Business Cycle Implications of Firm Market Power in Labor and Product Markets[*]

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October 20, 2021

Abstract

We analyze the business cycle implications of firms having *oligopsony* power in labor markets, as well as *oligopoly* power in product markets, within the context of an estimated New Keynesian dynamic stochastic general equilibrium model with firm entry and exit. The strategic interaction between firms results in larger price markups as well as wage markdowns, while the slopes of the aggregate price and wage Phillips curves become flatter, relative to the standard setup with monopolistic competition in goods and labor markets, and these effects are strengthened in a strongly non-linear fashion as the number of firms in each sector decline. Oligopsonistic labor markets also render wage shocks expansionary, unlike in the standard setup. Our results indicate that a secular increase in industry concentration would not only reduce the labor share of income, but also weaken the pass-through from firms' marginal costs to prices and from productivity increases to real wages.

Keywords: Market power, oligopoly, oligopsony, New Keynesian DSGE model, entry-exit.

JEL Classification: E25, E32, L13.

[*]We thank Esteban Argudo, Berrak Bahadir, Simcha Barkai, Vera Brencic, Roberto Burguet, Gino Cateau, Chetan Dave, Giuseppe Fiori, Sebastian Fossati, Carlos Garriga, Stefano Gnocchi, Daniela Hauser, Bart Hobijn, Serdar Kabaca, Loukas Karabarbounis, Ken Kuttner, Asli Leblebicioglu, Jesper Lindé, Federico Mandelman, Ioana Marinescu, Harry Paarsch, Tim Robinson, Paul Ruud, Manuel Santos, Tanseli Savaser, Eric Schmidbauer, Malik Shukayev, Katharine Sims, Anna Sokolova, Murat Tasci, Nicholas Trachter and David Vestin, as well as seminar participants at the Riksbank, University of Alberta, University of South Florida, Vassar College, Southern Economic Association Meetings 2018, XII. Winter Workshop in Economics at Koc University, Eastern Economic Association Meetings 2019, Symposium of the Society for Nonlinear Dynamics and Econometrics 2019, and Midwest Macro Meetings Fall 2019 for suggestions and comments. An earlier version of this paper was circulated as "Business Cycles with Oligopsonistic Competition in Labor Markets". All remaining errors are our own.

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1 Introduction

Recent decades in the U.S. economy have been characterized by a decline in the share of aggregate income that has accrued to labor, a slowdown in the pass-through from productivity growth to labor compensation, and a flattening of the price and wage Phillips curves. There are likely many different factors behind each of these developments, but this paper argues that a rise in industry concentration in product and labor markets can provide a potential explanation that can weave across and help account for them simultaneously.[1]

In order to analyze the implications of industry concentration on the aforementioned developments, we build a New Keynesian dynamic stochastic general equilibrium (DSGE) model where firms have oligopsony power in labor markets as well as oligopoly power in product markets. The model features a continuum of sectors, each of which has a finite number of firms that engage in Cournot-Nash type competition in both product and labor markets. The model here incorporates three key differences relative to the standard New Keynesian framework of Christiano et al. (2005) and Smets and Wouters (2007), all of which are important in generating the main results of the paper: (i) labor supply is firm-specific rather than economy-wide, (ii) labor market power is modeled on the firm (i.e., demand) side rather than the household (i.e., supply) side of the market, and (iii) there is a finite number of firms within each sector, and therefore, competition in the goods and labor markets are characterized by oligopolistic and oligopsonistic competition, respectively, rather than monopolistic competition.[2] In addition, we allow for endogenous firm entry and exit, in the spirit of Jaimovich and Floetotto (2008).

The first two features mentioned above imply that the model features a different labor wedge from the *business cycle accounting* perspective of Chari et al. (2009); in particular, real wages are not marked up relative to the marginal rate of substitution of households as in the standard New Keynesian setup, but instead they are *marked down* relative to the marginal product of labor. Furthermore, the third feature related to the finite number of firms in each industry leads to strategic interaction between firms' decisions, which results in flatter price and wage Phillips curves. In particular, firms now internalize the fact that their price and wage decisions affect the industry-wide prices and wages, and this pass-through from the firm-specific to industry-wide prices and wages gets stronger as the number of competitors in each industry falls. Thus, with reduced competition, firms do not have to respond as much to changes in their marginal cost or labor productivity when they alter prices and wages, which in the aggregate gives rise to the flattening of the price and the wage Phillips curves, and thereby the weakening of the pass-through from marginal costs to prices

[1] We provide a description of the related literature establishing these phenomena in the following section.

[2] The model features firm-specific labor supply with a more generalized form than used in the earlier literature (Woodford, 2003; Carvalho and Nechio, 2016), differentiating between the elasticities of labor supply to firms within an industry and across industries, as well as for aggregate labor supply (i.e., labor versus leisure). Also see Mongey (2018), which features a continuum of sectors, but only two firms within each sector that engage in duopolistic competition in the goods sector subject to menu costs in pricing. In contemporaneous work to this paper, Berger et al. (2019) consider oligopsonistic competition in labor markets within a real business cycle setup with heterogenous firms. Differently from us, their focus is on the measurement of labor market concentration and the welfare implications of changes in labor market power over time.

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and from productivity to real wages. Increased industry concentration also leads to larger price markups and wage markdowns at the steady state, which raises the profit share while reducing the labor share of income.[3] We estimate the model parameters using Bayesian likelihood techniques and U.S. macroeconomic data, and show that an increase in industry concentration can potentially be important, both qualitatively and quantitatively, to account for the stylized facts we mentioned in the beginning.[4]

This paper contributes to the business cycle literature utilizing New Keynesian DSGE frameworks by modeling labor market power on the demand side (i.e., firms), rather than the supply side (i.e., to households), of the labor market. As mentioned before, the latter is typically assumed in the standard DSGE framework, which in effect captures the role of labor unions in wage setting (Gnocchi, 2009). Note, however, that the role of labor unions has significantly declined in post-war U.S. (Schnabel, 2013), while labor-replacing technological progress and the increase in market concentration in key industries have increased the bargaining power of firms in hiring and wage setting (Haldane et al., 2018). Thus, it is important to analyze alternatives to the labor market structure typically assumed in the standard DSGE setup. In order to show the importance of how labor market power is modeled, we compare the impulse responses from the baseline model with oligopsonistic competition in labor markets to the standard DSGE setup where labor market power is on the household side. This analysis reveals that dynamics are qualitatively similar in the two models, except for the effects of "wage shocks". These shocks act analogous to adverse labor supply shocks in the standard DSGE framework, increasing the marginal cost of firms, and thereby prompting them to cut hiring and output while raising prices.[5] Thus, in equilibrium, aggregate output and labor decline, while inflation and real wages increase. In the oligopsony labor setup here, positive wage shocks reduce the magnitude of the markdown in wages relative to the marginal product of labor, prompting firms to instead increase hiring and production, while cutting prices in order to sell their increased output. In equilibrium, this results in a simultaneous increase in real wages, labor services, and output, while inflation declines.[6]

In the next subsection, we start by summarizing the empirical evidence on the main motivating feature behind our analysis: rising industry concentration. Section 2 introduces the baseline model, while Sections 3 and 4 present the main results of the paper discussing the implications of market

[3]The model also predicts that increased concentration would lead to a decline in capital's income share as well, while the share of pure profits in total income rises. This prediction is consistent with Barkai (2020), who uses an opportunity cost of capital measure to separate the returns to capital from pure profits in the national income accounts, and shows that both the shares of labor and capital in total income have declined over time.

[4]Although the model is silent about the underlying causes for the increase in industry concentration, one could capture higher entry barriers as the driver of increased concentration (Van Reenen, 2018) by increasing the firms' fixed costs over time.

[5]As Chari et al. (2009) and Gali et al. (2012) note, labor supply shocks and wage markup shocks cannot be separately identified in the standard setup unless one puts more structure into the labor side of the model or on the two exogenous processes. This is not the case for the model with oligopsonistic competition in labor markets featured in this paper.

[6]This result is consistent with some of the empirical literature on minimum wages, which find that minimum wage increases have often led to an increase rather than a decrease in employment. See for example, Card and Krueger (1994).

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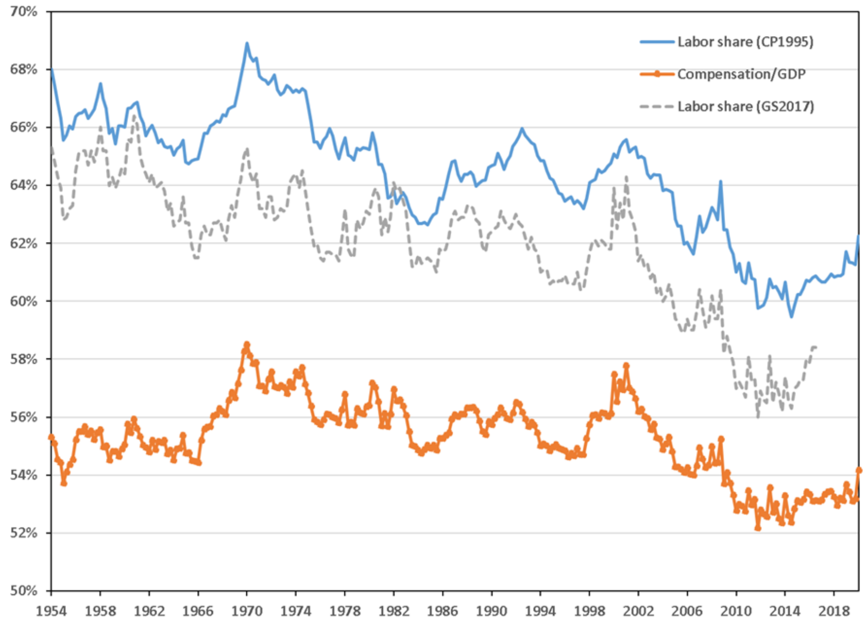

Figure 1: Labor's share in total income in the post-war period. CP series uses the Cooley and Prescott (1995) methodology to allocate proprietors' income to labor and capital in proportion to the rest of the economy, while the GS2017 series is the labor share constructed by Giandrea and Sprague (2017).

power in labor and product markets on business cycles, qualitatively and quantitatively, and Section 5 concludes.

1.1 Related literature

We start by providing some of the existing evidence underpinning our analysis: the decline in the share of aggregate income that has accrued to labor, the slowdown in the pass-through from productivity growth to labor compensation, and the flattening of the price and wage Phillips curves.

Figure 1 plots three different measures for the labor share in income: (i) the ratio of the total compensation of employees relative to GDP in the U.S. national accounts, (ii) a Bureau of Labor Statistics (BLS) measure of labor's income share in non-farm business constructed by Giandrea and Sprague (2017), and (iii) an alternative measure for the whole economy constructed using the methodology in Cooley and Prescott (1995), which allocates proprietor's income to labor and capital in the same proportion as the rest of the economy.[7] These measures suggest that the labor share in total income has declined by about 3-4 percentage points (pp) since the early 1980s, with the

[7] In contrast to Cooley and Prescott (1995), the Giandrea and Sprague (2017) measure allocates proprietors' income to labor based on the share of labor hours of the proprietors versus employees in these establishments. All data, except for consumption of fixed capital are from Table 1.12, titled "National Income by Type of Income" of the National Income and Product Accounts prepared by the Bureau of Economic Analysis (BEA), while the consumption of fixed capital figures are from Table 1.7.5, which relates Gross and Net National Product.

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declining trend becoming stronger since the 2000s.[8] The decline in labor's share is apparent in micro-level data as well. In particular, Autor et al. (2017b) show that the change in the payroll share of value added in the 388 manufacturing industries has been negatively correlated with the change in the concentration ratios in these industries since 1987, and this negative correlation has strengthened over time.[9]

A second and related development is the stagnation of labor compensation growth relative to labor productivity. Giandrea and Sprague (2017) report that the gap between the growth of labor productivity and compensation has increased over time, from an average of 0.63 pp between 1973-1990 to 0.68 pp between 1990-2000, and to 1.13 pp between 2000-2015. Brill et al. (2017) analyze this *productivity-compensation gap* at the industry level, and report that the average annual percent change in labor productivity outpaced compensation between 1987-2015 in 83% of the 183 industries covered in their study.[10] A third, and seemingly unrelated development is the flattening of the price and wage Phillips curves. Kuttner and Robinson (2010) use 15-year rolling regressions on the hybrid form of the New-Keynesian Phillips curve, and show that the slope parameter on the marginal cost measure has declined from around 0.04 in the 1980s to around 0.01 in the 2000s. Del Negro et al. (2020) provide further evidence of a flattening of the price Phillips curve due to a muted reaction of inflation to cost pressures in recent times. Similarly, Leduc and Wilson (2018) and Gali and Gambetti (2019) find substantial evidence of flattening in the empirical wage Phillips curve linking the unemployment gap to wage inflation.

There is growing evidence that industry concentration in the U.S. has increased during the last several decades. Autor et al. (2017a) document that top firms in 2012 account for a significantly larger share of sales and employment in their respective industries relative to 1982. In particular, the sales concentration ratio of the top 4 firms in manufacturing industries has increased from 38% to 43% on average, while there has been a corresponding increase from 24% to 35% in finance, from 11% to 15% in services, from 29% to 37% in utilities and transportation, from 15% to 30% in retail trade, and from 22% to 28% in wholesale trade. Autor et al. (2017b) report similar findings of rising concentration using Herfindahl-Hirschman indexes (HHI) for U.S. industries.[11]

[8] Also see Elsby et al. (2013) for the labor share decline in the U.S. over the last three decades, and Karabarbounis and Neiman (2014), who document a similar decline in other countries. Blanchard and Giavazzi (2003) argue that the decline in the labor share is related to the decrease in the bargaining power of labor.

[9] The literature has also considered automation in certain parts of the production process (Acemoglu and Autor, 2011), decline in the relative price of investment goods (Bergholt et al., 2021), access to foreign capital (Leblebicioglu and Weinberger, 2021), and changes in corporate taxation (Kaymak and Schott, 2018) as possible alternative explanations for the decline in the labor share.

[10] See also Kehrig and Vincent (2021), who find that labor share dynamics in manufacturing establishments are largely driven by employment, and not the wage rate, and employment has become less responsive to positive technology shocks over time.

[11] See Grullon et al. (2017), Van Reenen (2018), and Philippon (2019) for arguments put forward to explain the increase in industry concentration. These include the weakening of anti-trust enforcement, increase in the regulatory burden, and the rise in technological barriers to entry. Whether industry consolidation observed at the national level has the same impact on competition at the local level is contested however. Using the National Establishment Time Series (NETS) dataset, Rossi-Hansberg et al. (2018) find that, although product market concentration has increased at the national level, it has declined at the local level, with an overall fewer number of national firms competing in more local markets. Karabarbounis and Neiman (2018) and Bridgman (2019), who use Compustat and National Accounts

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The increase in industry concentration can have consequences, not only in product markets, but also in labor markets. The types of labor services supplied by households can be fairly specialized to specific industries, while there may exist various frictions in labor markets that prevent employees to switch jobs costlessly even within the same industry, such as locational preferences or "no-compete" clauses in existing labor contracts barring them from working for their employer's rivals. As noted above, Autor et al. (2017a, 2017b) show increasing industry concentration not only by sales, but also by employment. Azar et al. (2017) document significant labor market concentration in the U.S. using HHI indexes for job vacancies by occupation within each commuting zone, and estimate that "going from the 25th percentile to the 75th percentile in concentration is associated with a 15-25% decline in posted wages, suggesting that concentration increases labor market power". Similarly, Benmelech et al. (2018) use Census data over 1977-2009, and find that local-level employer concentration has increased over time, with the employment-weighted mean local-level employer HHI index defined at the four-digit SIC (Standard Industrial Classification) level increasing by about 5.8 percentage points (pp) between the late 70s and the 2000s. Furthermore, they find that wages are negatively related to labor market concentration, consistent with monopsony power in labor markets.

The U.S. Treasury (2016) reports that around 18% of all workers, or nearly 30 million people, are covered by no-compete agreements in their labor contracts, even though only less than half of these workers report possessing some form of trade secrets. Similarly, Krueger and Ashenfelter (2018) document that 58% of all major franchise chains in the U.S. use "no-poaching" language in their franchise contracts. Recent evidence from a variety of settings also suggests that firms face upward-sloping labor supply curves, thus possessing some monopsony power in their labor markets (Boal and Ransom, 1997; Manning, 2011). As Manning (2003) and Hirsch et al. (2010) indicate, monopsony power may arise even when there are many firms competing for workers due to the presence of search frictions, heterogeneous preferences among workers, and mobility costs or barriers.[12] An increase in industry concentration could thus enhance firms' market power in wage setting, especially when labor markets are characterized more in line with oligopsonistic competition.

2 Model

In this paper, we consider a setting where labor market power rests with firms. Notably, the model features firms that possess oligopsony power in labor markets and face upward-sloping firm-specific labor supply curves, while households are price and wage takers. Similar to Jaimovich and Floetotto (2008), it features oligopolistic competition in product markets and firm entry-exit.

data, respectively, find only a modest increase in firm markups in the last few decades.

[12]For labor markets with search and matching frictions where firms enjoy some bargaining power, see for example Walsh (2005), Ravenna and Walsh (2012), Colciago and Rossi (2015), and Christiano et al. (2016). Bhaskar and To (1999) develop a model of monopsonistic competition in which workers have heterogeneous preferences over a non-wage characteristic of jobs, such as the distance from home to work. Azar and Vives (2018) consider the effects of an increase in "effective" market concentration, defined as the overlapping ownership of various non-financial firms by the same few financial firms, which can lead to declines in employment, real wages, and the labor share. Goetz (2013) argue that the decrease in house prices following the recent financial crisis has reduced the labor mobility of homeowners.

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The model also incorporates real frictions in the form of external habit formation in consumption, investment adjustment costs, and costs of capital utilization, as well as nominal frictions in the form of price- and wage-stickiness, similar to the standard New Keynesian DSGE setups of Christiano et al. (2005) and Smets and Wouters (2007). Price- and wage-stickiness are introduced through quadratic adjustment costs in the price- and wage-setting decisions of firms similar to Rotemberg (1982), while monetary policy is conducted via a Taylor rule on the policy rate.

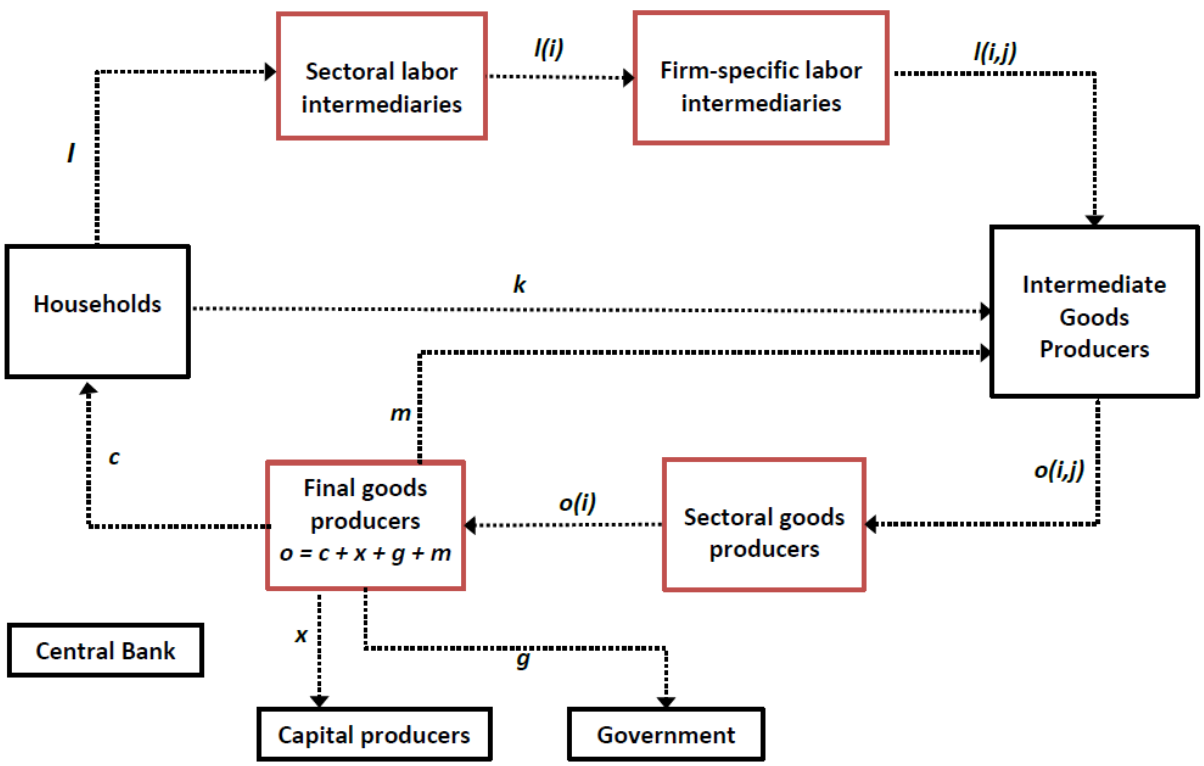

Figure 2: Bird's-eye view of the model

Figure 2 provides a bird's-eye view of the model. Households supply homogenous capital and (through intermediaries) firm-specific labor to firms. There is a unit measure of sectors in the economy indexed by $i \in [0, 1]$, and there are a finite number N_t intermediate-goods firms indexed by $j \in \{1, 2, ..., N_t\}$ in each sector. Within each sector, these firms engage in Cournot-Nash competition in both the product and labor markets. The labor intermediaries and goods aggregators are perfectly competitive, and are added to the model for convenience. In particular, the labor intermediaries differentiate the homogenous aggregate labor supplied by households, l_t, into first sector-specific labor, $l_t(i)$, and then firm-specific labor, $l_t(i, j)$, while the goods aggregators combine the intermediate output goods, $o_t(i, j)$, into first the sectoral output goods, $o_t(i)$, and then into the final output goods, o_t. These final output goods can then be used for households' consumption, c_t, investment

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in new capital, i_t, government expenditure, g_t, or as material intermediates utilized in production, m_t.

In what follows, we focus on the optimization problems of labor intermediaries and intermediate goods producers, relegating the more standard parts of the model to Appendix A.[13]

2.1 Labor intermediaries and firm-specific labor supply

The disaggregation from aggregate labor to sector-specific labor conforms with the following aggregator function:

$$l_t = \left[\int_0^1 l_t(i)^{\frac{\eta_l+1}{\eta_l}} di \right]^{\frac{\eta_l}{\eta_l+1}},$$

where η_l denotes the labor supply elasticity at the sectoral level. Given perfect competition across the labor intermediaries, the above formulation gives rise to a sector-specific labor supply curve for sector i as

$$l_t(i) = \left(\frac{W_t(i)}{W_t} \right)^{\eta_l} l_t, \tag{1}$$

where $W_t(i)$ denotes the nominal wage index in sector i, and the aggregate wage index, W_t, is linked to the sector-specific wage indexes by

$$W_t = \left(\int_0^1 W_t(i)^{1+\eta_l} di \right)^{\frac{1}{1+\eta_l}}.$$

Similarly, the disaggregation from sector-specific labor to firm-specific labor conforms with the following aggregator function:

$$l_t(i) = N_t^{\frac{1}{\chi_l+1}} \left(\sum_{j=1}^{N_t} l_t(i,j)^{\frac{\chi_l+1}{\chi_l}} \right)^{\frac{\chi_l}{\chi_l+1}}, \tag{2}$$

where χ_l denotes the labor supply elasticity at the firm level. We assume that $\chi_l > \eta_l$, indicating that labor supply is more elastic within a sector relative to across sectors.[14] The first-term on the right-hand side of equation (2) ensures that there is no "variety effect" on sectoral labor supply, and implies that, in a symmetric equilibrium, $N_t l_t(i,j) = l_t(i) = l_t$ for all i and j. Given perfectly competitive labor intermediaries, the above formulation implies that the firm-specific labor supply curve for firm j in sector i is

$$l_t(i,j) = \left(\frac{W_t(i,j)}{W_t(i)} \right)^{\chi_l} \frac{l_t(i)}{N_t}, \tag{3}$$

[13] We also provide a complete list of the equilibrium conditions of the model after detrending and log-linearization at the end of Appendix A.

[14] Note that when $\chi_l = \eta_l = 1/\varphi$, the labor intermediaries' problem can be imbedded easily into the household's problem, where the disutility term from labor in the period utility expression of households can be written as $\frac{N_t(i)^{\vartheta}}{1+\vartheta} \int_0^1 \sum_{j=1}^{N_t(i)} l_t(i,j)^{1+\vartheta} di$, similar to the firm-specific labor supply specification in Carvalho and Nechio (2016).

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where $W_t(i,j)$ denotes the wage rate paid by firm j in sector i. Accordingly, the sector-specific wage index in sector i is linked to the firm-specific wages in that sector by

$$W_t(i) = N_t^{-\frac{1}{1+\chi_l}} \left(\sum_{j=1}^{N_t} W_t(i,j)^{1+\chi_l} \right)^{\frac{1}{1+\chi_l}}, \tag{4}$$

which also indicates that, in a symmetric equilibrium, $W_t(i,j) = W_t(i) = W_t$ for all i and j.

Note that the intermediate goods firms that will be introduced in the next subsection are oligopsonistic competitors in labor markets. Combining (1) and (3), the intermediate goods firm j in sector i faces a labor supply function for its individual type of labor as

$$l_t(i,j) = \left(\frac{W_t(i,j)}{W_t(i)} \right)^{\chi_l} \left(\frac{W_t(i)}{W_t} \right)^{\eta_l} \frac{l_t}{N_t}, \tag{5}$$

where it takes into account that its firm-specific wage rate, $W_t(i,j)$, will have an impact on the sectoral wage, $W_t(i)$, based on equation (4). This effect can be measured as

$$\frac{\partial W_t(i)}{\partial W_t(i,j)} = \left(\frac{W_t(i)}{W_t(i,j)} \right)^{-\chi_l} \frac{1}{N_t}, \tag{6}$$

implying that, in a symmetric equilibrium, the pass-through from the firm-specific to the sectoral wage rate is equal to the inverse of the number of firms in each sector, $1/N_t$. When $N_t = 1$, there is complete pass-through by construction (with the labor supply elasticity faced by the single firm equaling η_l), while as N_t increases to infinity, the pass-through from the firm-level to sectoral wages goes to 0 (with the labor supply elasticity effectively increased to χ_l). As will be discussed later, the above expressions are the source of the strategic interaction term in the wage Phillips curve.

2.1.1 Final goods producers and firm-specific goods demand

Similar to the setup for labor supply, the demand curve faced by each intermediate goods firm for its differentiated good is derived by considering the problems of perfectly competitive sectoral and final goods aggregators. As explained in more detail in Appendix A, the resulting goods demand curve facing an intermediate goods firm (i,j) is given by

$$o_t(i,j) = \left(\frac{P_t(i,j)}{P_t(i)} \right)^{-\chi_y} \left(\frac{P_t(i)}{P_t} \right)^{-\eta_y} \frac{o_t}{N_t}, \tag{7}$$

where η_y and χ_y are the elasticity of substitution between the sectoral goods and between the firm-specific goods within each sector, respectively, while $P_t(i,j)$, $P_t(i)$, and P_t denote output prices at the firm, sector and aggregate levels. Note that firm-specific goods prices are related to the

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sector-specific price index as

$$P_t(i) = N_t^{\frac{1}{\chi_y - 1}} \left(\sum_{j=1}^{N_t} P_t(i,j)^{1-\chi_y} \right)^{\frac{1}{1-\chi_y}}, \tag{8}$$

and this effect is internalized by the intermediate goods firms when they make pricing decisions.

2.2 Intermediate goods producers

Intermediate goods firms possess oligopoly power in the goods market as well as oligopsony power in labor markets.[15] The gross output of firm j in sector i, is described by the following Leontief function:

$$o_t(i,j) = \min \left\{ \frac{m_t(i,j)}{s_m}, \frac{y_t(i,j)}{1-s_m} \right\}, \tag{9}$$

where $m_t(i,j)$ is the material inputs used in production with s_m denoting the share of materials in gross output, while $y_t(i,j)$ denotes the value added of the firm. This value added is in turn described by a Cobb-Douglas production function as

$$y_t(i,j) = z_t \left[u_t(i,j) k_{t-1}(i,j) \right]^{\alpha} \left[\gamma^t l_t(i,j) \right]^{1-\alpha} - \gamma^t f, \tag{10}$$

where k_t denotes capital, u_t is the capital utilization rate, α is the capital share parameter, γ is the deterministic growth factor of labor efficiency, and z_t denotes the total factor productivity (TFP) shock following an AR(1) process. f denotes the fixed cost of production, and is scaled by γ^t to ensure that it does not become negligible as the economy grows.

The intermediate goods firm's profits in period t is given by

$$\frac{\Pi_t(i,j)}{P_t} = \frac{P_t(i,j)}{P_t} o_t(i,j) - m_t(i,j) - \frac{W_t(i,j)}{P_t} l_t(i,j) - r_{k,t} k_{t-1}(i,j) - \frac{\kappa_u}{1+\varpi} \left(u_t(i,j)^{1+\varpi} - 1 \right) k_{t-1}(i,j) \tag{11}$$
$$- \frac{\kappa_p}{2} \left(\frac{P_t(i,j)/P_{t-1}(i,j)}{\pi_{t-1}^{\varsigma_p} \pi^{1-\varsigma_p}} - 1 \right)^2 \frac{o_t}{N_t} - \frac{\kappa_w}{2} \left(\frac{W_t(i,j)/W_{t-1}(i,j)}{\gamma \pi_{t-1}^{\varsigma_w} \pi^{1-\varsigma_w}} - 1 \right)^2 \frac{W_t}{P_t} \frac{l_t}{N_t},$$

where $r_{k,t}$ is the real rental rate of capital, and the last three terms denote the firm's costs related to capital utilization, price adjustment, and wage adjustment, respectively. κ_u and ϖ are the level and elasticity parameters for the utilization cost specification, while κ_p and κ_w denote the level parameters for the price- and wage-adjustment costs, and ς_p and ς_w control the degree to which adjustments in prices and wages are indexed to past inflation.[16]

[15] For tractability, we assume that firms are facing the same number of competitors in both the goods and labor markets. Furthermore, the model abstracts from geographic differentiation and focuses on market power at the sectoral level. One could potentially interpret each "sector" in this model as a "sector-location" combination, with equal elasticities of substitution assumed across sectors as well as geographical locations.

[16] As is standard, κ_u is set equal to the steady-state value of $r_{k,t}$ to ensure that the capital utilization rate, u_t, is,

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An intermediate goods firm chooses its input quantities, $m_t(i,j)$, $l_t(i,j)$ and $k_{t-1}(i,j)$, capital utilization rate, $u_t(i,j)$, value added and gross output quantities, $y_t(i,j)$ and $o_t(i,j)$, output price, $P_t(i,j)$, and the firm-specific wage rate, $W_t(i,j)$, while taking as given the decisions of its competitors in the same industry i and economy-wide aggregates for the current period as well as all future periods and states. In particular, intermediate firms maximize the present value of their profits (using the households' stochastic discount factor) as

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\lambda_\tau}{\lambda_t} \frac{\Pi_\tau(i,j)}{P_\tau}, \tag{12}$$

where β and λ_t denote the households' time-discount parameter and their marginal utility of consumption, respectively; *subject to* their production technology described in (9) and (10), the firm-specific labor supply of labor intermediaries in (5) along with the corresponding sectoral wage index in (4), and the firm-specific goods demand of final goods producers in (7) along with the corresponding sectoral price index in (8). When solving this maximization problem, each firm takes into account how its own wage and price decisions would impact the sectoral wages and prices based on the sectoral wage and price indexes defined in (4) and (47), respectively, while treating its rivals' current and future actions as parameters. As such, we are considering "open-loop" strategies for these firms with respect to the dynamic effects of their actions (Fershtman and Kamien, 1987; Fudenberg and Levine, 1988; Jun and Vives, 2004).[17]

The first-order-conditions of the intermediate goods firms with respect to capital and the utilization rate are given (after imposing a symmetric equilibrium) by:[18]

$$\Omega_t \alpha \frac{y_t/N_t + \gamma^t f}{k_{t-1}/N_{t-1}} = r_{k,t} + \frac{\kappa_u}{1+\varpi}\left(u_t^{1+\varpi} - 1\right), \tag{13}$$

$$\Omega_t \alpha \frac{y_t/N_t + \gamma^t f}{u_t} = \kappa_u u_t^{\varpi} \frac{k_{t-1}}{N_{t-1}}, \tag{14}$$

where Ω_t denotes the Lagrange multiplier on the production function in (10), capturing the firm's real marginal cost of production.

We present the first-order conditions with respect to the firm's pricing and wage decisions in Section 3, along with a detailed discussion regarding the relationship between the average number of firms, N_t, and the Phillips curve slopes as well as the labor share of income. In what follows, we endogenize N_t by allowing firm firm entry and exit.

without loss of generality, equal to 1 at the steady state.

[17]Thus, the equilibria we consider are open-loop Nash equilibria, which are not necessarily subgame perfect. Considering subgame perfect "closed-loop" equilibria is significantly challenging given our setup, and is thus not attempted here.

[18]Needless to say, we are imposing symmetry *after* taking the first-order conditions with respect to the firm's choice variables, including its price, $P_t(i,j)$, and wage, $W_t(i,j)$. As noted before, each firm treats its sectoral rivals' current and future prices as given, and internalizes the effect of its own decisions on the sectoral price and wage indexes.

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2.3 Firm entry-exit

We follow Jaimovich and Floetotto (2008) and include free entry-exit of firms based on sectoral profitability.[19] Let N_t^* denote the number of firms that would ensure that intermediate goods firms make zero profits under no nominal rigidities. Given the firms' profit expression, this *long-run target* number of firms is given by

$$N_t^* = \left(\frac{\theta_{p,t}}{(1-\alpha)\,\theta_{w,t} + \alpha} - 1 \right) \frac{y_t\,(i)}{\gamma^t f}, \tag{15}$$

where $\theta_{p,t} > 1$ is the firms' *gross markup of price* over marginal cost in the absence of price rigidities and $\theta_{w,t} < 1$ is the firms' *gross wage markdown* relative to the marginal revenue product of labor (MRPL) in the absence of wage rigidities. We discuss these price markup and wage markdown expressions, and how they relate to the average number of firms N_t, in more detail in Section 3.

We posit that there is inertia in the number of firms operating at any time based on short-run frictions in reaching the aforementioned long-run number of firms. Thus, the actual number of firms in the economy, N_t, is determined partly by the past number of firms, N_{t-1}, and partly by the long-run target number of firms, N_t^*, as

$$N_t = \left\lfloor N_{t-1}^{\rho_N} \left(N_t^*\right)^{1-\rho_N} \right\rfloor, \tag{16}$$

where ρ_N is the persistence parameter and $\lfloor . \rfloor$ denotes the "floor" function (i.e., the greatest integer equaling or less than its argument).[20]

2.4 Monetary and fiscal policy

The central bank targets the nominal interest rate using the following Taylor rule:

$$\log R_t = \rho \log R_{t-1} + (1-\rho) \left(\log R + a_\pi \log \frac{\pi_t}{\pi} + a_y \log \frac{y_t}{y} \right) + \widetilde{\varepsilon}_{R,t}, \tag{17}$$

where ρ determines the degree of interest rate smoothing, R is the steady-state value of the (gross) nominal policy rate, and a_π and a_y are the long-run response coefficients for inflation and output gap, respectively. $\widetilde{\varepsilon}_{R,t}$ denotes the monetary policy shock, which follows an AR(1) process.

On the fiscal policy side, I assume that government bonds are in zero supply; hence, $B_t = 0$ for all t. The government runs a balanced budget each period, financing its expenditures with lump-sum taxes from households as $T_t = P_t g_t$, where g_t denotes real government expenditures, which are assumed to be exogenous and follow an AR(1) process in detrended form.

[19] Also see Bilbiie et al. (2012), Etro and Colciago (2010), and Lewis and Poilly (2012) for the interaction between firm entry and markups.

[20] Since we log-linearize the model, we will ignore this floor function in our simulations in Section 4, and treat N_t as a continuous variable. In the estimation, we also add a shock to this expression to be able to use the number of firms as an observable in the estimation.

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2.5 Market clearing conditions

The final goods market clearing condition is given by

$$c_t + x_t + g_t = y_t = o_t - m_t, \tag{18}$$

where total materials is given by $m_t = \int_0^1 \sum_{j=1}^{N_t} m_t(i,j)\,di$, and the costs related to capital utilization costs as well as price and wage adjustment are assumed to have no resource consequences, and are therefore treated as lump-sum transfers to households along with firms' profits. All input markets clear as well. Thus, the demand for labor services of firm j in sector i is equal to the firm-specific labor supply of the labor intermediaries for each i and j every period. Similarly, in the context of capital, market clearing implies that $k_t = \int_0^1 \sum_{j=1}^{N_t} k_t(i,j)\,di$.

The model's equilibrium is defined as prices and quantities, such that households maximize the expected discounted present value of utility and firms maximize expected profits, subject to their constraints, monetary policy follows the Taylor rule, and all markets clear. We only consider symmetric equilibria where firm-specific variables indexed by i and j are equal across all firms.

3 Qualitative Implications of Market Power

In this section we consider the qualitative implications of firms' market power in labor and product markets on the price and wage Phillips curves and the labor share of income.

3.1 Price Phillips curve

The intermediate goods firms' pricing decision gives rise to the following Phillips curve expression:

$$\begin{aligned}\left(\frac{\pi_t}{\pi_{t-1}^{\varsigma_p}\pi^{1-\varsigma_p}} - 1\right)\frac{\pi_t}{\pi_{t-1}^{\varsigma_p}\pi^{1-\varsigma_p}} = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{\pi_{t+1}}{\pi_t^{\varsigma_p}\pi^{1-\varsigma_p}} - 1\right)\frac{\pi_{t+1}}{\pi_t^{\varsigma_p}\pi^{1-\varsigma_p}}\frac{y_{t+1}/N_{t+1}}{y_t/N_t}\right] \\ - \frac{(1-s_m)\left(\chi_y - \frac{\chi_y-\eta_y}{N_t}\right) - 1}{\kappa_p}\left(1-\theta_{p,t}\Omega_t\right),\end{aligned} \tag{19}$$

where $\pi_t = P_t/P_{t-1}$ denotes the aggregate inflation factor, and $\theta_{p,t}$ is the firms' *gross markup of price* over marginal cost in the absence of price rigidities given by

$$\theta_{p,t} = \frac{(1-s_m)\left(\chi_y - \frac{\chi_y-\eta_y}{N_t}\right)}{(1-s_m)\left(\chi_y - \frac{\chi_y-\eta_y}{N_t}\right) - 1} > 1. \tag{20}$$

There are several things to note regarding the markup expression above. First, the presence of material inputs in production (i.e., $s_m > 0$) leads to a larger price markup relative to the standard setup, since firms are marking up their output prices including the costs related to their material

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inputs. Second, $\theta_{p,t}$ is inversely related to the number of firms, N_t, since $\chi_y > \eta_y$. Thus, the gross price markup in the model, $1/\Omega_t$, is endogenously *countercyclical* over the business cycle not only due to the presence of price adjustment costs as in the standard setup (i.e., $\kappa_p > 0$), but also due to endogenous firm entry-exit as expansions result in increases in the number of firms. Third, if the economy becomes more concentrated over the long run (i.e., the average number of firms at the steady state, N, decreases over time), this would generate a higher steady-state price markup, θ_p.

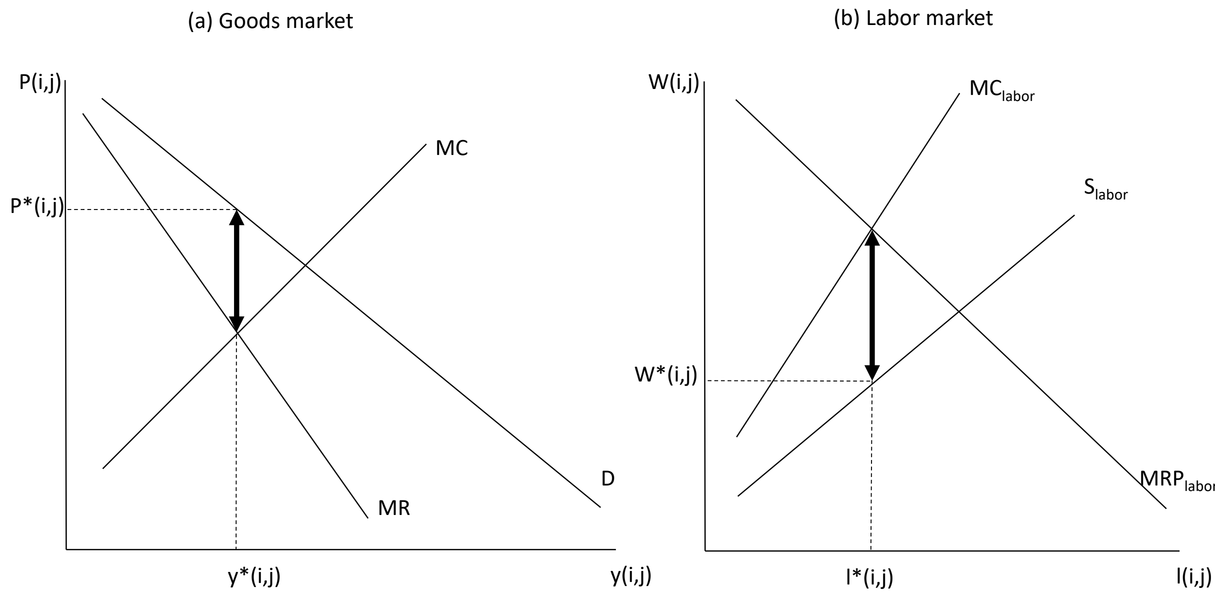

Figure 3: Firms take as given the goods demand and labor supply curves, and set prices at a markup relative to the marginal cost of production and wages at a markdown relative to the marginal value product of labor.

Panel (a) of Figure 3 illustrates an intermediate firm's price markup in the goods market in the absence of price rigidities. In the figure, D denotes the downward-sloping demand curve facing the individual firm's output as in equation (48), while the MR and the MC curves denote the marginal revenue and the marginal cost of production, respectively.[21] Note that MC is upward sloping, since the firm internalizes the fact that it will have to increase the wage rate as it hires more labor to increase output. Similarly, MR is below price for a given output level, since the firm internalizes the fact that it would need to cut its price as it increases output. At the optimum, the firm produces where MR equals MC, and sets the price at a markup relative to its marginal cost, as shown by the arrow on the figure.

[21]The use of straight-line demand curves in the Figure is for illustrative purposes only.

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After detrending and log-linearization, the Phillips curve expression in (19) can be written as

$$\widehat{\pi}_t = \frac{\varsigma_p}{1+\beta\varsigma_p}\widehat{\pi}_{t-1} + \frac{\beta}{1+\beta\varsigma_p}E_t\widehat{\pi}_{t+1} + \frac{(1-s_m)\left(\chi_y - \frac{\chi_y-\eta_y}{N}\right)-1}{(1+\beta\varsigma_p)\,\kappa_p}\left(\widehat{\Omega}_t + \widehat{\theta}_{p,t}\right) + \widetilde{\varepsilon}_{p,t}, \tag{21}$$

with

$$\widehat{\theta}_{p,t} = -\left(1-s_m\right)\left(\frac{\chi_y-\eta_y}{N}\right)\frac{(\theta_p-1)^2}{\theta_p}\widehat{N}_t, \tag{22}$$

where $\widetilde{\varepsilon}_{p,t}$ is an AR(1) cost-push shock added to the Phillips curve expression above to capture exogenous variation in price markups and facilitate the estimation of the model in Section 4.[22]

Since the slope of the Phillips curve in (21) is positively related to the steady-state number of firms, N, it predicts a flattening of the Phillips curve as industry concentration increases (i.e., as N declines). Note that the above expression reduces to a more standard Phillips curve expression if we abstract from material inputs (i.e., $s_m = 0$) and let the number of firms in each sector approach infinity (i.e., $N \to \infty$). In particular, the demand elasticity facing each firm would be equal to χ_y, and the gross markup of price over marginal cost would be $\chi_y/\left(\chi_y-1\right)$. With Rotemberg-type price rigidities, the slope of the Phillips curve would now be $\left(\chi_y-1\right)/[(1+\beta\varsigma_p)\,\kappa_p]$. With a finite number of firms however, the *effective* elasticity of demand facing a firm, and therefore its gross markup, are altered by a strategic interaction term that arises from the oligopolistic competition between firms. This strategic interaction term reduces the effective elasticity of demand facing the firm to $\chi_y - \frac{\chi_y-\eta_y}{N}$, thereby altering the steady-state gross markup of firms as in (20) and the slope of the aggregate price Phillips curve as in (21).[23]

To build intuition for this result, remember from the previous section that the goods demand facing firm j in sector i given in (48) can be written as

$$o_t(i,j) = P_t(i,j)^{-\chi_y}\, P_t(i)^{\chi_y-\eta_y}\, P_t^{-\eta_y}\frac{o_t}{N_t}, \tag{23}$$

and in a symmetric equilibrium, the pass-through from firm-specific price, $P_t(i,j)$, to the sectoral price, $P_t(i)$, is given by $1/N_t$. The latter is the source of the strategic interaction term discussed above, as firms internalize the impact of their own pricing on the sectoral price, and this effect is inversely related to the number of firms, N_t. With lower N, they do not have to respond as much to changes in their marginal cost when they alter prices, which in the aggregate gives rise to the flattening of the Phillips curve. This strategic effect is proportional to $\chi_y-\eta_y$, which is the difference between the within-sector and across-sector demand elasticities. When these elasticities are close to each other, the goods across sectors are viewed close substitutes to goods within the same sector, which effectively reduces the market power of firms within the industry.

[22]These price shocks can, for example, result from exogenous variation in the within- and across-sector demand elasticities, χ_y and η_y, both of which are assumed to be constant in our setup.

[23]Note that $\chi_y - \frac{\chi_y-\eta_y}{N} = \frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y$; thus, the effective demand elasticity facing the firm is determined by a weighted average of the demand elasticity parameters, χ_y and η_y, with the corresponding weights determined by N.

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3.2 Wage Phillips curve

Similar to the pricing decision, the intermediate goods firms' wage decision gives rise to the following wage-Phillips curve expression:

$$\left(\frac{\pi_{w,t}}{\gamma\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}}-1\right)\frac{\pi_{w,t}}{\gamma\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}}=E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{\pi_{w,t+1}}{\gamma\pi_t^{\varsigma_w}\pi^{1-\varsigma_w}}-1\right)\frac{\pi_{w,t+1}}{\gamma\pi_t^{\varsigma_w}\pi^{1-\varsigma_w}}\frac{\pi_{w,t+1}}{\pi_{t+1}}\frac{l_{t+1}/N_{t+1}}{l_t/N_t}\right]$$
$$-\frac{\chi_l-\frac{\chi_l-\eta_l}{N_t}+1}{\kappa_w}\left\{1-\theta_{w,t}\frac{\Omega_t\left(1-\alpha\right)z_t\left(u_t\frac{k_{t-1}/N_{t-1}}{l_t/N_t}\right)^{\alpha}}{w_t}\right\}, \tag{24}$$

where $w_t=W_t/P_t$ denotes the real wage rate, $\pi_{w,t}=W_t/W_{t-1}=\pi_t w_t/w_{t-1}$ refers to the nominal wage-inflation factor, and $\theta_{w,t}$ denotes the firms' *gross wage markdown* relative to the marginal revenue product of labor (MRPL) in the absence of wage rigidities:

$$\theta_{w,t}=\frac{\chi_l-\frac{\chi_l-\eta_l}{N_t}}{\chi_l-\frac{\chi_l-\eta_l}{N_t}+1}<1. \tag{25}$$

In particular, when $\kappa_w=0$, the wage Phillips curve expression reduces to

$$\frac{w_t}{\Omega_t\left(1-\alpha\right)z_t\left(u_t\frac{k_{t-1}/N_{t-1}}{l_t/N_t}\right)^{\alpha}}=\theta_{w,t}<1, \tag{26}$$

which indicates that real wages are marked down relative to the marginal revenue product of labor by a gross factor $\theta_{w,t}<1$. Note that $\theta_{w,t}$ is positively related to the number of firms, N_t, since $\chi_l>\eta_l$. Thus, the *net* markdown in real wages, $1-\theta_{w,t}$, becomes *countercyclical* as $\theta_{w,t}$ gets closer to 1 in expansions and move away from 1 in recessions. Similarly, a secular increase in market concentration (i.e., a lower steady state N) would drive θ_w further below 1, generating a larger gross markdown in real wages in the long run.

Panel (b) of Figure 3 illustrates the markdown of wages in the labor market in the absence of wage rigidities. S_{labor} denotes the upward-sloping labor supply curve facing the individual firm as in equation (5), the MC_{labor} curve is the (nominal) marginal cost of hiring an additional unit of labor, and MRP_{labor} denotes the marginal revenue product of labor. Note that MC_{labor} is above the wage rate for a given level of labor, since the firm internalizes the fact that it would need to raise its wage for all workers as it hires more labor. Similarly, MRP_{labor} is downward sloping, since the firm has to reduce its goods price as it hires more labor and increase its output. At the optimum, the firm equates MC_{labor} to MRP_{labor} when hiring labor, and sets the wage rate at a markdown relative to the marginal revenue product, as shown by the arrow on the figure.

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After detrending and log-linearization, the wage-Phillips curve expression can be written as

$$\widehat{\pi}_{w,t}-\varsigma_w\widehat{\pi}_{t-1}=\beta\left(E_t\widehat{\pi}_{w,t+1}-\varsigma_w\widehat{\pi}_t\right)+\frac{\chi_l-\frac{\chi_l-\eta_l}{N}+1}{\kappa_w}\left[\widehat{\Omega}_t+\widehat{z}_t+\alpha\left(\widehat{u}_t+\widehat{N}_t-\widehat{N}_{t-1}+\widehat{k}_{t-1}-\widehat{l}_t\right)-\widehat{w}_t+\widehat{\theta}_{w,t}\right]+\widetilde{\varepsilon}_{w,t}, \tag{27}$$

with

$$\widehat{\theta}_{w,t}=\left(\frac{\chi_l-\eta_l}{N}\right)\frac{\left(1-\theta_w\right)^2}{\theta_w}\widehat{N}_t, \tag{28}$$

where $\widetilde{\varepsilon}_{w,t}$ is an exogenous AR(1) wage shock.[24] Similar to the price Phillips curve, the slope of the wage-Phillips curve is increasing in the steady-state number of firms, N, given $\chi_l>\eta_l$. Thus, increased concentration is also consistent with a flattening of the wage Phillips curve, which would result in a slower pass-through from productivity shocks, z_t, to wages.

Similar to the price Phillips curve, oligopsonistic competition among firms generates a strategic effect on the *effective* firm-specific labor supply elasticity, since a firm's wage decision affects the sectoral wage and the firm internalizes this effect. If there were infinitely many firms within the industry, and thus firms were engaging in monopsonistic competition instead of oligopsonistic competition in labor markets, then the firm-specific labor supply elasticity would be χ_l, the gross markdown of real wages relative to the marginal product of labor would be equal to $\chi_l/\left(\chi_l+1\right)$, and the slope of the wage Phillips curve would be $\left(\chi_l+1\right)/\kappa_w$. With finite number of firms and oligopsonistic competition, the firm-specific labor supply facing firms is given in (5) and the pass-through from the firm-specific wage, $W\left(i,j\right)$, to the sectoral wage, $W\left(i\right)$ is $1/N_t$ in a symmetric equilibrium as in (6). Thus, the firm effectively faces a labor supply function with an elasticity of $\chi_l-\frac{1}{N_t}\left(\chi_l-\eta_l\right)$, which results in a larger (gross) wage markdown and a flattening of the wage Phillips curve slope, relative to the monopsonistic competition case.

Intuitively, with oligopsony power, firms do not have to alter their wages as much when they respond changes in productivity, since their decisions have an impact on the sectoral wage, and firms internalize this effect. This in the aggregate gives rise to the flattening of the wage Phillips curve. Furthermore, similar to the price Phillips curve case, the strategic effect with oligopsonistic competition depends on the difference between the within-sector and the across-sector labor supply elasticities, $\chi_l-\eta_l$. When this difference is close to 0, labor can move within a sector and across sectors with almost equal ease, and therefore the effective labor market power of firms is reduced.

3.3 Labor share of income

The factor shares of income can also be obtained from the intermediate goods producers' optimality conditions. At the steady state of the (detrended) model, the labor share of income is given by

$$\frac{wl}{y}=\frac{\left(1-\alpha\right)\theta_w}{\theta_p}\left(1+\frac{Nf}{y}\right), \tag{29}$$

[24] Similar to the price shocks, these wage shocks can, for example, result from exogenous variation in the within- and across-sector labor supply elasticities, χ_l and η_l, both of which are assumed to be constant in our setup.

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while the capital's share is

$$\frac{r_k k}{y} = \frac{\alpha}{\theta_p}\left(1 + \frac{Nf}{y}\right), \tag{30}$$

and the intermediate goods producers earn oligopoly and oligopsony profits equaling

$$\frac{\Pi/P}{y} = 1 - \frac{r_k k}{y} - \frac{wl}{y} = 1 - \frac{(1-\alpha)\,\theta_w + \alpha}{\theta_p}\left(1 + \frac{Nf}{y}\right). \tag{31}$$

As discussed in the previous subsections, the gross price markup factor, θ_p, is inversely related to the steady-state number of firms, N, while the wage gross markdown factor, θ_w, is positively related to N. Thus, as N decreases, the model predicts a secular decline in the labor share of income, consistent with the data presented in the Introduction, while the sum of the shares that accrue to capital and to firm owners as pure profits would rise. As N decreases and therefore θ_p increases, the model would also predict a secular decline in the capital share of income in (30), but this effect would be smaller than the effect on the labor share, since the latter is adversely effected by the decrease in θ_w as well as the increase in θ_p.

4 Quantitative Implications of Market Power

In order to conduct quantitative analyses using the model, we first estimate the parameters of the model using Bayesian likelihood methods (An and Schorfheide, 2007; Fernández-Villaverde, 2010) and U.S. macroeconomic data (see Appendix B for details). We then use the estimated model to quantitatively assess the importance of industry concentration for the labor income share, as well as the slopes of the price and wage Phillips curves and business cycle dynamics. We also explore the role of entry-exit for model dynamics, and compare the model's predictions relative to alternative labor market power specifications used in the literature.

4.1 Parameterization

Several standard parameters that primarily affect the steady state are calibrated prior to the estimation (see Table B1 in Appendix B). The trend growth factor, γ, is set to 1.005, while the time-discount factor of households, β, is set to 0.995 to match an annualized 4% real interest rate at the steady state. The depreciation rate of capital, δ, is set to 0.02 to match a 8% depreciation rate in annualized terms, and the share of materials in gross output, s_m, is set to 0.45 based on the difference of GDP and gross national output in the NIPA accounts of the Bureau of Economic Analysis during the post-war period. Similarly, the capital in the value-added production function, α, is set to 0.3, while the share of government expenditure in GDP, g/y, is set to 0.2. Finally, the average number of firms at the steady-state, N, is set equal to 8.

The remaining parameters are estimated using Bayesian likelihood methods and 8 quarterly data series from the U.S. between 1990Q1-2020Q1. The observables used in the estimation are GDP ($\widehat{y}_t$), consumption ($\widehat{c}_t$), investment ($\widehat{x}_t$), labor ($\widehat{l}_t$), real wage rate ($\widehat{w}_t$), inflation rate ($\widehat{\pi}_t$), the policy rate

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($\widehat{R}_t$), and the number of firms ($\widehat{N}_t$). The quarterly series for the number of firms is derived using the number of establishments reported in the *Quarterly Census of Employment and Wages* (QCEW) of the Bureau of Labor Statistics (BLS). The other data series are standard, and are discussed further in Appendix B.

The prior and posterior distributions for the estimated structural and shock parameters are presented in Tables B2a and B2b, respectively, in Appendix B.[25] The prior specifications are by and large standard, and are discussed in Appendix B. In what follows, we discuss some of the posterior estimates that are key to determine the Phillips curve slopes and the size of the price markup and wage markdown. The discussion related to the relatively more standard parameters is also relegated to Appendix B.

The estimate for the posterior mean for ϑ is 2.62, implying a labor supply elasticity of around 0.38 for households' choice of labor versus leisure for a marginal change in the wage rate. This is by and large in line with the micro literature, which finds fairly inelastic labor supply elasticities at the individual level. This estimate also applies to our cross-sector labor supply elasticity parameter, η_l, given the restriction we imposed in the estimation as $\eta_l = 1/\vartheta$.[26] The within-sector labor supply elasticity, χ_l, however is far more elastic, with an estimate of 11.08 at the posterior mean. This is also consistent with the recent micro-level evidence on *firm-specific* labor supply elasticities, which suggest a fairly inelastic labor supply (see Appendix B for a discussion of this literature). Note that, as expected, $\chi_l > \eta_l$, indicating far more willingness of workers to switch jobs within a sector, relative to jobs across sectors, for the same wage differential. These elasticity estimates also imply that the gross wage markdown at the steady state, θ_w, is around 0.9, indicating a 10 percent markdown in wages relative to the marginal revenue product of labor.

On the demand side, the cross-sector demand elasticity, η_y, is estimated as 1.98 at the mode, while the within-sector elasticity of substitution, χ_y, is estimated as 10.08, by and large consistent with the related literature (also discussed in Appendix B). The gross price markup at the steady state, θ_p, is thus 1.25, implying a net markup in prices of 25%, which is within the range of estimates reported in Barkai (2020) and De Loecker et al. (2020). These price markup and wage markdown estimates imply that the size of fixed costs relative to GDP at the steady state, Nf/y, is equal to 33.7%. The labor share of income is 67.9%, while the capital share of income is 32.1% along with zero pure profits at the steady state.[27]

The posterior mean estimates for the price adjustment cost parameter, κ_p, and the price indexation parameter, ς_p, are 236 and 0.82, respectively. Based on (21), these estimates imply a slope

[25]We conduct the estimation using the Matlab routines in Dynare v4.6.4 (Adjemian et al., 2011).

[26]We impose this restriction to provide stronger identification for the different labor supply elasticities in the estimation. One interpretation of setting $\eta_l = 1/\vartheta$ is to consider leisure time as encompassing non-market work, which is regarded as just another sector in the economy by households. The same elasticity would then apply to decisions in regards to switching between labor and leisure as well as switching between two different sectors. We thank Roberto Burguet for this insight.

[27]The capital-output ratio at the steady state is 2.67 in annualized terms, while the expenditure components of GDP are 53.3%, 26.7%, and 20.0% for consumption, investment and government expenditure, respectively. Note that we have considered consumer durables as part of investment in our data treatment.

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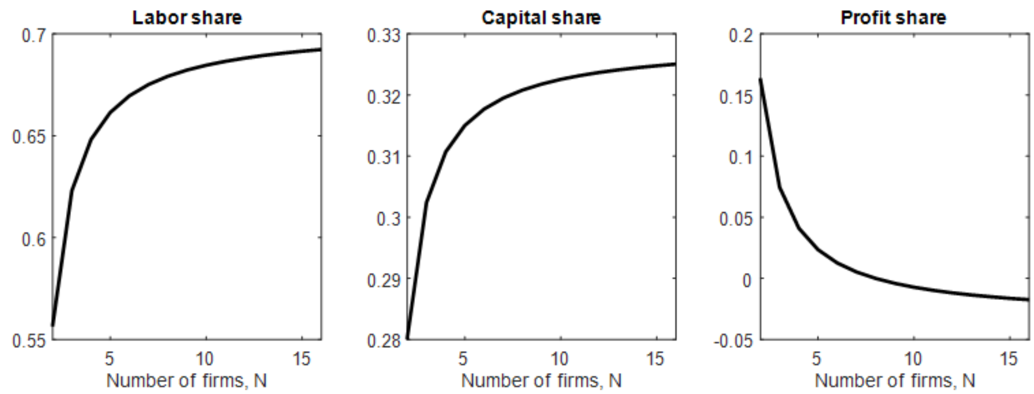

Figure 4: The steady-state share of income accruing to labor, capital, and pure profits as a function of the number of firms in each industry, N.

for the price Phillips curve equal to 0.009. Similarly, the mean estimate for the wage adjustment cost parameter, κ_w, is around 170, which implies a slope for the wage Phillips curve equal to 0.064 based on (27). Thus, both Phillips curves are fairly flat, consistent with empirical estimates of their slopes in the recent literature. Finally, we estimate the persistence parameter in the firm entry-exit specification, ρ_N, as 0.97, implying high persistence in the average number of firms.

4.2 Industry concentration and labor share of income

Figure 4 presents the distribution of aggregate income between labor, capital and pure profits at the steady state of the baseline model with $N = 8$, and analyzes how these would change as the steady-state number of competitors, N, is altered. The steady-state income share figures are calculated using the expressions derived in (29)-(31).

As noted before, in the baseline case with $N = 8$, the labor share in total income is 67.9%, capital share is 32.1%, while pure profits make up 0% of total income. The results indicate a non-linearity in the distribution of income with respect to changes in N, capturing changes in industry concentration. In particular, the distribution of income does not significantly change as N increases relative to the baseline case, with the labor share increasing only to 69.2% with $N = 16$. Going to the extreme case with infinitely many firms (i.e., monopolistic and monopsonistic competition in the goods and labor markets, respectively) generates a labor share of around 70%, again only slightly higher than the baseline case. However, the results are materially affected when industry concentration increases (i.e., N declines). The labor share is reduced to 64.8% with $N = 4$, while a duopoly-duopsony structure with $N = 2$ reduces the labor share further to 55.7%.

The decline in the labor share of income seen in the aggregate data since the 1990s has been of the order of 4-5 pp. Generating this type of a change solely through increased industry concentration would require N to decrease from 8 to around 3. Thus, the analysis here suggests that, while increased industry concentration has likely contributed to the decline in the labor share of income, it cannot account for the change fully given that N is not likely to be less than 4-5 for most industries

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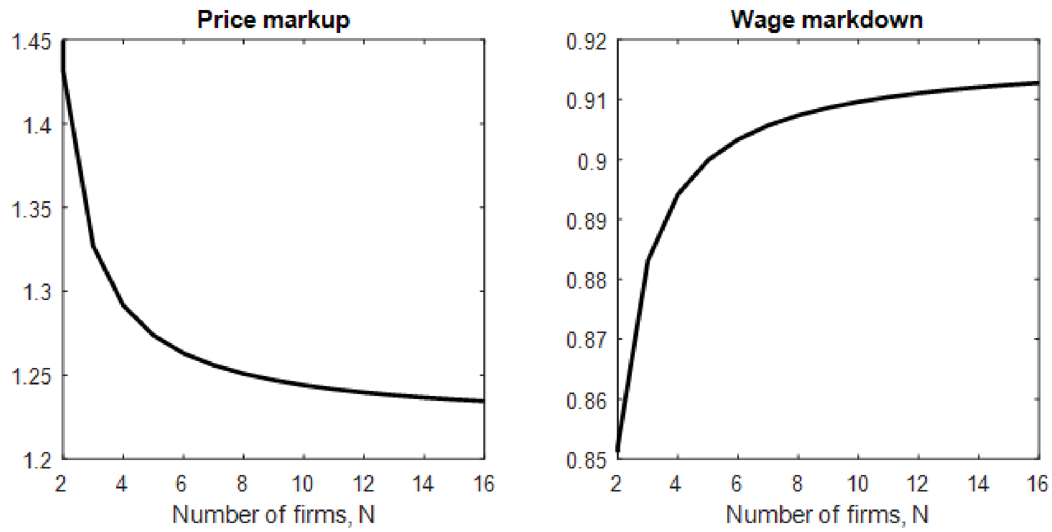

Figure 5: The firms' gross price markup and wage markdown as a function of the number of firms in their industry, N.

based on regulations imposed on mergers and acquisitions by the FTC. Figure 4 shows that as N becomes smaller we also see a decline in capital income share, though this decline is smaller than the one for labor income share. This is accompanied by a rise in profit share.[28]

Note that industry concentration affects the distribution of income through its effects on the firms' price markups and wage markdowns at the steady state (see Equations (29)-(31)), and is therefore also the source of the non-linearity in its effects on income shares. Figure 5 presents the price markup, θ_p and the wage markdown, θ_w, based on steady-state expressions shown (20) and (25), respectively, as we vary the steady-state number of competitors, N. The figure shows that the gross price markups and wage markdowns are fairly stable past a threshold level of N, while they change significantly when N is low. As N declines, we see larger price markups and wage markdowns. In particular, the net price markup and wage markdown is only 1-2 pp different for $N = 1,000,000$ relative to the baseline case with $N = 8$, while reducing the goods and labor markets to duopoly-duopsony (i.e., $N = 2$) affects these wedges by 6-20 pp.[29]

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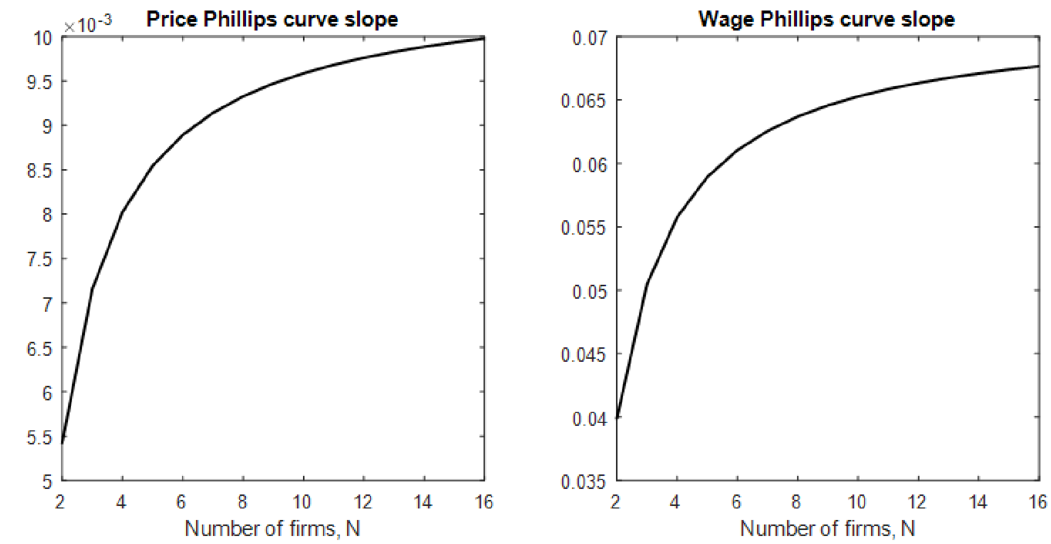

Figure 6: Slope of the price and wage Phillips curves as a function of the number of firms, N.

4.3 Industry concentration and the Phillips curve slopes

Figure 6 plots the slopes of the price and wage Phillips curves with the baseline $N = 8$, and shows how the slopes would adjust as N changes while keeping all other parameters the same as in the baseline case. The non-linearity that was evident for the income shares is also evident here. The Phillips curve slopes are not materially affected when N is above a certain threshold. However, if we consider a reduction in N, to capture industry concentration, then both the price and wage Phillips curve slopes are substantially reduced. If we consider a steady-state number of competitors to be 4 instead of the baseline 8, we see a 14% and 12% decline in the slopes of the price and wage Phillips curve, respectively. This suggests that the rise in industry concentration has the potential to partially explain the reduction in the price and wage Phillips curve seen in recent decades.

In summary, the strategic interaction effect arising from oligopolistic-oligopsonistic competition is shown to be inversely and non-linearly related to the steady-state number of firms in each industry, N. When N is relatively high (i.e., $N \geq 4$), a decrease from N to $N-1$ firms have only a negligible impact on the labor share of income or on the slopes of the Phillips curves. Once N decreases below a certain threshold however, further decreases in N start to have a much more sizable impact.[30]

[28] This is largely consistent with Barkai (2020), who uses an opportunity cost of capital measure to separate the returns to capital from pure profits in the national income accounts data, and shows that both the shares of labor and capital in total income have declined over time. However, he finds that the capital share has declined by about the same percentage points as the labor share, where both decline by about 7 percentage points while pure profits increase by about 14 pp, over 1984-2014. (Since the capital share is smaller, this amounts to a much larger percent decline in the capital share.)

[29] The evidence in De Loecker et al. (2020) points to an almost doubling of price markups between the pre and post 1980s periods, but the model here can generate this type of a markup increase only if N is reduced to 1 (i.e., a monopoly-monopsony setup). Since this is unlikely for the economy as a whole, other factors that increased concentration are likely to be at play as well.

[30] Note that all one requires is that there are only few *significant* competitors within each industry. Thus, the results would go through in a setup where there are N dominant firms that lead the market, along with a unit measure of

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This suggests that earlier rounds of industry consolidation observed in the U.S. may not have had noticeable effects on the labor share of income or Phillips curves' slopes, but the more recent waves of mergers and acquisitions have likely had a larger impact.

4.4 Role of endogenous firm entry-exit

We next consider the importance of firm entry and exit in this model in the propagation of shocks for business cycle implications. In particular, we compare the model with firm entry and exit and without, as well as with firm entry and exit with $\rho_n = 0$ in (16). In order to conduct this analysis, we set all parameter to the same estimated values, and either allow firm entry/exit, shut off the channel or consider an alternative value of $\rho_n = 0$ to consider a larger variation in number of firms, in the absence of persistence. Figure 7 shows the responses to a number of shocks in the baseline model, along with one where we do not allow for firm entry and exit and set $\widehat{N}_t = 0$. A contractionary monetary policy shock, shown in the top panel, has standard effects on macroeconomic variables. In addition, the fall in output due to a rise in interest rates results in firm exit, and the number of firms, N_t, falls. This reduced competition implies that the gross price markup rises, as it is countercyclical, and the gross wage markdown falls. These effects are amplified in the case where we set $\rho_n = 0$. In comparison, in the case where we do not allow firm entry/exit, N is fixed and the gross price markup and wage markdown in the absence of price and wage rigidities, $\theta_{p,t}$ and $\theta_{w,t}$, respectively do not respond, and we see a dampening of the inflation response while the output response is larger.[31] However, note that the differences are quantitatively small. One reason is that we are considering a transitory shock, where the nominal interest rate returns to steady state in about 6 quarters. Also a shock this magnitude, while it results in firm exit and the number of firms deviates from its steady state level of $N = 8$, the movement is too small to generate more meaningful shifts in the Phillips curve seen in the previous sections.

The second panel of Figure 7 shows the responses to a positive technology shock, which leads to a rise in output and consumption and a fall in inflation. In this case, since this is an expansionary shock, the number of firms, N_t rises. Due to increased competition, the price markup falls and the wage markdown is reduced, as evident in (20) and (28), respectively. Overall relative to a model with no firm entry and exit, we thus see a relatively dampened response of inflation in the baseline case. Again, these effects are most visible when we consider firm entry/ exit with $\rho_n = 0$. Similarly, the lower wage markdown leads to higher wages and thus higher labor supply in a model with firm entry and exit. The output response in a model with firm entry and exit is smaller because total fixed costs increase as number of firms rises (see (33), where the second term dominates the first

competitive fringe firms that follow the pricing decisions of the industry leaders.

[31] After detrending and log-linearization, the long-run target number of firms can be written as

$$\widehat{N}_t^* = \widehat{y}_t + \frac{\theta_p}{\theta_p - [(1-\alpha)\,\theta_w + \alpha]} \left(\widehat{\theta}_{p,t} - \frac{(1-\alpha)\,\theta_w}{(1-\alpha)\,\theta_w + \alpha} \widehat{\theta}_{w,t} \right). \tag{32}$$

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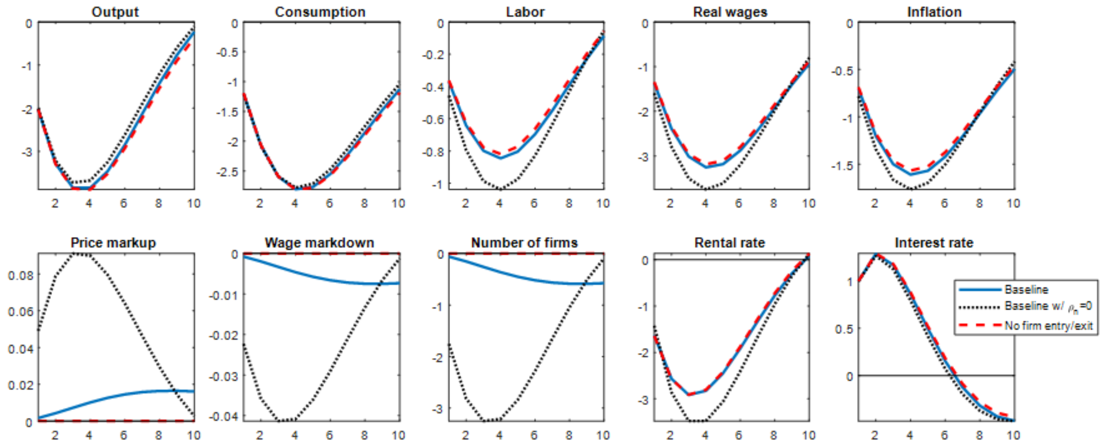
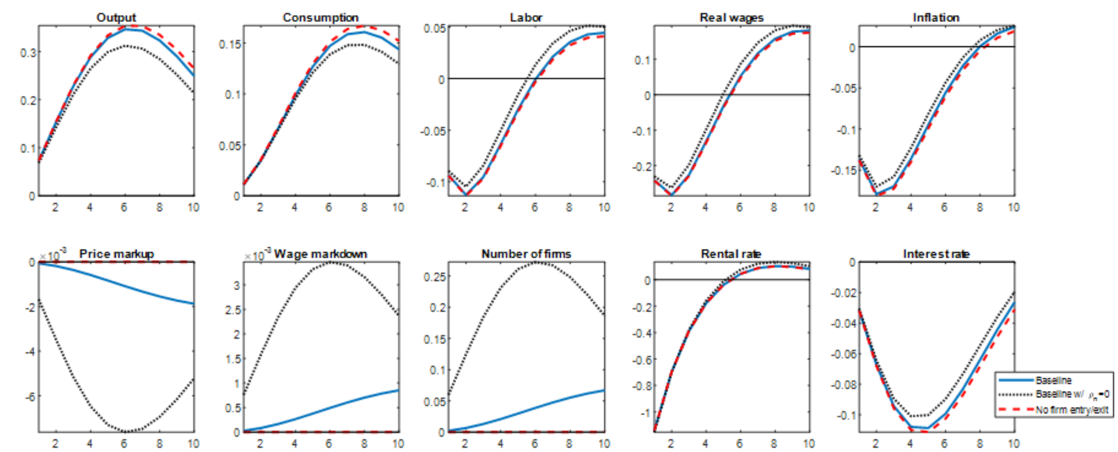
(a) Monetary shock



(b) Technology shock



(c) Wage shock

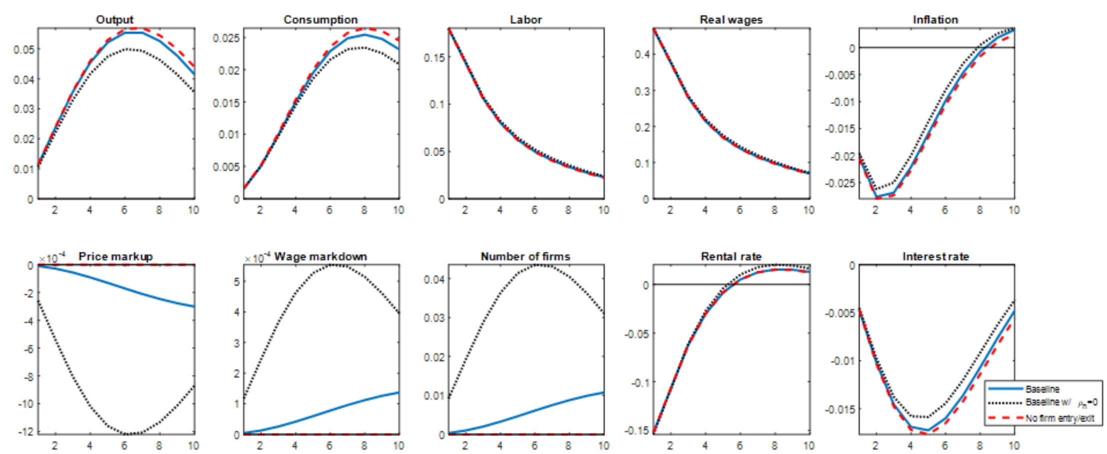


Figure 7: Response to shocks in the baseline estimated model (solid blue), baseline estimated model with $\rho_n = 0$ (black dotted) and one without firm entry/exit (red dashed).

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term given the respective coefficients).[32]

A wage shock has similar effects as a technology shock as it is an expansionary shock which leads to firm entry. Overall, in a model with firm entry and exit, the inflation response is relatively dampened due to declining price markups, and output response is also smaller due to increasing fixed costs.

The results here suggests that in our model, while secular trends in the number of firms plays a large role in explaining steady state shares of labor income or the slope of Phillips curve, smaller fluctuations due to endogenous firm entry and exit driven by transitory shocks also play a non-trivial role, depending on the source of fluctuations.

5 Comparison with oligopolistic competition in labor markets

In this section, we compare the labor market structure considered in this paper with the more commonly used structure in the literature where the labor market power rests with households.

In the baseline model with oligopsonist firms in labor markets presented in Section 2, the aggregate labor supply expression equates the households' marginal rate of substitution with the real wage rate, which, in log-linearized form can be written as

$$\widehat{\xi}_t + \widehat{h}_t + \vartheta \widehat{l}_t = \widehat{w}_t, \tag{34}$$

while the wage Phillips curve expression is obtained from the firms' problem as (27), whereby wage rigidities drive an additional wedge between the marginal product of labor and the real wage rate.

On the other hand, in the standard DSGE framework with labor market power on the household (i.e., supply) side, the wage Phillips curve expression is obtained from the households' problem, whereby wage rigidities drive a wedge between the households' marginal rate of substitution and the real wage rate as

$$\widehat{\pi}_{w,t} = \beta E_t \widehat{\pi}_{w,t+1} + \frac{\chi_l - \frac{1}{N}(\chi_l - \eta_l) - 1}{\kappa_w} \left(\widehat{\xi}_t + \widehat{h}_t + \vartheta \widehat{l}_t - \widehat{w}_t + \widehat{\theta}_{w,t} \right). \tag{35}$$

Note that χ_l and η_l are now interpreted as capturing the elasticity of labor demand at the firm and sectoral levels, respectively. Also, with oligopolistic labor, $\theta_w > 1$ at the steady state; thus, real wages are *marked up* relative to the marginal rate of substitution.[33] Similarly, the firms' problem now implies that the marginal cost of production is also obtained by the ratio of real wages to the

[32]The firm's production function in (10) can be aggregated and log-linearized to give

$$\widehat{y}_t = \left(1 + \frac{Nf}{y}\right) \left[\widehat{z}_t + \alpha \left(\widehat{u}_t + \widehat{N}_t - \widehat{N}_{t-1} + \widehat{k}_{t-1} \right) + (1-\alpha) \widehat{l}_t \right] - \frac{Nf}{y} \widehat{N}_t \tag{33}$$

[33]In this case θ_w, while affecting the steady state labor share of income, does not alter any of the dynamic equations of the model.

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marginal product of labor,

$$\widehat{\Omega}_t + \widehat{z}_t + \alpha\left(\widehat{u}_t + \widehat{k}_{t-1} - \widehat{l}_t\right) = \widehat{w}_t. \tag{36}$$

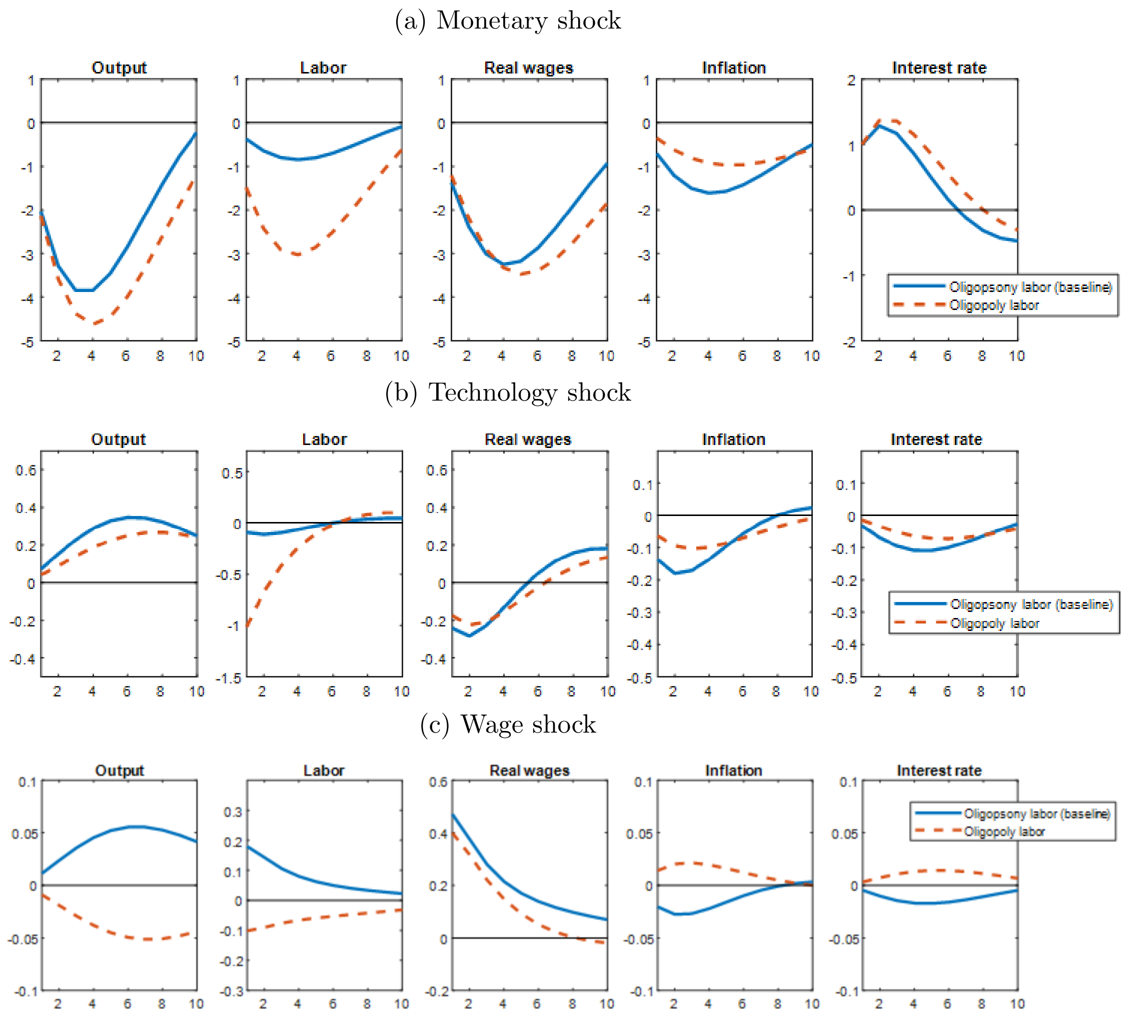

Figure 8: Response to shocks in the baseline model with labor market power on the firm side (solid blue) and alternative model with labor market power on the household side (red dashed).

In order to compare the implications of the labor market structure on the propagation of shocks, we compare the impulse responses of key model variables to shocks under the baseline model with oligopsonistic competition in labor markets versus the alternative model where households have labor market power and engage in oligopolistic competition in labor markets. We set all parameters to the same values across the two models, including those for χ_l and η_l, even though the interpretation of these two parameters are now slightly different as noted earlier.

Figure 8 top panel shows the responses to a monetary policy shock in the two models where the (annualized) nominal interest rate rises 100 bps. It shows that the transmission of the shocks to macroeconomic variables, particularly output and inflation are qualitatively not that different, although there are quantitative differences. In particular, the baseline model with oligopsony labor

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generates significantly weaker impulse responses for the equilibrium levels of labor relative to the oligopoly labor model. Since firms internalize the increase in the marginal cost of hiring an additional worker, they are less inclined to hire labor.

In both models, in response to a positive productivity shock, productivity shifts the firms' marginal cost curve, prompting them to increase their production levels, while cutting prices. The difference in the response of output to a productivity shock across the two models are far less pronounced (see the middle panel of Figure 8). This is primarily since capital utilization compensates for differences in labor on the production side. Inflation responses are also slightly more pronounced in the baseline case relative to the oligopoly labor case, for both technology and monetary shocks. Since capital utilization is higher in the baseline model, this has a larger impact on the rental of rate of capital and therefore the firms' marginal cost of production. In response to a technology shock, the response of labor is significantly muted in the oligopsony case. Positive wealth effects drive down labor supply, while the increase in productivity raises the marginal product of labor, but the decrease in the firm's price lowers their marginal value product. These opposing effects work to generate a negative response of labor in the short-run in the oligopolistic model, and a negligible response of labor in the baseline model with oligopsony. This is an equilibrium result that comes from some of the different factors affecting the household and firms' labor market decisions listed above and the specific parameterization.

In departure from productivity and monetary policy shocks, wage shocks generate qualitatively different dynamics in the two models for most variables of interest. In particular, in the oligopoly labor model, a positive shock to wages acts analogous to an adverse labor supply shock (see the bottom panel of Figure 8). Thus, the wage shock acts as a cost-push shock, effectively increasing the marginal costs of firms, and prompting them to lower their hiring and production levels while increasing their prices. In the baseline model with oligopsony labor however, positive wage shocks temporarily reduce the firm's net markdown in wages, which prompts them to instead increase their hiring and output levels, while cutting prices to be able to sell their increased output.[34] Thus, in equilibrium, a positive shock to the wage markdown leads to an increase, not only in the aggregate real wage rate, but also in aggregate labor, output, consumption and investment, while the inflation rate decreases.

Comparing impulse responses for the other shocks under different labor market power structures reveals that the dynamics are qualitatively similar (not shown). Thus, wage shocks are the exception, whereby they are contractionary in a standard setup with labor market power on the household side, but can lead to an increase in hiring and production when labor market power is on the firm side.

[34]Note that an exogenous increase in $\theta_{w,t}$ brings the *gross* markdown closer to 1; hence, the net markdown becomes smaller. In the model with oligopsony in the labor market, we introduce these wage shocks in an ad-hoc manner. However, these *i.i.d.* shocks can, for example, result from exogenous variation in the within- and across-sector demand elasticities, χ_y and η_y, both of which are assumed to be constant in our setup.

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6 Conclusion

This paper analyzes how changes in industry concentration can affect the slope of the Phillips curves as well as the labor share of income within the context of a medium-scale New Keynesian DSGE model with oligopsonistic competition in labor markets and oligopolistic competition in goods markets. The results indicate that an increase in industry concentration would lead to a flattening of the aggregate price and wage Phillips curves, and the increase in the oligopoly and the oligopsony power of firms in product and labor markets would result in a decline in the labor's income share as well as a weaker pass-through from productivity shocks to real wages. Fully accounting for these patterns through increased industry concentration would require a duopoly-duopsony structure within sectors, indicating that industry concentration can explain these developments only partially.

In terms of the policy implications of the paper, the results indicate that the Federal Trade Commission's recent stance of allowing mergers to go through uncontested when there are at least five remaining significant competitors may be by and large appropriate, as the effects of an increase in market power seem to be modest when there are more than five competitors. Given the results on wage shocks, the model also support the notion that higher minimum wages may not necessarily hurt the employment prospects of the lowest-paid households, if the related labor markets are characterized by oligopsony power. Finally, the analysis here indicates that increased industry concentration may have implications for monetary policy as well, since it does not solely affect the steady-state markup of firms, but also flattens the Phillips curves. While the former would not alter the monetary policy stance of the Federal Reserve from an optimal policy perspective (Ramey, 2018), the latter would lead to a worsening of the trade-off faced by the central bank with respect to cost-push shocks, while also increasing the effectiveness of monetary policy shocks on real variables (Kuttner and Robinson, 2010).

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A Details on the Model

A.1 Households

The economy is populated by a unit measure of infinitely-lived households, whose intertemporal preferences over consumption, c_t, and aggregate labor, l_t, are described by the following expected utility function:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \upsilon_\tau \left(\log\left(c_\tau - \zeta \overline{c}_{\tau-1}\right) - \xi_\tau \Theta_\tau \frac{l_\tau^{1+\vartheta}}{1+\vartheta} \right), \tag{37}$$

where t indexes time, $\beta < 1$ is the time-discount parameter, $\overline{c}_t$ denotes aggregate consumption, ζ is the (external) habit parameter, and $1/\vartheta$ is the Frisch-elasticity of aggregate labor supply. The time-preference shock, υ_t, follows an exogenous AR(1) process:

$$\log \upsilon_t = \rho_\upsilon \log \upsilon_{t-1} + \varepsilon_{\upsilon,t}, \tag{38}$$

where ρ_υ is the persistence parameter, and $\varepsilon_{\upsilon,t}$ is an *i.i.d.* normal innovation with mean 0 and standard deviation σ_υ. Similarly, ξ_t is a labor supply shock, modeled as an AR(1) process as well.[35] Θ_t is a labor supply externality, which helps reduce the income-elasticity of labor supply in the short-run as in Gali et al. (2012) and Jaimovich and Rebelo (2009). The specification here follows Gali et al. (2012), which preserves the existence of a balanced growth path with

$$\Theta_t = \frac{h_t}{\overline{c}_t - \zeta \overline{c}_{t-1}}, \text{ with } h_t = \left(\overline{c}_t - \zeta \overline{c}_{t-1}\right)^{\varrho} h_{t-1}^{1-\varrho}, \tag{39}$$

where h_t is the trend level of (surplus) consumption and ϱ is a persistence parameter which regulates the strength of the income-elasticity of labor supply in the short run. In particular, setting $\varrho = 1$ eliminates the externality altogether, while lowering ϱ towards 0 weakens the short-run income-elasticity of labor supply.[36]

The households' period budget constraint is given by

$$c_t + q_t \left[k_t - (1-\delta) k_{t-1}\right] + \frac{B_t}{\phi_t R_t P_t} \leq \frac{W_t}{P_t} l_t + r_{k,t} k_{t-1} + \frac{B_{t-1}}{P_t} + \frac{\Pi_t}{P_t} - \frac{T_t}{P_t}, \tag{40}$$

where P_t is the aggregate price index, k_t denotes capital, q_t is the relative price of installed capital, B_t is holdings of 1-period government bonds, R_t is the nominal interest rate set by the central bank, W_t is the aggregate nominal wage rate, $r_{k,t}$ is the real rental rate of capital, Π_t denotes the pure profits of firms, and T_t refers to lump-sum taxes paid to the government. ϕ_t is a risk-premium shock, specified as an exogenous AR(1) process, which drives a wedge between the risk-free rate and

[35] In what follows, we denote the persistence and standard deviation of all shocks as ρ and σ, respectively, with appropriate subscripts corresponding to each shock.

[36] Note that shocks that lead to an increase in aggregate consumption also reduce the labor supply externality term Θ_t, thereby reducing the short-run income-elasticity of labor supply. This feature is not key to obtain the main results in the paper, but provides a slightly better fit to the data by altering the short-run dynamics of labor with respect to productivity shocks.

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the cost-of-capital relevant for investment, thus affecting both the consumption and the investment demand equations simultaneously and generating co-movement in the model (Smets and Wouters, 2007).[37]

The households' objective is to maximize their utility subject to the budget constraint and appropriate No-Ponzi conditions. The first-order-conditions with respect to consumption, labor, government bonds and capital that arise from the households' problem are respectively given by

$$\frac{\upsilon_t}{c_t - \zeta c_{t-1}} = \lambda_t, \tag{41}$$

$$\xi_t h_t l_t^{\vartheta} = w_t, \tag{42}$$

$$1 = E_t \left[\left(\beta \frac{\lambda_{t+1}}{\lambda_t} \right) \frac{R_t \phi_t}{\pi_{t+1}} \right], \tag{43}$$

$$q_t = E_t \left[\left(\beta \frac{\lambda_{t+1}}{\lambda_t} \right) \left[(1-\delta) q_{t+1} + r_{k,t+1} \right] \right], \tag{44}$$

where λ_t denotes the Lagrange multiplier on the budget constraint, $w_t = W_t/P_t$ is the real wage rate, and $\pi_t = P_t/P_{t-1}$ is the aggregate inflation factor.

A.2 Final goods producers and firm-specific goods demand

Similar to the setup for labor supply, the demand curve faced by each intermediate goods firm for its differentiated good is derived by considering the problems of perfectly-competitive final goods and sectoral goods aggregators.[38] The aggregation from sector-specific output goods, $o_t(i)$, to the aggregate output good, o_t, is conducted by perfectly-competitive aggregators using the following function:

$$o_t = \left(\int_0^1 o_t(i)^{\frac{\eta_y - 1}{\eta_y}} di \right)^{\frac{\eta_y}{\eta_y - 1}},$$

where η_y is the elasticity of substitution between the sectoral goods. Thus, the demand curve for sectoral output goods is obtained as

$$o_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\eta_y} o_t, \tag{45}$$

where $P_t(i)$ denotes the price index in sector i, and the aggregate price index, P_t, is given by, $P_t = \left(\int_0^1 P_t(i)^{1-\eta_y} di \right)^{\frac{1}{1-\eta_y}}$.

Similarly, the aggregation from firm-specific goods, $o_t(i,j)$, to sector-specific goods, $o_t(i)$, is

[37] The risk shock can be motivated as a shock to the portfolio preferences or the risk appetite of investors, which prompts them to alternate between "search-for-yield" and "flight-to-safety" type behavior in their demand for holding equity in firms versus holding government bonds (Alpanda, 2013). Similarly, this shock can be interpreted as unexpected changes in the liquidity benefits arising from government bond holdings, such as their use in repo markets (Fisher, 2015).

[38] The setup for goods aggregators is similar to that in Jaimovich and Floetotto (2008).

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conducted by perfectly-competitive aggregators using the following function:

$$o_t(i) = N_t^{-\frac{1}{\chi_y - 1}} \left(\sum_{j=1}^{N_t} o_t(i,j)^{\frac{\chi_y - 1}{\chi_y}} \right)^{\frac{\chi_y}{\chi_y - 1}},$$

where χ_y is the elasticity of substitution between the firm-specific goods. Following Jaimovich and Floetotto (2008), we assume that $\chi_y > \eta_y$, implying that goods within a sector are more substitutable than goods across sectors. Similar to the setup for labor supply, the variety effect on sectoral output is eliminated and thus, in a symmetric equilibrium, $N_t o_t(i,j) = o_t(i) = o_t$ for all i and j. The resulting demand curve for firm-specific goods is then obtained as

$$o_t(i,j) = \left(\frac{P_t(i,j)}{P_t(i)} \right)^{-\chi_y} \frac{o_t(i)}{N_t}, \tag{46}$$

where $P_t(i,j)$ denotes the price of the output good of firm j in sector i, and the sector-specific price index in sector i is given by

$$P_t(i) = N_t^{\frac{1}{\chi_y - 1}} \left(\sum_{j=1}^{N_t} P_t(i,j)^{1-\chi_y} \right)^{\frac{1}{1-\chi_y}}, \tag{47}$$

with $P_t(i,j) = P_t(i) = P_t$ for all i and j in a symmetric equilibrium.

Combining (45) and (46), the goods demand curve facing firm j in sector i is given by

$$o_t(i,j) = \left(\frac{P_t(i,j)}{P_t(i)} \right)^{-\chi_y} \left(\frac{P_t(i)}{P_t} \right)^{-\eta_y} \frac{o_t}{N_t}, \tag{48}$$

where the firm takes into account that its firm-specific price, $P_t(i,j)$, will impact the sector-specific price index, $P_t(i)$, based on equation (47). The derivative of the sectoral price index to firm-specific prices is given by

$$\frac{\partial P_t(i)}{\partial P_t(i,j)} = \left(\frac{P_t(i)}{P_t(i,j)} \right)^{\chi_y} \frac{1}{N_t}, \tag{49}$$

which indicates that the pass-through from the firm-specific to the sectoral price level is inversely related to the number of firms in each sector.[39]

A.3 Capital producers

Capital producers are perfectly competitive. After goods production takes place, these firms purchase the undepreciated part of the installed capital from households at a relative price of q_t, and the new investment goods, x_t, from final goods producers at a (relative) price of 1, and produce the

[39] Thus, when $N_t = 1$, there is complete pass-through to sectoral prices with the own-price elasticity of demand faced by a single firm equaling $-\eta_y$, while as N_t increases, the pass-through is weakened and demand facing the firm effectively becomes more elastic, approaching $-\chi_y$.

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capital stock to be carried over to the next period. This production is subject to adjustment costs in the change in investment, and is described by the following law-of-motion for capital:

$$k_t = (1 - \delta_k)\, k_{t-1} + \left[1 - \frac{\kappa_x}{2}\left(\frac{x_t}{\gamma x_{t-1}} - 1\right)^2\right] \psi_t x_t, \tag{50}$$

where κ_x is the adjustment cost parameter, and ψ_t denotes shocks to investment-specific technological change following an AR(1) process.

After capital production, the end-of-period installed capital stock is sold back to households at the installed capital price of q_t. The capital producers' objective is thus to maximize

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\lambda_\tau}{\lambda_t} \left[q_\tau k_\tau - q_\tau (1-\delta)\, k_{\tau-1} - x_\tau\right], \tag{51}$$

subject to the law-of-motion of capital, where future profits are discounted using the patient households' stochastic discount factor. The first-order-condition of capital producers with respect to investment goods yields an investment demand expression relating investment to Tobin's marginal q, which, after detrending and log-linearization, can be written as[40]

$$\widehat{x}_t - \widehat{x}_{t-1} = \beta \left(E_t \widehat{x}_{t+1} - \widehat{x}_t\right) + \frac{1}{\kappa_x}\left(\widehat{q}_t + \widehat{\psi}_t\right). \tag{52}$$

A.4 Log-linearized equilibrium conditions

This subsection lists the equilibrium conditions of the model presented in Section 2 after detrending and log-linearization. A "hat" above a variable denotes the log-deviation of the detrended variable from its steady state (e.g., $\widehat{c}_t = \log\left(c_t/\gamma^t\right) - \log \overline{c}$).[41]

Consumption demand

$$\widehat{c}_t = \frac{\zeta/\gamma}{1+\zeta/\gamma}\widehat{c}_{t-1} + \frac{1}{1+\zeta/\gamma}E_t\widehat{c}_{t+1} - \frac{1-\zeta/\gamma}{1+\zeta/\gamma}\left(\widehat{R}_t - E_t\widehat{\pi}_{t+1} + \widehat{\phi}_t\right) + \widehat{\widehat{\upsilon}}_t \tag{53}$$

Investment demand

$$\widehat{x}_t = \frac{1}{1+\beta}\widehat{x}_{t-1} + \frac{\beta}{1+\beta}E_t\widehat{x}_{t+1} + \frac{1}{(1+\beta)\,\kappa_x}\left(\widehat{q}_t + \widehat{\psi}_t\right) \tag{54}$$

Aggregate labor supply

$$\widehat{\xi}_t + \widehat{h}_t + \vartheta \widehat{l}_t = \widehat{w}_t \tag{55}$$

[40] Note that the model counterpart of Tobin's marginal q is given by $q_t\psi_t$, which is the price of installed capital (q_t) relative to its replacement cost ($1/\psi_t$).

[41] k_t is detrended by γ^{t+1} for convenience.

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Labor supply externality

$$\widehat{h}_t = \frac{\varrho}{1-\zeta/\gamma}\left(\widehat{c}_t - \frac{\zeta}{\gamma}\widehat{c}_{t-1}\right) + \left(\frac{1-\varrho}{\gamma}\right)\widehat{h}_{t-1} \tag{56}$$

Relative price of capital

$$\widehat{q}_t = (1-\delta)\frac{\beta}{\gamma}E_t\widehat{q}_{t+1} + \left[1-(1-\delta)\frac{\beta}{\gamma}\right]E_t\widehat{r}_{k,t+1} - \left(\widehat{R}_t - E_t\widehat{\pi}_{t+1} + \widehat{\phi}_t\right) \tag{57}$$

Law of motion of capital

$$\widehat{k}_t = \left(\frac{1-\delta}{\gamma}\right)\widehat{k}_{t-1} + \left(1 - \frac{1+\delta}{\gamma}\right)\left(\widehat{x}_t + \widehat{\psi}_t\right) \tag{58}$$

Production function

$$\widehat{y}_t = \left(1+\frac{Nf}{y}\right)\left[\widehat{z}_t + \alpha\left(\widehat{u}_t + \widehat{N}_t - \widehat{N}_{t-1} + \widehat{k}_{t-1}\right) + (1-\alpha)\,\widehat{l}_t\right] - \frac{Nf}{y}\widehat{N}_t \tag{59}$$

Number of firms in each sector

$$\widehat{N}_t = \rho_N\widehat{N}_{t-1} + (1-\rho_N)\left[\widehat{y}_t + \frac{\theta_p}{\theta_p - [(1-\alpha)\,\theta_w + \alpha]}\left(\widehat{\theta}_{p,t} - \frac{(1-\alpha)\,\theta_w}{(1-\alpha)\,\theta_w + \alpha}\widehat{\theta}_{w,t}\right)\right] + \widetilde{\varepsilon}_{N,t} \tag{60}$$

Marginal cost of production

$$\widehat{\Omega}_t + \widehat{z}_t + (\alpha-1)\left(\widehat{u}_t + \widehat{N}_t - \widehat{N}_{t-1} + \widehat{k}_{t-1} - \widehat{l}_t\right) = \widehat{r}_{k,t} \tag{61}$$

Capital utilization rate

$$\widehat{u}_t = \frac{1}{\varpi}\widehat{r}_{k,t} \tag{62}$$

Price Phillips curve

$$\widehat{\pi}_t = \frac{\varsigma_p}{1+\beta\varsigma_p}\widehat{\pi}_{t-1} + \frac{\beta}{1+\beta\varsigma_p}E_t\widehat{\pi}_{t+1} + \frac{(1-s_m)\left(\chi_y - \frac{\chi_y-\eta_y}{N}\right)-1}{(1+\beta\varsigma_p)\,\kappa_p}\left(\widehat{\Omega}_t + \widehat{\theta}_{p,t}\right) + \widetilde{\varepsilon}_{p,t} \tag{63}$$

Price markup

$$\widehat{\theta}_{p,t} = -(1-s_m)\left(\frac{\chi_y-\eta_y}{N}\right)\frac{(\theta_p-1)^2}{\theta_p}\widehat{N}_t \tag{64}$$

Relating nominal wage inflation and real wage growth

$$\widehat{\pi}_{w,t} - \widehat{\pi}_t = \widehat{w}_t - \widehat{w}_{t-1} \tag{65}$$

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Wage Phillips curve

$$\widehat{\pi}_{w,t}-\varsigma_w\widehat{\pi}_{t-1}=\beta\left(E_t\widehat{\pi}_{w,t+1}-\varsigma_w\widehat{\pi}_t\right)+\frac{\chi_l-\left(\frac{\chi_l-\eta_l}{N}\right)+1}{\kappa_w}\left[\widehat{\Omega}_t+\widehat{z}_t+\alpha\left(\widehat{u}_t+\widehat{N}_t-\widehat{N}_{t-1}+\widehat{k}_{t-1}-\widehat{l}_t\right)-\widehat{w}_t+\widehat{\theta}_{w,t}\right]+\widetilde{\varepsilon}_{w,t} \tag{66}$$

Wage markdown

$$\widehat{\theta}_{w,t}=\left(\frac{\chi_l-\eta_l}{N}\right)\frac{\left(1-\theta_w\right)^2}{\theta_w}\widehat{N}_t \tag{67}$$

Goods market clearing

$$\frac{c}{y}\widehat{c}_t+\frac{x}{y}\widehat{x}_t+\frac{g}{y}\widehat{g}_t=\widehat{y}_t \tag{68}$$

Taylor rule

$$\widehat{R}_t=\rho\widehat{R}_{t-1}+\left(1-\rho\right)\left(a_\pi\widehat{\pi}_t+a_y\widehat{y}_t\right)+\widetilde{\varepsilon}_{R,t} \tag{69}$$

In the above expressions, the steady-state share of government expenditure, g/y, can be treated as a parameter, while the share of investment is given by $x/y=\left(\gamma-1+\delta\right)k/y$, where $k/y=\alpha\left(1+Nf/y\right)/\left[\theta_p\left(\gamma/\beta-1+\delta\right)\right]$ with $Nf/y=\theta_p/\left[\left(1-\alpha\right)\theta_w+\alpha\right]-1$, and the share of consumption can be calculated as a residual, $c/y=1-x/y-g/y$. Note that the steady-state price markup is $\theta_p=\left(1-s_m\right)\left(\chi_y-\frac{\chi_y-\eta_y}{N}\right)/\left[\left(1-s_m\right)\left(\chi_y-\frac{\chi_y-\eta_y}{N}\right)-1\right]$, while the steady-state wage markdown is $\theta_w=\left(\chi_l-\frac{\chi_l-\eta_l}{N}\right)/\left(\chi_l-\frac{\chi_l-\eta_l}{N}-1\right)$. Finally, the preference shock is rescaled without loss of generality as $\widehat{\widehat{\upsilon}}_t=\left[\left(1-\zeta/\gamma\right)\left(1-\rho_\upsilon\right)/\left(1+\zeta/\gamma\right)\right]\widehat{\upsilon}_t$ to facilitate easier estimation.

B Details on the Estimation

B.1 Calibrated parameters

As noted in the main text, several parameters are calibrated prior to the estimation. Also, there are restrictions imposed on the cross-sector labor supply elasticity parameter, η_l, for better identification, and the size of total fixed costs relative to GDP, Nf/y, to ensure zero profits in the long run of the

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baseline case. Table B1 presents these calibrated parameter values and restrictions.

Table B1. Calibrated values and restrictions used in the estimation

	Symbol	Value
Trend growth factor	γ	1.005
Time-discount factor	β	0.995
Depreciation rate of capital	δ	0.02
Capital share in production	α	0.3
Share of materials in gross output	s_m	0.45
Share of gov. expenditure in GDP	g/y	0.2
Steady-state no. of firms within each sector	N	8
Cross-sector labor supply elasticity	η_l	$= 1/\vartheta$
Fixed costs relative to GDP	Nf/y	$= \frac{\theta_p}{(1-\alpha)\theta_w+\alpha} - 1$

B.2 Data

We use 8 quarterly data series from the U.S. between 1990Q1-2020Q1 in the estimation. We start from 1990Q1 to capture the more recent stance of the Federal Reserve towards inflation in the post-war period, and end in 2020Q1 to exclude the effects of the Coronavirus crisis. The observables used in the estimation are GDP ($\widehat{y}_t$), consumption ($\widehat{c}_t$), investment ($\widehat{x}_t$), labor ($\widehat{l}_t$), real wage rate ($\widehat{w}_t$), inflation rate ($\widehat{\pi}_t$), the policy rate ($\widehat{R}_t$), and the number of firms ($\widehat{N}_t$). The quarterly series for the number of firms is derived using the number of establishments reported in the *Quarterly Census of Employment and Wages* (QCEW) of the Bureau of Labor Statistics (BLS). The rest of the data are obtained from the National Income and Product Accounts (NIPA) of the Bureau of Economic Analysis (BEA) and the FRED database of the Federal Reserve Bank of St. Louis.

Nominal figures are converted into real using the GDP deflator. The consumption series excludes durable goods, where the latter is added to the total investment series instead. For labor hours, we use the index series *Nonfarm Business Sector: Hours of All Persons*, constructed by the BLS. The real wage rate is constructed using the *Average Hourly Earnings of Production and Nonsupervisory Employees* in the private sector, also from the BLS. The policy rate refers to the effective Federal Funds rate, and was converted from monthly to quarterly by simple averaging. For the 2009Q3-2015Q4 period where the policy rate was at the zero lower bound, we replace the series with the *shadow* Federal Funds rate constructed by Wu and Xia (2016), thereby capturing the effects of unconventional monetary policy on the policy rate during this period. All relevant series were rendered per-capita by dividing by working-age population, and HP-filtered (except for inflation and the policy rate) prior to estimation.

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B.3 Prior and posterior distributions

Tables B2a and B2b report the prior distributions used for the estimated structural and shock parameters, respectively, along with the corresponding estimates for the posterior distribution (mode, mean and the 90% Highest Posterior Density cutoffs). For the Metropolis-Hastings algorithm, we used a single chain of 1,000,000 draws with a 45% initial burn-in phase, and the acceptance rate was around 29%.[42].

The prior specifications are by and large standard in the related DSGE literature, except for the cross-sector and within-sector goods demand and labor supply elasticities. For these, we use normally-distributed priors with means picked based on the following considerations: Hobijn and Nechio (2017) use a local projection method and European Union expenditure data at the 3-digit expenditure categories ("classes") around value-added tax changes, and find a cross-sector elasticity of substitution of around 3 with an upper bound of 5, while the parameterization used in Jaimovich and Floetotto (2008) implies an elasticity of substitution across sectors of close to 1. As a compromise, we set the prior mean for the cross-sector elasticity parameter, η_y, equal to 2. The within-sector elasticity of substitution used in the related literature is typically larger and ranges between 3 and 20, with a value of 3 in Midrigan (2011), 4 in Nakamura and Steinsson (2010), 5 in Eusepi et al. (2011), 7 in Carvalho and Nechio (2016), 8 in Woodford (2003) and Bouakez et al. (2009), 10 in Carvalho and Nechio (2011), 11 in Carvalho (2006), Hobijn et al. (2006), and Karadi and Reiff (2008), and close to 20 in Jaimovich and Floetotto (2008).[43] We thus use a value of 12 for

[42] We monitor and confirm convergence using trace plots and the chi-square convergence diagnostic test of Geweke (1999).

[43] See Figure 1 of the 2015 version of Hobijn and Nechio (2017) for a summary of this related literature.

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the prior mean of the within-sector elasticity parameter, χ_y.

Table B2a. Estimated structural and policy parameters (post-84 data)

	Symbol	Prior[a]	Posterior Mode	Posterior Mean	Posterior 90% HPD interval
Goods demand elast. of subst. - within sector	η_y	N(12,1)	9.9582	10.0799	[8.2808 - 11.9056]
- across sectors	χ_y	N(2,0.25)	1.9790	1.9831	[1.5641 - 2.3830]
Labor supply elasticity - within sector	η_l	N(10,1)	11.1791	11.1402	[9.5570 - 12.6602]
Habit in consumption	ζ	B(0.5,0.2)	0.9736	0.9097	[0.8319 - 0.9872]
Inverse aggregate labor supply elast.	ϑ	G(2,0.25)	2.5078	2.6179	[2.1720 - 3.0574]
Externality in labor supply	ϱ	B(0.5,0.2)	0.0030	0.0314	[0.0001 - 0.0955]
Investment adj. cost	κ_x	G(8,1.5)	6.5137	5.4688	[3.4396 - 7.6314]
Utilization cost elasticity	ϖ	G(1,0.5)	0.3053	0.3890	[0.0865 - 0.6562]
Price adjustment cost	κ_p	N(200,25)	236.3397	236.0242	[198.829 - 274.3852]
Wage adjustment cost	κ_w	N(200,25)	168.8219	169.5151	[124.7724 - 218.5151]
Indexation - price	ς_p	B(0.5,0.2)	0.9015	0.8156	[0.6628 - 0.9824]
- wage	ς_w	B(0.5,0.2)	0.6419	0.5875	[0.2856 - 0.8850]
Taylor rule - persistence	ρ	B(0.5,0.2)	0.8715	0.8697	[0.8376 - 0.9013]
- inflation	a_π	G(2,0.25)	1.7946	1.8766	[1.5385 - 2.2012]
- output gap	a_y	G(0.125,0.05)	0.2065	0.1965	[0.0763 - 0.3145]
Persistence in firm entry	ρ_N	B(0.5,0.2)	0.9737	0.9708	[0.9544 - 0.9875]

Note: (a) For the prior distributions, B stands for beta, G for gamma, IG for inverse gamma, and N for normal distribution.

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Table B2b. Estimated shock parameters (post-84 data)					
			Posterior		
	Symbol	Prior[a]	Mode	Mean	90% HPD interval
Persistence					
- risk	ρ_ϕ	B(0.5,0.2)	0.7450	0.8485	[0.6696 - 0.9736]
- preference	ρ_υ	B(0.5,0.2)	0.1192	0.1509	[0.0340 - 0.2570]
- investment	ρ_ψ	B(0.5,0.2)	0.4980	0.3587	[0.0806 - 0.6750]
- gov. exp.	ρ_g	B(0.5,0.2)	0.8514	0.8493	[0.7818 - 0.9158]
- productivity	ρ_z	B(0.5,0.2)	0.8266	0.7303	[0.5247 - 0.9845]
- labor supply	ρ_ξ	B(0.5,0.2)	0.8472	0.8410	[0.7826 - 0.8989]
- price	ρ_p	B(0.5,0.2)	0.0556	0.1049	[0.0120 - 0.1942]
- wage	ρ_p	B(0.5,0.2)	0.0533	0.0820	[0.0123 - 0.1483]
- monetary	ρ_R	B(0.5,0.2)	0.6632	0.6501	[0.5449 - 0.7541]
- firm entry	ρ_n	B(0.5,0.2)	0.0716	0.0935	[0.0173 - 0.1675]
Standard deviation					
- risk	σ_ϕ	IG(0.005,∞)	0.0198	0.0110	[0.0014 - 0.0281]
- preference	σ_υ	IG(0.005,∞)	0.0019	0.0018	[0.0015 - 0.0021]
- investment	σ_ψ	IG(0.005,∞)	0.0023	0.0375	[0.0012 - 0.0736]
- gov. exp.	σ_g	IG(0.005,∞)	0.0151	0.0152	[0.0137 - 0.0168]
- productivity	σ_z	IG(0.005,∞)	0.0044	0.0057	[0.0016 - 0.0092]
- labor supply	σ_ξ	IG(0.005,∞)	0.0188	0.0200	[0.0165 - 0.0234]
- price	σ_p	IG(0.005,∞)	0.0022	0.0020	[0.0016 - 0.0024]
- wage	σ_w	IG(0.005,∞)	0.0101	0.0099	[0.0087 - 0.0112]
- monetary	σ_R	IG(0.005,∞)	0.0009	0.0010	[0.0008 - 0.0011]
- firm entry	σ_n	IG(0.005,∞)	0.0038	0.0038	[0.0034 - 0.0042]

Recent micro-level studies on the firm-specific (within-sector) labor supply elasticity, χ_l, suggest a fairly inelastic labor supply. In particular, Staiger et al. (2010) estimates that nurses' labor supply to individual U.S. Veterans Administration hospitals has a short-run elasticity of around 0.1. Ransom and Sims (2010) and Falch (2010) estimate labor supply elasticity of teachers to individual schools in Missouri and Norway to be around 3.7 and 1.4, respectively. Hirsch et al. (2010) calculate a firm-specific labor supply elasticity between 1.9 and 2.6 for female and between 2.5 to 3.7 for male workers in western Germany. Similarly, Ransom and Oaxaca (2010) analyze grocery store chains in the U.S., and report a firm-specific labor supply elasticity between 1.5-2.5 for female and between 2.4-3.0 for male workers. As noted, these figures would indicate a fairly inelastic firm-specific labor supply elasticity, along with a significant amount of labor market power on behalf of firms leading to a markdown of wages relative to marginal product of labor in the order of 25%-35%. However, earlier studies on the issue, such as Nelson (1973), indicate a much more elastic labor supply to

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individual firms in the U.S., with estimates closer to 20, which would imply a 5% markdown on wages. Based on these figures, we use a prior mean value of 10 for the firm-specific labor supply elasticity parameter, χ_l. The labor supply elasticity at the sectoral level, η_l, is likely lower than χ_l, indicating less willingness of workers to switch jobs across sectors, relative to within a sector, for the same wage differential. There is not adequate micro-level evidence on this parameter however, and thus, we provide identification by assuming that the sectoral labor supply elasticity, η_l, is equal to the households' labor supply elasticity in the aggregate, $1/\varphi$, and impose this restriction in the estimation.

The estimates for the parameters that affect the Phillips curve slopes are discussed in the main text. The other parameter estimates are fairly standard. The Taylor rule parameters indicate an interest rate persistence, ρ, of 0.87, and long-run response coefficients for inflation, a_π, and output gap, a_y, of 1.88 and 0.2, respectively. The relatively high etimate for the inflation response is consistent with the evidence in the literature regarding the Federal Reserve's stance towards inflation during the Great Moderation period (Clarida et al., 1999). The estimate for the labor supply externality, ϱ, indicate a very low income-elasticity of labor supply in the short run, and the investment adjustment costs parameter, κ_x, indicates that the elasticity of investment to Tobin's q is around 0.18. The habit parameter, ζ, has a posterior mean of 0.91, consistent with earlier estimates in the DSGE literature. Similarly, the estimate for the utilization parameter, ϖ, implies that the elasticity of capacity utilization with respect to the rental rate of capital is around 2.6, while the estimate for the wage indexation parameter, ς_w, indicates that indexation to past inflation is fairly important in wage-setting. Finally, the shock processes are estimated to be fairly persistent, except for the preference, price, wage, and firm entry shocks.

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