Business Cycles with Oligopsonistic Competition in Labor Markets*

Sami Alpanda†
University of Central Florida

First version: October 2018
This version: November 2018

Abstract

Industry concentration has increased over the last few decades, raising the market power of firms in both product and labor markets. In this paper, I analyze the secular and business cycle implications of firms having oligopsony power in labor markets, as well as oligopoly power in goods markets, within the context of a New Keynesian dynamic stochastic general equilibrium model. The model features a continuum of sectors, each of which has a finite number of firms that engage in Cournot competition in goods and labor markets. The results indicate that an increase in industry concentration would lead to a flattening of the aggregate Phillips curve, as pricing decisions become less sensitive to changes in the marginal cost of firms. Relatedly, the increase in the oligopsony power of firms in the labor market would result in a decline in labor's share in total income and a weaker pass-through from productivity shocks to real wages.

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

JEL Classification: E25, E32, L13.

*I thank Berrak Bahadir, Simcha Barkai, Roberto Burguet, Gino Cateau, Bart Hobijn, Serdar Kabaca, Ken Kuttner, Federico Mandelman, Harry Paarsch, Tim Robinson, Eric Schmidbauer, and seminar participants at Southern Economic Association meetings 2018 for suggestions and comments. All remaining errors are my own.

†University of Central Florida, Department of Economics, College of Business, 4336 Scorpius Street, Orlando, FL 32816. Phone: (407) 823-1575, e-mail: sami.alpanda@ucf.edu.

1 Introduction

Industry concentration has increased significantly in recent decades. Autor et al. (2017a) document that, between 1982 and 2012, the sales share of the top 4 firms within each manufacturing sector has increased from 38% to 43% on average, while there has been a comparable increase in other industries; namely 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) document similar findings of rising concentration using Herfindahl-Hirschman indexes (HHI) for U.S. industries, and attribute this to the globalization of markets and the value chain as well as the introduction of new technologies, which have led to the proliferation of large "superstar" firms in many industries and transformed these markets into the "winner-take-most" variety.[1] An important example of this phenomenon is in the market for smartphones, where Apple and Samsung control about three fourths of the U.S. market. Similarly, four companies (Verizon, AT&T, T-Mobile and Sprint) make up essentially the whole market for wireless carriers.

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 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. Thus, an increase in industry concentration could enhance firms' market power in wage setting, especially when labor markets are characterized more in line with monopsonistic or oligopsonistic competition (Azar et al., 2017). Recent evidence from a variety of settings suggests that firms face upward-sloping labor supply curves, indicating that they possess monopsony power in labor markets to some degree (Boal and Ransom, 1997; Manning, 2011). For example, Staiger et al. (2010) estimate a fairly low firm-specific labor supply elasticity for nurses in U.S. Veterans Administration hospitals, while Ransom and Sims (2010) and Falch (2010) find similar results in the context of teacher labor supply to individual schools in Missouri and in Norway, respectively.[2] 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.[3]

The increase in industry concentration since the 1980s has been accompanied by several other developments in the economy: First, the share of aggregate income that has accrued to labor has

[1] See Grullon et al. (2016) and Van Reenen (2018) for a brief summary of arguments put forward to explain the increase in industry concentration, including the weakening of anti-trust enforcement, increase in the regulatory burden, and the rise in technological barriers to entry.

[2] Also see Hirsch et al. (2010), who document upward-sloping labor supply curves in the context of the German labor market. The aforementioned studies typically estimate a fairly low firm-specific labor supply elasticity, while earlier studies, such as Nelson (1973), indicate that labor supply curves to individual firms in the U.S. are fairly elastic on average.

[3] For example, 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.

declined over the same period. Figure 1 plots three different measures for labor's 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 a methodology similar to Cooley and Prescott (1995), which allocates proprietor's income to labor and capital in the same proportion as the rest of the economy.[4] These measures suggest that the labor share in total income has declined by about 3 to 5 percentage points (pp) since the early 1980s, with a strengthening in the declining trend since the 2000s.[5] 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. The second and related development is with regards to the stagnation of labor compensation relative to labor productivity. Giandrea and Sprague (2017) report that the gap between labor productivity growth and compensation growth 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 the 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. The third development is the flattening of the Phillips curve since the mid-1990s. 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.[6] There are likely many different factors behind each of the developments listed above, but the rise in industry concentration in product and labor markets is one that can weave across these developments and account for them simultaneously.[7]

In this paper, I analyze the secular and business cycle implications of firms having oligopsony power in labor markets as well as oligopoly power in product markets, within the context of a New

[4] In the Cooley and Prescott (CP) measure, the labor's income share is calculated as the ratio of compensation of employees to the sum of compensation, rental income, corporate profits, net interest income, business current transfer payments, current surplus of government enterprises and consumption of fixed capital. Proprietors' income and taxes on production and imports net of subsidies are thus allocated to labor and capital income in the same proportion as the rest of the economy. (In contrast, the Giandrea and Sprague (GS2017) 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.

[5] 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. Bental and Demougin (2010) and Blanchard and Giavazzi (2003) argue that the decline in labor share is related to the decline in the bargaining power of labor.

[6] Beaudry and Doyle (2000) report a similar decline in the slope of the Phillips curve in Canada during the 1990s. Also see Figure 3.5 in IMF's World Economic Outlook in April 2012, which shows a similar pattern for inflation and cyclical unemployment averaged over G7 countries. Dotsey et al. (2017) show that forecasts from Phillips curve models tend to be inferior to univariate forecasting models of inflation, especially for the post-1984 period.

[7] Sbordone (2008) attributes the decrease in the slope of the Phillips curve to rising competition from abroad, while Eichenbaum and Fisher (2007) shows that an increase in the steady-state markup would flatten the Phillips curve in a New Keynesian model where final goods aggregation is via Kimball, rather than Dixit-Stiglitz, aggregators.

Keynesian dynamic stochastic general equilibrium (DSGE) model. The model features a continuum of sectors, each of which has a finite number of firms that engage in Cournot competition in both product and labor markets. Thus, the model extends the oligopolistic competition model in Jaimovich and Floetotto (2008) with oligopsonistic competition in labor markets.[8] The model also features nominal and real rigidities, as in the standard medium-scale New Keynesian framework developed in Christiano et al. (2005) and Smets and Wouters (2007). The model's steady-state parameters are calibrated to match the long-run features of the U.S. economy, while the rest of the parameters that primarily determine dynamics are estimated using Bayesian likelihood techniques and U.S. macroeconomic data. The results from the model indicate that an increase in industry concentration at the sectoral level would lead to a flattening of the aggregate Phillips curve, as pricing decisions become less sensitive to changes in the marginal cost of firms. Relatedly, the increase in the oligopoly and the oligopsony power of firms in product and labor markets results in a decline in labor's share in total income, as well as a weaker pass-through from productivity shocks to real wages. Thus, the model does a good job in replicating the stylized facts described above as industry concentration increases.[9] The model also predicts that increased concentration would lead to, not only a decline in labor's income share, but also a decline in capital's income share, while the share of pure profits in total income would rise. This prediction is consistent with Barkai (2017), 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.

In terms of the theoretical contributions of the paper, this is the first paper in the DSGE literature that attributes labor market power to the demand side (i.e., to firms), rather than to the supply side (i.e., to households) of the labor market. The latter is typically assumed in the standard DSGE framework that has followed Christiano et al. (2005) and Smets and Wouters (2007), which in effect captures the role of labor unions in wage setting, as well as the specialization and differentiation of labor services that are demanded by firms over time.[10] Note however that the role of labor unions has significantly declined in post-war U.S., 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. Thus, it is arguably more realistic to model labor market power to be on the demand side, as is done in this paper, rather than on the supply side, as implemented in the standard DSGE framework. As a result, the wage Phillips curve featured in the baseline model here reflects, not the markup of the real wage rate relative to the marginal rate of substitution of households, but instead the *markdown* of the real wage relative to the marginal value product of labor. Comparing the impulse responses to various shocks in the two models with different labor market power structures reveals that dynamics are nevertheless qualitatively similar in most cases.

[8] Also see Mongey (2018), which also 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.

[9] The model is silent about the underlying causes for the increase in industry concentration however. This is an important issue, which is left for further research.

[10] See, for example, Gnocchi (2009).

The exception to this is “wage shocks”, which act analogous to adverse labor supply shocks in the standard DSGE framework with oligopoly labor. In particular, these shocks increase the markup in wages, leading to a decline in the equilibrium levels of labor services and output, while wages and inflation increase. In the oligopsony labor model here, positive wage shocks reduce the net mark down in wages, leading to a simultaneous increase in the equilibrium levels of wages, labor services, and output.

Another important theoretical result in the paper is that, to a first-order approximation, the model equations are isomorphic to assuming monopolistic versus oligopolistic competition in the goods markets, or to assuming monopsonistic versus oligopsonistic competition in the labor markets.[11] The slopes of the price and wage Phillips curves are shown to be functions of the number of Cournot competitors in the oligopoly-oligopsony case, and this is the reason why business dynamics are affected as the number of firms change. Nevertheless, the estimation can only identify the Phillips curve slope coefficients as a whole, but cannot identify their sub-components separately. Thus, the estimations are silent in terms of the data's preference for assuming monopoly and monopsony power in the goods and labor markets, respectively, versus assuming oligopoly and oligopsony power in these markets.

The next section introduces the baseline model. Section 3 describes the estimation of the parameters of the model, Section 4 presents the main results, and Section 5 concludes.

2 Model

The model is an extension of Jaimovich and Floetotto (2008), which features a closed-economy real business cycle (RBC) model, where firms in each sector have oligopoly power in the goods markets and engage in Cournot competition with other firms in their sector. In the extended model here, firms possess oligopsony power in the labor markets as well and face upward-sloping firm-specific labor supply curves, while households are price and wage takers. The model also features 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 and indexation to past inflation, 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). Finally, monetary policy is conducted via a Taylor rule on the policy rate. In what follows, I describe the key features and equilibrium conditions of the baseline model, while Appendix A provides a complete list of the log-linearized version of the model's equilibrium conditions.

[11] The same comment would hold if labor market power is modeled on the household side, whereby monopolistic versus oligopolistic competition in labor markets would yield isomorphic models.

2.1 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:

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

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, is an exogenous AR(1) process:

$$\log \upsilon_t = \rho_\upsilon \log \upsilon_{t-1} + \varepsilon_{\upsilon,t}, \tag{2}$$

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.[12] Θ_t is a labor supply externality, which helps to 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

$$\Theta_t = \frac{h_t}{\overline{c}_t - \zeta \overline{c}_{t-1}}, \text{ with } h_t = \left(\overline{c}_t - \zeta \overline{c}_{t-1} \right)^{\varrho} h_{t-1}^{1-\varrho}, \tag{3}$$

where ϱ 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.

The households' period budget constraint is given by

$$c_t + q_t \left[k_t - (1-\delta) k_{t-1} \right] + \frac{B_t}{\phi_t R_t P_t} \leq \frac{W_t}{P_t} l_t + r_{k,t} k_{t-1} + \frac{B_{t-1}}{P_t} + \frac{\Pi_t}{P_t} - \frac{T_t}{P_t}, \tag{4}$$

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 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).[13]

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

[13] 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 un-

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 standard, and are respectively given by

$$\frac{\upsilon_t}{c_t - \zeta c_{t-1}} = \lambda_t, \tag{5}$$

$$\xi_t h_t l_t^{\vartheta} = w_t, \tag{6}$$

$$1 = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{R_t\phi_t}{\pi_{t+1}}\right], \tag{7}$$

$$q_t = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\left(1-\delta\right)q_{t+1} + r_{k,t+1}\right]\right], \tag{8}$$

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.

2.2 Labor intermediaries and firm-specific labor supply

There is a unit measure of sectors in the economy indexed by $i \in [0,1]$, and there are a finite number N of Cournot-competitor firms indexed by $j \in \{1,2,...,N\}$ in each sector. The homogenous (aggregate) labor supplied by households is differentiated by perfectly-competitive labor intermediaries into first, sector-specific, and then into firm-specific, labor services.[14]

The disaggregation from aggregate labor, l_t, to sector-specific labor, $l_t\left(i\right)$, conforms with the following aggregator function:

$$l_t = \left[\int_0^1 l_t\left(i\right)^{\frac{\eta_l+1}{\eta_l}} di\right]^{\frac{\eta_l}{\eta_l+1}}, \tag{9}$$

where η_l denotes the labor supply elasticity at the sectoral level (i.e., it captures the percent increase in labor services supplied to a particular sector as the sectoral wage increases by 1%, all else equal). Given perfect competition across the labor intermediaries, the above formulation gives rise to a sector-specific labor supply curve for sector i given by

$$l_t\left(i\right) = \left(\frac{W_t\left(i\right)}{W_t}\right)^{\eta_l} l_t, \tag{10}$$

where $W_t\left(i\right)$ denotes the nominal wage index in sector i, and the aggregate wage index, W_t, is linked

expected changes in the liquidity benefits arising from government bond holdings, such as their use in repo markets (Fisher, 2015).

[14] Note that the problems of these labor intermediaries can alternatively be imposed directly within the households' labor supply problem, and one would obtain the exact same firm-specific labor supply expressions. We follow the labor intermediaries approach here for convenience, and for symmetry with the goods market specification.

to the sector-specific wage indexes by

$$W_t = \left(\int_0^1 W_t(i)^{1+\eta_l} \, di \right)^{\frac{1}{1+\eta_l}} . \tag{11}$$

Similarly, the disaggregation from sector-specific labor, $l_t(i)$, to firm-specific labor, $l_t(i,j)$, conforms with the following aggregator function:

$$l_t(i) = N^{\frac{1}{\chi_l+1}} \left(\sum_{j=1}^{N} l_t(i,j)^{\frac{\chi_l+1}{\chi_l}} \right)^{\frac{\chi_l}{\chi_l+1}} , \tag{12}$$

where χ_l denotes the labor supply elasticity at the firm level (i.e., it captures the percent increase in labor services supplied to a specific firm within a sector as the firm-specific wage increases by 1%, all else equal). We assume that $\chi_l > \eta_l$, indicating that labor supply within a sector is more elastic with respect to wages, relative to labor supply across sectors.[15] The first-term on the right-hand side of equation (12) ensures that there is no "variety effect" on sectoral labor supply, which also implies that, in a symmetric equilibrium, $Nl_t(i,j) = l_t(i) = l_t$ for all i and j. Given perfectly competitive labor intermediaries, the above formulation gives rise to a firm-specific labor supply curve for firm j in sector i given by

$$l_t(i,j) = \left(\frac{W_t(i,j)}{W_t(i)} \right)^{\chi_l} \frac{l_t(i)}{N}, \tag{13}$$

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

$$W_t(i) = N^{-\frac{1}{1+\chi_l}} \left(\sum_{j=1}^{N} W_t(i,j)^{1+\chi_l} \right)^{\frac{1}{1+\chi_l}} , \tag{14}$$

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 later in Section 2.4 are Cournot competitors in labor markets. Combining (10) and (13), firm j in sector i faces a labor supply function for its individual type of labor as

$$l_t(i,j) = \left(\frac{W_t(i,j)}{W_t(i)} \right)^{\chi_l} \left(\frac{W_t(i)}{W_t} \right)^{\eta_l} \frac{l_t}{N}, \tag{15}$$

where it takes into account that its firm-specific wage rate, $W_t(i,j)$, will have an impact on the

[15] 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 $\frac{N^{\vartheta}}{1+\vartheta} \int_0^1 \sum_{j=1}^{N} l_t(i,j)^{1+\vartheta} \, di$, similar to the firm-specific labor supply specification in Carvalho and Nechio (2016).

sectoral wage, $W_t(i)$, based on equation (14). This effect is given by

$$\frac{\partial W_t(i)}{\partial W_t(i,j)} = \left(\frac{W_t(i)}{W_t(i,j)}\right)^{-\chi_l} \frac{1}{N}, \tag{16}$$

which implies 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; i.e., $1/N$. When $N = 1$, there is complete pass-through by construction, and thus, the labor supply elasticity faced by a single firm is equal to η_l, while as N increases, the pass-through from the firm-level to sectoral wages is weakened, and the labor supply elasticity increases to χ_l.

2.3 Final goods producers and firm-specific goods demand

Similar to the set up 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.[16] The aggregation from sector-specific goods, $y_t(i)$, to the aggregate good, y_t, is conducted by final goods aggregators using the following aggregator function:

$$y_t = \left(\int_0^1 y_t(i)^{\frac{\eta_y-1}{\eta_y}} di\right)^{\frac{\eta_y}{\eta_y-1}}, \tag{17}$$

where η_y is the elasticity of substitution between the sectoral goods. Given perfect competition among final good producers, the above formulation gives rise to the following demand curve for sectoral goods:

$$y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\eta_y} y_t, \tag{18}$$

where $P_t(i)$ denotes the price index in sector i, and the aggregate price index, P_t, is linked to the sectoral price indexes as

$$P_t = \left(\int_0^1 P_t(i)^{1-\eta_y} di\right)^{\frac{1}{1-\eta_y}}. \tag{19}$$

Similarly, the aggregation from firm-specific goods, $y_t(i,j)$, to sector-specific goods, $y_t(i)$, is conducted by sectoral goods aggregators using the following aggregator function:

$$y_t(i) = N^{-\frac{1}{\chi_y-1}} \left(\sum_{j=1}^{N} y_t(i,j)^{\frac{\chi_y-1}{\chi_y}}\right)^{\frac{\chi_y}{\chi_y-1}}, \tag{20}$$

where χ_y is the elasticity of substitution between the firm-specific goods. Following Jaimovich and Floetotto (2008), I assume that $\chi_y > \eta_y$, indicating that goods within a sector are more substitutable than goods across sectors. The first-term on the right-hand side of the aggregator ensures that there is no variety effect on sectoral output; thus, in a symmetric equilibrium, $Ny_t(i,j) = y_t(i) = y_t$ for

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

all i and j. Given perfect competition across sectoral aggregators, the above formulation gives rise to a demand curve for firm-specific goods as

$$y_t(i,j) = \left(\frac{P_t(i,j)}{P_t(i)}\right)^{-\chi_y} \frac{y_t(i)}{N}, \tag{21}$$

where $P_t(i,j)$ denotes the price of the output good of firm j in sector i. Accordingly, the sector-specific price index in sector i is linked to firm-specific prices in that sector by

$$P_t(i) = N^{\frac{1}{\chi_y - 1}} \left(\sum_{j=1}^{N} P_t(i,j)^{1-\chi_y}\right)^{\frac{1}{1-\chi_y}}, \tag{22}$$

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

Combining (18) and (21), the goods demand curve facing firm j in sector i is given by

$$y_t(i,j) = \left(\frac{P_t(i,j)}{P_t(i)}\right)^{-\chi_y} \left(\frac{P_t(i)}{P_t}\right)^{-\eta_y} \frac{y_t}{N}, \tag{23}$$

where it 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 (22). Similar to the wage formulation, the derivative of sectoral price index to firm-specific prices is given by

$$\frac{\partial P_t(i)}{\partial P_t(i,j)} = \left(\frac{P_t(i)}{P_t(i,j)}\right)^{\chi_y} \frac{1}{N}, \tag{24}$$

which indicates that the pass-through from the firm-specific to the sectoral price level is also inversely related to the number of firms in each sector. When $N = 1$, 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 increases, the pass-through is weakened and demand facing the firm becomes more elastic, approaching $-\chi_y$.

2.4 Intermediate goods producers

As mentioned before, there is a unit measure of sectors in the economy indexed by $i \in [0,1]$, while there are a finite number N of Cournot-competitor intermediate goods producers indexed by $j \in \{1, 2, ..., N\}$ in each sector. The technology of firm j in sector i is described by the following production function:

$$y_t(i,j) = z_t \left[u_t(i,j)\, k_{t-1}(i,j)\right]^{\alpha} l_t(i,j)^{1-\alpha} - f/N, \tag{25}$$

where u_t is the capital utilization rate, α is the share of capital, and f/N denotes the fixed cost of production per firm.[17] z_t denotes the total factor productivity (TFP) shock, and follows an AR(1) process.

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

$$\frac{\Pi_t(i,j)}{P_t} = \frac{P_t(i,j)}{P_t} y_t(i,j) - \frac{W_t(i,j)}{P_t} l_t(i,j) - r_{k,t} k_{t-1}(i,j) - \frac{\kappa_u}{1+\varpi}\left(u_t(i,j)^{1+\varpi} - 1\right) k_{t-1}(i,j) - \frac{\kappa_p}{2}\left(\frac{P_t(i,j)/P_{t-1}(i,j)}{\pi_{t-1}^{\varsigma_p}\pi^{1-\varsigma_p}} - 1\right)^2 \frac{y_t}{N} - \frac{\kappa_w}{2}\left(\frac{W_t(i,j)/W_{t-1}(i,j)}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}} - 1\right)^2 \frac{W_t}{P_t}\frac{l_t}{N}, \tag{26}$$

where the last three terms are the costs related 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.

An intermediate goods firm's objective is to choose input quantities, $l_t(i,j)$ and $k_{t-1}(i,j)$, capital utilization rate, $u_t(i,j)$, output quantity, $y_t(i,j)$, output price, $P_t(i,j)$, and the firm-specific wage rate, $W_t(i,j)$, taking as given the decisions of the firm's Cournot competitors in the same industry i, and economy-wide aggregates. In particular, intermediate firms maximize the present value of their profits (using the households' stochastic discount factor) subject to their production function in (25), the firm-specific labor supply of labor intermediaries in (15) along with the corresponding sectoral wage index in (14), and the firm-specific goods demand of final goods producers in (23) along with the corresponding sectoral price index in (22).

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

$$\Omega_t \alpha \frac{y_t + f}{k_{t-1}} = r_{k,t} + \frac{\kappa_u}{1+\varpi}\left(u_t^{1+\varpi} - 1\right), \tag{27}$$

$$\Omega_t \alpha \frac{y_t + f}{u_t} = \kappa_u u_t^{\varpi} k_{t-1}, \tag{28}$$

where Ω_t is the Lagrange multiplier with respect to the production function constraint, and captures the marginal cost of production.[18]

[17] I thus assume that the aggregate amount of fixed costs, f, is constant in an industry regardless of the number of firms within an industry, N. This eliminates the effect of fixed costs on the results as N changes, and also makes the formulation that follows slightly easier.

[18] I set κ_u to the steady-state value of $r_{k,t}$ to ensure that the capital utilization rate, u_t, is, without loss of generality, equal to 1 at the steady-state.

2.4.1 Price Phillips curve

The intermediate goods firm's pricing decision gives rise to the following Phillips curve expression (after imposing a symmetric equilibrium):

$$\left(\frac{\pi_t}{\pi_{t-1}^{\varsigma_p}\pi^{1-\varsigma_p}}-1\right)\frac{\pi_t}{\pi_{t-1}^{\varsigma_p}\pi^{1-\varsigma_p}} = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{\pi_{t+1}}{\pi_t^{\varsigma_p}\pi^{1-\varsigma_p}}-1\right)\frac{\pi_{t+1}}{\pi_t^{\varsigma_p}\pi^{1-\varsigma_p}}\frac{y_{t+1}}{y_t}\right] - \frac{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y-1}{\kappa_p}\left(1-\Omega_t\frac{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y}{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y-1}\right). \tag{29}$$

Note that in the absence of price rigidities (i.e., $\kappa_p=0$), the gross markup of price over marginal cost equals $1/\Omega_t$, which is a constant θ_p as

$$\frac{1}{\Omega_t}=\frac{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y}{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y-1}=\theta_p>1. \tag{30}$$

The markup in price is determined by the weighted average of the demand elasticity parameters, χ_y and η_y, with the corresponding weights given by the number of Cournot competitors, N. The presence of price-adjustment costs (i.e., $\kappa_p>0$) introduces endogenous time variation in the price markup, at least in the short run. One could also introduce exogenous time variation in the price markup by assuming that the elasticity parameters in the goods aggregator functions, χ_y and η_y, are exogenously time-varying. In particular, I define $\theta_{p,t}$ as

$$\theta_{p,t}=\frac{\frac{N-1}{N}\chi_{y,t}+\frac{1}{N}\eta_{y,t}}{\frac{N-1}{N}\chi_{y,t}+\frac{1}{N}\eta_{y,t}-1}, \tag{31}$$

to capture this exogenous variation in the gross price mark-up (i.e., cost-push shocks), and assume $\theta_{p,t}$ is an *i.i.d.* process.

Panel (a) of Figure 2 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 (23), while the MR and the MC curves denote the marginal revenue and marginal cost of production, respectively. 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.

The non-linear Phillips curve in equation (29) can be log-linearized to yield

$$\widehat{\pi}_t=\frac{\varsigma_p}{1+\beta\varsigma_p}\widehat{\pi}_{t-1}+\frac{\beta}{1+\beta\varsigma_p}E_t\widehat{\pi}_{t+1}+\frac{\frac{N-1}{N}\chi_y+\frac{1}{N}\eta_y-1}{(1+\beta\varsigma_p)\,\kappa_p}\left(\widehat{\Omega}_t+\widehat{\theta}_{p,t}\right). \tag{32}$$

Note that the slope of the price Phillips curve, $\left(\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y - 1\right) / \left[\left(1 + \beta\varsigma_p\right)\kappa_p\right]$ is increasing in the number of Cournot competitors, N, given $\chi_y > \eta_y$.[19] This implies that the model predicts a flattening of the Phillips curve as the number of competitors within each industry declines and market concentration increases.[20]

2.4.2 Wage Phillips curve

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

$$\left(\frac{\pi_{w,t}}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}} - 1\right)\frac{\pi_{w,t}}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}} = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{\pi_{w,t+1}}{\pi_t^{\varsigma_w}\pi^{1-\varsigma_w}} - 1\right)\frac{\pi_{w,t+1}}{\pi_t^{\varsigma_w}\pi^{1-\varsigma_w}}\frac{\pi_{w,t+1}}{\pi_{t+1}}\frac{l_{t+1}}{l_t}\right] - \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1}{\kappa_w}\left\{1 - \Omega_t\frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l}{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1}\frac{(1-\alpha)\, z_t k_{t-1}^{\alpha} l_t^{-\alpha}}{w_t}\right\}, \quad (33)$$

where $\pi_{w,t} = W_t/W_{t-1} = \pi_t w_t / w_{t-1}$ refers to the nominal wage-inflation factor. Note that in the absence of wage rigidities (i.e., $\kappa_w = 0$), the above expression reduces to

$$\frac{w_t}{\Omega_t\,(1-\alpha)\, z_t k_{t-1}^{\alpha} l_t^{-\alpha}} = \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l}{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1} = \theta_w < 1, \quad (34)$$

whereby real wages are marked down relative to the marginal value product of labor by a constant factor $\theta_w < 1$, which in turn depends on the elasticity parameters in the goods aggregator functions, χ_y and η_y, and the number of Cournot competitors in each industry, N.

Similar to price setting, the presence of wage-adjustment costs (i.e., $\kappa_w > 0$) introduces endogenous time variation in the wage markdown in the short run, while one could also introduce exogenous time variation in this by assuming that the sectoral and firm-specific labor supply elasticity parameters, χ_l and η_l, are exogenously time-varying. In particular, I define $\theta_{w,t}$ as

$$\theta_{w,t} = \frac{\frac{N-1}{N}\chi_{l,t} + \frac{1}{N}\eta_{l,t}}{\frac{N-1}{N}\chi_{l,t} + \frac{1}{N}\eta_{l,t} + 1}, \quad (35)$$

to capture this exogenous variation in the gross wage mark-down (i.e., wage cost-push shocks), and assume $\theta_{w,t}$ is an *i.i.d.* process.

Panel (b) of Figure 2 illustrates the markdown of wages in the labor market in the absence of wage rigidities. In the figure, S_{labor} denotes the upward-sloping labor supply curve facing the individual firm as in equation (15), the MC_{labor} curve is the marginal cost of hiring an additional unit of labor, and MVP_{labor} denotes the marginal value product of labor revenue. Note that MC_{labor}

[19] Note also that when $N = 1$ or $N = \infty$, the Phillips curve above reduces to the standard expression obtained in DSGE models featuring monopolistic competition among a unit measure of firms. A similar comment would apply to the wage Phillips curve expression that will be discussed in the next subsection.

[20] See Lindé and Trabandt (2018) for potential pitfalls with using the linearized version of the Phillips curve, instead of the original non-linear version, in the presence of Kimball aggregators for final goods.

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, MVP_{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 MVP_{labor} when hiring labor services, and sets the wage rate at a markdown relative to the marginal value product, as shown by the arrow on the figure.

The non-linear wage Phillips curve above can be log-linearized to yield

$$\widehat{\pi}_{w,t} - \varsigma_w \widehat{\pi}_{t-1} = \beta \left(E_t \widehat{\pi}_{w,t+1} - \varsigma_w \widehat{\pi}_t \right) + \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1}{\kappa_w} \left[\widehat{\Omega}_t + \widehat{z}_t + \alpha \left(\widehat{u}_t + \widehat{k}_{t-1} - \widehat{l}_t \right) - \widehat{w}_t + \widehat{\theta}_{w,t} \right]. \tag{36}$$

Similar to the price Phillips curve, the slope of the wage Phillips curve, $\left(\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1\right)/\kappa_w$ is also increasing in the number of Cournot competitors, N, given $\chi_l > \eta_l$. Thus, the model is also consistent with a flattening of the wage Phillips curve as industry concentration increases (i.e., as N falls). This in turn would result in a slower pass-through from productivity to wage growth, consistent with the evidence presented in the Introduction.

2.4.3 Labor's share in aggregate income

At the steady state of the model, the labor's share in aggregate income is given by

$$\frac{wl}{y} = \frac{1-\alpha}{\theta_p} \left(1 + \frac{f}{y} \right) \theta_w, \tag{37}$$

while the capital's share is

$$\frac{r_k k}{y} = \frac{\alpha}{\theta_p} \left(1 + \frac{f}{y} \right), \tag{38}$$

and the intermediate goods producers earn oligopoly and oligopsony profits equaling[21]

$$\frac{\Pi/P}{y} = 1 - \frac{r_k k}{y} - \frac{wl}{y} = 1 - \frac{1+f/y}{\theta_p} \left[\alpha + (1-\alpha)\,\theta_w \right]. \tag{39}$$

Note that the price markup factor, θ_p, is inversely related to the number of firms, N, while the wage markdown factor, θ_w, is positively related to N. Thus, as N decreases, capturing the increase in industry concentration in the data, the model predicts a secular decline in labor's income share, consistent with the data presented in the Introduction, while the share of income that accrues to capital and to firm owners as pure profits together would rise. Note also that as N decreases, the model predicts a secular decline, not only in the labor's share, but also in the capital's share as well, both at the expense of pure profits. This prediction is consistent with Barkai (2017), 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.

[21] One can define the fixed costs in such a way as to eliminate pure profits at the steady state of the model. In particular, if $f/y = \theta_p / \left[\alpha + (1-\alpha)\,\theta_w \right] - 1$, then $\Pi/P = 0$. I do not pursue this route here.

2.5 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 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:

$$k_t = (1 - \delta_k) k_{t-1} + \left[1 - \frac{\kappa_x}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2\right] \psi_t x_t, \tag{40}$$

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

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\lambda_\tau}{\lambda_t} \left[q_\tau k_\tau - q_\tau (1-\delta) k_{\tau-1} - x_\tau\right], \tag{41}$$

subject to the law-of-motion of capital, where future profits are again discounted using the patient households' stochastic discount factor. The first-order-condition of capital producers with respect to investment goods yields the following investment demand expression relating investment to Tobin's marginal q as[22]

$$\left(\frac{x_t}{x_{t-1}} - 1\right)\frac{x_t}{x_{t-1}} = E_t\left[\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{x_{t+1}}{x_t} - 1\right)\left(\frac{x_{t+1}}{x_t}\right)^2 \frac{q_{t+1}}{q_t}\frac{\psi_{t+1}}{\psi_t}\right] + \frac{1}{\kappa_x}\left(1 - \frac{1}{q_t\psi_t}\right) - \frac{1}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2, \tag{42}$$

which, in log-linearized form, can be written as

$$\widehat{x}_t - \widehat{x}_{t-1} = \beta\left(E_t\widehat{x}_{t+1} - \widehat{x}_t\right) + \frac{1}{\varphi}\left(\widehat{q}_t + \widehat{\psi}_t\right), \tag{43}$$

where φ regulates the elasticity of investment demand with respect to Tobin's q.

2.6 Monetary and fiscal policy

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

$$\log R_t = \rho \log R_{t-1} + (1-\rho)\left(\log R + a_\pi \log\frac{\pi_t}{\pi} + a_y \log\frac{y_t}{y}\right) + \widetilde{\varepsilon}_{R,t}, \tag{44}$$

[22] 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 ($1/\psi_t$).

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, we 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.

2.7 Market clearing conditions

The final goods market clearing condition is given by

$$c_t + x_t + g_t = y_t, \tag{45}$$

where capital utilization costs and the quadratic costs to price and wage adjustments are assumed to have no resource consequences, and are therefore treated as lump-sum transfers to households. 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

$$k_t = \int_0^1 \sum\nolimits_{j=1}^{N} k_t\left(i, j\right) di. \tag{46}$$

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 Estimation

In order to conduct quantitative analyses using the model, I parameterize the model by first calibrating the parameters that primarily determine the steady state of the model, and then estimating the remaining parameters that mainly affect dynamics using U.S. macroeconomic data and Bayesian likelihood methods (An and Schorfheide, 2007; Fernández-Villaverde, 2010). In what follows, I discuss the choice of the calibrated parameter values, the data used in the Bayesian estimation of the other parameters, and the posterior estimates obtained.

3.1 Calibrated parameters

Table 1 presents a list of the calibrated parameter values. The time-discount factor of households, β, is set to 0.99 to match an annualized 4% real interest rate at the steady state.[23] The depreciation rate of capital, δ, is set to 0.02 to match a 8% depreciation rate in annualized terms, and the share of capital in the production function, α, is set to 0.3.

Note that the estimation cannot provide separate identification for the parameters that show up in the slope terms of the price and wage Phillips curve expressions in (32) and (36). In the case of the price Phillips curve, these parameters are the price-adjustment cost parameter, κ_p, the elasticity parameters in the goods aggregator functions, η_y and χ_y, and the number of firms in each sector, N. 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, I set η_y equal to 2, and conduct sensitivity analysis on this parameter using a range of 1 through 5 for some of the results presented in Section 4. The within-sector elasticity of substitution used in the related literature is typically larger and ranges between 3 and 20, with 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 around 20 in Jaimovich and Floetotto (2008).[24] In my baseline calibration, I use a value of 12 for χ_y, and conduct sensitivity analysis on this parameter based on a range of 5 to 20. Based on these figures, I set the number of Cournot competitors in each industry, N, equal to 8, to match a steady-state markup in prices of 10%, in the middle of the range of the mark-up figures reported in Barkai (2017).[25] The price-adjustment cost parameter, κ_p, on the other hand, is not calibrated, but instead estimated along with the other parameters affecting dynamics.

A similar identification issue arises for the parameters that show up in the slope term of the wage Phillips curve; thus, the labor supply elasticity parameters at the sectoral and firm levels, η_l and χ_l, and the wage adjustment cost parameter, κ_w, are not separately identified. Recent micro-level studies on the firm-specific labor supply elasticity 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

[23] The steady state inflation factor, π, does not enter the log-linearized expressions, but can be set to 1.005, corresponding to a 2% inflation rate in annualized terms. Similarly, the steady-state risk premium, ϕ, also does not enter the log-linearized expressions, but can be set to 1.005, implying a 2% annualized risk premium at the steady state. Thus, the real risk-free rate in the model implied by the calibrated value of β would thus be 2%, and the nominal neutral rate (i.e., the steady-state policy rate), R, would be 4%.

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

[25] De Loecker and Eeckhout (2017) report a higher markup during this period, which would imply a smaller N in the baseline case.

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 market power on behalf of firms leading to a markdown of wages relative to marginal value product of labor in the order of 25%-35%. Earlier studies on the issue such as Nelson (1973) though indicate a much more elastic labor supply to individual firms in the U.S., with estimates closer to 20, which would imply a 5% markdown on wages. Based on these figures, I use a value of 10 for the firm-specific labor supply elasticity parameter, χ_l, which implies a near 10% markdown in wages, and conduct sensitivity analysis on this parameter based on a range of 1 to 20 in Section 4.

As argued in the model section, 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, I will 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 conducted in the next subsection.[26] Note that, similar to the price adjustment cost parameter, the wage adjustment cost parameter, κ_w, will also be estimated to identify the slope of the wage Phillips curve expression.

Finally, I set the share of government expenditure in GDP, g/y, to 0.2, while fixed costs in production as a share of output, f/y, are assumed to be equal to 0.1. Together, these values imply that the labor's share in total income is 62.7% at the steady state, while the capital's share is 29.9% and pure profits account for 7.4% of total income. Furthermore, the capital-output ratio at the steady state is close to 2.5 in annualized terms, and the expenditure share components of GDP are 60.1%, 19.9%, and 20.0% for consumption, investment and government expenditure, respectively.

3.2 Data

I use 7 quarterly data series from the U.S. for the period from 1984Q1 to 2018Q2 in the estimation. The beginning of the sample is picked to coincide with the start of the Great Moderation period, and is aimed to capture the more recent stance of the Federal Reserve towards inflation. The observables in the estimation are output (y), consumption (c), investment (x), labor (l), real wage rate (w), inflation (π), and the policy rate (R), similar to Smets and Wouters (2007). All data were obtained from the Bureau of Labor Statistics (BLS) and the FRED database of the Federal Reserve Bank of St. Louis. Nominal GDP and its expenditure components were all deflated using the GDP deflator. The consumption series excludes durable goods, which is reflected in the total investment series instead. For labor hours, I use the index series *Nonfarm Business Sector: Hours of All Persons*, and for the real wage rate, I use the index series *Nonfarm Business Sector: Real*

[26] One interpretation of this is to think of leisure time as encompassing non-market work, which is then regarded as just another sector by households with the same inter-industry labor supply elasticity.

Compensation per Hour, constructed by the BLS. The policy rate refers to the effective Federal Funds rate, and was converted from monthly to quarterly by simple averaging. For 2009Q3-2015Q4, I replace the Federal Funds rate series with the *shadow* federal funds rate constructed by Wu and Xia (2016), since monetary policy was conducted via unconventional means given the zero lower bound on the policy rate during this period. All relevant series were rendered per-capita by dividing by working-age population. They were then logged and first-differenced (except for inflation and the policy rate) prior to estimation.

3.3 Prior distributions and posterior estimates

Tables 2 and 3 report the prior distributions used for the estimated structural and shock parameters, respectively, and the corresponding estimates for their posterior moments. The prior distributions used in the estimation are fairly standard in the related DSGE literature.[27]

The data are quite informative about the parameters, and the posterior estimates are by and large standard.[28] The habit parameter, ζ, has a posterior mode equal to 0.92, while the estimate for ϑ implies an aggregate labor supply elasticity of around 0.2, more in line with the micro literature on the issue. Note that this estimate also applies to the cross-sector labor supply elasticity parameter, η_l, given the restriction I imposed in the estimation. The persistence parameter for the labor supply externality, ϱ, is around 0.02, consistent with the estimates in Gali et al. (2012), and indicating that the income-elasticity of labor supply is fairly small in the short run. The estimate for the investment adjustment cost parameter, φ, is 3.4, while 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.

The estimates for the price and wage adjustment cost parameters, κ_p and κ_w, are 707.7 and 315.8, respectively, implying high levels of price and wage stickiness in the post-Great Moderation period; in particular, the estimates imply that the slope of the Phillips curves in (32) and (36) are 0.012 and 0.031, respectively. The indexation parameters, ς_p and ς_w, have estimated means of 0.12 and 0.53, respectively, indicating that indexation to past inflation is of moderate importance in wage setting. The Taylor rule is fairly persistent with mean ρ equal to 0.86, and the mean estimates for the long-run reaction coefficients, a_π and a_y, are 2.55 and 0.07, respectively. Finally, shock processes are estimated to be fairly persistent, especially for the risk, government expenditure, productivity, and labor supply shocks.

[27] I use beta priors for parameters that have a unit support; namely, the consumption habit parameter, ζ, the labor externality parameter, ϱ, price and wage indexation parameters, ς_p and ς_w, the Taylor rule smoothing parameter, ρ, and the shock persistence parameters. Similarly, I use gamma priors for the parameters that have positive support but are not necessarily constrained within the unit interval; namely, the inverse aggregate labor supply elasticity, ϑ, the investment adjustment cost parameter, φ, the utilization elasticity parameter, ϖ, the price and wage adjustment cost parameters, κ_p and κ_w, and the Taylor rule response coefficients, a_π and a_y. For the price and wage adjustment cost parameters, I use fairly wide gamma priors with mean 200 and standard deviation 100. Finally, for the shock standard deviations, I use inverse-gamma priors, as in Smets and Wouters (2007).

[28] I conduct the estimation using the Matlab routines in Dynare v4.5.6 (Adjemian et al., 2011). For the Metropolis-Hastings algorithm, I used a single chain of 1,000,000 draws with a 45% initial burn-in phase, and the acceptance rate was around 29%. I monitor and confirm convergence using trace plots and the chi-square convergence diagnostic test of Geweke (1999).

4 Results

In this section, I first present impulse responses of model variables to key shocks, and show how model dynamics change as the number of Cournot competitors, N, are altered. I then conduct comparative statics exercises to investigate how an increase in industry concentration would affect the steady state distribution of aggregate income among labor, capital, and pure profits. Finally, I compare the dynamics of the baseline model presented in Section 2 with the standard model used in the DSGE literature, where labor market power resides with households instead of firms (e.g., Smets and Wouters, 2007).

4.1 Impulse responses

Figure 3 plots the impulse responses of key model variables to an annualized 100 bps innovation in the monetary policy shock.[29] The solid blue line presents the results for the baseline case used in the estimation with $N = 8$ Cournot competitor firms in each sector, while the red dashed and black dotted lines present the corresponding results for $N = 2$ and $N = 32$, respectively (all other parameters are set equal to their baseline values as presented in Tables 1-3). The transmission mechanism of a monetary shock is qualitatively, and to a large degree quantitatively, similar to the standard medium-scale DSGE models in the literature. In particular, the increase in the nominal policy rate leads to a decline in the real interest rate due to the presence of price rigidities, and leads to a contraction in current demand for consumption goods by households. This prompts an overall contraction in the economy, as firms reduce their labor demand and the wage rate they pay to workers, and investment, output, and inflation rates all decline. In particular, output falls by about 64 bps at the peak, while annual inflation is reduced by about 77 bps.

The impulse responses from the alternative case with $N = 32$ is very close to those obtained from the baseline case with $N = 8$, indicating the number of Cournot competitors used in the baseline calibration is, for all practical purposes, equivalent to assuming monopolistically competitive markets with infinitely many firms.[30] To see why this is the case, note that N enters the linearized model only in the slope coefficients of the price and wage Phillips curves (see Appendix A for a complete list of the linearized model expressions). The numerator of these slope expressions are $\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y - 1$ and $\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1$, respectively; thus, as N increases above a certain threshold, the changes in the slope expressions are negligibly small since these numerators are close to $\chi_y - 1$ and $\chi_l + 1$ regardless of N. The changes in the Phillips curve slopes have more visible impact on the results as we reduce N below 8 however. In particular, as we reduce the number of firms from 8 to 2 in each sector, the Phillips curve flattens enough to reduce the monetary shock's effect on prices and inflation, while increasing its effects on output and components.

[29] I set the parameter values to their posterior mode estimates in these exercises. The results using the posterior mean estimates are fairly similar.

[30] A well known result in the industrial organization literature is that an industry with 5-6 oligopoly firms can reasonably approximate the equilibrium for monopolistically competitive markets.

Table 4 conducts sensitivity analysis on the Phillips curve slopes using alternative calibrated values for the goods elasticity parameters, χ_y and η_y, and the labor supply elasticity parameters, χ_l and η_l. The results confirm that the change in the Phillips curve slopes are significant when N declines from 8 to 2, but rather small and insignificant when N is increased from 8 to 32. Note also that the change in the Phillips curve slope is smaller when χ_y and η_y are closer to each other than in the baseline case, and a similar result holds for the wage Phillips curve when χ_l and η_l are closer to each other.

Figure 4 plots the impulse responses of key model variables to a 1% innovation in the productivity shock, $\varepsilon_{z,t}$. The transmission of the productivity shock to the economy is also similar. In particular, the increase in productivity prompts firms to increase their production levels and investment in capital, while reducing prices. Whether productivity shocks increase or reduce the equilibrium levels of labor and real wages is an unresolved issue in business cycle theory. In particular, DSGE models in the RBC realm imply that productivity gains lead to an increase in the equilibrium levels of labor as well as the wage rate, while medium-scale New Keynesian DSGE models typically find that labor demand declines following a gain in productivity (Smets and Wouters, 2007). Our model here is consistent with the latter in the short run, while being consistent with the former in the medium to long run. In particular, equilibrium levels of labor and real wage rate are below their steady-state levels during the first few periods, while they turn positive during the second year following the shock. Note that as the Phillips curves become flatter, demand side shocks (such as the monetary policy shocks) lead to a decline in the shock's effect on inflation while amplifying its effects on output. Conversely, with a supply side shock (such as the productivity shock), the flattening of the Phillips curves with $N = 2$ leads to a weakening of the responses of both inflation and output. Similar to the monetary policy shock, the impulse responses with $N = 32$ are very similar to those from the baseline case with $N = 8$.

4.2 Labor's share in total income

Table 5 presents the distribution of income between labor, capital and pure profits in the baseline calibration of the economy, and analyzes how the distribution changes when the number of Cournot competitors, N, is altered. I also conduct sensitivity analysis on these figures using alternative calibrated values for the goods demand and labor supply elasticities.

In the baseline calibration with $N = 8$, the labor's share in total income is 62.7%, capital's share is 29.9%, while pure profits make up 7.4% of total income. The distribution of income is not materially affected as N increases to 32, while there is a significant decline in the labor's share in income when N declines to 2. In particular, in the latter case, the labor's share in total income is reduced by 7.5 pp to 55.2%, while capital's share decreases by 1.6 pp to 28.3%. The sensitivity analysis conducted in Table 5 using alternative numbers for the goods demand and labor supply elasticities shows that the decline in the labor's share predicted by the model as N decreases from 8 to 2 is relatively robust. Thus, the results indicate that the 3-5 pp decline in labor's share observed in the data can be, at least partially, accounted by an increase in industry concentration. To capture the whole decline in the labor's share in the data, the average N across sectors would need to decrease from 8 to around 3.

4.3 Comparison to model with oligopolistic competition in labor markets

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

$$\widehat{\xi}_t + \widehat{h}_t + \vartheta \widehat{l}_t = \widehat{w}_t, \tag{47}$$

while the wage Phillips curve expression is obtained from the firms' problem as (36), whereby wage rigidities drive a wedge between the marginal value product of labor and the real wage rate.

On the other hand, in the standard DSGE framework where labor market power is held by households, 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

$$\widehat{\pi}_{w,t} - \varsigma_w \widehat{\pi}_{t-1} = \beta \left(E_t \widehat{\pi}_{w,t+1} - \varsigma_w \widehat{\pi}_t \right) + \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l - 1}{\kappa_w} \left(\widehat{\xi}_t + \widehat{h}_t + \vartheta \widehat{l}_t - \widehat{w}_t + \widehat{\theta}_{w,t} \right). \tag{48}$$

Note that χ_l and η_l are now interpreted as capturing the elasticity of substitution for labor demand at the firm and sectoral levels, respectively.[31] Similarly, the firms' problem now implies that the real wage rate is equal to the marginal value product of labor; hence,

$$\widehat{\Omega}_t + \widehat{z}_t + \alpha \left(\widehat{u}_t + \widehat{k}_{t-1} - \widehat{l}_t \right) = \widehat{w}_t. \tag{49}$$

Figures 5 and 6 compare the impulse responses of key model variables to monetary policy and productivity shocks, respectively, under the baseline model presented here with oligopsonistic competition in labor markets versus the alternative model where households have labor market power and engage in oligopolistic competition in labor markets.[32] The figures indicate that the transmission of the shocks to output and inflation are not qualitatively that different, although there are some quantitative differences. In particular, the baseline model with oligopsony labor generates significantly weaker impulse responses for the equilibrium level of labor relative to the oligopoly labor

[31] Note that $\theta_w > 1$ at the steady state of this model; thus, real wages are *marked up* relative to the marginal rate of substitution. θ_w, while affecting the steady state share of labor in total income, does not alter any of the dynamic equations of the model. Note also that labor supply shocks, $\widehat{\xi}_t$, and wage markup shocks, $\widehat{\theta}_{w,t}$, cannot be separately identified in this wage Phillips curve expression unless one puts more structure into the model or these two exogenous processes (Chari et al., 2009; Gali et al., 2012). This is not the case for the baseline model with oligopsonistic labor markets, which allows for the separate identification of labor supply and wage mark-up shocks.

[32] In making this comparison, I set all parameters to the same values in the two models (as in Tables 1-3), including those for χ_l and η_l.

model. With a monetary shock, this also leads to smaller responses for output and its consumption and investment components in the baseline case, while the response of inflation is slightly amplified. With productivity shocks, the differences between the two models are far less pronounced for the responses of output and its expenditure components, while the response of inflation is again slightly more pronounced in the baseline case.

Finally, Figure 7 compares the impulse responses of the baseline model and the oligopoly model for the other shocks in the economy. Note that, except for the wage shock, the two models generate similar dynamics qualitatively, and to a large degree quantitatively, although the baseline model generates slightly larger responses for output and slightly lower responses for inflation in general. An interesting difference is apparent in the transmission of wage shocks in the two models. In particular, in the oligopoly labor model, a positive shock to wages acts analogous to an adverse labor supply shock. To see this, observe that the labor supply shock, $\widehat{\xi}_t$, and the wage shock, $\widehat{\theta}_{w,t}$, enters the wage Phillips curve equation (48) with the same sign, and this is the only equation where these shocks appear in the model. This adverse shock effectively increases the marginal costs of firms, prompting them to lower their hiring and production levels while increasing prices. On the other hand, in the baseline model with oligopsony labor, positive wage shocks temporarily reduce the firm's markdown in wages, which prompts firms to increase their hiring and output levels, while cutting prices to be able to sell the increased output.[33] Thus, in equilibrium, a positive shock to the wage markdown leads to an increase in the aggregate real wage rate, labor, output (and in aggregate consumption and investment), but to a decrease in the inflation rate.

5 Conclusion

In this paper, I analyze how changes in industry concentration can affect business cycle dynamics and the labor's share in aggregate income within the context of a medium-scale New Keynesian DSGE model with oligopsonistic competition in labor markets. The results indicate that an increase in industry concentration would lead to a flattening of the aggregate Phillips curve, 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. Thus, the model does a good job in replicating the stylized facts described in the Introduction through a rise in industry concentration. As noted before however, the model is silent regarding the underlying causes for the increase in industry concentration, which in itself is an important issue that is left for further research. The framework here can potentially be extended to investigate the effects of anti-trust legislation on overall welfare, and analyze how changes in industry concentration can affect incentives to innovate and invest in research and development, thereby linking developments in industry concentration and the recent slowdown in productivity growth (Van Reenen, 2018).

[33] Note that an exogenous increase in $\theta_{w,t}$ brings the *gross* markdown closer to 1; hence, the net markdown becomes smaller.

References

[1] Adjemian, S., H. Bastani, M. Juillard, F. Karamé, F. Mihoubi, G. Perendia, J. Pfeifer, M. Ratto, and S. Villemot (2011). "Dynare: Reference Manual, Version 4," Dynare Working Papers, 1, CEPREMAP.

[2] Alpanda, Sami (2013). "Identifying the Role of Risk Shocks in the Business Cycle Using Stock Price Data," *Economic Inquiry*, 51, 304-335.

[3] An, S., and F. Schorfheide (2007). "Bayesian Analysis of DSGE Models," *Econometric Reviews*, 26, 211-219.

[4] Autor, David, David Dorn, Lawrence F. Katz, Christina Patterson, and John Van Reenen (2017a). "Concentrating on the Fall of the Labor Share," *American Economic Review Papers and Proceedings*, 107, 180-185.

[5] Autor, David, David Dorn, Lawrence F. Katz, Christina Patterson, and John Van Reenen (2017b). "The Fall of the Labor Share and the Rise of Superstar Firms," mimeo, Massachusetts Institute of Technology (http://economics.mit.edu/faculty/dautor/policy).

[6] Azar, José, Ioana Marinescu, and Marshall I. Steinbaum (2017). "Labor Market Concentration," NBER Working Paper No. 24147.

[7] Azar, José, and Xavier Vives (2018). "Oligopoly, Macroeconomic Performance, and Competition Policy," mimeo, IESE Business School.

[8] Barkai, Simcha (2017). "Declining Labor and Capital Shares," mimeo, London Business School.

[9] Beaudry, P., and M. Doyle (2000). "What happened to the Phillips curve in the 1990s in Canada?," in *Price stability and the long-run target for monetary policy*, 51-82.

[10] Bental, Benjamin, and Dominique Demougin (2010). "Declining Labor Shares and Bargaining Power: An Institutional Explanation," *Journal of Macroeconomics*, 32, 443-456.

[11] Bhaskar, V., and Ted To (1999). "Minimum wages for Ronald McDonald monopsonies: A theory of monopsonistic competition," *Economic Journal*, 109, 190-203.

[12] Blanchard, Olivier, and Francesco Giavazzi (2003). "Macroeconomic Effects of Regulation and Deregulation in Goods and Labor Markets," *Quarterly Journal of Economics*, 118, 879-907.

[13] Boal, William M., and Michael R Ransom (1997). "Monopsony in the Labor Market," *Journal of Economic Literature*, 35, 86-112.

[14] Brill, Michael, Corey Holman, Chris Morris, Ronjoy Raichoudhary, and Noah Yosif (2017). "Understanding the labor productivity and compensation gap," *Beyond the Numbers: Productivity*, vol. 6, U.S. Bureau of Labor Statistics, June 2017, www.bls.gov/opub/btn/volume-6/understanding-the-labor-productivity-and-compensation-gap.htm.

[15] Bouakez, Hafedh, Emanuela Cardia, and Francisco Ruge-Murcia (2009). "The Transmission of Monetary Policy in a Multi-sector Economy," *International Economic Review*, 50, 1243-1266.

[16] Carvalho, Carlos (2006). "Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks," *Frontiers of Macroeconomics*, 2, Article 1.

[17] Carvalho, Carlos, and Fernanda Nechio (2011). "Aggregation and the PPP Puzzle in a Sticky-Price Model," *American Economic Review*, 101, 2391-2424.

[18] Carvalho, Carlos, and Fernanda Nechio (2016). "Factor specificity and real rigidities," *Review of Economic Dynamics*, 22, 208-222.

[19] Chari, V. V., Patrick J. Kehoe, Ellen R. McGrattan (2009). "New Keynesian Models: Not Yet Useful for Policy Analysis," *American Economic Journal: Macroeconomics*, 1, 242-266.

[20] Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113, 1-45.

[21] Christiano, Lawrence J., Martin Eichenbaum, and Mathias Trabandt (2016). "Unemployment and Business Cycles," *Econometrica*, 84, 1523-1569.

[22] Cooley, Thomas F., and Edward C. Prescott (1995). "Economic Growth and Business Cycles," in *Frontiers of Business Cycle Research*, Thomas F. Cooley (ed.), p. 1-38. Princeton University Press: Princeton, New Jersey.

[23] De Loecker, Jan, and Jan Eeckhout (2017). "The Rise of Market Power and the Macroeconomic Implications," mimeo, Princeton University.

[24] Dotsey, Michael, Shigeru Fujita, and Tom Stark (2017). "Do Phillips Curves Conditionally Help to Forecast Inflation?," Federal Reserve Bank of Philadelphia Working Paper No. 17-26.

[25] Eichenbaum, Martin, and Jonas D. M. Fisher (2007). "Estimating the frequency of price re-optimization in Calvo-style models," *Journal of Monetary Economics*, 54, 2032-2047.

[26] Elsby, Michael W.L., Bart Hobijn, and Aysegul Sahin (2013). "The Decline of the U.S. Labor Share," *Brookings Papers on Economic Activity*, Fall 2013, 1-63.

[27] Eusepi, Stefano, Bart Hobijn, and Andrea Tambalotti (2011). "CONDI: A Cost-of-Nominal-Distortions Index," *American Economic Journal: Macroeconomics*, 3, 53-91.

[28] Falch, Torberg (2010). "The Elasticity of Labor Supply at the Establishment Level," Journal of Labor Economics, 28, 237-266.

[29] Fernández-Villaverde, Jesus (2010). "The Econometrics of DSGE Models," *SERIEs*, 1, 3-49.

[30] Fisher, J. D. M. (2015). "On the Structural Interpretation of the Smets-Wouters "Risk Premium" Shock," *Journal of Money, Credit and Banking*, 47, 2-3.

[31] Gali, Jordi (2008). *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

[32] Gali, Jordi, Frank Smets, and Rafael Wouters (2012). "Unemployment in an Estimated New Keynesian Model," in NBER Macroeconomics Annual 2011, Daron Acemoglu and Michael Woodford (eds.), vol. 26, p. 329-360. University of Chicago Press.

[33] Geweke, John F. (1999). "Using Simulation Methods for Bayesian Econometric Models: Inference, Development, and Communication," *Econometric Reviews*, 18, 1-73.

[34] Giandrea, Michael D., and Shawn A. Sprague (2017). "Estimating the U.S. labor share," *Monthly Labor Review*, U.S. Bureau of Labor Statistics, February 2017 (https://doi.org/10.21916/mlr.2017.7).

[35] Gnocchi, Stefano (2009). "Non-Atomistic Wage Setters and Monetary Policy in a New Keynesian Framework," *Journal of Money, Credit and Banking*, 41, 1613-1630.

[36] Grullon, Gustavo, Yelena Larkin, and Roni Michaely (2016). "Are US Industries Becoming More Concentrated?," mimeo, Rice University.

[37] Hirsch, Boris, Thorsten Schank, and Claus Schnabel (2010). "Differences in Labor Supply to Monopsonistic Firms and the Gender Pay Gap: An Empirical Analysis Using Linked Employer-Employee Data from Germany," *Journal of Labor Economics*, 28, 291-330.

[38] Hobijn, Bart, and Fernanda Nechio (2017). "Sticker Shocks: Using VAT Changes to Estimate Upper-Level Elasticities of Substitution," Federal Reserve Bank of San Francisco Working Paper 2015-17.

[39] Hobijn, Bart, Frederico Ravenna, and Andrea Tambalotti (2006). "Menu costs at work: restaurant prices and the introduction of the euro," *Quarterly Journal of Economics*, 121, 1103-1131.

[40] Jaimovich, Nir, and Max Floetotto (2008). "Firm dynamics, markup variations, and the business cycle," *Journal of Monetary Economics*, 55, 1238-1252.

[41] Jaimovich, Nir, and Sergio Rebelo (2009). "Can News about the Future Drive the Business Cycle?" *American Economic Review*, 99, 1097-1118.

[42] Karabarbounis, Loukas, and Brent Neiman (2014). "The Global Decline of the Labor Share," *Quarterly Journal of Economic*s, 129, 61-103.

[43] Karadi, Peter and Reiff, Adam (2007). "Menu Costs and Inflation Asymmetries - Some Micro Data Evidence," MPRA Paper No. 7102.

[44] Kuttner, Ken, and Tim Robinson (2010). "Understanding the flattening Phillips curve," *North American Journal of Economics and Finance*, 21, 110-125.

[45] Lindé, Jesper, and Mathias Trabandt (2018). "Resolving the Missing Deflation Puzzle," mimeo, Sveriges Riksbank.

[46] Manning, Alan (2003). *Monopsony in motion: Imperfect competition in labor markets*. Princeton, NJ: Princeton University Press.

[47] Manning, Alan (2011). "Imperfect competition in the labor market," in *Handbook of Labor Economics*, 4, 973-1041.

[48] Midrigan, Virgiliu (2011). "Menu costs, multiproduct firms, and aggregate fluctuations," *Econometrica*, 79, 1139-1180.

[49] Nakamura, Emi, and Jon Steinsson (2010). "Monetary Non-Neutrality in a Multi-Sector Menu Cost Model," *Quarterly Journal of Economics*, 125, 961-1013.

[50] Mongey, Simon (2018). "Market Structure and Monetary Non-Neutrality," mimeo, Federal Reserve Bank of Minneapolis.

[51] Nelson, Phillip (1973). "The Elasticity of Labor Supply to the Individual Firm," *Econometrica*, 41, 853-866.

[52] Ransom, Michael R., and Ronald L. Oaxaca (2010). "New Market Power Models and Sex Differences in Pay," *Journal of Labor Economics*, 28, 267-289.

[53] Ransom, Michael R., and David P. Sims (2010). "Estimating the Firm's Labor Supply Curve in a "New Monopsony" Framework: Schoolteachers in Missouri," *Journal of Labor Economics*, 28, 331-355.

[54] Rotemberg, J. J. (1982). "Monopolistic Price Adjustment and Aggregate Output," *Review of Economic Studies*, 49, 517–531.

[55] Sbordone, Argia M. (2008). "Globalization and Inflation Dynamics: The Impact of Increased Competition," Federal Reserve Bank of New York Staff Reports No. 324.

[56] Smets, F., and R. Wouters (2007). "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97, 586-606.

[57] Staiger, Douglas, Joanne Spetz, and Ciaran Phibbs (2010). "Is there monopsony in the labor market? Evidence from a natural experiment," *Journal of Labor Economics*, 28, 211-236.

[58] Van Reenen, John (2018). "Increasing Differences between firms: Market Power and the Macro-Economy," mimeo, Massachusetts Institute of Technology.

[59] Woodford, M. (2003). *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton University Press.

[60] Wu, J. C., and F. Xia (2016). "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound, "*Journal of Money, Credit and Banking*, 48, 253-291.

A Log-linearized model

Consumption demand

$$\widehat{c}_t = \frac{\zeta}{1+\zeta}\widehat{c}_{t-1} + \frac{1}{1+\zeta}E_t\widehat{c}_{t+1} - \frac{1-\zeta}{1+\zeta}\left(\widehat{R}_t - E_t\widehat{\pi}_{t+1} + \widehat{\phi}_t\right) + \frac{1-\zeta}{1+\zeta}\left(\widehat{\upsilon}_t - E_t\widehat{\upsilon}_{t+1}\right) \tag{50}$$

Investment demand

$$\widehat{x}_t = \frac{1}{1+\beta}\widehat{x}_{t-1} + \frac{\beta}{1+\beta}E_t\widehat{x}_{t+1} + \frac{1}{(1+\beta)\varphi}\left(\widehat{q}_t + \widehat{\psi}_t\right) \tag{51}$$

Aggregate labor supply

$$\widehat{\xi}_t + \widehat{h}_t + \vartheta\widehat{l}_t = \widehat{w}_t \tag{52}$$

Labor supply externality

$$\widehat{h}_t = \frac{\varrho}{1-\zeta}\left(\widehat{c}_t - \zeta\widehat{c}_{t-1}\right) + (1-\varrho)\,\widehat{h}_{t-1} \tag{53}$$

Relative price of capital

$$\widehat{q}_t = (1-\delta)\,\beta E_t\widehat{q}_{t+1} + \left[1-(1-\delta)\,\beta\right]E_t\widehat{r}_{k,t+1} - \left(\widehat{R}_t - E_t\widehat{\pi}_{t+1} + \widehat{\phi}_t\right) \tag{54}$$

Law of motion of capital

$$\widehat{k}_t = (1-\delta)\,\widehat{k}_{t-1} + \delta\left(\widehat{x}_t + \widehat{\psi}_t\right) \tag{55}$$

Production function

$$\widehat{y}_t = \left(1 + \frac{f}{y}\right)\left[\widehat{z}_t + \alpha\left(\widehat{u}_t + \widehat{k}_{t-1}\right) + (1-\alpha)\,\widehat{l}_t\right] \tag{56}$$

Marginal cost of production

$$\widehat{\Omega}_t + \widehat{z}_t + (\alpha-1)\left(\widehat{u}_t + \widehat{k}_{t-1} - \widehat{l}_t\right) = \widehat{r}_{k,t} \tag{57}$$

Capital utilization rate

$$\widehat{u}_t = \frac{1}{\varpi}\widehat{r}_{k,t} \tag{58}$$

Price Phillips curve

$$\widehat{\pi}_t = \frac{\varsigma_p}{1+\beta\varsigma_p}\widehat{\pi}_{t-1} + \frac{\beta}{1+\beta\varsigma_p}E_t\widehat{\pi}_{t+1} + \frac{\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y - 1}{(1+\beta\varsigma_p)\,\kappa_p}\left(\widehat{\Omega}_t + \widehat{\theta}_{p,t}\right) \tag{59}$$

Relating nominal wage inflation and real wage growth

$$\widehat{\pi}_{w,t} - \widehat{\pi}_t = \widehat{w}_t - \widehat{w}_{t-1} \tag{60}$$

Wage Phillips curve

$$\widehat{\pi}_{w,t} - \varsigma_w \widehat{\pi}_{t-1} = \beta \left(E_t \widehat{\pi}_{w,t+1} - \varsigma_w \widehat{\pi}_t \right) + \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1}{\kappa_w} \left[\widehat{\Omega}_t + \widehat{z}_t + \alpha \left(\widehat{u}_t + \widehat{k}_{t-1} - \widehat{l}_t \right) - \widehat{w}_t + \widehat{\theta}_{w,t} \right] \tag{61}$$

Goods market clearing

$$\frac{c}{y}\widehat{c}_t + \frac{x}{y}\widehat{x}_t + \frac{g}{y}\widehat{g}_t = \widehat{y}_t \tag{62}$$

Taylor rule

$$\widehat{R}_t = \rho \widehat{R}_{t-1} + (1-\rho)\left(a_\pi \widehat{\pi}_t + a_y \widehat{y}_t \right) + \widetilde{\varepsilon}_{R,t} \tag{63}$$

In the above expressions, the steady-state share of government expenditure, g/y, and the ratio of fixed costs to output, f/y, can be treated as parameters, while the share of investment is given by $x/y = \delta k/y$ with $k/y = \alpha\left(1 + f/y\right) / \left[\theta_p \left(1/\beta - 1 + \delta\right)\right]$ and $\theta_p = \left(\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y\right) / \left(\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y - 1\right)$, and the share of consumption is calculated as a residual, $c/y = 1 - x/y - g/y$.

Table 1. Calibrated parameters		
	Symbol	Value
Time-discount factor	β	0.99
Depreciation rate of capital	δ	0.02
Capital share in production	α	0.3
Share of gov. expenditure in GDP	g/y	0.2
Fixed costs to output ratio	f/y	0.1
No. of Cournot competitors within each sector	N	8
Intermediate goods elast. of subst. - within sector	χ_y	12
- across sectors	η_y	2
Labor supply elasticity - within sector	χ_l	10
- across sectors	η_l	$= 1/\varphi$

Table 2: Estimated structural and policy parameters					
			Posterior distribution		
	Symbol	Prior[a]	Mode	Mean	90% HPD interval
Habit in consumption	ζ	B(0.5,0.2)	0.9194	0.8776	0.7527 - 0.9515
Inverse aggregate labor supply elast.	ϑ	G(2,0.75)	4.8128	5.3771	3.8520 - 6.9342
Externality in labor supply	ϱ	B(0.5,0.2)	0.0229	0.1804	0.0011 - 0.6711
Investment adj. cost	φ	G(4,1.5)	3.4269	3.6713	1.9990 - 5.3401
Utilization cost elasticity	ϖ	G(1,0.5)	0.4914	0.6624	0.2371 - 1.0485
Price adjustment cost	κ_p	G(200,100)	707.71	713.70	495.33 - 928.54
Wage adjustment cost	κ_w	G(200,100)	315.77	411.27	223.01 - 599.34
Indexation - price	ς_p	B(0.5,0.2)	0.1190	0.1595	0.0336 - 0.2765
- wage	ς_w	B(0.5,0.2)	0.5268	0.5033	0.1869 - 0.8185
Taylor rule - persistence	ρ	B(0.5,0.2)	0.8590	0.8537	0.8205 - 0.8892
- inflation	a_π	G(1.5,0.2)	2.5521	2.6825	2.1795 - 3.1919
- output gap	a_y	G(0.25,0.1)	0.0680	0.0678	0.0296 - 0.1035

Table 3: Estimated shock parameters					
			Posterior distribution		
	Symbol	Prior[a]	Mode	Mean	90% HPD interval
Persistence - risk	ρ_ϕ	B(0.5,0.2)	0.9065	0.9055	0.8489 - 0.9626
- preference	ρ_υ	B(0.5,0.2)	0.2288	0.2414	0.1003 - 0.3757
- investment	ρ_ψ	B(0.5,0.2)	0.2830	0.3827	0.1356 - 0.6527
- gov. exp.	ρ_g	B(0.5,0.2)	0.9338	0.9284	0.8952 - 0.9635
- productivity	ρ_z	B(0.5,0.2)	0.9185	0.9180	0.8788 - 0.9569
- labor supply	ρ_ξ	B(0.5,0.2)	0.9933	0.9917	0.9871 - 0.9965
- monetary	ρ_R	B(0.5,0.2)	0.5377	0.5436	0.4357 - 0.6567
St. dev. - risk	σ_ϕ	IG(0.5%,∞)	0.0029	0.0030	0.0013 - 0.0047
- preference	σ_υ	IG(0.5%,∞)	0.0016	0.0016	0.0013 - 0.0019
- investment	σ_ψ	IG(0.5%,∞)	0.0416	0.0432	0.0211 - 0.0671
- gov. exp.	σ_g	IG(0.5%,∞)	0.0136	0.0138	0.0124 - 0.0151
- productivity	σ_z	IG(0.5%,∞)	0.0092	0.0093	0.0070 - 0.0115
- labor supply	σ_ξ	IG(0.5%,∞)	0.0363	0.0418	0.0293 - 0.0536
- price cost-push	σ_p	IG(0.5%,∞)	0.0023	0.0064	0.0010 - 0.0132
- wage cost-push	σ_w	IG(0.5%,∞)	0.3409	0.4284	0.2517 - 0.5993
- monetary	σ_R	IG(0.5%,∞)	0.0011	0.0012	0.0010 - 0.0013

Note: a Prior distributions: B: beta, G: gamma, IG: inverse gamma.

Table 4: Slope of price and wage Phillips Curves (PC)				
	PC slope $= \frac{\frac{N-1}{N}\chi_y + \frac{1}{N}\eta_y - 1}{(1+\beta\varsigma_p)\kappa_p}$		Wage PC slope $= \frac{\frac{N-1}{N}\chi_l + \frac{1}{N}\eta_l + 1}{\kappa_w}$	
Baseline ($\chi_y = 12, \eta_y = 2, \chi_l = 10, \eta_l = 1/\varphi = 0.208$)				
$N = 2$	0.0076		0.0193	
$N = 8$	0.0123		0.0310	
$N = 32$	0.0135		0.0339	
	$\chi_y = 5$	$\eta_y = 1$	$\chi_l = 1$	$\eta_l = 0.1$
$N = 2$	0.0032	0.0070	0.0051	0.0192
$N = 8$	0.0046	0.0122	0.0060	0.0309
$N = 32$	0.0049	0.0135	0.0063	0.0339
	$\chi_y = 20$	$\eta_y = 5$	$\chi_l = 20$	$\eta_l = 5$
$N = 2$	0.0126	0.0095	0.0352	0.0269
$N = 8$	0.0212	0.0128	0.0587	0.0329
$N = 32$	0.0233	0.0136	0.0645	0.0343

Table 5: Distribution of income at the steady state (% of total income)						
	Labor	Capital	Pure Profits	Labor	Capital	Pure Profits
Baseline ($\chi_y = 12, \eta_y = 2, \chi_l = 10, \eta_l = 1/\varphi = 0.208$)						
$N = 2$	55.2%	28.3%	16.5%			
$N = 8$	62.7%	29.9%	7.4%			
$N = 32$	63.8%	30.2%	6.0%			
Alternative χ_y	$\chi_y = 5$			$\chi_y = 20$		
$N = 2$	46.0%	23.6%	30.4%	58.5%	30.0%	11.5%
$N = 8$	54.2%	25.9%	20.0%	65.2%	31.1%	3.6%
$N = 32$	55.6%	26.3%	18.2%	66.2%	31.3%	2.5%
Alternative η_y	$\eta_y = 1$			$\eta_y = 5$		
$N = 2$	54.5%	27.9%	17.6%	56.8%	29.1%	14.1%
$N = 8$	62.6%	29.9%	7.5%	62.9%	30.0%	7.1%
$N = 32$	63.8%	30.2%	6.0%	63.9%	30.2%	5.9%
Alternative χ_l	$\chi_l = 1$			$\chi_l = 20$		
$N = 2$	24.9%	28.3%	46.9%	60.1%	28.3%	11.7%
$N = 8$	33.1%	29.9%	37.0%	66.1%	29.9%	4.0%
$N = 32$	34.8%	30.2%	35.1%	67.0%	30.2%	2.9%
Alternative η_l	$\eta_l = 0.1$			$\eta_l = 5$		
$N = 2$	55.1%	28.3%	16.6%	58.2%	28.3%	13.5%
$N = 8$	62.7%	29.9%	7.4%	63.1%	29.9%	7.0%
$N = 32$	63.8%	30.2%	6.0%	63.9%	30.2%	5.9%

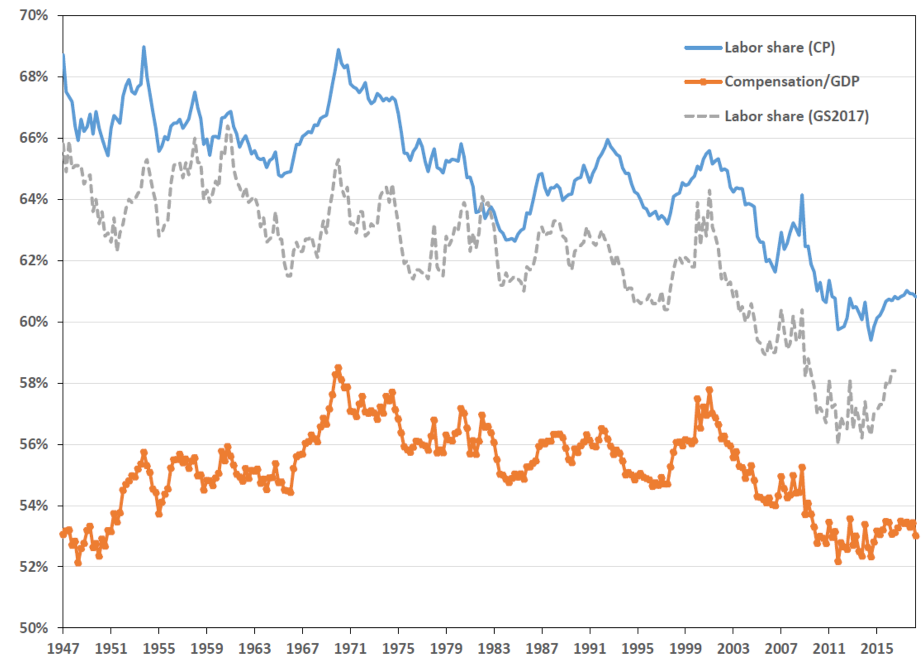

Figure 1: Labor's share in total income in the post-war period. CP series uses the Cooley and Prescott (1995) methodology to allocate proprietors' income to labor and capital in proportion to the rest of the economy, while the GS2017 series is the labor share constructed by Giandrea and Sprague (2017).

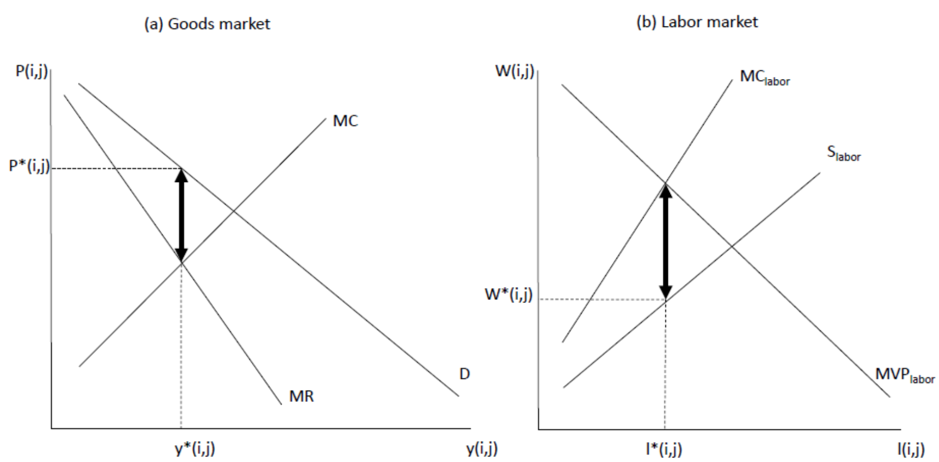

Figure 2: Firms have monopoly power in the goods market and monopsony power in the labor market.

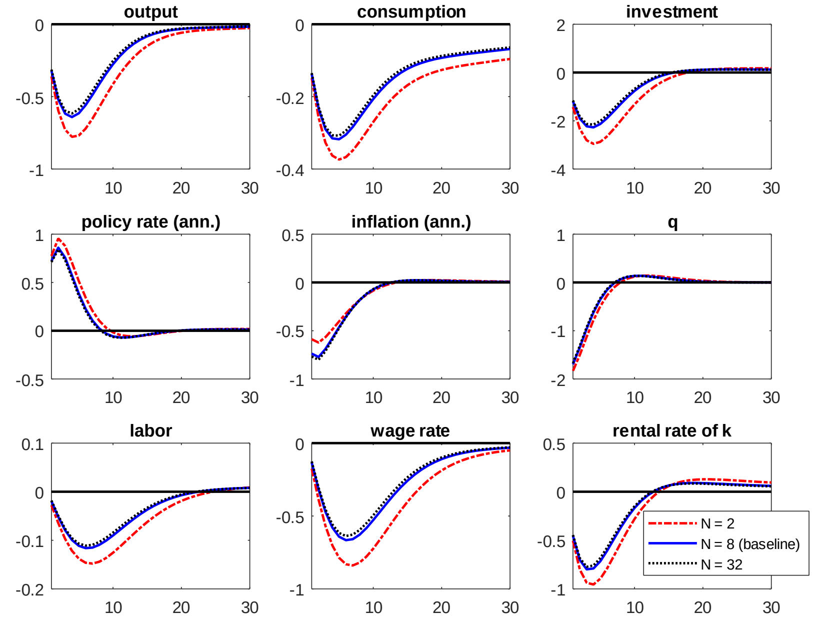

Figure 3: Impulse responses to an annualized 100 bps innovation in the monetary policy shock, $\varepsilon_{R,t}$, for different number of Cournot competitors in each sector, N.

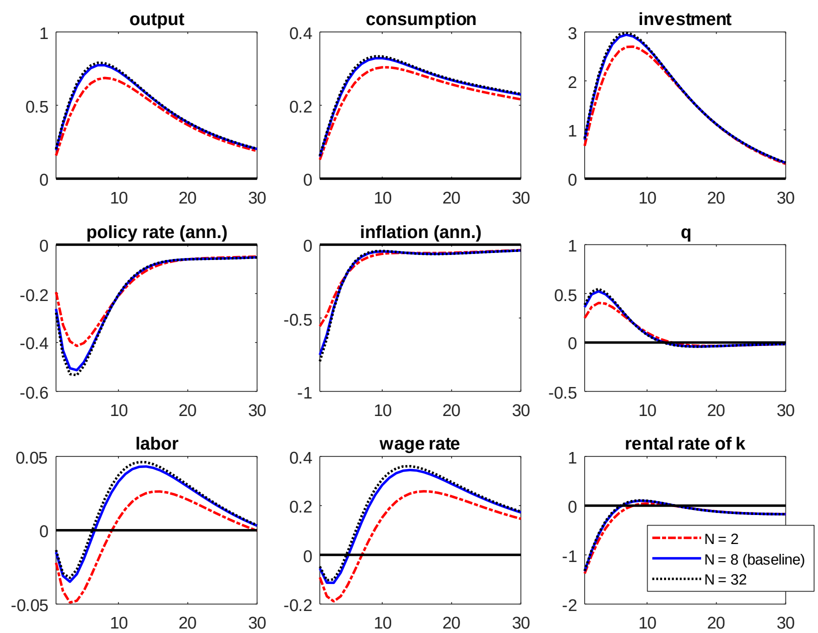

Figure 4: Impulse responses to a 1% innovation in the productivity shock, $\varepsilon_{z,t}$, for different number of Cournot competitors in each sector, N.

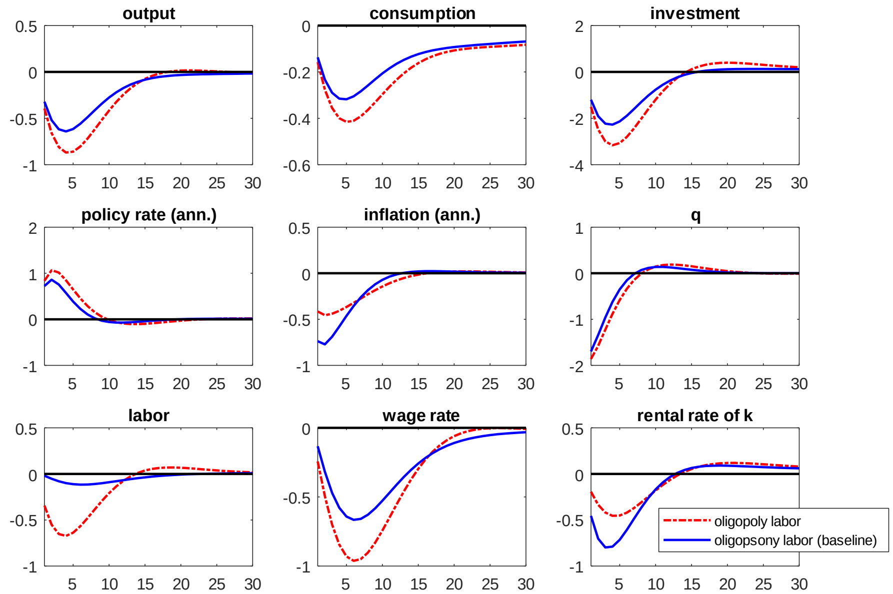

Figure 5: Impulse responses to an annualized 100 bps innovation in the monetary policy shock, $\varepsilon_{R,t}$, in the baseline model with oligopsonistic competition in labor markets versus alternative model with oligopolistic competition in labor markets.

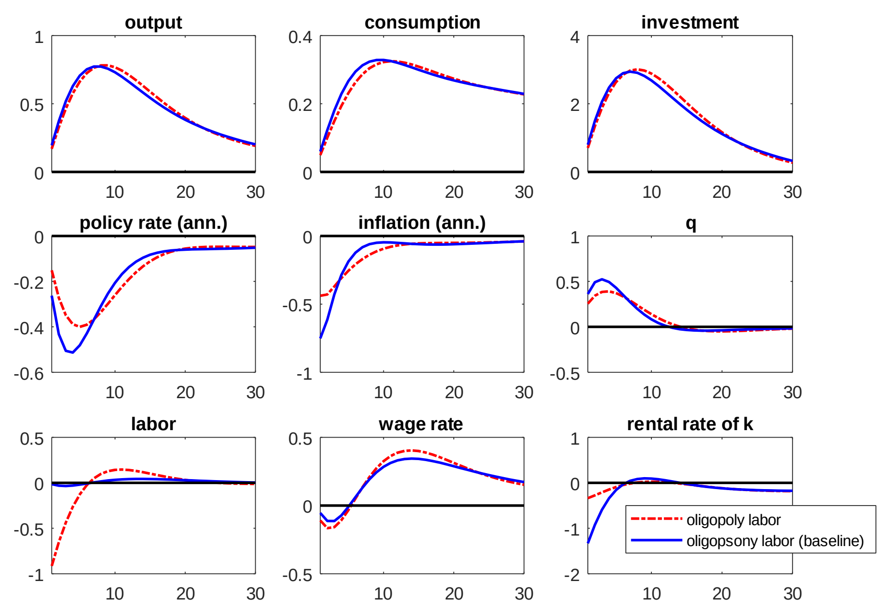

Figure 6: Impulse responses to a 1% innovation in the productivity shock, $\varepsilon_{z,t}$, in the baseline model with oligopsonistic competition in labor markets versus alternative model with oligopolistic competition in labor markets.

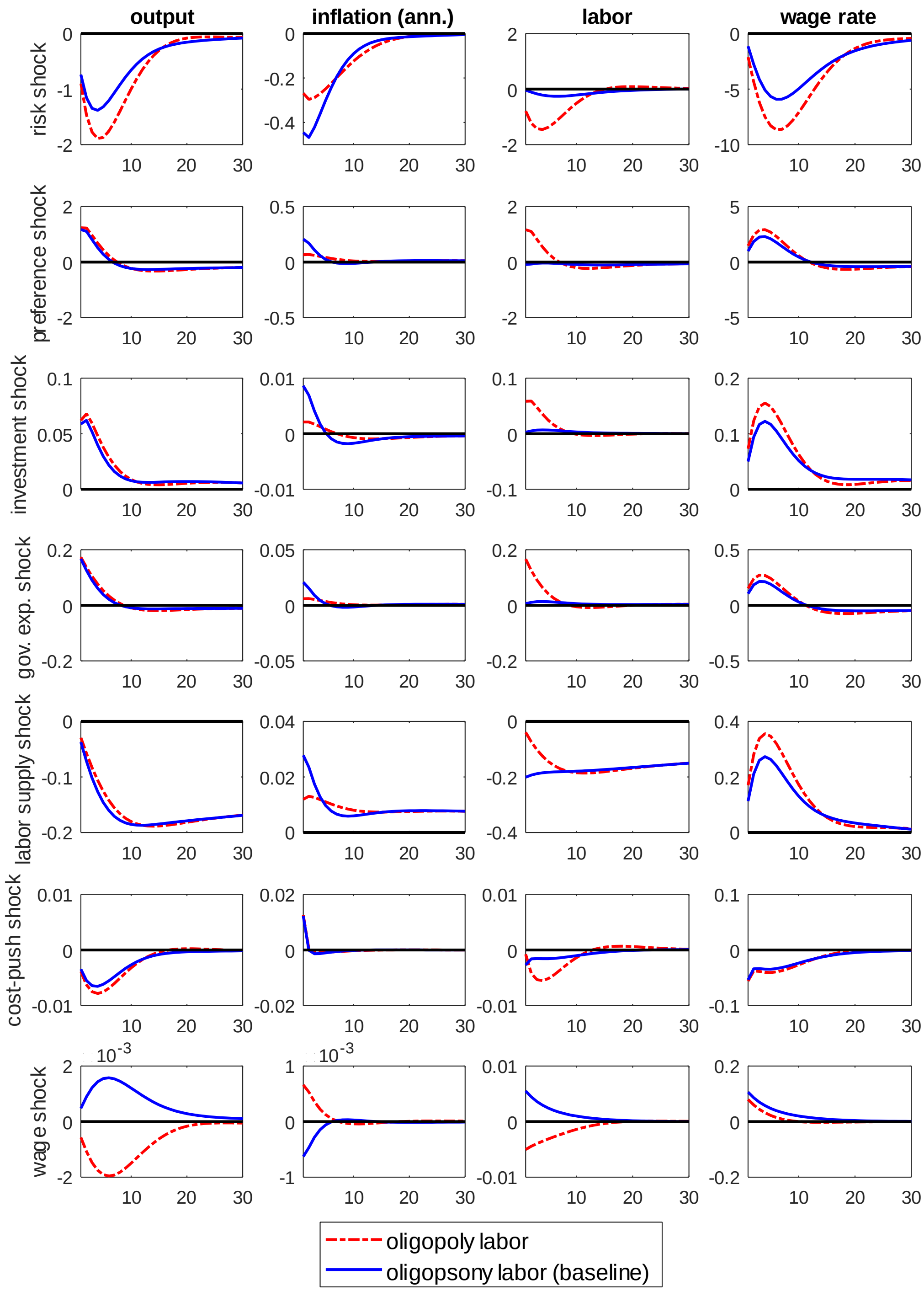

Figure 7: Impulse responses to a 1% innovation in the other shocks in the baseline model with oligopsonistic competition in labor markets versus alternative model with oligopolistic competition in labor markets.