $\eta = \{\omega_0, \omega_1, \omega_2, ..., \omega_t\}$ where

$$\omega_0 = \theta^t \quad \text{and} \quad \omega_k = (1-\theta)\theta^{t-k} \quad \text{for} \quad 0 < k \leq t \tag{173}$$

Since the aggregate price index moves in each period, relative prices are given by

$$\boldsymbol{p}_t^* = \boldsymbol{P}_t^* - \widetilde{P}_t \tag{174}$$

where $\widetilde{P}_t$ is the aggregate price index. The set of corresponding markups is similarly

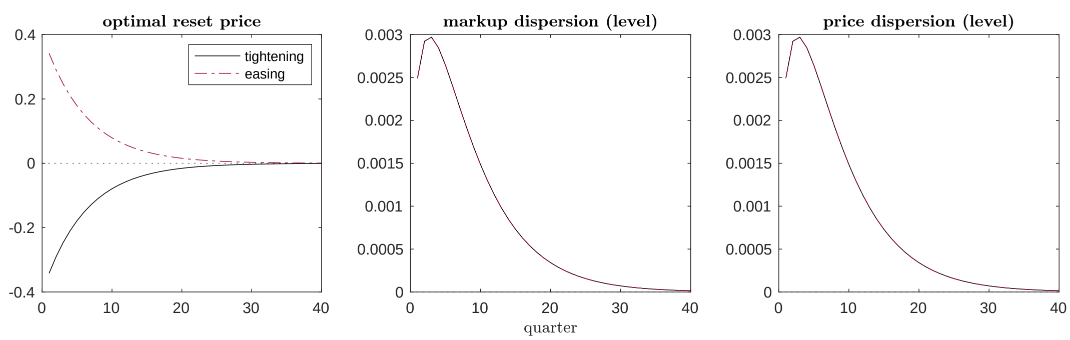
$$\boldsymbol{\mu}_t^* = \boldsymbol{P}_t^* - \widetilde{\boldsymbol{\mathcal{C}}}_t \tag{175}$$

To solve for the optimal reset price P^* in each period, the relation between inflation and prices is given by

$$\widetilde{P}_t = \theta \widetilde{P}_{t-1} + (1-\theta)\widetilde{P}_t^* \quad \Longrightarrow \quad \tilde{\pi}_t = \frac{1-\theta}{\theta}(\widetilde{P}_t^* - \widetilde{P}_t) \quad \text{since} \quad \tilde{\pi}_t = \widetilde{P}_t - \widetilde{P}_{t-1} \tag{176}$$

This is sufficient to both derive the reset price and calculate the weighted standard deviation of log prices and markups. Both the monetary and productivity shocks are implemented

Figure 17: Impulse Response to a Monetary Shock (Standard NK Model)



The figure shows the response of prices and markups in a model with Calvo pricing. For a 1 percent decrease in the nominal interest rate, there is an increase in the dispersion of log markups and log prices. The same applies if there is a negative shock with a 1 percent increase.

The results for the monetary shock are presented in figure 17. Because there is no price or markup dispersion in the steady state, both are presented in levels (using log markups and log prices). Output and inflation are identical to the baseline results in figure 6. The initial effect of the shock on markup and price dispersion grows since only a fraction $1-\theta$ of firms can reset their price. The change in dispersion over time relates to two factors: (i) the size of the price reset and (ii) movement of the aggregate price index. Given monetary tightening, a resetting firm will choose a price below the aggregate price index. This increases dispersion. Now take that the firm does not reset its price again. First, the aggregate price index will gradually converge to the reset price, reducing price dispersion. After this point, it will continue to move below the reset price, increasing dispersion.

Unlike the baseline model, both monetary tightening and easing increase markup and price dispersion (see figure 17). There is no price dispersion in equilibrium, so this is expected. Still, results in Sheremirov

(2020) suggest dispersion in regular prices and inflation are positively correlated, meaning a deflationary shock should also lead to price compression. This is not the case. In addition, Calvo prices implies an excessive level of price dispersion. In Sheremirov (2020), a 1 percentage point increase in annual inflation raises the standard deviation of log prices by 0.057 where the model returns almost 11x the appropriate level.[72] Table 10 presents the corresponding estimates.

Table 10: OLS Regression of Price Dispersion on Inflation Following a Productivity Shock (Simulated Data)

Price dispersion	NK Model (1)	Baseline (2)
Inflation	0.612***	0.027***
	(0.054)	(0.003)
Constant	-0.001***	0.069***
	(0.000)	(0.000)
R-squared	0.769	0.616

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[72] The coefficient reported above omits industry as a control. It falls to 0.026 when controlling for industry.