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The sectoral origins of heterogeneous spending multipliers ☆

Hafedh Bouakez [a,*], Omar Rachedi [b], Emiliano Santoro [c]

[a] HEC Montreal and CIREQ, Montréal, Canada
[b] ESADE Business School, Universitat Ramon Llull, Barcelona, Spain
[c] Catholic University of Milan, Milan, Italy

HIGHLIGHTS

- We map the aggregate effects of sectoral government purchases into the characteristics of the recipient industry.
- The spending multiplier is larger when government purchases originate in sectors with a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the supply chain.
- Differences in the sectoral composition of purchases across U.S. government levels lead to large variation in the spending multiplier.

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ABSTRACT

The aggregate spending multiplier crucially depends on the sectoral origin of government purchases. To establish this result, we characterize analytically the response of aggregate output to sector-specific government spending shocks in a tractable production-network economy, showing how it maps into various characteristics of the shocked sector. The response is larger when government spending originates in sectors with a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the supply chain. We confirm these predictions and evaluate their quantitative relevance within a calibrated multi-sector model of the U.S. economy that embeds several dimensions of sectoral heterogeneity. Leveraging this model, we illustrate how differences in the sectoral composition of purchases across U.S. government levels lead to large variation in the spending multiplier. The latter ranges from 0.47 for federal defense spending, which is relatively concentrated in upstream capital-intensive manufacturing, to 0.82 for state and local spending, which is mainly oriented towards downstream labor-intensive services. Finally, we exploit heterogeneity in the sectoral composition of military spending across U.S. states to provide empirical evidence supporting our theoretical predictions.

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* Corresponding author.
Email addresses: hafedh.bouakez@hec.ca (H. Bouakez), omar.rachedi@esade.edu (O. Rachedi), emiliano.santoro@unicatt.it (E. Santoro).

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1. Introduction

Government purchases of goods and services from the private sector are heterogeneously distributed across highly diverse industries.[1] Until recently, however, this basic observation was largely overlooked by theoretical studies of fiscal policy, which tend to condense the economy into a representative sector, and lump government purchases from the different industries into a single aggregate. By construction, such an approach conceals the role of sectoral characteristics and inter-sectoral linkages in the transmission of government spending shocks. This limitation becomes even more severe when assessing large stimulus plans, which typically target specific industries.

A number of recent contributions have moved away from the one-sector framework, studying various contexts in which the sectoral composition of government purchases matters for the aggregate spending multiplier (e.g., Baqaee and Farhi, 2019, Proebsting, 2022, Cox et al., 2024, and Flynn et al., 2024). While pointing to the importance of the sectoral origins of spending shocks for aggregate outcomes, none of these contributions has systematically assessed how various structural characteristics of the shocked sector, together with its position in the supply chain, influence the aggregate multiplier. This is the task we undertake in this paper, both analytically and quantitatively, offering novel insights: the aggregate multiplier is larger when government spending originates in sectors with a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the production network. Learning these properties is of paramount importance to identify the industries the government needs to target in order to maximize the output effects of public spending.

Our analytical insights are based on a stylized two-sector Cobb–Douglas economy, in which production is carried out using labor and intermediate inputs, and prices are set by imposing a markup over marginal costs. The two sectors differ in their contribution to private final demand (i.e., their consumption share), markup, labor intensity, and position in the production network, one sector being located upstream and the other downstream. To transparently illustrate how these characteristics shape the aggregate effects of sectoral spending shocks, we assume that labor supply is infinitely elastic. As a result, consumption is proportional to the real wage, in equilibrium.[2] Furthermore, we allow labor to be imperfectly mobile across the two sectors, thus enabling relative prices to vary in response to demand shocks.[3]

By construction, the response of aggregate output to a sectoral spending shock comprises a direct effect, which we assume to be symmetric across sectors,[4] and a general-equilibrium effect. We show that the latter involves the product of two statistics pertaining to the sector being shocked: the response of its relative price, and a loading factor that depends (i) positively on the gap between the sector's steady-state contribution to *total* and *private* final demand, and (ii) negatively on the distortion in the sector's relative size – measured by its steady-state employment share — arising from markup pricing.

An immediate corollary of this result is that the aggregate effects of sectoral spending shocks are independent of their origin when relative prices do not adjust. In other words, sectoral characteristics and the production network are completely irrelevant to the response of aggregate quantities. When relative prices adjust, however, an increase in government purchases from a given sector raises its relative price and leads to a larger effect on aggregate output when the recipient sector is a relatively small contributor to private final demand or is less distorted.

The intuition underlying these implications hinges primarily on how total labor demand responds under different assumptions about labor mobility across sectors. In our constant-returns-to-scale economy, the real wage can be expressed as a weighted average of sectoral relative prices, where the weights correspond to each sector's contribution to total final demand, adjusted for its relative size distortion. A positive spending shock in a given sector raises its demand for labor. When the latter is perfectly mobile, sectoral wages are equalized and thus sectoral relative prices are constant. In this case, the aggregate real wage, along with sectoral and aggregate consumption levels, remains unchanged and the total increase in labor demand is independent of the recipient sector's characteristics. As a result, the sectoral origin of the shock is irrelevant to its aggregate outcomes. Under imperfect labor mobility, however, higher demand in the recipient sector raises its real wage and relative price, triggering an expenditure switching effect whereby consumption is diverted away from the more expensive good and towards the cheaper one. To the extent that this substitution impacts the aggregate real wage, it gives rise to an income effect that affects total labor demand in a way that depends on the sectoral origin of the shock.

All else equal, when government spending rises in the sector that contributes less to private consumption, that sector becomes more biased towards government spending. Consequently, its relative price rises more than it would have if the sector had been the larger contributor to consumption. Since this relative price receives a larger weight in the aggregate real wage index than the sector's consumption share (reflecting its relative bias towards public demand), the aggregate real wage rises, inducing additional demand from the private sector and leading to a larger rise in total labor demand and aggregate output. The pass-through from the relative price of the shocked sector to the aggregate real wage is also higher when the shock originates in the less distorted sector, leading to a larger increase in aggregate output, *ceteris paribus*. In our setting, sectoral heterogeneity in the size distortion stems from differences in the markup, labor intensity, and position in the production network: (i) when the two sectors are otherwise symmetric, the one with less market power is naturally less distorted; (ii) holding markups constant, the sector with higher labor intensity is less distorted, as it relies more heavily on the non-marked-up input (labor); (iii) finally, when markups and labor intensities are equal, the upstream sector is more distorted than the downstream one because it supplies all intermediate inputs, and these are subject to double marginalization, as they are marked-up both when they are produced and when they are used.

We then ask whether these findings carry over to a richer and more realistic setting. To do so, we develop a quantitative multi-sector model that features multiple sources of sectoral heterogeneity and a complex production network, and calibrate it to 57 industries of the U.S. economy. The model's predictions corroborate those of the stylized

[1] The standard deviation of sectoral government purchases is 45 % larger than that of sectoral value added. The correlation between the sectoral contribution to government purchases and sectoral value added is 0.39. These figures are based on information from the 2018 U.S. Input–Output Tables at the 3-digit level of the North American Industry Classification System (NAICS). Furthermore, using information on the universe of procurement contracts by the U.S. federal government, Cox et al. (2024) document that government spending is granular, being concentrated among few firms and sectors, and that its sectoral allocation differs from that of private spending.

[2] The assumption of an infinitely elastic labor supply neutralizes the resource-constraint effect associated with government spending shocks. This assumption is relaxed in the quantitative analysis.

[3] Under perfect labor mobility and constant returns to scale in production, relative prices are independent of the demand side of the economy, and are therefore unresponsive to government spending shocks (see also Acemoglu et al., 2016). Imperfect labor mobility, however, is not the only technical expedient to generate variation in relative prices. For instance, one could alternatively assume that the production technology exhibits decreasing returns to scale.

[4] Our primary focus is not to explain the difference in the aggregate effects of sectoral spending shocks induced mechanically by heterogeneity in the sectors' exposure to their own shocks, but instead to relate those effects to the (non-policy) structural characteristics of the shocked sectors.

economy: The aggregate value-added multiplier is larger when spending shocks originate in sectors with a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the production network. In contrast, sectoral heterogeneity in the degree of price rigidity is found to be less important in explaining differences in the aggregate multiplier of sectoral shocks.

Next, we leverage the fully fledged structure of the calibrated model to offer quantitative insights into the extent to which the aggregate spending multiplier is (i) asymmetric across sectoral spending shocks and (ii) varies with the sectoral allocation of government purchases. We find significant dispersion in the size of the aggregate multiplier of U.S. sectoral government purchases, which ranges from 0.23 to 1.13. Overall, the output response is lower when the government buys from upstream industries with a relatively large contribution to investment and low labor intensity, like manufacturing. On the other hand, it is larger when the government raises its demand for goods produced by downstream labor-intensive industries, such as retail trade and educational and health-care services.

To illustrate the quantitative relevance of the sectoral composition of spending for the aggregate multiplier, we exploit the differences in the sectoral content of purchases across layers of the U.S. government — general, federal (defense and non-defense), and state and local.[5] While the aggregate value-added multiplier associated with spending by the general government amounts to 0.72, this figure masks substantial heterogeneity across government levels, with values ranging from 0.47 for federal defense spending to 0.82 for spending by the state and local government. Likewise, we find significant differences in the aggregate consumption multiplier, which is negative (−0.17) for defense spending, but positive (0.13) for state and local government purchases. This variance is due to the fact that defense spending is mainly concentrated in upstream industries with low labor intensity, whereas state and local spending is mostly oriented towards downstream labor-intensive sectors. Importantly, these findings contribute to explaining the large dispersion in the empirical estimates of the effects of government spending: studies that rely on federal defense spending tend to report small output multipliers and a crowding-out of consumption (e.g., Barro and Redlick, 2011; Ramey, 2011); instead, measuring spending at the general-government level typically leads to large output multipliers and a crowding-in of consumption (e.g., Blanchard and Perotti, 2002; Auerbach and Gorodnichenko, 2012).

Testing our predictions in the data requires identifying sectoral spending shocks and tracing their effects on aggregate output. Sectoral shocks are typically identified in panel settings, so as to control for changes in the entire stream of spending across industries while addressing potential endogeneity stemming from sectoral public purchases being dependent on the state of the economy. By construction, however, a panel setting forces estimates to be pooled across industries, so that only the effects of the *average* shock and a given *average* sectoral characteristic can be uncovered. This rules out the possibility of testing our predictions in a direct way.

We devise an indirect test that exploits heterogeneity in the sectoral composition of public spending across U.S. states. This approach allows us to estimate how the response of aggregate (state-level) output changes when total (state-level) spending is tilted towards sectors with a given characteristic.[6] To do so, we use the universe of contracts awarded by the U.S. Department of Defense within each state. For a given sectoral characteristic, we run a regression that estimates the average local multiplier – defined as the dollar change in the GDP of a given state following a dollar increase in defense spending in that state — as well as its interaction with a term that represents the extent to which spending is concentrated in sectors with the characteristic of interest. Thus, although estimates are pooled across states, the coefficients on the interaction terms are informative about the way in which the multiplier changes with the sectoral composition of spending. The estimates corroborate our predictions: the local multiplier tends to be larger when government purchases from a given state are more skewed towards sectors that contribute relatively less to private final demand, have lower markups, are labor intensive, and are located downstream in the supply chain.

Related literature. Our paper builds on the large literature that studies the spending multiplier, focusing predominantly on government consumption in the form of purchases of goods and services from the private sector (see Ramey, 2019 for a recent survey). A rapidly growing branch of this literature examines the effects of government purchases within multi-sector production-network economies.[7] In Bouakez et al. (2023), we employ a quantitative model akin to the one in this paper. However, we abstract from sectoral shocks and focus on examining the extent to which input–output interactions and sectoral differences in price rigidity amplify the impact of aggregate spending shocks on output, compared to a single-sector framework. That paper is therefore silent on how the sectoral composition of spending matters in the aggregate. Acemoglu et al. (2016) examine the propagation of sectoral spending shocks via the production network, but their framework inhibits relative-price adjustment, implying that inter-sectoral linkages are irrelevant for the aggregate spending multiplier. Devereux et al. (2023) build on Acemoglu et al. (2016) to study the cross-country spillovers of government spending shocks through international production networks. Dong and Wen (2019) compare the transmission of money injections via the production network with that of sectoral technology and government spending shocks.

Closer to our paper, Baqaee and Farhi (2019), Proebsting (2022), Cox et al. (2024), and Flynn et al. (2024), study environments in which the sectoral composition ofgovernment purchases matters in the aggregate. Baqaee and Farhi (2019), and Flynn et al. (2024) consider economies in which workers with different marginal propensities to consume are heterogeneously distributed across industries,[8] Proebsting (2022) shows how labor-market and government-demand segmentation across sectors affect the aggregate effects of public spending. Cox et al. (2024) use U.S. procurement data to establish a number of facts about federal spending. In particular, they observe that the composition of federal purchases is biased towards sectors in which private-sector prices are sticky. Using a two-sector model, they show that this feature amplifies the aggregate spending multiplier. We share with these papers the idea that the spending multiplier depends on the sectoral composition of public purchases. However, we offer a novel perspective on what drives this dependence, mapping the aggregate effects of sectoral government spending into various primitives of the recipient industry and its position in the supply chain.[9] We believe we are the first to provide a comprehensive treatment of this aspect.

Our paper is also related to recent research that examines the macroeconomic implications of microeconomic shocks in inefficient

[5] We study otherwise identical versions of the model that only differ in the sectoral composition of government spending. More specifically, we consider different linear combinations of sectoral spending shocks, where the weights replicate the sectoral composition of purchases at each U.S. government level.

[6] We also perform an alternative exercise in which we estimate multipliers at the aggregate level, and exploit changes in the sectoral composition of aggregate government spending.

[7] The first work on the effects of government spending within a multi-sector model is Ramey and Shapiro (1998), which shows that costly capital reallocation across sectors alters the spending multiplier relative to the one-sector framework. This paper, however, abstracts from production networks.

[8] Relatedly, Guerrieri et al. (2022) show how the interplay between households with different marginal propensities to consume and input–output linkages affects the effectiveness of fiscal policy in responding to supply shocks.

[9] In doing so, we complement earlier work that shows the effects of government spending are not invariant to considerations such as the financing scheme (e.g., Leeper et al., 2010), the stance of monetary policy (e.g., Christiano et al., 2011), and the state of the economy (e.g., Auerbach and Gorodnichenko, 2012).

production-network economies. Existing papers in this literature, however, have focused on sectoral productivity and markup shocks, showing, in particular, how sectoral distortions affect aggregate efficiency in the presence of input–output linkages (e.g., Jones, 2013; Liu, 2019; Baqaee and Farhi, 2020; Bigio and La'O, 2020).

Finally, this paper connects to a body of applied work that studies highly disaggregated public purchases and estimates their effects at the industry/firm level (e.g., Nekarda and Ramey, 2011; Acemoglu et al., 2016; Slavtchev and Wiederhold, 2016; Auerbach et al., 2020; Kim and Nguyen, 2020; Hebous and Zimmermann, 2021; Coviello et al., 2022, and Barattieri et al., 2023). These studies typically adopt identification strategies that difference out the aggregate general-equilibrium effects of sectoral shocks, thus preventing a clear mapping between the estimated cross-industry multipliers of government purchases and their aggregate counterparts. Our paper complements this strand of the literature by developing a structural framework that takes into account the general-equilibrium interactions shaping the aggregate effects of sector-specific government spending shocks.

Structure of the paper. The rest of the paper is organized as follows. In Section 2, we introduce a stylized model to establish analytical results on the mapping between the aggregate effects of sectoral government purchases and the characteristics of the recipient sector. In Section 3, we validate the analytical predictions within a quantitative multi-sector model, calibrated to the U.S. economy. We also use this model to evaluate the dispersion in the aggregate multipliers associated with U.S. sectoral government spending shocks, and to compare the aggregate multipliers implied by the sectoral composition of purchases across the different levels of the U.S. government. In Section 4, we provide empirical evidence supporting the theoretical predictions. Section 5 concludes.

2. Sectoral characteristics and the aggregate effects of sectoral government spending: analytical results

The purpose of this section is to relate the aggregate output effects of sectoral government spending shocks to the attributes of the sector in which those shocks originate, including its position in the production network. We characterize this mapping analytically, in a tractable two-sector economy.

2.1. A stylized model

Consider a flexible-price economy with two inter-connected sectors that use labor and intermediate inputs to produce, and sell goods to both consumers and the government. Firms in each sector produce differentiated varieties and operate under monopolistic competition. The two sectors differ along four structural dimensions: (i) their contribution to private final demand, as they have different shares in aggregate consumption, (ii) their elasticity of substitution across varieties, such that they have different steady-state markups, (iii) their labor intensity, and (iv) their position in the production network. To capture (iv) in a tractable and parsimonious way, we consider an upstream sector, denoted by u, which supplies all the intermediate inputs used by both sectors, and a downstream sector, denoted by d, which demands intermediate inputs, but provides none. The model allows for imperfect labor mobility across sectors, and nests the limiting case in which labor is perfectly mobile. Because the model has no endogenous state variable, it can be solved period by period. Thus, we drop the time subscript in the remainder of this section.

2.1.1. The environment

Households. The representative household has a utility function that is logarithmic in consumption, C, and linear in total labor, N:

$$u(C, N) = \log C - \theta N, \qquad \theta > 0. \tag{1}$$

The linearity of the utility function with respect to labor means that the latter is indivisible, as in Hansen (1985), which in turn implies that the Frisch elasticity of labor supply is infinite. This assumption, which we relax in Section 3, is convenient because it neutralizes the resource-constraint effect associated with changes in government spending, thereby greatly simplifying the algebra.

To allow for imperfect labor mobility across sectors, we follow Huffman and Wynne (1999), Horvath (2000), and Bouakez et al. (2009), and posit that the total amount of labor provided by the household is a CES function of the labor supplied to each sector, that is,[10]

$$N = \left[\omega_{N,u}^{-\frac{1}{\nu_N}} N_u^{\frac{1+\nu_N}{\nu_N}} + \omega_{N,d}^{-\frac{1}{\nu_N}} N_d^{\frac{1+\nu_N}{\nu_N}} \right]^{\frac{\nu_N}{1+\nu_N}}, \tag{2}$$

where $\omega_{N,u} + \omega_{N,d} = 1$, with $\omega_{N,s}$ being the weight attached to labor provided to sector s ($s = u, d$), and $\nu_N \geq 0$ is (the absolute value of) the elasticity of substitution of labor across sectors. This specification nests the special case in which $\nu_N \to \infty$, so that labor is perfectly mobile and, as a result, nominal wages are equalized across sectors. Under fully flexible prices, this also implies that sectoral relative prices are unresponsive to demand shocks. Instead, as long as $\nu_N < \infty$, labor is imperfectly mobile and both sectoral wages and relative prices can differ.[11]

The household's supply of labor to sector s is given by

$$N_s = \omega_{N,s} \left(\frac{\mathcal{W}_s}{\mathcal{W}} \right)^{\nu_N} N, \qquad s = u, d, \tag{3}$$

where $\mathcal{W}_s$ denotes the nominal wage in sector s, and $\mathcal{W} = \left[\omega_{N,u} \mathcal{W}_u^{1+\nu_N} + \omega_{N,d} \mathcal{W}_d^{1+\nu_N} \right]^{\frac{1}{1+\nu_N}}$ is the aggregate nominal wage index, which satisfies $\mathcal{W}_u N_u + \mathcal{W}_d N_d = \mathcal{W} N$.

The household receives aggregate profits, D, and pays a nominal lump-sum tax, T, to the government, so that its budget constraint is

$$PC + T = \mathcal{W} N + D, \tag{4}$$

where P denotes the consumption-based price index.

Firms

Producers. The production process is split in two stages. A continuum of monopolistically competitive producers, indexed by $j \in [0, 1]$, combine labor and intermediate inputs to produce differentiated varieties of goods. These varieties are then aggregated into a single good in each sector by a representative perfectly competitive wholesaler.

Producer j in sector s has the following Cobb–Douglas production technology:

$$Z_s^j = \left(N_s^j \right)^{1-\alpha_{H,s}} \left(H_{s,u}^j \right)^{\alpha_{H,s}}, \qquad \text{for } j \in [0, 1] \text{ and } s = u, d, \tag{5}$$

where Z_s^j denotes its gross output, N_s^j denotes its use of labor, and $H_{s,u}^j$ denotes the intermediate inputs it buys from the upstream sector. The parameter $\alpha_{H,s} \in [0, 1]$ measures the gross-output-based intensity of intermediate inputs in sector s.

[10] Note that this assumption does not contradict labor indivisibility, as one can think of the representative household as a family consisting of two members, each working in a different sector.

[11] Empirically, imperfect labor mobility across sectors is certainly a more plausible characterization of the labor market than perfect mobility. Lee and Wolpin (2006) find that labor adjusts very sluggishly in response to shocks, and is reallocated imperfectly across sectors in the short and medium run. Moreover, Krueger and Summers (1988), Gibbons and Katz (1992), and Neumuller (2015), among others, document large sectoral wage differentials. Finally, Katayama and Kim (2018) show that imperfect labor mobility provides a better account of the comovement between output and hours worked than alternative explanations based on the wealth effects associated with labor supply.

The representative wholesaler in sector s has the following CES aggregation technology:

$$Z_s = \left[\int_0^1 Z_s^{j\,\frac{\epsilon_s-1}{\epsilon_s}}\, dj\right]^{\frac{\epsilon_s}{\epsilon_s-1}}, \quad s = u, d, \tag{6}$$

where Z_s denotes total output of good s, and ϵ_s is the elasticity of substitution across varieties within sector s. Denoting by P_s^j the price set by producer j in sector s, the price of good s is then given by $P_s = \left[\int_0^1 P_s^{j\,1-\epsilon_s} dj\right]^{\frac{1}{1-\epsilon_s}}$. In each sector, prices are flexible and set as a constant markup, $\vartheta_s \equiv \frac{\epsilon_s}{\epsilon_s-1}$, over marginal cost.

Wholesalers' output in both sectors is sold as final goods to both a representative consumption-good retailer and the government. The output of the upstream sector is also sold as intermediate inputs to producers in both sectors. Imposing symmetry across producers within each sector yields the following market-clearing conditions at the sectoral level[12]:

$$Z_u = C_u + G_u + H_{u,u} + H_{d,u}, \tag{7}$$

$$Z_d = C_d + G_d, \tag{8}$$

where C_s denotes the retailer's purchase of consumption goods from sector s, and G_s denotes government purchases from sector s.

Consumption-good retailers. A representative consumption-good retailer purchases goods from each sector and assembles them into a consumption bundle sold to the households. Its technology is given by

$$C = C_u^{\omega_{C,u}} C_d^{\omega_{C,d}}, \tag{9}$$

where $\omega_{C,u}+\omega_{C,d} = 1$, with $\omega_{C,s}$ being the consumption share of sector s. The retailer's optimal demand for the good produced by sector s is

$$C_s = \omega_{C,s}\left(\frac{P_s}{P}\right)^{-1} C, \qquad s = u, d, \tag{10}$$

where P_s denotes the nominal price of the good produced in sector s. The zero-profit condition of the consumption-good retailer implies that $P = \omega_{C,u}^{-\omega_{C,u}} \omega_{C,d}^{-\omega_{C,d}} P_u^{\omega_{C,u}} P_d^{\omega_{C,d}}$.

Government. Government purchases from the two sectors are exogenously determined and are financed through lump-sum taxes paid by the household, which implies the following budget constraint for the government:

$$P_u G_u + P_d G_d = T. \tag{11}$$

Aggregation and auxiliary assumptions. Defining $Q_s \equiv \frac{P_s}{P}$ as the real price of the good produced by sector s, real value added in this sector is obtained by subtracting the real cost of the intermediate inputs it uses from the real value of its gross output:

$$Y_s = Q_s Z_s - Q_u H_{s,u}, \qquad s = u, d. \tag{12}$$

By consolidating the household's and government's budget constraints, one can then express aggregate real value added as

$$Y \equiv Y_u + Y_d = C + Q_u G_u + Q_d G_d. \tag{13}$$

To solve the model, we log-linearize the equilibrium conditions around a non-stochastic steady state in which, for convenience, sectoral nominal wages are constrained to be equal. This property, which we obtain by equating the sectoral weights $\omega_{N,s}$ to the steady-state employment share, $\varpi_s \equiv N_s^*/N^*$, ensures that versions of the model with different degrees of labor mobility share the same steady state.[13]

Based on the log-linear model, we derive analytical results regarding the propagation of sectoral government spending shocks and their aggregate effects, which we relate to the characteristics of the sector being shocked and its position in the network. In the remainder of this section, lowercase variables denote percentage deviations of their uppercase counterparts from their steady-state values.

2.1.2. Analytical results

Let us introduce the following notation: $\gamma \equiv \frac{\sum_{s=u,d} Q_s^* G_s^*}{Y^*}$ denotes the steady-state share of total government spending in aggregate value added, $\omega_{G,s} \equiv \frac{Q_s^* G_s^*}{\sum_{s=u,d} Q_s^* G_s^*}$ denotes the steady-state contribution of sector s to total public spending, and $\mu_s \equiv \frac{Q_s^*(C_s^*+G_s^*)}{Y^*} = (1-\gamma)\,\omega_{C,s} + \gamma\omega_{G,s}$ denotes its steady-state contribution to total final demand.

In Appendix A, we show that the response of aggregate value added to a spending shock in sector s is given by

$$\frac{dy}{dg_s} = \gamma\omega_{G,s} + \left[\frac{\psi_1\left(\mu_s - \omega_{C,s}\right) - \psi_2\left(\varpi_s^e - \varpi_s\right)}{1-\omega_{C,s}}\right]\frac{dq_s}{dg_s}, \qquad s = u, d, \tag{14}$$

where $\psi_1 = 2-\gamma > 0$, $\psi_2 \equiv \frac{1-\gamma}{1-\alpha_{H,d}} > 0$, and ϖ_s^e is the steady-state employment share of sector s in the absence of markup pricing (i.e., under efficiency). By definition, ϖ_s collapses to ϖ_s^e when both sectoral markups are equal to 1 (see Eqs. (A.26) and (A.27) in Appendix A).

The first term on the left-hand side of Eq. (14) measures the direct effect of the shock, whereas the second term captures its general-equilibrium effect. The latter is characterized by the product of two statistics pertaining to the sector being shocked: the response of its relative price, and a loading factor that is (i) increasing in the gap between the sector's contribution to total final demand and its consumption share $\left(\mu_s - \omega_{C,s}\right)$, and (ii) decreasing in the sector's relative size distortion – measured by its steady-state employment share – arising from markup pricing $(\varpi_s^e - \varpi_s)$.

In order to study the mapping between the aggregate effects of sectoral spending shocks and the non-policy characteristics of the shocked sector, we henceforth assume that the two sectors contribute equally to total public spending in the steady state, by imposing that $\omega_{G,u} = \omega_{G,d} = \frac{1}{2}$. This allows us to isolate the role of the sector's contribution to private final demand and its size distortion, *ceteris paribus*.[14] We start by presenting an irrelevance result stating the general conditions under which the composition of government spending – or, alternatively, the sectoral origin of spending shocks – is irrelevant for aggregate output.

Proposition 1. *An irrelevance result. The response of aggregate value added is independent of the sectoral origin of a spending shock if*

(i) relative prices do not respond to the shock, or
(ii) the economy is efficient (i.e., $\vartheta_s = 1$ for $s = u, d$) and the sectors contribute equally to private (and total) final demand (i.e., $\omega_{C,s} = \mu_s = \frac{1}{2}$ for $s = u, d$).

Proof. See Appendix A. □

[12] These market-clearing conditions reflect the assumption that the input–output matrix has a column of ones and a column of zeros, as the upstream sector provides intermediate inputs to itself and to the downstream sector, whereas the latter provides none. This structure is the most parsimonious way to allow for differences in the sectors' position in the production network, while holding constant all the remaining sectoral attributes.

[13] Steady-state variables are denoted by an asterisk. Appendix A reports the list of non-linear equilibrium conditions, the steady-state equilibrium, and the log-linearized equations.

[14] The assumption that the sectors contribute equally to government spending in the steady state is relaxed in the quantitative analysis carried out in Section 3.4.

The intuition underlying these results (and those stated in Propositions 3 and 4) mainly rests on the adjustment of the labor market. On the one hand, a positive spending shock in a given sector raises its demand for labor. On the other hand, under the simplifying assumption of an infinite Frisch elasticity, labor supply is given by $w = c$. Given the constant-returns-to-scale production technology, the aggregate real wage can be expressed as a weighted average of sectoral relative prices, where the weights correspond to each sector's contribution to total final demand, adjusted for its relative size distortion[15]:

$$w = c = \frac{\varpi_u - \alpha_{H,d}}{\varpi_u^e - \alpha_{H,d}} \mu_u q_u + \frac{\varpi_d}{\varpi_d^e} \mu_d q_d. \tag{15}$$

Absent relative-price adjustment, the aggregate real wage, along with sectoral and aggregate consumption levels, remains unchanged and there is no further effect on labor demand. In turn, the assumption of constant returns to scale implies that the shift in labor demand is independent of the recipient sector's characteristics, such that the sectoral origin of the shock is irrelevant to the response of aggregate output, as stated in part (i) of the proposition. Note that this setting, in which relative prices are unresponsive to demand shocks, is similar to that considered by Acemoglu et al. (2016), who show that sectoral spending shocks propagate upstream through the production network, from downstream sectors to their input supplying industries. Part (i) of the proposition, however, shows that this upstream propagation of sectoral shocks is entirely irrelevant to their aggregate implications.[16]

Changes in relative prices induce an expenditure-switching effect, whereby consumers substitute the more expensive good with the cheaper one. However, when the economy is efficient (i.e., $\varpi_s = \varpi_s^e$ for $s = u, d$) and each of the two sectors contributes equally to total and private final demand (i.e., $\mu_s = \omega_{C,s}$ for $s = u, d$) – such that the loading factor in (14) becomes nil – the weights in Eq. (15) collapse to the sectoral consumption shares. Under this knife-edge condition, the nominal wage coincides with the nominal price index, becoming effectively the numeraire, and implying that the real wage (and thus consumption) is constant. In this case, changes in relative prices only cause consumers' budget line to rotate, without inducing any income effect. The result in part (ii) follows immediately if the two sectors are symmetric in their contribution both to private and total demand. Importantly, this result implies that, in efficient economies, the aggregate effects of sectoral government spending shocks are independent of the production network, even when relative prices adjust.

The response of relative prices to sectoral spending shocks. Given that relative-price adjustment is a necessary condition for the response of aggregate value added to depend on the sectoral origin of the shock, Proposition 2 below shows how relative prices respond to sectoral government spending shocks.

Proposition 2. *Sectoral government spending shocks have no effect on relative prices if labor is perfectly mobile. Under imperfect labor mobility, an increase in government spending in a given sector raises its relative price and lowers the relative price of the other sector. That is, for $s, x = u, d$ and $s \neq x$,*

$$\frac{dq_s}{dg_s} = \frac{dq_s}{dg_x} = 0 \qquad \text{if } \nu_N \to \infty,$$

$$\frac{dq_s}{dg_s} > 0 \;\; \text{and} \;\; \frac{dq_s}{dg_x} < 0 \qquad \text{otherwise.}$$

Proof. See Appendix A. □

Under perfect labor mobility, sectoral nominal wages are equalized across sectors. In this case, the assumption of constant returns to scale in production implies that relative prices are independent of the demand side of the economy, and are therefore unresponsive to government spending shocks, as is also shown by Acemoglu et al. (2016). When labor is imperfectly mobile, however, government purchases from a given sector raise its demand for labor and hence its real wage and relative price. The change in total labor demand depends on the response of aggregate consumption and, thus, on that of the aggregate real wage. Below, we explain how this response varies with the characteristics of the recipient sector.

Role of the sectoral consumption share. Expression (14) shows that, to the extent that relative prices adjust, the consumption share of the shocked sector affects the response of aggregate output explicitly – through the loading factor – and implicitly – through the response of the sector's relative price. Proposition 3 below formally establishes the relationship between the response of aggregate output and the consumption share of the recipient sector, *ceteris paribus*. Since we know from Propositions 1 and 2 that the consumption share is irrelevant to the response of aggregate output under perfect labor mobility, we only focus on the case of imperfect labor mobility.

Proposition 3. *Consider a sectoral spending shock and assume that the two sectors are otherwise identical. Under imperfect labor mobility ($\nu_N < \infty$), the response of aggregate value added is decreasing in the consumption share of the shocked sector. That is,*

$$\frac{\partial \left(\frac{dy}{dg_s} \right)}{\partial \omega_{C,s}} < 0.$$

Proof. See Appendix A. □

Intuitively, all else being equal, when government spending rises in the sector that contributes less to private consumption, that sector becomes more biased towards government spending. Consequently, its relative price rises more than it would have if the sector had been the larger contributor to consumption. Since this relative price receives a larger weight in the aggregate real wage index than the sector's consumption share (reflecting its relative bias towards public demand), the aggregate real wage rises, inducing additional demand from the private sector and leading to a larger increase in total labor demand and aggregate output.[17]

Fig. B.1 in Appendix B illustrates the effects of sectoral spending shocks in the stylized economy, where the two sectors s and x differ only in their consumption share, with $\omega_{C,s} = 0.25$ and $\omega_{C,x} = 0.75$. The responses are shown both under perfectly mobile and immobile labor.[18] Under perfect labor mobility, relative prices are constant, labor only increases in the recipient sector (since there is no input–output interaction), and the aggregate effects of spending shocks are identical regardless of their origin. Under immobile labor, a spending shock in a given sector raises its relative price, which increases private demand for the good produced by the other sector. As a result, labor rises by the same percentage in both sectors, but the increase in the aggregate real wage, consumption, labor, and value added is larger when the shock originates in the sector with a smaller consumption share (i.e., sector s).

[15] See Appendix A.

[16] In Section 3.3, we show that the irrelevance of the network to the aggregate effects of sectoral spending shocks under constant relative prices continues to hold in a more general setting that takes into account the resource-constraint effect (i.e., in which the Frisch elasticity is finite).

[17] Note that the increase in aggregate consumption brings about a negative wealth effect that shifts labor supply upward and mitigates the increase in labor demand. However, labor income still rises more than it does when the shock originates in the sector with a larger consumption share.

[18] The parameter values used to generate the results are reported in Appendix B.

Role of the sectoral relative size distortion. Expression (14) also implies that, for a given change in the relative price of the shocked sector, the response of aggregate value added decreases with the sector's relative size distortion. When the shock originates in the less distorted sector, *ceteris paribus*, there is higher pass-through from its relative price to the aggregate real wage, leading to higher (private) demand for goods and ultimately for labor. In our economy, heterogeneity in the sectors' relative size distortion may stem from heterogeneity in the markup, labor intensity, or position in the network. Proposition 4 below formalizes the mapping between the response of aggregate output and each of these characteristics in the relevant case of imperfect labor mobility.

Proposition 4. *Consider a sectoral spending shock and assume that the economy is inefficient and the two sectors are otherwise identical. Under imperfect labor mobility* ($\nu_N < \infty$), *the response of aggregate value added is:*

(i) decreasing in the markup of the shocked sector. That is,

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\vartheta_s} < 0,$$

(ii) increasing in the labor intensity of the shocked sector. That is,

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\left(1-\alpha_{H,s}\right)} > 0,$$

(iii) larger when the shock originates in the downstream sector than when it originates in the upstream sector. That is,

$$\frac{dy}{dg_d} > \frac{dy}{dg_u}.$$

Proof. See Appendix A. □

The results stated in parts (i) and (ii) are straightforward. When the two sectors are otherwise symmetric, the one with less market power is naturally less distorted. On the other hand, holding markups constant, the sector with higher labor intensity is also less distorted, as it relies more heavily on the non-marked-up input (labor).[19] The intuition behind the result in part (iii) lies in the way inefficiency affects the employment share of the shocked sector, depending on its position in the network. Under equal markups and labor intensities, the upstream sector is more distorted than the downstream sector because it provides all intermediate inputs, and these are subject to double marginalization, as they are marked up both when they are produced and when they are used (see also Liu, 2019).[20][21] Note that the logic behind the result in part (iii) is similar to that underpinning Diamond and Mirrlees (1971) production efficiency theorem, which implies that, in a competitive economy (i.e., with no markups), the optimal tax policy should leave intermediate goods untaxed. This is because intermediate-good taxation drives a wedge between the marginal product of labor in the intermediate-good sector and that in the final-good sector, distorting the allocation of factors of production between sectors, and lowering production efficiency. In our monopolistically competitive economy, spending shocks drive a wedge between the marginal product of labor in the upstream sector and that in the downstream sector, even when the two sectors are otherwise symmetric (including in their markup). Because of the double marginalization, the economic pie is smaller when the government buys goods and services from the upstream sector.[22]

Figs. B.2–B.4 in Appendix B illustrate these implications under the assumption that sector s is always the less distorted. More specifically, in Fig. B.2, $\vartheta_s = 1.2$ and $\vartheta_x = 1.5$; in Fig. B.3, $1-\alpha_s = 0.7$ and $1-\alpha_x = 0.3$; and in Fig. B.4, sector s is downstream while sector x is upstream. In all three cases, the two sectors are otherwise identical. Again, under perfect labor mobility, relative prices do not adjust and the aggregate effects of spending shocks do not depend on the characteristics of the shocked sector. In contrast, when labor is immobile, the responses of the aggregate real wage, consumption, and output are larger when the recipient sector has a lower markup, higher labor intensity, and is located downstream.

3. Quantitative analysis

The stylized model considered in Section 2.1 provides sharp insights into how the response of aggregate value added to sector-specific government spending shocks depends on the intrinsic characteristics of the sector being shocked and its position in the supply chain. The analytical tractability of the stylized model, however, requires abstracting from certain features – including other dimensions of sectoral heterogeneity — that might be empirically relevant for the propagation of government spending shocks and their aggregate effects. In this section, we develop a quantitative, highly disaggregated, multi-sector model that allows for multiple sources of sectoral heterogeneity and a complex production network.

The economy consists of S production sectors, which differ in their price rigidity, markup, factor intensities, use of intermediate inputs, and contribution to consumption, investment, and government purchases. Households accumulate physical capital, which they rent to firms, and producers face price-setting frictions that give rise to nominal price stickiness. Both features make the model dynamic in nature.

We describe below the most distinctive features of the economy (relative to the stylized model), and refer the reader to Appendix C for a thorough discussion of its structure. The parameter restrictions under which the multi-sector model nests exactly the one presented in Section 2.1 are specified in Appendix C.5.[23]

3.1. The environment

Households. We alter household preferences in three ways. First, the representative household receives utility not only from private consumption but also from the sum of government purchases from all sectors, where the two arguments enter the utility function in a non-separable

[19] Our result that aggregate output responds more strongly when the recipient sector is more labor-intensive is distinct from that derived by Hall (2009) in the context of a one-sector economy with decreasing returns to scale. He shows that higher labor intensity raises the employment/output multiplier associated with an *aggregate* spending shock because it weakens the extent of diminishing returns, which in turn mitigates the substitution effect (of lower real wages) on labor.

[20] Relatedly, Bigio and La'O (2020) study the aggregate implications of sectoral distortions stemming, for instance, from monopolistic competition. They show that these distortions result in an inefficient reallocation of resources across the input–output network, and that the aggregate effects of individual labor wedges compound as firms buy and sell from one another within the network. As a result, distortions in upstream sectors have larger effects on the aggregate labor wedge than distortions in downstream sectors.

[21] It is easy to extend our stylized economy to allow for monopolistic competition in the labor market. Without input–output interaction, wage markups would be isomorphic to price markups, thus implying that the response of aggregate output to a sectoral spending shock would be larger when the shock originates in the sector with a lower wage markup or higher labor intensity, *ceteris paribus*. On the other hand, wage markups *per se* do not lead to double marginalization, such that the sector's position in the network would be irrelevant to the response of aggregate variables.

[22] We thank the editor for suggesting this interpretation to us.

[23] The structure of the model is graphically summarized by Fig. C.1 in Appendix C.

manner, as in Bouakez and Rebei (2007).[24] Second, we allow the elasticity of intertemporal substitution to be different from 1 by adopting a general CRRA function (over total consumption) rather than a logarithmic one. Third, we relax the assumption of linear disutility of labor, allowing the Frisch elasticity to be finite. We also assume that the representative household trades one-period nominal bonds. In each period, the household purchases investment goods, which increase the undepreciated stock of capital subject to convex adjustment costs.

As in the stylized model, we allow for imperfect labor mobility across sectors by assuming that total labor is given by:

$$N_t = \left[\sum_{s=1}^{S} \omega_{N,s}^{-\frac{1}{\nu_N}} N_{s,t}^{\frac{1+\nu_N}{\nu_N}} \right]^{\frac{\nu_N}{1+\nu_N}}, \tag{16}$$

where $\sum_{s=1}^{S} \omega_{N,s} = 1$. Analogously, we assume that the total capital stock supplied by the representative household, K_t, is a CES aggregator of the capital stocks it rents to all the sectors, with $\nu_K \geq 0$ being (the absolute value of) the elasticity of substitution of capital across sectors, and $\omega_{K,s}$ denoting the weight attached to the capital provided to sector s, such that $\sum_{s=1}^{S} \omega_{K,s} = 1$. As is the case for labor, this assumption allows capital to be imperfectly mobile across sectors, consistent with its sluggish reallocation across industries over the business cycle (e.g., Lanteri, 2018).[25]

Production. A continuum of monopolistically competitive producers, indexed by $j \in [0,1]$, combine labor, capital, and a bundle of intermediate inputs to produce differentiated varieties of goods. These varieties are then aggregated into a single good in each sector by a representative perfectly competitive wholesaler.

Producer j in sector s has the following Cobb–Douglas production technology:

$$Z_{s,t}^j = \left(N_{s,t}^{j\ \alpha_{N,s}} K_{s,t}^{j\ 1-\alpha_{N,s}} \right)^{1-\alpha_{H,s}} H_{s,t}^{j\ \alpha_{H,s}}, \tag{17}$$

where $Z_{s,t}^j$ denotes gross output, and $N_{s,t}^j$, $K_{s,t}^j$, and $H_{s,t}^j$ denote labor, capital, and the bundle of intermediate inputs used by the producer. The parameters $\alpha_{N,s}$ and $\alpha_{H,s}$ are the value-added-based labor intensity and the gross-output-based intensity of intermediate inputs, respectively. Producers face price-setting frictions, such that they can reset their prices according to a Calvo-type mechanism, with ϕ_s being the sector-specific probability of not changing prices.

The representative wholesaler in sector s aggregates (using a CES technology with an elasticity of substitution across varieties ϵ_s) the different varieties supplied by the producers into a single final good, $Z_{s,t}$, which is then sold to consumption-good, investment-good, and intermediate-input retailers, as well as to the fiscal authority. Thus, the following market-clearing condition holds for sector s:

$$Z_{s,t} = C_{s,t} + I_{s,t} + \sum_{x=1}^{S} H_{x,s,t} + G_{s,t}, \tag{18}$$

where $C_{s,t}$ and $I_{s,t}$ denote, respectively, the retailers' purchases of consumption and investment goods from the wholesaler of sector s, $H_{x,s,t}$ denotes the intermediate inputs produced by sector s and used in the production of sector x, and $G_{s,t}$ denotes government purchases from sector s.

Consumption-good, investment-good, and intermediate-input retailers. The consumption-good retailer differs from that of the stylized model in that the elasticity of substitution of consumption across sectors is allowed to be non-unitary. More specifically, we assume that

$$C_t = \left[\sum_{s=1}^{S} \omega_{C,s}^{\frac{1}{\nu_C}} C_{s,t}^{\frac{\nu_C-1}{\nu_C}} \right]^{\frac{\nu_C}{\nu_C-1}}, \tag{19}$$

where ν_C is the elasticity of substitution of consumption across sectors, and $\omega_{C,s}$ denotes the weight of good s in the consumption bundle, such that $\sum_{s=1}^{S} \omega_{C,s} = 1$. Analogously, we consider a representative investment-good retailer, which assembles the aggregate investment good, I_t, that is then sold to the household. In this case, the elasticity of substitution is ν_I, while the sectoral weights are denoted by $\omega_{I,s}$.

Finally, a representative intermediate-input retailer assembles the goods supplied by the wholesalers of all sectors into a bundle of intermediate inputs destined exclusively for the producers of a specific sector. The representative intermediate-input retailer that sells exclusively to sector s produces the bundle $H_{s,t}$ using the CES technology

$$H_{s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x}^{\frac{1}{\nu_H}} H_{s,x,t}^{\frac{\nu_H-1}{\nu_H}} \right]^{\frac{\nu_H}{\nu_H-1}}, \tag{20}$$

where $H_{s,x,t}$ is the quantity of goods purchased from the wholesaler of sector x, ν_H is the elasticity of substitution of intermediate inputs across sectors, and $\omega_{H,s,x}$ is the weight of the intermediate inputs produced by sector x in the total amount of intermediate inputs used by firms in sector s, such that $\sum_{x=1}^{S} \omega_{H,s,x} = 1$.

Government. The government consists of a monetary and a fiscal authority. The monetary authority sets the nominal interest rate following a standard Taylor rule that responds to aggregate inflation and the aggregate output gap. The fiscal authority purchases goods from each sector. The amount of government spending in sector s is governed by the following auto-regressive process:

$$\log G_{s,t} = (1-\rho) \log G_s^* + \rho \log G_{s,t-1} + \upsilon_{s,t}, \tag{21}$$

where $\rho \in (0,1)$ measures the persistence of the process. Sectoral government spending changes over time following the realizations of the unique source of uncertainty in the model: sectoral government spending shocks, $\upsilon_{s,t}$, which are zero-mean innovations. As in the stylized model, government purchases are financed through lump-sum taxes paid by the households.

3.2. Calibration

Parameter values. We calibrate the model to the U.S. economy, assuming that it consists of $S = 57$ sectors, which roughly correspond to the 3-digit level of the NAICS code list.[26] Throughout the analysis, we assume that one period in the model corresponds to a quarter. In what follows, we describe the calibration of the parameters that govern sectoral heterogeneity and interaction in the model, as well as those

[24] As we show in Bouakez et al. (2023), assuming that private and public consumption spending are complements is helpful in generating aggregate spending multipliers that are in line with those reported in the empirical literature. In Appendix F, however, we show that this feature mainly exerts a level effect, as there is close-to-perfect correlation between the aggregate spending multipliers implied by the models with and without complementarity.

[25] Miranda-Pinto and Young (2019) show that a model with imperfect mobility of capital across industries can fit well both the volatility of aggregate output and the comovement of sectoral output.

[26] We go from the original 66 to 57 industries by removing sectors that broadly operate in financial, insurance and real estate services, and by collapsing sectors that operate in oil and gas extraction and mining into a single sector. More details and the complete list of sectors are reported in Appendix D.

characterizing the exogenous process of government spending. Appendix D describes the calibration of the remaining parameters.

We set the elasticity of substitution of consumption across sectors to $\nu_C = 2$, in line with the estimates reported by Hobijn and Nechio (2019) based on the 2-digit and 3-digit levels of disaggregation of the expenditure categories included in the calculation of the Harmonized Index of Consumer Prices. The same value is assigned to the elasticity of substitution of investment across industries, i.e., $\nu_I = 2$. We set the elasticity of substitution of intermediate inputs across sectors following the estimates of Barrot and Sauvagnat (2016), Atalay (2017), and Boehm et al. (2019), who find a strong degree of complementarity across industries, and do not reject the hypothesis that the aggregator of intermediate inputs is a Leontief function. Accordingly, we set $\nu_H = 0.1$.

We calibrate the sectoral weights $\omega_{C,s}$, $\omega_{I,s}$, and $\omega_{H,s,x}$ using information from the Input–Output Tables of the U.S. economy provided by the Bureau of Economic Analysis. The consumption weights, $\omega_{C,s}$, target the average contribution of each sector to personal consumption expenditures over the period 1997–2015. Analogously, the investment weights, $\omega_{I,s}$, and the intermediate-input weights, $\omega_{H,s,x}$, target the average contribution of each sector to nonresidential private fixed investment in structures and equipment, and the average use of intermediate inputs from sector x in the production of sector s, respectively.[27] The joint calibration of $\omega_{C,s}$, $\omega_{I,s}$, and $\omega_{H,s,x}$ allows the model to match the sectoral shares in private final demand.

To set the factor intensities, $\alpha_{N,s}$ and $\alpha_{H,s}$, we use information from the Input–Output Tables on value added, labor compensation, and use of intermediate inputs. More specifically, we posit that the gross output of each sector equals the sum of the compensation of employees, the gross operating surplus, and the cost of intermediate inputs.[28] Since we consider a constant-return-to-scale Cobb–Douglas production function for gross output, we can compute $\alpha_{H,s}$ as the sectoral share of intermediate inputs in gross output (net of the share accrued to the markup). Analogously, we set $\alpha_{N,s}$ as the sectoral share of the compensation of employees in value added.

We calibrate the sectoral elasticities of substitution across varieties based on the markup estimates obtained by de Loecker et al. (2020) using sales-weighted firm-level data for the U.S. economy in 2016. To assign values to the sectoral Calvo probabilities, ϕ_s, we match our sectors with the items/industries analyzed by Nakamura and Steinsson (2008) and Bouakez et al. (2023), and rely on their estimates of the sectoral durations of price spells to back out the values of ϕ_s. Following Horvath (2000), we set the parameter governing the elasticity of substitution of labor across sectors to $\nu_N = 1$.[29] Analogously, we set $\nu_K = 1$. We calibrate the weights $\omega_{N,s}$ and $\omega_{K,s}$ such that the model features identical wages and rental rates of capital across sectors in the steady state. To do so, we set $\omega_{N,s} = \frac{N_s^*}{N^*}$ and $\omega_{K,s} = \frac{K_s^*}{K^*}$.

We normalize total government spending such that it sums up to 20 % of aggregate value added in the steady state. Finally, we set the autoregressive parameter of the sectoral processes of government spending to $\rho = 0.90$, and calibrate the steady-state sectoral government purchases, G_s^*, using information from the Input–Output Tables on the average contribution of each industry to general government purchases.

Appendix D.2 reports an exercise aimed at validating the goodness of our calibration strategy. Specifically, we compare a non-targeted moment of U.S. sectoral data, namely the partial-equilibrium cross-industry elasticity of output to government purchases, with an analogous statistic estimated based on simulated data from our calibrated model.

3.3. Counterfactual experiments

We use the calibrated model to determine the way in which a government spending shock in a given sector affects aggregate value added, depending on that sector's characteristics. To parallel the analysis based on the stylized model, we study the role of the sectoral contribution to final demand, measured by the consumption and investment weights, $\omega_{C,s}$ and $\omega_{I,s}$, respectively, and size distortion, which depends on the steady-state markup, ϑ_s, labor intensity, $\alpha_{N,s}$, and position in the network.[30] In addition, we examine the role of the sectoral degree of price stickiness, ϕ_s. While several studies have emphasized the importance of sectoral heterogeneity in price rigidity in amplifying the macroeconomic effects of aggregate demand shocks (e.g., Carvalho, 2006; Nakamura and Steinsson, 2010; Bouakez et al., 2014; Bouakez et al., 2023), little is known about how the aggregate implications of a demand shock in a given sector depend on its pricing frictions.

To take into consideration the dynamic nature of the response of aggregate value added to spending shocks, we henceforth follow the standard practice of measuring this response as a multiplier, which we compute as the present-value change in aggregate output resulting from a dollar increase in government purchases from a given sector (e.g., Uhlig, 2010). That is, for a spending shock originating in sector s, the aggregate value-added multiplier is given by[31]

$$\mathcal{M}_{G_s} = \frac{\sum_{j=0}^{\infty} \beta^j \left(Y_{t+j} - Y^*\right)}{\sum_{j=0}^{\infty} \beta^j \left(Q_{s,t} G_{s,t+j} - Q_s^* G_s^*\right)}, \qquad s = 1, \ldots, S. \tag{22}$$

We perform counterfactual simulations by computing the spending multiplier in a sequence of model versions that allow for one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the remaining sectoral attributes. The scatter plots relating the aggregate multiplier to the sectoral characteristics are depicted in Fig. 1. The figure shows the results based on the calibrated multi-sector model (to which we refer as the baseline model) as well as those

[27] The calibration of the sectoral weights is conditional on the values of the elasticities ν_C, ν_I, and ν_H.

[28] We leave out taxes and subsidies from the computation of gross output.

[29] Our calibration choice for ν_N and ν_K implies a larger extent of labor and capital reallocation across sectors than in the case where these inputs are either firm- or sector-specific (e.g., Matheron, 2006; Altig et al., 2011; Carvalho and Nechio, 2016).

[30] To rank the sectors' positions in the production network, we construct the Katz–Bonacich measure of centrality for each industry:

$$\mathbf{c} = \frac{\alpha_H}{S}\left(\mathbf{I} - \alpha_H \mathbf{W}'\right)^{-1}\mathbf{1},$$

where α_H is the average gross-output intensity of intermediate inputs, S is the number of sectors, $\mathbf{I}$ is a diagonal matrix, $\mathbf{W} = \left\{\omega_{H,s,x}\right\}_{s,x=1}^{S}$ is the Input–Output matrix of economy, and $\mathbf{1}$ is a vector of ones. According to this measure, more central industries are those located upstream in the network, supplying most of the intermediate inputs to the other industries. Instead, sectors with low levels of centrality are mainly users of intermediate inputs and are therefore located downstream. Notice that such definition does not imply that downstream industries are necessarily those that contribute the most to final consumption. In fact, based on the sectors upon which we calibrate the model, the correlation between centrality and contribution to final demand only amounts to 0.0631. Notable examples of sectors that are both upstream and large contributors to final demand are broadcasting and telecommunications and wholesale trade, which are among the top-10 industries both in terms of centrality and contribution to final demand.

[31] Thus, the effects quantified in this section correspond to those of an additional dollar spent by the government, whereas those discussed in the analytical results are those of an additional unit of goods purchased by the government.

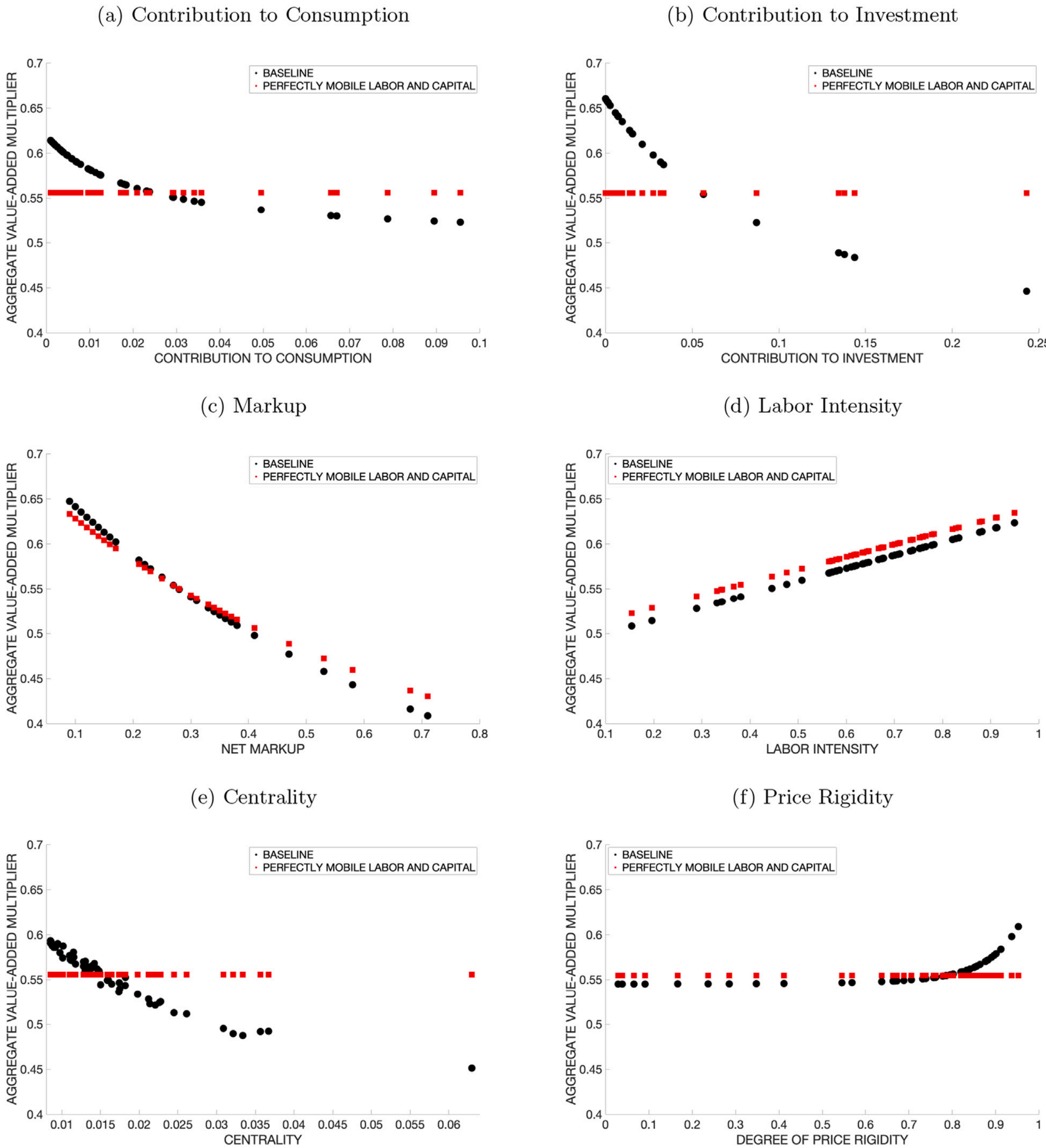

Fig. 1. Sectoral characteristics and the aggregate value-added multiplier. Notes: The figure reports the aggregate value-added multiplier in counterfactual economies in which we allow for one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the remaining sectoral attributes. We consider both the baseline case of imperfect mobility of labor and capital (black dots), as well as the extreme case of perfect mobility (red squares). Each dot/square represents one of the 57 sectors of the economy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

predicted by a counterfactual economy with perfect labor and capital mobility.

The baseline model predicts that the aggregate value-added multiplier is larger when spending shocks originate in sectors with a relatively small contribution to final demand, low markup, high labor intensity, and in those located downstream in the production network. These findings corroborate the analytical results discussed in Section 2. Quantitatively, the multiplier varies from roughly 0.52 to 0.62 as a function of the consumption share, from 0.45 to 0.66 as a function of the investment share, from 0.41 to 0.65 as a function of the markup, from 0.51 to 0.62 as a function of labor intensity, and from 0.45 to 0.59 as a function of centrality. Instead, heterogeneity in price rigidity generates limited variation in the aggregate multiplier: while the sectoral Calvo probabilities span almost the entire range of possible values, the

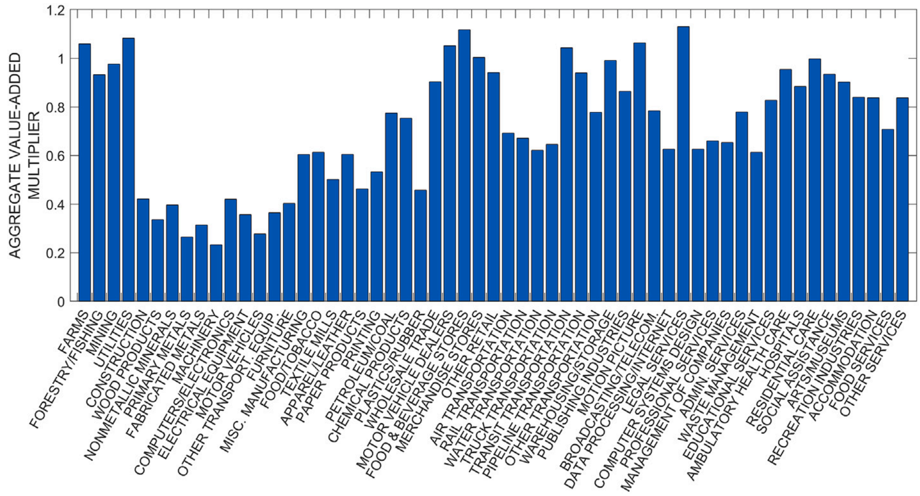

Fig. 2. Aggregate output multiplier of sectoral government spending shocks. Notes: The figure plots the aggregate value-added multiplier associated with each sectoral government spending shock, obtained from the fully heterogeneous economy.

multiplier varies only from 0.55 to 0.61, and is flat over most of the spectrum of these probabilities.[32,33]

Next, consider the model with perfectly mobile labor and capital. In this environment, the shocked sector's contribution to consumption, investment, and government spending, as well as its degree of centrality, are irrelevant to the aggregate spending multiplier, just as predicted by the stylized model. Moreover, the multiplier, albeit not constant, is barely sensitive to the sectoral degree of price rigidity. On the other hand, the multiplier is larger when spending originates in sectors with lower markups and higher labor intensities. To understand why the latter prediction deviates from that of the stylized model results, notice that the baseline model relaxes the assumption of an infinite Frisch elasticity of labor supply (i.e., $\eta = 0$), which in turn implies that relative-price adjustment is no longer a necessary condition for the sectoral origin to matter. When $\eta > 0$, the response of aggregate value added also depends on the resource-constraint effect, as the aggregate real wage depends on aggregate labor demand. The fact that the multiplier still falls with the markup and rises with labor intensity even when relative prices are unresponsive (as a result of perfect labor and capital mobility) indicates that the resource-constraint effect strengthens the role of these two characteristics in accounting for the dispersion in the aggregate output effects of sectoral spending shocks.

3.4. Quantitative implications

We now leverage the fully fledged structure of the calibrated model presented in Section 3 to provide quantitative insights into two corollaries of our findings. First, we measure the dispersion in the aggregate multiplier associated with U.S. sectoral government purchases. Second, we evaluate the extent to which differences in the sectoral composition of purchases across U.S. government levels (i.e., general, federal, and state and local) translate into significant differences in the spending multiplier.

3.4.1. Dispersion of the aggregate spending multiplier

So far, we have studied the aggregate effects of sectoral spending shocks in environments that only allow for one source of sectoral heterogeneity at a time. In what follows, we use the calibrated model to determine whether the heterogeneity across U.S. industries implies substantial dispersion in the size of the aggregate spending multiplier associated with sectoral government purchases. Such an exercise is not only useful to quantify the extent to which the aggregate effects of government purchases depend on their sectoral origin, but also to identify the industries associated with a large "bang for the buck". In that regard, our findings can inform policymakers about the industries they should target to maximize the aggregate spending multiplier.

Fig. 2 presents a bar plot of the aggregate multipliers associated with the different sectoral spending shocks, taken in isolation. The multiplier ranges from 0.23 when government spending originates in machinery manufacturing to 1.13 when it originates in legal services. In general, the multiplier is lower when the government buys from upstream industries with a relatively large contribution to investment and low labor intensity, like manufacturing. On the other hand, it is larger when the government raises its demand for goods produced by downstream labor-intensive industries that contribute little to investment, such as retail trade, and educational and health-care services.

Figs. 3 and 4 report the bar plots associated with the aggregate consumption and investment multipliers. While both multipliers are correlated with that of aggregate output, the consumption multiplier exhibits much larger dispersion – as compared with the investment multiplier – with values ranging from −0.36 for purchases from motor vehicles to 0.44 for purchases from legal services. Interestingly, our assumption of complementarity between aggregate consumption and total government purchases does not affect the dispersion of the aggregate multipliers, as it only shifts upward the response of aggregate variables

[32] In Bouakez et al. (2023), we show that heterogeneity in the sectoral degree of price rigidity raises the size of the aggregate multiplier relative to an economy with a common average duration of prices across industries. Hence, this dimension of sectoral heterogeneity acts mainly as a level shifter, but has little bearing on the heterogeneity in the spending multipliers associated with sector-specific shocks.

[33] These findings are quantitatively similar to those obtained in the case of immobile labor and capital ($\nu_N = \nu_K = 0$) and under constant nominal interest rate, as reported in Appendix E.

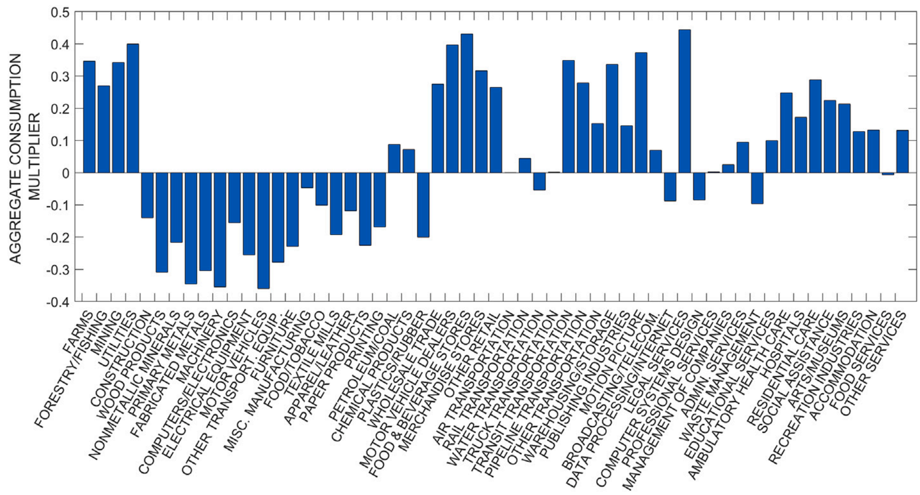

Fig. 3. Aggregate consumption multiplier of sectoral government spending shocks. Notes: The figure plots the aggregate consumption multiplier associated with each sectoral government spending shock, obtained from the fully heterogeneous economy.

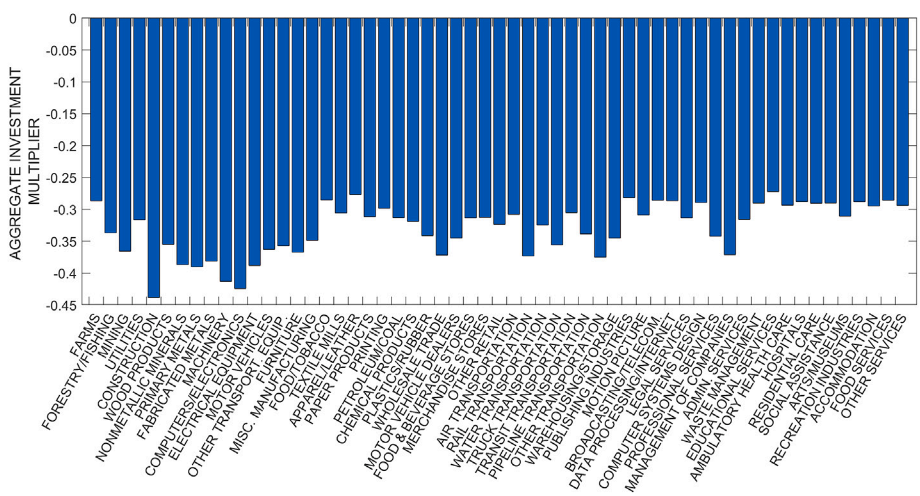

Fig. 4. Aggregate investment multiplier of sectoral government spending shocks. Notes: The figure plots the aggregate investment multiplier associated with each sectoral government spending shock, obtained from the fully heterogeneous economy.

to all sectoral shocks (see Figs. F.2 and F.3 in Appendix F).[34] In doing so, however, it generates heterogeneity in the sign of the response of aggregate consumption, implying a negative consumption multiplier for 23 of the 57 sectoral spending shocks. Instead, the aggregate investment multiplier is uniformly negative across all sectoral shocks, and ranges from −0.27 for spending on educational services to −0.44 for purchases from the construction sector.

These findings underscore the importance of conditioning on the nature of government purchases when estimating their macroeconomic effects. Depending on the sectoral origin of the spending shock, the output multiplier can be small or large, and the response of aggregate consumption can be either positive or negative. From this perspective, our approach has the potential to reconcile divergent views about the effectiveness of spending-based fiscal policy. The next section sheds further light on this issue.

3.4.2. *The sectoral composition of government purchases across government levels*

Heterogeneity in the size of the aggregate spending multiplier across sectoral spending shocks implies that changes in the sectoral allocation of government spending translate into changes in the multiplier. To measure the extent to which the sectoral composition of government spending matters, we evaluate the aggregate output and consumption multipliers associated with public purchases at the different layers of the U.S. government – general, federal (defense and non-defense), and state and local. For each of these levels, the shares of government spending pertaining to the 57 sectors are computed based on the entries of the Input–Output Tables of the U.S. Bureau of Economic Analysis, averaged over the period 1997–2015. In evaluating the aggregate multipliers associated with the different government levels, we consider otherwise

[34] The correlation between the aggregate output multipliers of sectoral spending implied by the models with and without complementarity is 0.98.

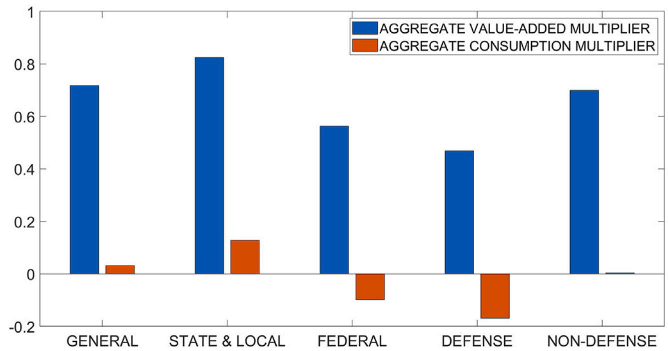

Fig. 5. The aggregate spending multiplier across government levels. Notes: The figure reports the aggregate value-added multipliers across the different levels of the U.S. government. The multipliers are computed from otherwise identical economies that only differ in the sectoral composition of the government spending shock, which is calibrated based on the Input–Output Tables of the U.S. Bureau of Economic Analysis.

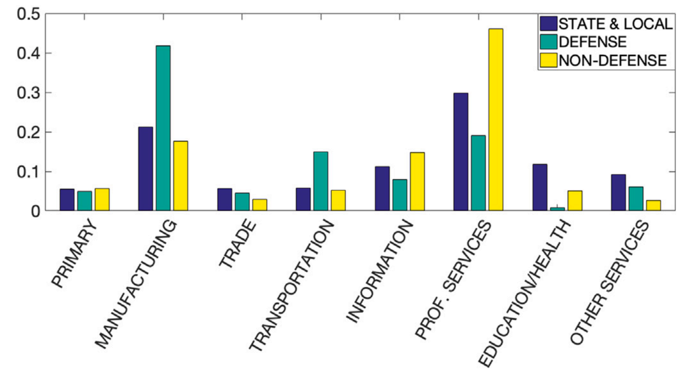

Fig. 6. The sectoral composition of government spending in the United States. Notes: The figure reports the sectoral shares of government spending at the different levels of the U.S. government across eight macro-industries. Primary refers to farms, forestry, mining, utilities, and construction. Other services include arts, recreation industries, accommodation services, and food services. The shares are computed based on the Input–Output Tables of the U.S. Bureau of Economic Analysis.

identical versions of the quantitative model that differ only in the spending shares assigned to the different sectors outside the steady state.[35] In this way, we can isolate differences in the multipliers that are to be attributed to differences in the sectoral allocation of government spending (i.e., spending in excess of its steady-state level).[36,37]

Fig. 5 reports the aggregate output and consumption multipliers associated with the different levels of the U.S. government. An additional dollar spent by the general government raises aggregate value added by 72 cents. This value, however, masks substantial heterogeneity in the output effects of spending across government levels. The aggregate output multiplier associated with spending by the state and local government amounts to 0.82, and is 46 % larger than that associated with spending by the federal government, which equals 0.58. There is large variation in the output multipliers even within federal spending: the one associated with non-defense spending amounts to 0.70, and is almost 50 % larger than that associated with defense spending, which equals 0.47.

A similar pattern holds for the aggregate consumption multiplier, which is close to 0 when measured at the general-government level, but negative (−0.10) for federal spending and positive (0.13) for state and local spending. A large disparity in the consumption multiplier is also observed when federal purchases are split into defense and non-defense spending. The multiplier amounts to −0.17 for the former and 0 for the latter.

To understand the large variation in the aggregate output multiplier across the different levels of the U.S. government, Fig. 6 reports the sectoral composition of state and local, federal non-defense, and defense spending. For expositional simplicity, we look at eight macro industries: primary (including agriculture, mining, utilities, and construction), manufacturing, trade, transportation, information, professional services, education and health-care services, and other services (including arts, recreation services, and food and hotel services). Defense spending is largely concentrated in manufacturing industries, for which we found lower multipliers. Instead, both federal non-defense and state and local spending are mostly oriented towards services, which have relatively large multipliers.

These results imply that the spending multiplier crucially depends on the sectoral composition of government purchases. This observation has consequential implications for empirical work on the effects of fiscal policy. First, it may provide a rationale for the wide range of estimates of the spending multiplier reported in the literature: Studies that rely on federal defense spending tend to report small output multipliers and a crowding-out of consumption (e.g., Barro and Redlick, 2011; Ramey, 2011); instead, measuring spending at the general-government level typically leads to large output multipliers and a crowding-in of consumption (e.g., Blanchard and Perotti, 2002; Auerbach and Gorodnichenko, 2012).[38] Second, our analysis poses yet another challenge for the identification of government spending shocks based on time-series data, which should not only exploit exogenous shifts in total government spending, but also control for time variation in the sectoral allocation of public expenditure.

4. Testing the theoretical predictions

In this section, we provide empirical evidence supporting the theoretical predictions mapping the aggregate effects of government spending shocks to the structural characteristics of the sectors in which those shocks originate. These characteristics are the contribution to consumption and investment (measured by ω_C and ω_I, respectively), steady-state markup, ϑ, labor intensity, α_N, position in the network

[35] All the deep parameters are calibrated identically across the model versions we consider, which therefore share the same steady state. We compute the spending multipliers associated with different linear combinations of sectoral spending shocks, where the weights replicate the average sectoral composition of purchases by each of the U.S. government levels.

[36] It should be emphasized that our analysis is strictly positive in nature, and does not imply ranking the sectoral allocations of government spending at the different levels of the U.S. government in terms of their desirability from a welfare perspective.

[37] In Appendix G, we report the results from a similarly devised exercise, in which we compare the aggregate output and consumption multipliers implied by the quantitative model based on the sectoral composition of national government spending in 28 OECD countries. We show that the spending multiplier of the U.S. economy could be as low as 0.54 if additional spending by the U.S. government had the same sectoral composition as that of the general government of Slovakia, and as high as 0.95 if it reflected the sectoral composition of purchases by the United Kingdom's general government.

[38] While our analysis controls for the financing scheme and the stance of monetary policy when comparing the aggregate multipliers associated with the different sectoral shocks, these considerations can play a role in explaining the differences in the empirical estimates reported in the literature.

(measured by centrality, c), and price rigidity (measured by the Calvo probability, ϕ).[39]

Testing our predictions in the data requires identifying sectoral spending shocks and tracing their effects on aggregate output. Ideally, if sectoral government purchases were exogenous and unanticipated, we could run separate regressions of changes in national aggregate output on each of these spending shocks, and then examine how the estimated multipliers correlate with the sectoral characteristics of interest. Unfortunately, the sectoral allocation of government spending is hardly exogenous with respect to the state of the economy. To address this concern, the empirical literature typically identifies sectoral shocks in panel settings, controlling for changes in the entire stream of spending across industries. By construction, however, a panel setting forces estimates to be pooled across industries, so that only the effects of the *average* shock and a given *average* sectoral characteristic can be uncovered. This rules out the possibility of testing our predictions in a direct way.[40]

To circumvent this limitation, we devise an indirect test. Specifically, we leverage heterogeneity in the sectoral composition of public spending across U.S. states, and estimate how the response of aggregate (state-level) output changes when total (state-level) spending is tilted towards sectors with a given characteristic. The argument underlying this strategy is that if the spending multiplier increases with a given characteristic C of sector s, then it ought to be larger the more public purchases are concentrated in sectors with a relatively high C. Notice that, even though estimates are pooled across states, this approach is still informative about the way in which the local multiplier changes with the sectoral composition of spending.

Our indirect test exploits variation in spending across U.S. states because it allows us to saturate the regression with year fixed effects, which improve the identification of the spending shocks (see below). However, we also consider an alternative exercise in which we estimate multipliers at the aggregate level as in Ramey and Zubairy (2018), and exploit changes in the sectoral composition of aggregate government spending.

4.1. Evidence from the sectoral composition of U.S. state public spending

To estimate how the local multiplier depends on the sectoral composition of local public spending, we retrieve comprehensive data on U.S. federal defense spending from www.usaspending.gov to construct a dataset comprising information at both the sectoral level (as classified by the Bureau of Economic Analysis) and at the state level. For each year, sectoral data are then aggregated at the state level, spanning the 2001–2021 time window. The resulting panel is used to estimate, for each of the six sectoral characteristics listed above, the following regression:

$$\frac{Y_{i,t}-Y_{i,t-2}}{Y_{i,t-2}} = \beta_1 \frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} + \beta_2 \frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}} \times \left(C_{i,t}-\bar{C}\right) + \beta_3 C_{i,t} + \alpha_i + \delta_t + \epsilon_{i,t}, \tag{23}$$

where $Y_{i,t}$ and $G_{i,t}$ are, respectively, real GDP per-capita and real federal defense spending per-capita in state i and year t. The variable $C_{i,t}$ is our object of interest and denotes the weighted-average sectoral characteristic C in state i and year t in total public spending (i.e., $C_{i,t} = \sum_{s=1}^{S} C_s \frac{\mathcal{G}_{s,i,t}}{\mathcal{G}_{i,t}}$, where $\frac{\mathcal{G}_{s,i,t}}{\mathcal{G}_{i,t}}$ is the ratio between nominal federal defense spending in sector s, state i and year t, over total nominal federal defense spending in state i and year t). The term $\bar{C} = \frac{1}{\mathcal{I}}\frac{1}{\mathcal{T}}\sum_{i=1}^{\mathcal{I}}\sum_{t=1}^{\mathcal{T}} C_{i,t}$ is the mean of the weighted-average sectoral characteristic of public spending C.[41] The regression also includes state fixed effects, α_i, and year fixed effects, δ_t. As in Nakamura and Steinsson (2014), we estimate the local fiscal multiplier by considering the effect of a 2-year change in local government spending on the 2-year change in local value added. In Appendix H, we generalize this approach by considering the impact of government spending on 1-year, 2-year, 3-year, 4-year, and 5-year changes in local GDP.

To test our predictions, we interact our measure of the government spending shock with the demeaned value of the characteristic of interest. Thus, β_1 captures the local spending multiplier for a state whose weighted-average sectoral characteristic of public spending equals the average in the sample,[42] and β_2 informs us on how the local multiplier varies with each of the sectoral characteristics. The predicted sign of β_2 is therefore negative for ω_C, ω_I, ϑ, and c, but positive for α_N and ϕ.

Because state-level defense purchases are likely to depend on the economic conditions of the recipient state, we identify state-level shocks to public spending by assuming that the allocation of aggregate defense spending across states remains constant over time. More specifically, we use a shift-share approach as in Nakamura and Steinsson (2014) and Auerbach et al. (2020), and instrument $\frac{G_{i,t}-G_{i,t-2}}{Y_{i,t-2}}$ with the product of the 2-year growth rate in real federal defense spending at the national level, $\frac{G_t-G_{t-2}}{G_{t-2}}$, and the average ratio of nominal federal defense spending over nominal GDP, $\frac{\mathcal{G}_i}{\mathcal{Y}_i}$.[43,44] We then multiply this Bartik variable by the demeaned characteristic of interest to instrument the interaction term.

It is important to emphasize that the presence of time fixed effects in Eq. (23) is key to the identification of government spending shocks. These terms absorb any common variation in $C_{i,t}$ across states, *de facto* allowing us to isolate changes in the sectoral composition of government spending at the local level that are not endogenous to aggregate business-cycle conditions. While time fixed effects also absorb any national general-equilibrium effect of state-level spending shocks, this is not a concern for our empirical test, as we can still exploit the general-equilibrium forces that operate at the local level.[45]

We first estimate a version of Eq. (23) that abstracts from interaction terms, obtaining an estimate of β_1 of 0.9, with a p-value of around 2 %. While the point estimate is below the value of 1.4 reported by

[39] While other sectoral characteristics, such as the durability of consumption goods (Boehm, 2020) and their tradability (Cardi and Restout, 2015), may lead to differences in the aggregate spending multiplier, we focus on the specific set of characteristics examined in our model to directly test its theoretical predictions against the data.

[40] A strand of the literature studies the sectoral effects of government spending by estimating how a shock originating in a sector affects its own output relative to that of all the other industries (Nekarda and Ramey, 2011; Acemoglu et al., 2016; Proebsting, 2022; Barattieri et al., 2023). This approach derives the partial-equilibrium cross-industry elasticity of output to government purchases, which is the strategy we use to validate the calibration of the model (see Appendix D.2).

[41] $\mathcal{I}$ denotes the number of states in our sample, while $\mathcal{T}$ denotes the length of the time-series dimension of the panel.

[42] That is, β_1 measures the dollar response in the GDP of state i with $C_{i,t} = \bar{C}$ following a dollar increase in federally financed defense spending in that state.

[43] We compute this ratio by averaging over the first 4 years of our sample, from 2001 to 2004.

[44] We focus on military spending to mitigate endogeneity concerns, as this component of government expenditures is widely perceived to be least dependent on national and local economic conditions. Although Cox et al. (2024) show that military spending is highly concentrated in a few industries, insofar as its composition varies across states, it provides us with the required variation in order to identify the coefficient β_2 in regression (23).

[45] The additional layer of the state dimension ensures that time fixed effects absorb only aggregate general-equilibrium effects, but not local ones. This is not the case in sector-level panels, in which the estimated multiplier has to be interpreted as a partial-equilibrium object.

Table 1
Local spending multiplier and sectoral characteristics.

	Characteristics					
	Contribution to consumption (ω_C)	Contribution to investment (ω_I)	Markup (ϑ)	Labor intensity (α_N)	Centrality (c)	Price rigidity (ϕ)
Baseline	−0.281 (0.030)	−0.323 (0.125)	−0.255 (0.025)	0.371 (0.021)	−0.309 (0.010)	0.239 (0.018)
Tax control	−0.263 (0.028)	−0.393 (0.077)	−0.245 (0.031)	0.375 (0.022)	−0.294 (0.014)	0.239 (0.020)
Baseline (2001–2019)	−0.254 (0.044)	−0.260 (0.106)	−0.253 (0.035)	0.368 (0.034)	−0.293 (0.017)	−0.199 (0.038)
Tax control (2001–2019)	−0.234 (0.055)	−0.309 (0.072)	−0.231 (0.051)	0.356 (0.043)	−0.268 (0.028)	0.199 (0.050)

Notes: The table reports the estimates of β_2 in Eq. (23), as well as the corresponding p-values (in parentheses). Estimates are based on a state-level panel, measured at an annual frequency, from 2001 to 2021. Standard errors are clustered at the state level. *Baseline* refers to the estimation considering the entire sample, while *Tax control* refers to the case in which we control for the contemporaneous change in the ratio of personal federal taxes over personal income. The additional label *2001–2019* refers to the estimations that exclude the years 2020 and 2021. All coefficients are normalized so that they represent the change in the average local spending multiplier associated with a one-standard-deviation increase in each of the weighted-average sectoral characteristics.

Nakamura and Steinsson (2014), we cannot reject at the 10 % level the null hypothesis that our estimate equals 1.4. Since the sectoral characteristics included in the interaction terms are demeaned, the estimate of β_1 is uninformative about the effect that different weighted-average sectoral characteristics of public spending have on local output. Hence, we only focus on the estimates of β_2. For ease of interpretation, Table 1 reports the estimates of β_2, normalized to measure the change in the local spending multiplier associated with a one-standard-deviation change in each of the weighted-average sectoral characteristics.[46] *Baseline* refers to the estimation considering the entire sample, while *Tax control* refers to the case in which we control for the contemporaneous change in the ratio of personal federal taxes over personal income. In both cases, we also consider a restricted sample period that ends before the start of the COVID-19 episode (i.e., that excludes the years 2020 and 2021), and refer to this configuration using the additional *2001–2019 label*.

In the baseline regressions, all the estimates of β_2 (associated with the interaction term) have the correct sign and, with one exception, are significant at conventional statistical levels. These effects are also economically relevant: a one-standard-deviation increase in the weighted-average sectoral characteristics leads to variation in the local spending multiplier that ranges between 23.9 % (for price rigidity) and 37.1 % (for labor intensity). These results remain remarkably robust when we control for taxes and/or exclude the post-2019 period. In fact, in the regressions that include the tax control, all the estimates of β_2 are statistically significant, indicating that the local multiplier tends to be larger when government purchases from a given state are more skewed towards sectors that contribute relatively less to private final demand, have lower markups, are labor intensive, and are located downstream in the supply chain.[47]

4.2. Evidence from the sectoral composition of U.S. national public spending

In this section, we consider an alternative indirect test of our theoretical predictions, in which we focus on aggregate data. More specifically, we estimate how changes in the sectoral composition of national public spending affect the aggregate (national) multiplier. To carry out the exercise, we posit a linear-projection regression as in Ramey and Zubairy (2018), and estimate it on annual frequency data as follows:

$$\sum_{t=0}^{\mathcal{H}} \frac{Y_t}{\tilde{Y}_t} = \beta_1 \sum_{t=0}^{\mathcal{H}} \frac{G_t}{\tilde{Y}_t} + \beta_2 \sum_{t=0}^{\mathcal{H}} \frac{G_t}{\tilde{Y}_t} \times \left(C_t - \bar{C}\right) + trend + \varepsilon_t, \tag{24}$$

where Y_t and G_t are, respectively, real aggregate GDP per-capita and real federal defense spending per-capita in year t, $\tilde{Y}_t$ is potential GDP per capita in year t, C_t denotes the weighted-average sectoral characteristic of national public spending in year t (i.e., $C_t = \sum_{s=1}^{S} C_s \frac{G_{s,t}}{G_t}$, where $\frac{G_{s,t}}{G_t}$ is the ratio between nominal federal defense spending in sector s and year t, over total nominal federal defense spending in year t). The term $\bar{C} = \frac{1}{\mathcal{T}} \sum_{t=1}^{\mathcal{T}} C_t$ is the mean of the weighted-average sectoral characteristic C_s, and $trend$ is a time trend. In this equation, β_1 captures the aggregate spending multiplier and β_2 measures the way in which the multiplier varies with the different sectoral characteristics. Again, the predicted sign of β_2 is negative for ω_C, ω_I, ϑ, and c, but positive for α_N and ϕ. To be consistent with the analysis in the previous section, we set $\mathcal{H} = 2$ and focus on 2-year multipliers.

As in Ramey and Zubairy (2018), government spending is instrumented by the military-spending news variable constructed by Ramey (2011) and current spending as in Blanchard and Perotti (2002).[48] Both instruments are interacted with the (demeaned) weighted-average sectoral characteristic C_t. As in the previous exercise, we consider a baseline regression and one that includes a tax control. The sample period is 1963–2015. The yearly frequency of the data and the beginning of the sample are dictated by the availability of disaggregated I-O data, while the final period is the last year of Ramey's news series.

In this setting, the estimate of the aggregate multiplier β_1 in a specification without interaction terms equals 0.31, but is not statistically different from zero. Table 2 reports the estimation results for the coefficient β_2, normalizing again the estimates so that they represent the change in the aggregate spending multiplier associated with a one-standard-deviation increase in each of the weighted-average sectoral characteristics. We find that our coefficients of interest are almost always statistically significant. While the estimates of β_2 are smaller (in absolute value) than their counterparts in the state-level regressions,

[46] We report the raw non-normalized estimates of β_2 in Appendix H.

[47] In the spirit of Barnichon et al. (2022), we also considered an extension of regression (23) that allows for potential asymmetries in the propagation of government spending shocks. Within this specification, we test whether the effect of the interaction between those shocks and the weighted-average sectoral characteristics differs depending on whether the change in government spending is positive or negative. We find no evidence of asymmetric interaction. These results are available upon request.

[48] An alternative instrumenting strategy is chosen by Barattieri et al. (2023), who estimate the aggregate effects of sectoral government spending in the U.S. using a granular instrumental-variable approach.

Table 2
Aggregate spending multiplier and sectoral characteristics.

	Characteristics					
	Contribution to consumption (ω_C)	Contribution to investment (ω_I)	Markup (ϑ)	Labor intensity (α_N)	Centrality (c)	Price rigidity (ϕ)
Baseline	−0.150 (0.017)	−0.218 (0.065)	−0.134 (0.001)	0.222 (0.226)	−0.236 (0.011)	0.136 (0.000)
Tax control	−0.139 (0.030)	−0.223 (0.032)	−0.141 (0.008)	0.226 (0.210)	−0.240 (0.016)	0.139 (0.000)

Notes: The table reports the estimates of β_2 in Eq. (24), as well as the corresponding p-values (in parentheses). Estimates are based on annual data covering the period 1963–2015. *Baseline* refers to the estimation considering the entire sample, while *Tax control* refers to the case in which we control for the contemporaneous change in the ratio of personal federal taxes over personal income. All coefficients are normalized so that they represent the change in the aggregate spending multiplier associated with a one-standard-deviation increase in each of the weighted-average sectoral characteristics.

they are still highly economically significant. Importantly, the signs of the estimates are consistent with our theoretical predictions, both in the baseline regression and the one with the tax control. The aggregate multiplier is larger when the government buys goods and services from sectors that are characterized by a smaller contribution to consumption and investment, lower markups, higher labor intensity, and more downstreamness.

Admittedly, a potential limitation of this approach is that it does not allow the inclusion of time fixed effects, thus preventing us from addressing any potential endogeneity in the sectoral allocation of government spending with respect to aggregate output. Nonetheless, we view the results from this exercise as further validation of those from the previous section.

5. Conclusion

This paper has explored the role of sectoral characteristics and network linkages in shaping the aggregate effects of sector-specific government spending shocks. Based on a tractable multi-sector model, we have derived a formula that characterizes the response of aggregate output to an increase in government purchases from a given sector. Our analytical results indicate that sectoral spending shocks tend to have larger aggregate output effects when they originate in sectors that have a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the production network. These insights carry over to a quantitative multi-sector model that incorporates several realistic dimensions of sectoral heterogeneity and input–output interactions, which we calibrate to the U.S. economy. The model implies substantial heterogeneity in the aggregate output and consumption multipliers of sectoral spending shocks. It also reveals sizable differences in the aggregate multipliers across the different layers of the U.S. government. Together, these findings have important implications regarding the sectoral composition of spending-based stimulus plans that aim at generating sizable “bangs for the buck”. Exploiting the heterogeneity in the sectoral composition of contracts awarded by the U.S. Department of Defense across states, we find empirical support for our theoretical predictions.

We conclude the paper by making the following remarks. First, while our analysis has focused on government spending shocks, our conclusions extend to other sectoral shocks that exogenously change the composition of final demand. An example would be preference shocks that alter the weights attached to the different goods in the consumption basket. The aggregate implications of such shocks and the conditions under which they are not invariant to the characteristics of the shocked sector are similar to those pertaining to government spending shocks. For the purpose of testing our theoretical implications, however, it is arguably easier to construct instruments for government spending shocks than for preference shocks.

Second, as in the vast majority of papers studying the spending multiplier, we have focused on a specific component of government consumption: purchases of goods and services from the private sector. While a branch of the literature studies the aggregate effects of government employment/wages (e.g., Finn, 1998; Pappa, 2009; Chang et al., 2021), little is known, however, about the government aggregate production function that regulates the interaction between public employment and public purchases. In the spirit of Baqaee and Farhi (2018), our bottom-up approach could in principle help micro-found such a construct. Unfortunately, data on public employment are not available at the same level of sectoral disaggregation as for government purchases, precluding researchers from pursuing this line of inquiry.[49]

Third, our analysis has abstracted from the fact that a non-negligible fraction of government purchases consists of durables and capital goods, for which Boehm (2020) estimates a smaller multiplier than for non-durable goods. Given that the government mostly buys durables and capital goods from the manufacturing sector, this could provide a complementary explanation for our empirical result of a lower multiplier associated with government purchases from manufacturing.

Finally, while this paper proposes a novel perspective to think about the transmission of government spending, the analysis has remained positive in nature. The marked heterogeneity in the aggregate effects of sectoral public spending, however, suggests that, from a normative standpoint, an optimizing fiscal authority needs to determine not only the optimal level of government spending, but also its composition. We leave this issue for future research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

[49] This data limitation might explain why only a handful of papers allow for the interaction between public purchases and public employment through an aggregate production function of the government (e.g., Moro and Rachedi, 2022).

Appendix A. Stylized model

This appendix solves the stylized model employed to derive the analytical results discussed in Section 2, and reports the proofs of the propositions contained therein.

A.1. Non-linear economy

This subsection reports the necessary set of equations to solve the stylized model. From households' optimal allocation between consumption and labor hours we obtain

$$\theta = C^{-1}W, \tag{A.1}$$

where $W = \mathcal{W}/P$ is the aggregate real wage and $P = \omega_{C,d}^{-\omega_{C,d}}\omega_{C,u}^{-\omega_{C,u}}P_d^{\omega_{C,d}}P_u^{\omega_{C,u}}$ is the aggregate price level, so that

$$Q_d^{\omega_{C,d}}Q_u^{\omega_{C,u}} = \omega_{C,d}^{\omega_{C,d}}\omega_{C,u}^{\omega_{C,u}} \tag{A.2}$$

defines the connection between the sectoral relative prices. The optimal consumption demand for the goods produced the two sectors are given by

$$C_u = \omega_{C,u}\frac{C}{Q_u}, \tag{A.3}$$

$$C_d = \omega_{C,d}\frac{C}{Q_d}, \tag{A.4}$$

where $Q_s = \frac{P_s}{P}$ for $s = u, d$.

Households' supply of labor to the two sectors is given by

$$N_u = \omega_{N,u}\left(\frac{W_u}{W}\right)^{\nu_N}N, \tag{A.5}$$

$$N_d = \omega_{N,d}\left(\frac{W_d}{W}\right)^{\nu_N}N, \tag{A.6}$$

where $W_s = \mathcal{W}_s/P$ is the real wage in sector s ($s = u, d$). The aggregate real wage satisfies

$$W = \left[\omega_{N,d}W_d^{1+\nu_N} + \omega_{N,u}W_u^{1+\nu_N}\right]^{\frac{1}{1+\nu_N}}. \tag{A.7}$$

Recall that the sectoral production technologies read as

$$Z_u = N_u^{1-\alpha_{H,u}}H_{u,u}^{\alpha_{H,u}}, \tag{A.8}$$

$$Z_d = N_d^{1-\alpha_{H,d}}H_{d,u}^{\alpha_{H,d}}. \tag{A.9}$$

Thus, producers' cost-minimization returns the following first-order conditions:

$$W_u = \left(1-\alpha_{H,u}\right)\frac{MC_uZ_u}{N_u}, \tag{A.10}$$

$$Q_u = \alpha_{H,u}\frac{MC_uZ_u}{H_{u,u}}, \tag{A.11}$$

$$W_d = \left(1-\alpha_{H,d}\right)MC_d\frac{Z_d}{N_d}, \tag{A.12}$$

$$Q_u = \alpha_{H,d}\frac{MC_dZ_d}{H_{d,u}}, \tag{A.13}$$

where MC_s is the real marginal cost of production in sector s, which satisfies $Q_s = \vartheta_s MC_s$, where $\vartheta_s \equiv \frac{\epsilon_s}{\epsilon_s-1}$ denotes the sectoral markup ($s = u, d$). Finally, the model is closed by the sectoral resource constraints

$$Z_u = C_u + G_u + H_{u,u} + H_{d,u}, \tag{A.14}$$

$$Z_d = C_d + G_d. \tag{A.15}$$

A.2. Steady state

This sub-section describes the steady state. Steady-state variables are denoted by an asterisk. We start by rearranging the production function of sector u as

$$1 = \left(\frac{N_u^*}{Z_u^*}\right)^{1-\alpha_{H,u}} \left(\frac{H_{u,u}^*}{Z_u^*}\right)^{\alpha_{H,u}}. \tag{A.16}$$

From (A.10) and (A.11), we have

$$\frac{N_u^*}{Z_u^*} = \left(1-\alpha_{H,u}\right)\frac{MC_u^*}{W_u^*} = \vartheta_u^{-1}\left(1-\alpha_{H,u}\right)\left(\frac{Q_u^*}{W_u^*}\right) \quad \text{and} \quad \frac{H_{u,u}^*}{Z_u^*} = \alpha_{H,u}\frac{MC_u^*}{Q_u^*} = \vartheta_u^{-1}\alpha_{H,u}, \tag{A.17}$$

which can be combined with (A.16) to obtain

$$\left(\frac{W_u^*}{Q_u^*}\right)^{1-\alpha_{H,u}} = \vartheta_u^{-1}\left(1-\alpha_{H,u}\right)^{1-\alpha_{H,u}}\alpha_{H,u}^{\alpha_{H,u}}. \tag{A.18}$$

Analogously, the following result holds for sector d:

$$\left(\frac{W_d^*}{Q_d^*}\right)^{1-\alpha_{H,d}} = \vartheta_d^{-1}\left(1-\alpha_{H,d}\right)^{1-\alpha_{H,d}}\alpha_{H,d}^{\alpha_{H,d}}\left(\frac{Q_d^*}{Q_u^*}\right)^{\alpha_{H,d}}. \tag{A.19}$$

Under our calibration $\omega_{N,s} = \frac{N_s^*}{N^*}$ for $s = u, d$, (A.5) and (A.6) imply that $W_u^* = W_d^* = W^*$. Therefore, (A.18) and (A.19) lead to

$$\frac{Q_d^*}{Q_u^*} = \frac{\left[\vartheta_u^{-1}\left(1-\alpha_{H,u}\right)^{1-\alpha_{H,u}}\alpha_{H,u}^{\alpha_{H,u}}\right]^{\frac{1-\alpha_{H,d}}{1-\alpha_{H,u}}}}{\vartheta_d^{-1}\left(1-\alpha_{H,d}\right)^{1-\alpha_{H,d}}\alpha_{H,d}^{\alpha_{H,d}}}.$$

Let $\omega_{G,s} \equiv \frac{Q_s^* G_s^*}{Q_u^* G_u^* + Q_d^* G_d^*}$ denote the steady-state share of government spending allocated to sector s ($s = u, d$), and $\gamma \equiv \frac{Q_u^* G_u^* + Q_d^* G_d^*}{Y^*}$ denote the share of total government spending in total value added, Y^*. It follows that

$$Q_u^* G_u^* = \gamma\omega_{G,u} Y^*, \tag{A.20}$$

$$Q_d^* G_d^* = \gamma\omega_{G,d} Y^*, \tag{A.21}$$

and

$$Q_d^* C_d^* = (1-\gamma)\,\omega_{C,d} Y^*, \tag{A.22}$$

$$Q_u^* C_u^* = (1-\gamma)\,\omega_{C,u} Y^*. \tag{A.23}$$

Noting that $Y_d^* = Q_d^* Z_d^* - Q_u^* H_{d,u}^* = \left(1-\alpha_{H,d}\vartheta_d^{-1}\right) Q_d^* Z_d^* = \left(1-\alpha_{H,d}\vartheta_d^{-1}\right)\left(Q_d^* C_d^* + Q_d^* G_d^*\right)$ and using the fact that $\frac{Y_u^*}{Y^*} + \frac{Y_d^*}{Y^*} = 1$, we obtain the following expression for the sectoral value added as a fraction of aggregate value added:

$$\frac{Y_u^*}{Y^*} = 1 - \left(1-\tilde{\alpha}_{H,d}\right)\mu_d, \tag{A.24}$$

$$\frac{Y_d^*}{Y^*} = \left(1-\tilde{\alpha}_{H,d}\right)\mu_d, \tag{A.25}$$

where $\tilde{\alpha}_{H,d} \equiv \alpha_{H,d}\vartheta_d^{-1}$ and $\mu_d \equiv \frac{Q_d^* C_d^* + Q_d^* G_d^*}{Y^*} = (1-\gamma)\,\omega_{C,d} + \gamma\omega_{G,d}$ is the steady-state contribution of sector d to total final demand.

Moreover, (A.10) and (A.12), combined with $W_u^* = W_d^*$, imply that $\frac{N_u^*}{(1-\alpha_{H,u})\vartheta_u^{-1} Q_u^* Z_u^*} = \frac{N_d^*}{(1-\alpha_{H,d})\vartheta_d^{-1} Q_d^* Z_d^*}$. Since $Y_d^* = \left(1-\alpha_{H,d}\vartheta_d^{-1}\right) Q_d^* Z_d^*$, $Y_u^* = \left(1-\alpha_{H,u}\vartheta_u^{-1}\right) Q_u^* Z_u^*$, and $N^* = N_u^* + N_d^*$, it follows that

$$\varpi_u \equiv \frac{N_u^*}{N^*} = \frac{\left(1-\alpha_{H,u}\right)\left(\vartheta_d-\alpha_{H,d}\right)\left[1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d\right]}{\left(1-\alpha_{H,u}\right)\left(\vartheta_d-\alpha_{H,d}\right)\left[1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d\right] + \left(1-\alpha_{H,d}\right)\left(\vartheta_u-\alpha_{H,u}\right)\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}, \tag{A.26}$$

$$\varpi_d \equiv \frac{N_d^*}{N^*} = \frac{\left(1-\alpha_{H,d}\right)\left(\vartheta_u-\alpha_{H,u}\right)\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}{\left(1-\alpha_{H,u}\right)\left(\vartheta_d-\alpha_{H,d}\right)\left[1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d\right] + \left(1-\alpha_{H,d}\right)\left(\vartheta_u-\alpha_{H,u}\right)\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}. \tag{A.27}$$

Finally, to determine the ratio $\frac{Q_u^* H_{d,u}^*}{Y^*}$, we combine the expression for the value added of sector u (i.e., $Y_u^* = Q_u^* Z_u^* - Q_u^* H_{u,u}^*$) with its resource constraint, obtaining

$$\frac{Y_u^*}{Y^*} = \frac{Q_u^* C_u^* + Q_u^* G_u^*}{Y^*} + \frac{Q_u^* H_{d,u}^*}{Y^*}. \tag{A.28}$$

Letting $\mu_u \equiv \frac{Q_u^* C_u^* + Q_u^* G_u^*}{Y^*} = (1-\gamma)\,\omega_{C,u} + \gamma\omega_{G,u}$, noting that $\mu_u + \mu_d = 1$, and using (A.24), we get

$$\frac{Q_u^* H_{d,u}^*}{Y^*} = \tilde{\alpha}_{H,d}\mu_d. \tag{A.29}$$

A.3. Log-linear economy

We solve the model by log-linearizing its equilibrium conditions around the non-stochastic steady state. The log-linearized counterparts of Eqs. (A.1)–(A.15) are, respectively:

$$c = w, \tag{A.30}$$

$$c_u = c - q_u, \tag{A.31}$$

$$c_d = c - q_d, \tag{A.32}$$

$$q_d = -\frac{\omega_{C,u}}{\omega_{C,d}} q_u, \tag{A.33}$$

$$n_u = \nu_N (w_u - w) + n, \tag{A.34}$$

$$n_d = \nu_N (w_d - w) + n, \tag{A.35}$$

$$w = \varpi_u w_u + \varpi_d w_d, \tag{A.36}$$

$$z_u = \left(1 - \alpha_{H,u}\right) n_u + \alpha_{H,u} h_{u,u}, \tag{A.37}$$

$$z_d = \left(1 - \alpha_{H,d}\right) n_d + \alpha_{H,d} h_{d,u}, \tag{A.38}$$

$$w_u = q_u + z_u - n_u, \tag{A.39}$$

$$h_{u,u} = z_u, \tag{A.40}$$

$$w_d = q_d + z_d - n_d, \tag{A.41}$$

$$h_{d,u} = z_d + q_d - q_u, \tag{A.42}$$

$$z_u = \frac{\gamma \omega_{G,u}}{1 - \left(1 - \tilde{\alpha}_{H,d}\right) \mu_d} g_u + \frac{(1-\gamma)\,\omega_{C,u}}{1 - \left(1 - \tilde{\alpha}_{H,d}\right) \mu_d} c_u + \frac{\tilde{\alpha}_{H,d} \mu_d}{1 - \left(1 - \tilde{\alpha}_{H,d}\right) \mu_d} h_{d,u}, \tag{A.43}$$

$$z_d = \frac{\gamma \omega_{G,d}}{\mu_d} g_d + \frac{(1-\gamma)\,\omega_{C,d}}{\mu_d} c_d. \tag{A.44}$$

A.4. Derivation of equation (14)

In a log-linearized form, the aggregate resource constraint is given by

$$y = (1-\gamma) c + \gamma \omega_{G,u} \left(g_u + q_u\right) + \gamma \omega_{G,d} \left(g_d + q_d\right). \tag{A.45}$$

From (A.30) and (A.36), we obtain

$$c = \varpi_u w_u + \varpi_d w_d. \tag{A.46}$$

Eqs. (A.37) and (A.40) imply that $z_u = h_{u,u} = n_u$. In light of (A.39), this yields

$$w_u = q_u. \tag{A.47}$$

Using (A.38) to substitute for z_d in both (A.41) and (A.42), and combining the resulting two equations, we get

$$q_d = \left(1 - \alpha_{H,d}\right) w_d + \alpha_{H,d} q_u. \tag{A.48}$$

Using (A.47) and (A.48) to substitute for w_u and w_d in (A.46) returns

$$c = \frac{\varpi_u - \alpha_{H,d}}{\varpi_u^e - \alpha_{H,d}} \mu_u q_u + \frac{\varpi_d}{\varpi_d^e} \mu_d q_d, \tag{A.49}$$

where $\varpi_u^e \equiv 1 - \left(1 - \alpha_{H,d}\right) \mu_d = \alpha_{H,d} + (1 - \alpha_{H,d})\mu_u$ and $\varpi_d^e \equiv \left(1 - \alpha_{H,d}\right) \mu_d$ are the steady-state employment shares of sectors u and d, respectively, when the economy is efficient (i.e., $\vartheta_u = \vartheta_d = 1$).

Using (A.33) and the identities $\varpi_d = 1 - \varpi_u$, $\omega_{C,d} = 1 - \omega_{C,u}$, and $\mu_d = 1 - \mu_u$, we can express (A.49) as

$$c = \left[\frac{\left(1-\alpha_{H,d}\right)\left(\mu_u - \omega_{C,u}\right) - \left(\varpi_u^e - \varpi_u\right)}{\left(1-\alpha_{H,d}\right)\left(1-\omega_{C,u}\right)}\right] q_u \tag{A.50}$$

$$= \left[\frac{\left(1-\alpha_{H,d}\right)\left(\mu_d - \omega_{C,d}\right) - \left(\varpi_d^e - \varpi_d\right)}{\left(1-\alpha_{H,d}\right)\left(1-\omega_{C,d}\right)}\right] q_d. \tag{A.51}$$

Plugging (A.50) into (A.45), using (A.33), and taking the derivative with respect to g_u, we get

$$\frac{dy}{dg_u} = \gamma\omega_{G,u} + \left\{(1-\gamma)\left[\frac{\left(1-\alpha_{H,d}\right)\left(\mu_u-\omega_{C,u}\right) + \varpi_u^e - \varpi_u}{\left(1-\alpha_{H,d}\right)\left(1-\omega_{C,u}\right)}\right] + \frac{\mu_u - \omega_{C,u}}{1-\omega_{C,u}}\right\}\frac{dq_u}{dg_u}$$
$$= \gamma\omega_{G,u} + \left[\frac{(2-\gamma)\left(\mu_u-\omega_{C,u}\right) - (1-\gamma)\left(1-\alpha_{H,d}\right)^{-1}\left(\varpi_u^e-\varpi_u\right)}{1-\omega_{C,u}}\right]\frac{dq_u}{dg_u}.$$

Analogously, substituting (A.51) into (A.45), using (A.33) and taking the derivative with respect to g_d, we obtain,

$$\frac{dy}{dg_d} = \gamma\omega_{G,d} + \left\{(1-\gamma)\left[\frac{\left(1-\alpha_{H,d}\right)\left(\mu_d-\omega_{C,d}\right) - \left(\varpi_d^e - \varpi_d\right)}{\left(1-\alpha_{H}\right)\left(1-\omega_{C,d}\right)}\right] + \frac{\mu_d - \omega_{C,d}}{1-\omega_{C,d}}\right\}\frac{dq_d}{dg_d}$$
$$= \gamma\omega_{G,d} + \left[\frac{(2-\gamma)\left(\mu_d-\omega_{C,d}\right) - (1-\gamma)\left(1-\alpha_{H,d}\right)^{-1}\left(\varpi_d^e-\varpi_d\right)}{1-\omega_{C,d}}\right]\frac{dq_d}{dg_d}.$$

We can therefore write

$$\frac{dy}{dg_s} = \gamma\omega_{G,s} + \left[\frac{\psi_1\left(\mu_s-\omega_{C,s}\right) - \psi_2\left(\varpi_s^e - \varpi_s\right)}{1-\omega_{C,s}}\right]\frac{dq_s}{dg_s}, \quad s = u, d, \tag{A.52}$$

where $\psi_1 \equiv 2-\gamma$ and $\psi_2 \equiv \frac{1-\gamma}{1-\alpha_{H,d}}$.

A.5. Proofs

Proof (Proposition 1). Part (i): From (A.52), it is immediate to see that, if $\frac{dq_s}{dg_s} = 0$, the response of aggregate value added only depends on the direct effect of the shock, which is symmetric if $\omega_{G,s} = \frac{1}{2}$ for $s = u, d$.
Part (ii): Under efficiency, $\varpi_s^e = \varpi_s$. If, in addition, $\mu_s = \omega_{C,s}$, we again have $\frac{dy}{dg_s} = \gamma\omega_{G,s} = \frac{\gamma}{2}$ for $s = u, d$. □

Proof (Proposition 2). Notice first that (A.50) implies that

$$c = \left[1 - \frac{\varpi_d}{\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right] q_u. \tag{A.53}$$

Combining (A.33) and (A.42) to obtain $h_{d,u} = z_d - \frac{1}{\omega_{C,d}} q_u$, substituting the latter into (A.38), and rearranging, we get

$$z_d = n_d - \frac{\alpha_{H,d}}{\left(1-\alpha_{H,d}\right)\omega_{C,d}} q_u. \tag{A.54}$$

Inserting this expression into (A.44) and using (A.32), (A.33), and (A.53) we obtain

$$n_d = \frac{\gamma\omega_{G,d}}{\mu_d} g_d + \frac{1-\gamma}{\mu_d}\left[1 - \frac{\varpi_d}{1-\alpha_{H,d}} + \frac{\alpha_{H,d}\mu_d}{(1-\gamma)\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right] q_u. \tag{A.55}$$

Combining (A.33), (A.42), and (A.54) yields

$$h_{d,u} = n_d - \frac{1}{\left(1-\alpha_{H,d}\right)\omega_{C,d}} q_u.$$

Substituting this expression into (A.43) and using (A.31), (A.37), (A.40), (A.53), and (A.55), we get

$$n_u = \frac{\gamma\omega_{G,u}}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d} g_u + \frac{\gamma\tilde{\alpha}_{H,d}\omega_{G,d}}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d} g_d + \frac{(1-\gamma)\tilde{\alpha}_{H,d}}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}\left[1 - \frac{\varpi_d}{1-\alpha_{H,d}} + \frac{\alpha_{H,d}\mu_d}{(1-\gamma)\left(1-\alpha_{H,d}\right)\omega_{C,d}} - \frac{\tilde{\alpha}_{H,d}\mu_d + (1-\gamma)\varpi_d\omega_{C,u}}{(1-\gamma)\left(1-\alpha_{H,d}\right)\tilde{\alpha}_{H,d}\omega_{C,d}}\right] q_u.$$

Using (A.47) and (A.48) to substitute for w_u and w_d in (A.34) and (A.35), respectively, as well as (A.30), (A.33), and (A.50), we obtain (after rearranging)

$$n = n_u - \nu_N\left[\frac{\varpi_d}{\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right] q_u,$$

$$n = n_d + \nu_N\left[\frac{\varpi_u}{\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right] q_u.$$

Substituting the expressions of n_u and n_d into the equations above yields, respectively,

$$n = \frac{\gamma\omega_{G,u}}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}g_u + \frac{\gamma\tilde{\alpha}_{H,d}\omega_{G,d}}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}g_d + \left\{\frac{\tilde{\alpha}_{H,d}(1-\gamma)}{1-\left(1-\tilde{\alpha}_{H,d}\right)\mu_d}\left[1-\frac{\varpi_d}{1-\alpha_{H,d}}+\frac{\alpha_{H,d}\mu_d}{(1-\gamma)\left(1-\alpha_{H,d}\right)\omega_{C,d}}-\frac{\mu_d\tilde{\alpha}_{H,d}+(1-\gamma)\varpi_d\omega_{C,u}}{(1-\gamma)\left(1-\alpha_{H,d}\right)\tilde{\alpha}_{H,d}\omega_{C,d}}\right]-\nu_N\left[\frac{\varpi_d}{\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right]\right\}q_u,$$

and

$$n = \frac{\gamma\omega_{G,d}}{\mu_d}g_d + \left\{\frac{1-\gamma}{\mu_d}\left[1-\frac{\varpi_d}{1-\alpha_{H,d}}+\frac{\alpha_{H,d}\mu_d}{(1-\gamma)\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right]+\nu_N\left[\frac{\varpi_u}{\left(1-\alpha_{H,d}\right)\omega_{C,d}}\right]\right\}q_u$$

Equating the two expressions yields, after some algebra

$$q_u = \frac{1}{\Upsilon}\left(\frac{\omega_{G,u}}{\mu_u}g_u - \frac{\omega_{G,d}}{\mu_d}g_d\right), \tag{A.56}$$

where $\Upsilon \equiv \frac{1}{\gamma}\left\{(1-\gamma)\left[\frac{1}{\mu_d}-\frac{\varpi_d}{\varpi_d^e}\left(1-\frac{\mu_d}{\mu_u}\frac{\omega_{C,u}}{\omega_{C,d}}\right)\right]+\frac{\alpha_{H,d}\mu_u+\tilde{\alpha}_{H,d}\mu_d}{(1-\alpha_{H,d})\mu_u\omega_{C,d}}+\nu_N\left[\frac{1-(1-\tilde{\alpha}_{H,d})\mu_d}{(1-\alpha_{H,d})\omega_{C,d}}\right]\right\} > 0$. In the case of perfect labor mobility (i.e., $\nu_N \to \infty$), $\Upsilon \to \infty$, so that $q_u = 0$, and $q_d = -\frac{\omega_{C,u}}{\omega_{C,d}}q_u = 0$. In the case of imperfect labor mobility (i.e., $\nu_N < \infty$), since $\mu_d, \mu_u > 0$, it is straightforward to show that

$$\frac{dq_u}{dg_u} = \frac{1}{\Upsilon}\frac{\omega_{G,u}}{\mu_u} > 0,$$

$$\frac{dq_d}{dg_d} = -\frac{\omega_{C,u}}{\omega_{C,d}}\frac{dq_u}{dg_d} = \frac{1}{\Upsilon}\frac{\omega_{C,u}}{\omega_{C,d}}\frac{\omega_{G,d}}{\mu_d} > 0,$$

and

$$\frac{dq_u}{dg_d} = -\frac{1}{\Upsilon}\frac{\omega_{G,d}}{\mu_d} < 0,$$

$$\frac{dq_d}{dg_u} = -\frac{\omega_{C,u}}{\omega_{C,d}}\frac{dq_u}{dg_u} = -\frac{1}{\Upsilon}\frac{\omega_{C,u}}{\omega_{C,d}}\frac{\omega_{G,u}}{\mu_u} < 0.$$

□

Proof (Proposition 3). Setting $\alpha_{H,s} = 0$ and $\vartheta_s = \vartheta$ implies that $\varpi_s = \varpi_s^e = \mu_s$ for $s = u, d$. Thus, (A.52) becomes

$$\frac{dy}{dg_s} = \gamma\omega_{G,s} + \left[\frac{(2-\gamma)\left(\mu_s-\omega_{C,s}\right)}{1-\omega_{C,s}}\right]\frac{dq_s}{dg_s},$$

Taking the derivative with respect to $\omega_{C,s}$ and using the definition of μ_s, we obtain

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\omega_{C,s}} = \frac{\gamma(2-\gamma)}{1-\omega_{C,s}}\left[-\frac{1-\omega_{G,s}}{1-\omega_{C,s}}\frac{dq_s}{dg_s}+\left(\omega_{G,s}-\omega_{C,s}\right)\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\omega_{C,s}}\right]. \tag{A.57}$$

In addition, based on (A.56), we have

$$\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\omega_{C,s}} = -\frac{\omega_{G,s}\left[(1-\gamma)\Upsilon+\frac{\partial\Upsilon}{\partial\omega_{C,s}}\mu_s\right]}{\left(\Upsilon\mu_s\right)^2} = -\Theta\frac{dq_s}{dg_s}, \tag{A.58}$$

where

$$\Theta \equiv \frac{(1-\gamma)\Upsilon+\frac{\partial\Upsilon}{\partial\omega_{C,s}}\mu_s}{\Upsilon\mu_s} > 0.$$

Substituting (A.58) into (A.57) yields

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\omega_{C,s}} = -\frac{\gamma(2-\gamma)}{1-\omega_{C,s}}\left[\frac{1-\omega_{G,s}}{1-\omega_{C,s}}+\left(\omega_{G,s}-\omega_{C,s}\right)\Theta\right]\frac{dq_s}{dg_s}. \tag{A.59}$$

Proving the proposition amounts to showing that the term in square brackets is positive. This is always the case, for $\omega_{G,s} \geq \omega_{C,s}$. To prove it when $\omega_{G,s} < \omega_{C,s}$, we express $\frac{1-\omega_{G,s}}{1-\omega_{C,s}} + \left(\omega_{G,s} - \omega_{C,s}\right)\Theta$ in terms of deep parameters, and rewrite it as

$$\begin{aligned}\frac{1-\omega_{G,s}}{1-\omega_{C,s}} + \left(\omega_{G,s}-\omega_{C,s}\right)\Theta = & \underbrace{(1-\gamma)\left[\frac{1-\omega_{G,s}}{1-\omega_{C,s}}\mu_s + \left(\omega_{G,s}-\omega_{C,s}\right)(1-\gamma)\right]\left[\frac{\left(1-\omega_{C,s}\right)\mu_s^2 + \left(1-\mu_s\right)^2\omega_{C,s}}{\left(1-\mu_s\right)\left(1-\omega_{C,s}\right)\mu_s}\right]}_{\Sigma_1} \\ & \underbrace{+\mu_s\left(\omega_{G,s}-\omega_{C,s}\right)(1-\gamma)\left[\frac{(1-\gamma)^2}{\left(1-\mu_s\right)^2} + \frac{1-\gamma}{\left(1-\omega_{C,s}\right)^2}\frac{\left(1-\mu_s\right)\mu_s - (1-\gamma)\left(1-\omega_{C,s}\right)\omega_{C,s}}{\mu_s^2}\right]}_{\Sigma_2} \\ & \underbrace{+\nu_N\frac{\left[\left(1-\omega_{G,s}\right)\mu_s + (1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right)\left(1-\omega_{C,s}+\mu_s\right)\right]}{\left(1-\omega_{C,s}\right)^2}}_{\Sigma_3}.\end{aligned}$$

Consider first the terms Σ_3. Using the definition of μ_s, we can write it as

$$\Sigma_3 = \nu_N\left\{\frac{\left[(1-\gamma)\left(1-\omega_{C,s}\right)+\gamma\left(1-\omega_{G,s}\right)\right]\omega_{G,s} + \gamma(1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right)^2}{\left(1-\omega_{C,s}\right)^2}\right\},$$

which is always positive. It is therefore sufficient to prove that $\Sigma_1 + \Sigma_2 > 0$. After some algebra, this sum can be expressed as

$$\Sigma_1 + \Sigma_2 = \left[\left(1-\omega_{G,s}\right)\mu_s + (1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right)\Lambda\right]\left[\frac{\left(1-\omega_{C,s}\right)\mu_s^2 + \left(1-\mu_s\right)^2\omega_{C,s}}{\left(1-\mu_s\right)\left(1-\omega_{C,s}\right)^2\mu_s}\right],$$

where

$$\Lambda \equiv \frac{\left(2-\mu_s-\gamma\right)\left(1-\omega_{C,s}\right)^2\mu_s^2 + \left(1-\mu_s\right)^3\left[\left(1-\omega_{C,s}\right)\omega_{C,s}+\mu_s\right] - (1-\gamma)\left(1-\mu_s\right)^2\left(1-\omega_{C,s}\right)\omega_{C,s}}{\left(1-\mu_s\right)\left[\left(1-\omega_{C,s}\right)\mu_s^2 + \left(1-\mu_s\right)^2\omega_{C,s}\right]}.$$

Since $\frac{\left(1-\omega_{C,s}\right)\mu_s^2+\left(1-\mu_s\right)^2\omega_{C,s}}{\left(1-\mu_s\right)\left(1-\omega_{C,s}\right)^2\mu_s} > 0$, we can focus on proving that $\mu_s\left(1-\omega_{G,s}\right) + \left(\omega_{G,s}-\omega_{C,s}\right)(1-\gamma)\Lambda > 0$. We do this in two steps: first, we prove that $\left(1-\omega_{G,s}\right)\mu_s + (1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right) > 0$, which implies that $\Lambda < 1$ is a sufficient condition for $\Sigma_1 + \Sigma_2$ to be strictly positive. The second step consists in proving that this sufficient condition holds.

Step 1:

$$\begin{aligned}\left(1-\omega_{G,s}\right)\mu_s + (1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right) &= (1-\gamma)\left(1-\omega_{G,s}\right)\omega_{C,s} + \gamma\left(1-\omega_{G,s}\right)\omega_{G,s} + (1-\gamma)\left(\omega_{G,s}-\omega_{C,s}\right) \\ &= -(1-\gamma)\omega_{C,s}\omega_{G,s} + \gamma\left(1-\omega_{G,s}\right)\omega_{G,s} + (1-\gamma)\omega_{G,s} \\ &= (1-\gamma)\left(1-\omega_{C,s}\right)\omega_{G,s} + \gamma\left(1-\omega_{G,s}\right)\omega_{G,s} > 0.\end{aligned}$$

Step 2: Since $\left(1-\mu_s\right)\left[\left(1-\omega_{C,s}\right)\mu_s^2 + \left(1-\mu_s\right)^2\omega_{C,s}\right] > 0$, proving that $\Lambda < 1$ amounts to proving that the numerator of $\Lambda - 1$ is strictly negative. Denoting this object by Γ, we have

$$\begin{aligned}\Gamma &= \left(2-\mu_s-\gamma\right)\left(1-\omega_{C,s}\right)^2\mu_s^2 + \left(1-\mu_s\right)^3\left[\left(1-\omega_{C,s}\right)\omega_{C,s}+\mu_s\right] - (1-\gamma)\left(1-\mu_s\right)^2\left(1-\omega_{C,s}\right)\omega_{C,s} - \left(1-\mu_s\right)\left[\left(1-\omega_{C,s}\right)\mu_s^2 + \left(1-\mu_s\right)^2\omega_{C,s}\right] \\ &= \left(1-\mu_s\right)^2\left[\left(1-\mu_s\right)\left(\mu_s-\omega_{C,s}^2\right) - (1-\gamma)\left(1-\omega_{C,s}\right)\omega_{C,s}\right] + \mu_s^2\left(1-\omega_{C,s}\right)\left[(1-\gamma)\left(1-\omega_{C,s}\right) - \omega_{C,s}\left(1-\mu_s\right)\right] \\ &= (1-\gamma)\left(1-\omega_{C,s}\right)\left[\left(1-\omega_{C,s}\right)\mu_s^2 - \left(1-\mu_s\right)^2\omega_{C,s}\right] + \left(1-\mu_s\right)\left[\left(1-\mu_s\right)^2\left(\mu_s-\omega_{C,s}^2\right) - \left(\omega_{C,s}-\omega_{C,s}^2\right)\mu_s^2\right].\end{aligned}$$

If $\left(1-\omega_{C,s}\right)\mu_s^2 - \left(1-\mu_s\right)^2\omega_{C,s} > 0$, then we can write

$$\begin{aligned}\Gamma &< \left(1-\omega_{C,s}\right)\left[\left(1-\omega_{C,s}\right)\mu_s^2 - \left(1-\mu_s\right)^2\omega_{C,s}\right] + \left(1-\mu_s\right)\left[\left(1-\mu_s\right)^2\left(\mu_s-\omega_{C,s}^2\right) - \left(\omega_{C,s}-\omega_{C,s}^2\right)\mu_s^2\right] \\ &= \left(1-\mu_s\right)^2\left[\left(\mu_s-\omega_{C,s}^2\right)\left(1-\mu_s\right) - \left(\omega_{C,s}-\omega_{C,s}^2\right)\right] + \mu_s^2\left(1-\omega_{C,s}\right)\left[\left(1-\omega_{C,s}\right) - \left(1-\mu_s\right)\omega_{C,s}\right] \\ &< \left(1-\mu_s\right)^2\left[\left(\omega_{C,s}-\omega_{C,s}^2\right)\left(1-\mu_s\right) - \left(\omega_{C,s}-\omega_{C,s}^2\right)\right] + \mu_s^2\left(1-\omega_{C,s}\right)\left[\left(1-\omega_{C,s}\right) - \left(1-\mu_s\right)\omega_{C,s}\right] \\ &= \mu_s\left(1-\omega_{C,s}\right)\left[-\left(1-\mu_s\right)^2\omega_{C,s} + \left(1-\omega_{C,s}\right)\mu_s - \left(1-\mu_s\right)\mu_s\omega_{C,s}\right] \\ &= \left(1-\omega_{C,s}\right)\left(\mu_s-\omega_{C,s}\right)\mu_s < 0,\end{aligned}$$

where the last inequality follows from the fact that $\mu_s < \omega_{C,s}$ when $\omega_{G,s} < \omega_{C,s}$. In turn, this inequality implies that $\left(1-\mu_s\right)\left[\left(1-\mu_s\right)^2(\mu_s-\omega_{C,s}^2)-(\omega_{C,s}-\omega_{C,s}^2)\mu_s^2\right]<0$.

If $\left(1-\omega_{C,s}\right)\mu_s^2-\left(1-\mu_s\right)^2\omega_{C,s}<0$, then it follows immediately that $\Gamma<0$. □

Proof (Proposition 4). Part (i) To isolate the role of the sectoral markup, ϑ_s, we assume that the two sectors are otherwise identical by setting $\omega_{C,s}=\omega_{G,s}=1/2$ and $\alpha_{H,s}=0$ for $s=u,d$. Thus, (A.52) becomes

$$\frac{dy}{dg_s}=\frac{\gamma}{2}-2\left(1-\gamma\right)\left(\varpi_s^e-\varpi_s\right)\frac{dq_s}{dg_s},$$

where

$$\varpi_s^e-\varpi_s=\frac{\vartheta_s}{\sum_{s=u,d}\vartheta_s}-\frac{1}{2}.$$

Taking the derivative with respect to ϑ_s yields

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\vartheta_s}=-2\left(1-\gamma\right)\left\{\left[\frac{\sum_{s=u,d}\vartheta_s-\vartheta_s}{\left(\sum_{s=u,d}\vartheta_s\right)^2}\right]\frac{dq_s}{dg_s}+\left[\frac{\vartheta_s}{\sum_{s=u,d}\vartheta_s}-\frac{1}{2}\right]\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\vartheta_s}\right\}<0,$$

since $\frac{dq_s}{dg_s}>0$ and $\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\vartheta_s}=0$ for $s=u,d$.

Part (ii) To isolate the role of the sectoral labor intensity, $1-\alpha_{H,s}$, while maintaining the assumption of constant returns to scale in production, it would be natural to consider an economy with a roundabout production structure with two identical sectors that only use their own goods as intermediate inputs, such that there is no difference in their position in the network. One could then study the role of $1-\alpha_{H,s}$ by varying it in one of the two sectors. Although our simple economy does not allow for an identity Input–Output matrix, the exercise just described is equivalent to varying the labor intensity of sector u while assuming that sector d uses no intermediate inputs. This is the argument underlying the proof below.

Setting $\omega_{C,u}=\omega_{C,d}=\omega_{G,u}=\omega_{G,d}=1/2$, $\vartheta_u=\vartheta_d=\vartheta$, $\alpha_{H,d}=0$, and referring to sector u generically as sector s, (A.52) becomes

$$\frac{dy}{dg_s}=\frac{\gamma}{2}-\left[2\left(1-\gamma\right)\left(\varpi_s^e-\varpi_s\right)\right]\frac{dq_s}{dg_s},$$

where

$$\varpi_s^e-\varpi_s=\frac{1}{2}-\frac{\vartheta\left(1-\alpha_{H,s}\right)}{\vartheta\left(1-\alpha_{H,s}\right)+\left(\vartheta-\alpha_{H,s}\right)}.$$

Taking the derivative with respect to $\alpha_{H,s}$ yields

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\left(1-\alpha_{H,s}\right)}=-\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\alpha_{H,s}}=2\left(1-\gamma\right)\left\{\frac{\partial\left(\varpi_s^e-\varpi_s\right)}{\partial\alpha_{H,s}}\frac{dq_s}{dg_s}+\left(\varpi_s^e-\varpi_s\right)\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\alpha_{H,s}}\right\},$$

Since

$$\frac{\partial\left(\varpi_s^e-\varpi_s\right)}{\partial\alpha_{H,s}}=-\frac{\vartheta\left(1-\vartheta\right)}{\left[\vartheta\left(1-\alpha_{H,s}\right)+\left(\vartheta-\alpha_{H,s}\right)\right]^2}>0,$$

and

$$\frac{\partial\left(\frac{dq_s}{dg_s}\right)}{\partial\alpha_{H,s}}=0,$$

we have

$$\frac{\partial\left(\frac{dy}{dg_s}\right)}{\partial\left(1-\alpha_{H,s}\right)}>0.$$

Part (iii) To isolate the role of the position in the network, we assume that the two sectors are otherwise identical by setting $\omega_{C,s}=\omega_{G,s}=1/2$, $\alpha_{H,s}=\alpha_H$, and $\vartheta_s=\vartheta$ for $s=u,d$, which yields

$$\varpi_u^e-\varpi_u=\frac{(1-\vartheta^{-1})\alpha_H}{2},$$

$$\varpi_d^e-\varpi_d=-\frac{(1-\vartheta^{-1})\alpha_H}{2}.$$

Thus, (A.52) implies

$$\frac{dy}{dg_u}=\frac{\gamma}{2}-\frac{1}{2}\left[\frac{(1-\gamma)(1-\vartheta^{-1})\alpha_H}{1-\alpha_H}\right]\frac{dq_u}{dg_u},$$

$$\frac{dy}{dg_d}=\frac{\gamma}{2}+\frac{1}{2}\left[\frac{(1-\gamma)(1-\vartheta^{-1})\alpha_H}{1-\alpha_H}\right]\frac{dq_d}{dg_d}.$$

Since $(1-\vartheta^{-1})>0$ and $\frac{dq_s}{dg_s}>0$ for $s=u,d$, it follows that $\frac{dy}{dg_d}>\frac{dy}{dg_u}$. □

Appendix B. Impulse responses

This section shows the impulse responses to sectoral government spending shocks obtained from the stylized two-sector model under different scenarios. In each scenario, we assume that the two sectors differ in a given dimension but are otherwise identical. Fig. B.1 depicts the case where the two sectors differ in their consumption share. Fig. B.2 depicts the case where the two sectors differ in their price markup. Fig. B.3 depicts the case where the two sectors differ in their labor intensity. Fig. B.4 depicts the case where the two sectors differ in their position in the supply chain. We consider both the cases of perfectly mobile labor ($\nu_N \to \infty$) and immobile labor ($\nu_N = 0$). In all cases, we set $\gamma = 0.2$ and assume that the shocks follow an AR(1) process with an autocorrelation coefficient of 0.9.

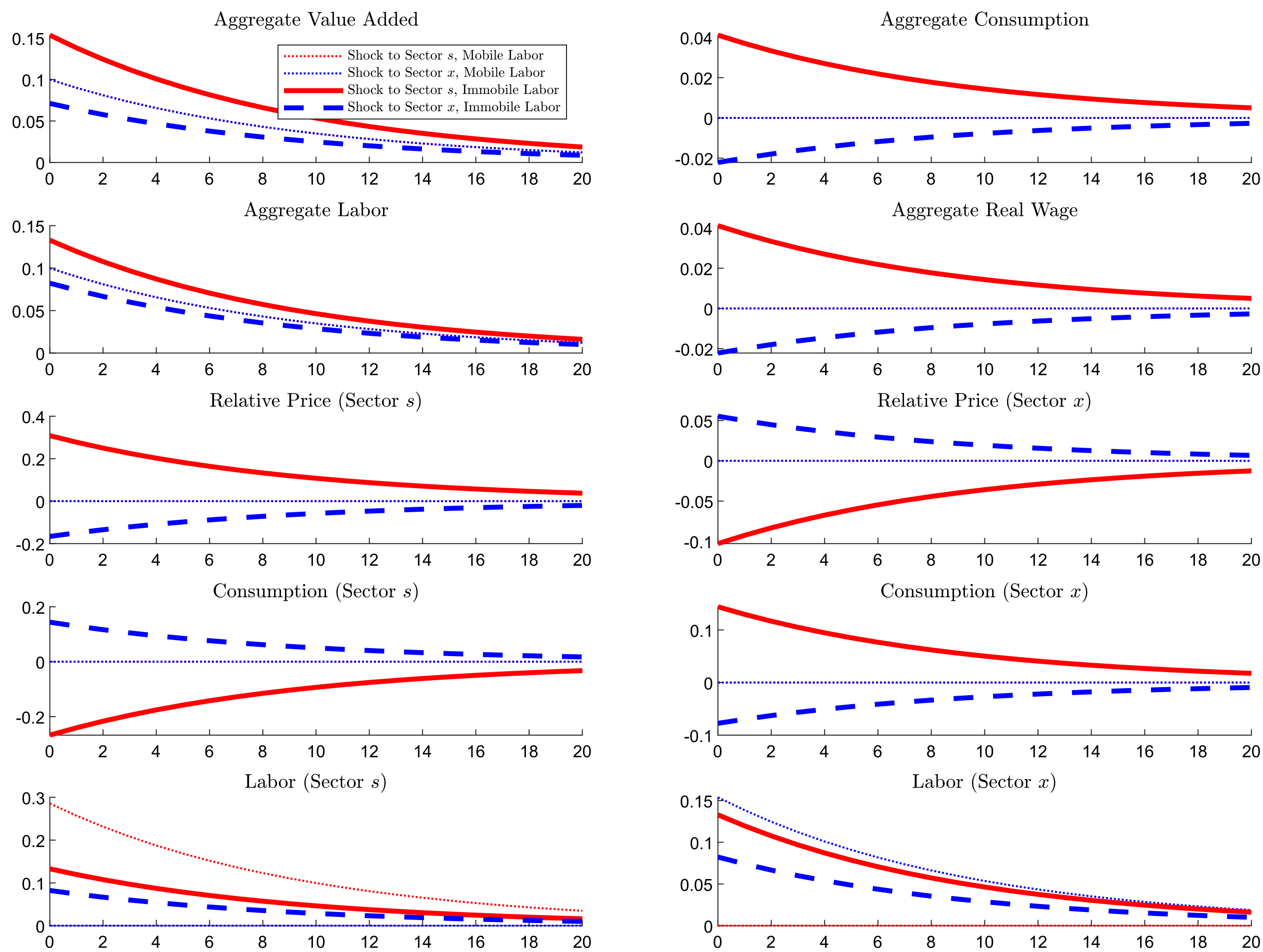

Fig. B.1. Effects of sectoral government spending shocks: Sectors differ in their consumption share. Notes: The figure reports the impulse responses to government spending shocks in sectors s and x under the following calibration: $\omega_{C,s} = 0.25$, $\omega_{C,x} = 0.75$. The remaining sectoral parameters are assigned the following values: $\alpha_{H,s} = \alpha_{H,x} = 0$; $\vartheta_s = \vartheta_x = 1.2$.

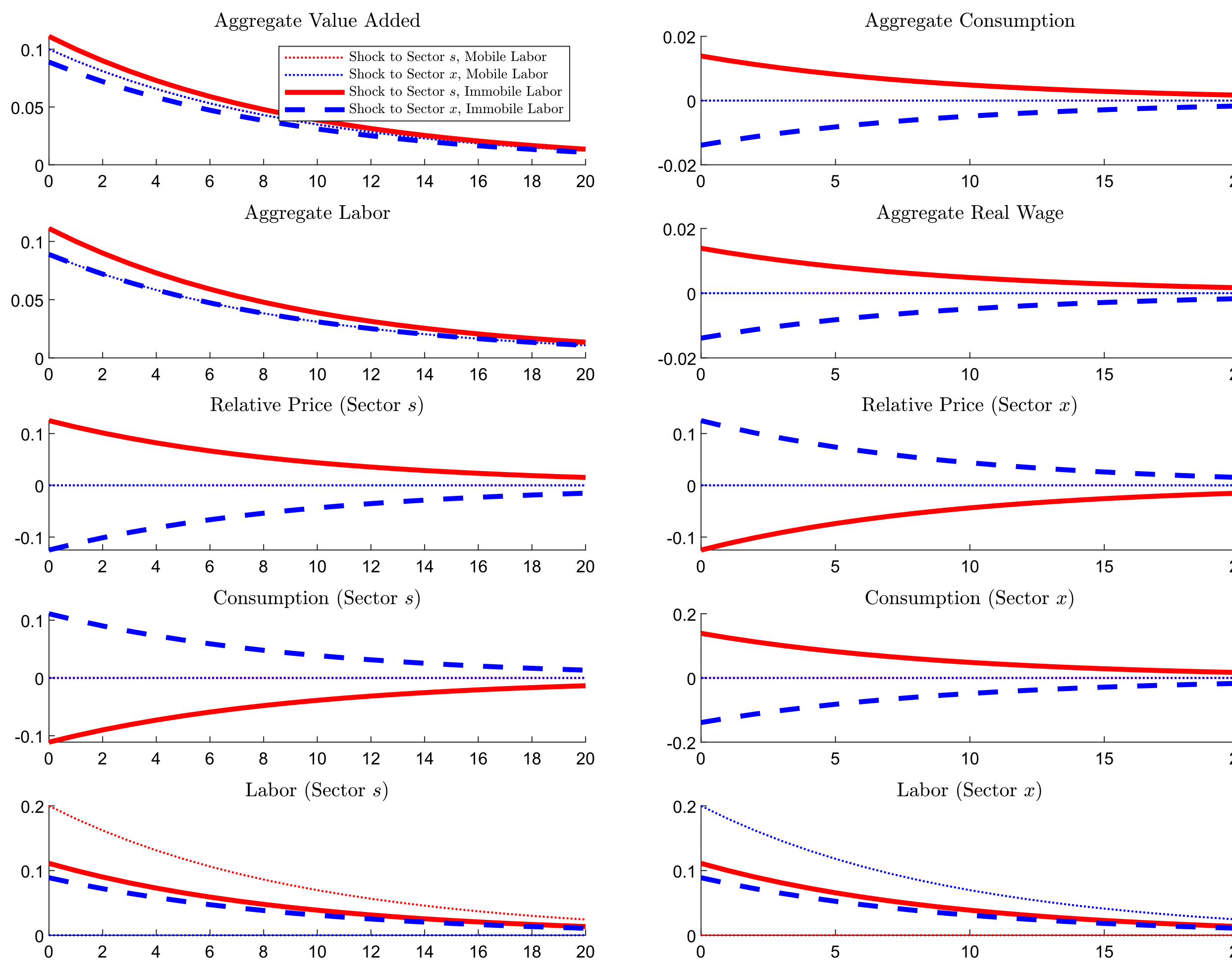

Fig. B.2. Effects of sectoral government spending shocks: Sectors differ in their markup. Notes: The figure reports the impulse responses to government spending shocks in sectors s and x under the following calibration: $\vartheta_s = 1.2$, $\vartheta_x = 1.5$. The remaining sectoral parameters are assigned the following values: $\omega_{C,s} = \omega_{C,x} = 0.5$; $\alpha_{H,s} = \alpha_{H,x} = 0$. The shocks have an autocorrelation coefficient of 0.9.

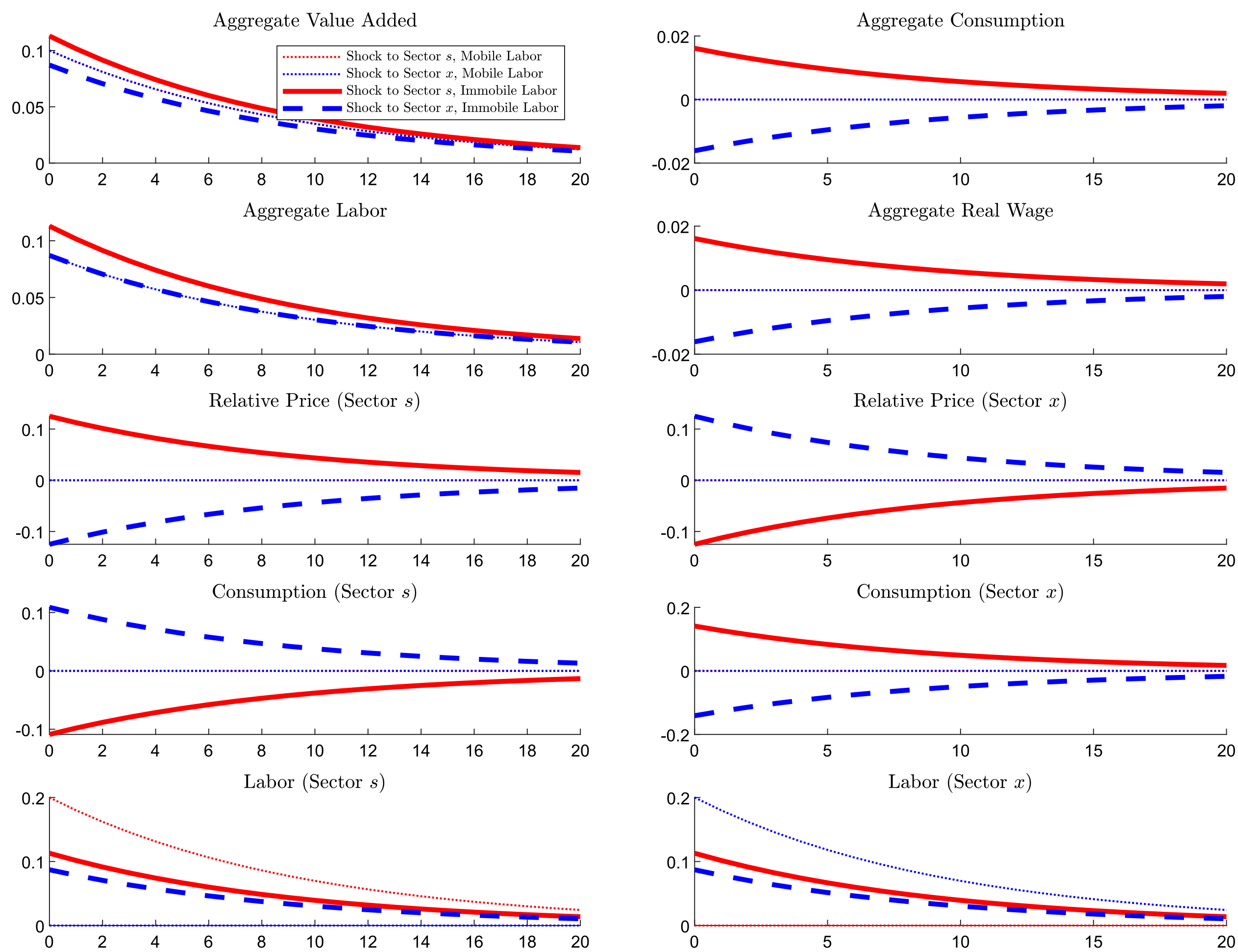

Fig. B.3. Effects of sectoral government spending shocks: Sectors differ in their labor intensity. Notes: The figure reports the impulse responses to government spending shocks in sectors s and x under the assumption that each sector uses only its own good as an intermediate input, with $1-\alpha_{H,s}=0.7$, $1-\alpha_{H,x}=0.3$. The remaining sectoral parameters are assigned the following values: $\omega_{C,s}=\omega_{C,x}=0.5$; $\vartheta_s=\vartheta_x=1.2$.

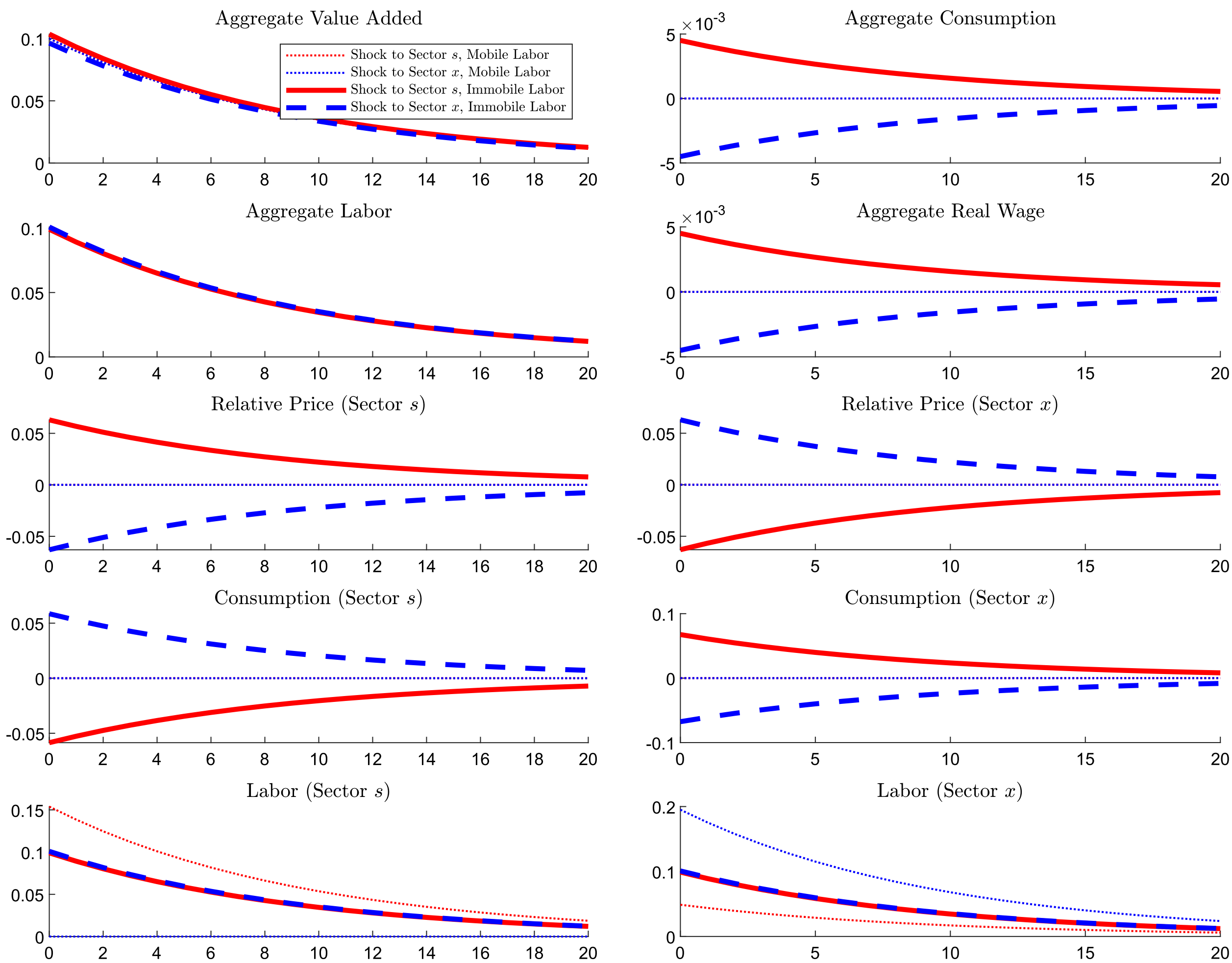

Fig. B.4. Effects of sectoral government spending shocks: Sectors differ in their position within the production network. Notes: The figure reports the impulse responses to government spending shocks in sectors s and x under the assumption that sector s is downstream and sector x is upstream. The sectoral parameters are assigned the following values: $\omega_{C,s} = \omega_{C,x} = 0.5$; $\alpha_{H,s} = \alpha_{H,x} = 0.3$; and $\vartheta_s = \vartheta_x = 1.2$.

Appendix C. Full description of the quantitative model

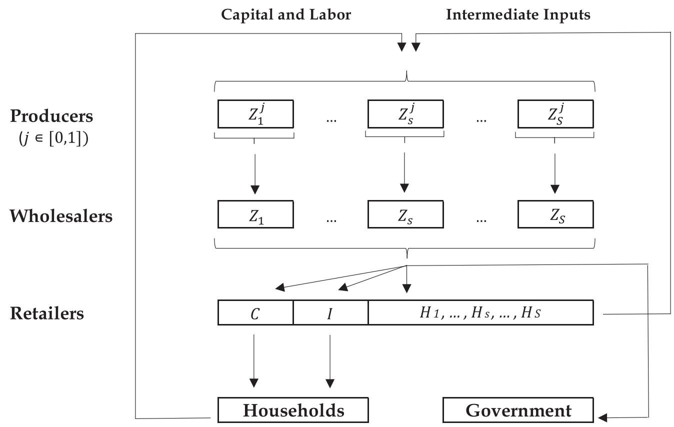

Fig. C.1. Structure of the quantitative model.

C.1. Households

The economy is populated by an infinitely-lived representative household that has preferences over aggregate consumption, C_t, the sum of government purchases from all sectors, G_t, and aggregate labor, N_t , so that its expected lifetime utility is

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{X_t^{1-\sigma}}{1-\sigma} - \theta \frac{N_t^{1+\eta}}{1+\eta} \right\}, \tag{C.1}$$

$$X_t = \left[\zeta^{\frac{1}{\xi}} C_t^{\frac{\xi-1}{\xi}} + (1-\zeta)^{\frac{1}{\xi}} G_t^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}, \tag{C.2}$$

where β is the subjective time discount factor, σ captures the degree of risk aversion, θ is a preference parameter that affects the disutility of labor, and η is the inverse of the Frisch elasticity of labor supply. As in Bouakez and Rebei (2007), preferences are non-separable in consumption and government services. In this specification, the parameter ζ denotes the weight of aggregate consumption in total consumption services, X_t, whereas ξ is the elasticity of substitution between aggregate consumption and aggregate government services.

The household enters period t with a stock of nominal bonds, B_t, and a stock of physical capital, K_t. During the period, it receives the principal and the interest on its bond holdings – with R_t denoting the gross nominal interest rate – provides labor and rents physical capital to the intermediate-good producers in exchange for a nominal wage rate, W_t, and a nominal rental rate, $R_{K,t}$. It also receives nominal profits from intermediate-good producers in all sectors, $\sum_{s=1}^{S} D_{s,t}$, and pays a nominal lump-sum tax, T_t, to the government. The household purchases a bundle of consumption goods at price $P_{C,t}$, and one of investment goods, I_t, at price $P_{I,t}$, and allocates its remaining income to the purchase of new bonds. Its budget constraint is therefore given by

$$P_{C,t}C_t + P_{I,t}I_t + B_{t+1} + T_t = W_t N_t + R_{K,t}K_t + B_t R_{t-1} + \sum_{s=1}^{S} D_{s,t}. \tag{C.3}$$

Investment is subject to convex adjustment costs, so that the stock of physical capital evolves over time according to

$$K_{t+1} = (1-\delta) K_t + I_t \left[1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right], \tag{C.4}$$

where δ is the depreciation rate and Ω captures the magnitude of the adjustment cost. The household chooses C_t, N_t, I_t, K_{t+1}, and B_{t+1} to maximize life-time utility (C.1) subject to the budget constraint (C.3), the accumulation Eq. (C.4), and a no-Ponzi-game condition.

The total amount of labor provided by the household is a CES function of the labor supplied to each sector, that is

$$N_t = \left[\sum_{s=1}^{S} \omega_{N,s}^{-\frac{1}{\nu_N}} N_{s,t}^{\frac{1+\nu_N}{\nu_N}} \right]^{\frac{\nu_N}{1+\nu_N}}, \tag{C.5}$$

where $\omega_{N,s}$ is the weight attached to labor provided to sector s , and ν_N denotes (the absolute value of) the elasticity of substitution of labor across sectors. When $\nu_N \to \infty$, labor is perfectly mobile and nominal wages are equalized across sectors. Instead, as long as $\nu_N < \infty$, labor is imperfectly mobile and sectoral wages can differ. The nominal wage rate is defined as a function of the nominal sectoral wages, $W_{s,t}$, and is expressed as

$$W_t = \left[\sum_{s=1}^{S} \omega_{N,s} W_{s,t}^{1+\nu_N}\right]^{\frac{1}{1+\nu_N}}. \tag{C.6}$$

Analogously, the total amount of physical capital is given by the CES function

$$K_t = \left[\sum_{s=1}^{S} \omega_{K,s}^{-\frac{1}{\nu_K}} K_{s,t}^{\frac{1+\nu_K}{\nu_K}}\right]^{\frac{\nu_K}{1+\nu_K}}, \tag{C.7}$$

where $\omega_{K,s}$ is the weight attached to capital provided to sector s, and ν_K is (the absolute value of) the elasticity of substitution of capital across sectors. The aggregate nominal rental rate of capital is defined as

$$R_{K,t} = \left[\sum_{s=1}^{S} \omega_{K,s} R_{K,s,t}{}^{1+\nu_K}\right]^{\frac{1}{1+\nu_K}}, \tag{C.8}$$

where $R_{K,s,t}$ is the nominal rental rate of capital in sector s. equilibrium, capital is allocated across sectors such that the following first-order conditions hold

$$K_{s,t} = \omega_{K,s}\left(\frac{R_{K,s,t}}{R_{K,t}}\right)^{\nu_K} K_t, \qquad s = 1, \dots, S. \tag{C.9}$$

C.2. Firms

In each sector, there is a continuum of producers that assemble differentiated varieties of output using labor, capital, and a bundle of intermediate inputs. These varieties are then aggregated into a single good in each sector by a representative wholesaler. The goods produced by the S representative wholesalers are then purchased by the retailers, who assemble them into consumption and investment bundles sold to the households, and intermediate-input bundles sold to the producers.

C.2.1. Producers

In each sector, there is a continuum of monopolistically competitive producers, indexed by $j \in [0,1]$, that use labor, capital, and a bundle of intermediate inputs to assemble a differentiated variety using the Cobb–Douglas technology

$$Z_{s,t}^j = \left(N_{s,t}^{j\ \alpha_{N,s}} K_{s,t}^{j\ 1-\alpha_{N,s}}\right)^{1-\alpha_{H,s}} H_{s,t}^{j\ \alpha_{H,s}}, \tag{C.10}$$

where $Z_{s,t}^j$ is the gross output of the variety of producer j, $N_{s,t}^j$, $K_{s,t}^j$, and $H_{s,t}^j$ denote labor, capital, and the bundle of intermediate inputs used by this producer. The parameters $\alpha_{N,s}$ and $\alpha_{H,s}$ are the value-added labor intensity and the gross-output intensity of intermediate inputs, respectively.

As producer j sells its output $Z_{s,t}^j$ at price $P_{s,t}^j$ to the wholesalers, hires labor at the wage $W_{s,t}$, rents capital at the rate $R_{K,s,t}$, and purchases intermediate inputs at the price $P_{H,s,t}$, its nominal profits equal

$$D_{s,t}^j\left(P_{s,t}^j\right) = P_{s,t}^j Z_{s,t}^j - W_{s,t} N_{s,t}^j - R_{K,s,t} K_{s,t}^j - P_{H,s,t} H_{s,t}^j. \tag{C.11}$$

Producers set their price according to a Calvo-type pricing protocol. The Calvo probability that the price remains fixed from one period to the next is constant and identical across producers within the same sector. However, we allow this probability to differ across sectors, and denote it by ϕ_s. By the law of large numbers, a fraction $1-\phi_s$ of producers are able to reset their prices in each period.

C.2.2. Wholesalers

In each sector, perfectly competitive wholesalers aggregate the different varieties supplied by the producers into a single final good. The representative wholesaler in sector s has the following CES production technology:

$$Z_{s,t} = \left[\int_0^1 Z_{s,t}^{j\ \frac{\epsilon_s-1}{\epsilon_s}} dj\right]^{\frac{\epsilon_s}{\epsilon_s-1}}, \tag{C.12}$$

where $Z_{s,t}$ is the output of sector s, and ϵ_s is the elasticity of substitution across varieties within sector s. The price of the final good s is then given by

$$P_{s,t} = \left[\int_0^1 P_{s,t}^{j\ 1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}. \tag{C.13}$$

and the problem of the representative wholesaler in sector s is described as follows

$$\max_{Z_{s,t}^j} P_{s,t} Z_{s,t} - \int_0^1 P_{s,t}^j Z_{s,t}^j dj$$

$$s.t. \qquad Z_{s,t} = \left[\int_0^1 Z_{s,t}^{j\ \frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}},$$

which implies the following first-order conditions:

$$Z^j_{s,t} = \left(\frac{P^j_{s,t}}{P_{s,t}}\right)^{-\epsilon} Z_{s,t}, \qquad j \in [0,1], \; s = 1,\dots,S. \tag{C.14}$$

The final good of sector s is sold to consumption, investment, and intermediate-input retailers, as well as to the fiscal authority. This yields the following market-clearing condition:

$$Z_{s,t} = C_{s,t} + I_{s,t} + \sum_{x=1}^{S} H_{x,s,t} + G_{s,t}, \tag{C.15}$$

where $C_{s,t}$ and $I_{s,t}$ denote, respectively, the retailer's purchase of consumption and investment goods from the wholesaler of sector s, $H_{x,s,t}$ denotes the intermediate inputs produced by sector s and used in the production of sector x, and $G_{s,t}$ denotes government purchases from sector s.

C.2.3. Consumption-good retailers

Perfectly competitive consumption-good retailers purchase goods from the wholesalers of each sector and assemble them into a consumption bundle sold to households. The representative consumption-good retailer uses the following CES technology:

$$C_t = \left[\sum_{s=1}^{S} \omega_{C,s}^{\frac{1}{\nu_C}} C_{s,t}^{\frac{\nu_C-1}{\nu_C}}\right]^{\frac{\nu_C}{\nu_C-1}}, \tag{C.16}$$

where ν_C is the elasticity of substitution of consumption across sectors, and $\omega_{C,s}$ denotes the weight of good s in the consumption bundle, such that $\sum_{s=1}^{S} \omega_{C,s} = 1$. The consumption bundle is sold to the households at the equilibrium price $P_{C,t}$, defined as

$$P_{C,t} = \left[\sum_{s=1}^{S} \omega_{C,s} P_{s,t}^{1-\nu_C}\right]^{\frac{1}{1-\nu_C}}. \tag{C.17}$$

Therefore, the consumption-good retailer solves the following problem:

$$\max_{C_{s,t}} P_{C,t} C_t - \sum_{s=1}^{S} P_{s,t} C_{s,t}$$

$$s.t. \qquad C_t = \left[\sum_{s=1}^{S} \omega_{C,s}^{\frac{1}{\nu_C}} C_{s,t}^{\frac{\nu_C-1}{\nu_C}}\right]^{\frac{\nu_C}{\nu_C-1}},$$

which yields the following first-order conditions:

$$C_{s,t} = \omega_{C,s}\left(\frac{P_{s,t}}{P_{C,t}}\right)^{-\nu_C} C_t, \qquad s = 1,\dots,S. \tag{C.18}$$

C.2.4. Investment-good retailers

Investment-good retailers behave analogously to the consumption-good retailers. The representative investment-good retailer buys goods from the representative wholesaler of each sector and assembles them into an investment bundle using the CES technology

$$I_t = \left[\sum_{s=1}^{S} \omega_{I,s}^{\frac{1}{\nu_I}} I_{s,t}^{\frac{\nu_I-1}{\nu_I}}\right]^{\frac{\nu_I}{\nu_I-1}}, \tag{C.19}$$

where ν_I is the elasticity of substitution of investment across sectors, and $\omega_{I,s}$ denotes the weight of good s in the investment bundle, such that $\sum_{s=1}^{S} \omega_{I,s} = 1$. The investment bundle is sold to the households at the equilibrium price $P_{I,t}$, defined as

$$P_{I,t} = \left[\sum_{s=1}^{S} \omega_{I,s} P_{s,t}^{1-\nu_I}\right]^{\frac{1}{1-\nu_I}}. \tag{C.20}$$

and the first-order conditions associated with the retailer's optimization problem are given by

$$I_{s,t} = \omega_{I,s}\left(\frac{P_{s,t}}{P_{I,t}}\right)^{-\nu_I} I_t, \qquad s = 1,\dots,S. \tag{C.21}$$

C.2.5. Intermediate-input retailers

Perfectly competitive intermediate-input retailers transform the goods assembled by the wholesale producers of all sectors into a bundle of intermediate inputs destined exclusively for the producers of a specific sector. The representative intermediate-input retailer that sells exclusively to sector s produces the bundle $H_{s,t}$ using the CES technology

$$H_{s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x}^{\frac{1}{\nu_H}} H_{s,x,t}^{\frac{\nu_H-1}{\nu_H}}\right]^{\frac{\nu_H}{\nu_H-1}}, \tag{C.22}$$

where $H_{s,x,t}$ is the quantity of goods purchased from the wholesaler of sector x, ν_H is the elasticity of substitution of intermediate inputs across sectors, and $\omega_{H,s,x}$ is the weight of the intermediate inputs produced by sector x in the total amount of intermediate inputs used by firms in sector s, such that $\sum_{x=1}^{S} \omega_{H,s,x} = 1$. The intermediate-input bundle is sold to firms in sector s at the equilibrium price $P_{H,s,t}$, which satisfies

$$P_{H,s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x} P_{x,t}^{1-\nu_H}\right]^{\frac{1}{1-\nu_H}}. \tag{C.23}$$

The problem of this intermediate-input retailer, therefore, is

$$\max_{H_{s,x,t}} P_{H,s,t} H_{s,t} - \sum_{x=1}^{S} P_{x,t} H_{s,x,t}$$
$$s.t. \qquad H_{s,t} = \left[\sum_{x=1}^{S} \omega_{H,s,x}^{\frac{1}{\nu_H}} H_{s,x,t}^{\frac{\nu_H-1}{\nu_H}}\right]^{\frac{\nu_H}{\nu_H-1}},$$

which implies the following first-order conditions:

$$H_{s,x,t} = \omega_{H,s,x} \left(\frac{P_{x,t}}{P_{H,s,t}}\right)^{-\nu_H} H_{s,t}, \qquad s, x = 1, \dots, S. \tag{C.24}$$

C.3. Government

The government consists of a monetary and a fiscal authority. The monetary authority sets the nominal interest rate, R_t, according to the Taylor rule

$$\frac{R_t}{R^*} = \left(\frac{R_{t-1}}{R^*}\right)^{\varphi_R} \left[(1+\pi_t)^{\varphi_\Pi} \left(\frac{Y_t}{Y_t^{\text{flex}}}\right)^{\varphi_Y}\right]^{1-\varphi_R}, \tag{C.25}$$

where R^* denotes the steady-state nominal interest rate, φ_R is the degree of interest rate inertia, Y_t is aggregate real value added, Y_t^{flex} is the aggregate real value added of a counterfactual economy with fully flexible prices, φ_Π and φ_Y measure the degree to which the monetary authority adjusts the nominal interest rate in response to changes in aggregate inflation π_t and the output gap $\frac{Y_t}{Y_t^{\text{flex}}}$, respectively. The aggregate inflation is derived over the GDP deflator P_t, that is, $\pi_t = \frac{P_t}{P_{t-1}} - 1$.

Government purchases from sector s are governed by the following auto-regressive process:

$$\log G_{s,t} = (1-\rho)\log G_s^* + \rho \log G_{s,t-1} + \upsilon_{s,t}, \tag{C.26}$$

where ρ measures the persistence of the process. Sectoral government spending changes over time following the realizations of the unique source of uncertainty in the model: sectoral government spending shocks, $\upsilon_{s,t}$, which are zero-mean innovations. Once the spending shocks are realized, the government purchases goods from the representative wholesaler at price $P_{s,t}$. Government purchases are financed through lump-sum taxes paid by the household, which implies the following budget constraint for the government:

$$\sum_{s=1}^{S} P_{s,t} G_{s,t} = T_t. \tag{C.27}$$

C.4. Aggregation

Let $Y_{s,t}$ denote the nominal value added of producer j in sector s, defined as the value of gross output produced by the producer less the cost of the intermediate inputs it uses. That is,

$$\mathcal{Y}_{s,t}^j = P_{s,t}^j Z_{s,t}^j - P_{H,s,t} H_{s,t}^j. \tag{C.28}$$

Aggregating the nominal value added of all the producers in sector s yields

$$\mathcal{Y}_{s,t} = \int_0^1 \mathcal{Y}_{s,t}^j dj = P_{s,t} Z_{s,t} - P_{H,s,t} H_{s,t}. \tag{C.29}$$

Moreover, summing up nominal profits across firms within sector s yields

$$\begin{aligned} D_{s,t} &= \int_0^1 D_{s,t}^j dj = P_{s,t} Z_{s,t} - W_{s,t} N_{s,t} - R_{K,s,t} K_{s,t} - P_{H,s,t} H_{s,t} \\ &= \mathcal{Y}_{s,t} - W_{s,t} N_{s,t} - R_{K,s,t} K_{s,t}. \end{aligned} \tag{C.30}$$

Aggregating nominal profits across sectors and substituting them into the households' budget constraint (C.3), we obtain[50]

$$\mathcal{Y}_t = \sum_{s=1}^{S} \mathcal{Y}_{s,t} = P_{C,t}C_t + P_{I,t}I_t + \sum_{s=1}^{S} P_{s,t}G_{s,t}. \tag{C.31}$$

Eq. (C.31) states that aggregate nominal value added, Y_t, equals the sum of the nominal values of consumption, investment, and government spending.

Aggregate real value added is defined as the ratio between aggregate nominal value added and the GDP deflator:

$$Y_t = \frac{\mathcal{Y}_t}{P_t}. \tag{C.32}$$

Using an analogous definition for sectoral real value added, $Y_{s,t}$, aggregate real value added satisfies the following identity:

$$Y_t = \frac{\sum_{s=1}^{S} \mathcal{Y}_{s,t}}{P_t} = \sum_{s=1}^{S} Y_{s,t}. \tag{C.33}$$

C.5. Nesting the stylized economy

The multi-sector model collapses to the stylized two-sector economy of Section 2.1 under the following parameter restrictions:

1. The economy consists of two sectors: $S = 2$, and $s = u, d$;
2. The upstream sector (u) supplies all the intermediate inputs, whereas the downstream sector (d) demands intermediate inputs, but provides none: $\omega_{H,u,u} = \omega_{H,d,u} = 1$;
3. Cobb–Douglas consumption-good aggregator: $\nu_C = 1$;
4. No capital in the production function: $\alpha_{N,u} = \alpha_{N,d} = 1$;
5. Equal gross-output factor intensities across sectors: $\alpha_{H,u} = \alpha_{H,d} = \alpha_H$;
6. Fully flexible prices: $\phi_u = \phi_d = 0$;
7. Equal steady-state ratio of the sectoral contribution to government spending to aggregate value added: $\frac{Q_u^* G_u^*}{Y^*} = \frac{Q_d^* G_d^*}{Y^*}$;
8. Households receive no utility from government spending: $\zeta = 1$;
9. Logarithmic preference over consumption: $\sigma = 1$;
10. Infinite Frisch elasticity of labor supply: $\eta = 0$.

Appendix D. More on the calibration of the quantitative model

This section presents further information on the calibration of the quantitative model. Tables D.1–D.3 report the list of the 57 production sectors we consider. This level of disaggregation roughly corresponds to the three-digit level of the NAICS codes. In fact, we go from the original 66 to 57 industries by removing sectors that broadly operate in financial, insurance and real estate services—namely: i) Federal Reserve banks, credit intermediation, and related activities; ii) Securities, commodity contracts, and investments; iii) Insurance carriers and related activities; iv) Funds, trusts, and other financial vehicles; v) Housing; vi) Other real estate; vii) Rental and leasing services and lessors of intangible assets—and collapse viii) Oil and gas extraction, ix) Mining, except oil and gas, and x) Support activities for mining into a single sector we label Mining.

D.1. Parameter values

In what follows, we discuss the calibration of the parameters that are common to all sectors and that we have not mentioned in Section 3.2. All these values are also reported in Table D.4, together with the target or the source that disciplines our calibration choice. We calibrate the time discount factor to $\beta = 0.995$, such that the annual steady-state nominal interest rate equals 2 %, while the risk-aversion parameter is set to the standard value of $\sigma = 2$. Moreover, we choose $\eta = 1.25$, such that the Frisch elasticity equals 0.8, in line with the estimate of the labor supply elasticity derived by Chetty et al. (2013). We set $\theta = 41.57$, such that the steady-state level of total hours, N, equals 0.33. We choose the elasticity of substitution between consumption and government spending to be $\xi = 0.3$, in line with the estimates of Bouakez and Rebei (2007) and Sims and Wolff (2018),[51] and the relative weight of consumption to be $\zeta = 0.7$, which corresponds to the ratio of the nominal value of consumption expenditures over the sum of consumption and government expenditures.

We set $\delta = 0.025$, which implies that physical capital depreciates by 10 % on an annual basis. We calibrate the investment-adjustment-cost parameter such that the response of aggregate inflation to a common government spending shock peaks after eight quarters, in line with the empirical evidence of Blanchard and Perotti (2002). Accordingly, we set $\Omega = 25$.

[50] To derive this equation, we have used the market clearing conditions $N_{s,t} = \int_0^1 N_{s,t}^j dj$, $K_{s,t} = \int_0^1 K_{s,t}^j dj$, and $H_{s,t} = \int_0^1 H_{s,t}^j dj$, the government budget constraint (C.27), the retailers' zero-profit conditions $\sum_s W_{s,t}N_{s,t} = W_t N_t$ and $\sum_s R_{K,s,t}K_{s,t} = R_{K,t}K_t$, as well as the fact that the net supply of private bonds equals zero in equilibrium: $B_t = 0, \forall t$.

[51] Consumption and government spending are therefore Edgeworth complements in utility. This assumption is supported by the empirical evidence reported by Fève et al. (2013) and Leeper et al. (2017).

Table D.1
Sectors 1–20.

1	Farms
2	Forestry, fishing, and related activities
3	Mining
4	Utilities
5	Construction
6	Wood products
7	Nonmetallic mineral products
8	Primary metals
9	Fabricated metal products
10	Machinery
11	Computer and electronic products
12	Electrical equipment, appliances, and components
13	Motor vehicles, bodies and trailers, and parts
14	Other transportation equipment
15	Furniture and related products
16	Miscellaneous manufacturing
17	Food and beverage and tobacco products
18	Textile mills and textile product mills
19	Apparel and leather and allied products
20	Paper products

Table D.2
Sectors 21–40.

21	Printing and related support activities
22	Petroleum and coal products
23	Chemical products
24	Plastics and rubber products
25	Wholesale trade
26	Motor vehicle and parts dealers
27	Food and beverage stores
28	General merchandise stores
29	Other retail
30	Air transportation
31	Rail transportation
32	Water transportation
33	Truck transportation
34	Transit and ground passenger transportation
35	Pipeline transportation
36	Other transportation and support activities
37	Warehousing and storage
38	Publishing industries, except internet (includes software)
39	Motion picture and sound recording industries
40	Broadcasting and telecommunications

Table D.3
Sectors 41–57.

41	Data processing, internet publishing, and other information services
42	Legal services
43	Computer systems design and related services
44	Miscellaneous professional, scientific, and technical services
45	Management of companies and enterprises
46	Administrative and support services
47	Waste management and remediation services
48	Educational services
49	Ambulatory health care services
50	Hospitals
51	Nursing and residential care facilities
52	Social assistance
53	Performing arts, spectator sports, museums, and related activities
54	Amusements, gambling, and recreation industries
55	Accommodation
56	Food services and drinking places
57	Other services, except government

Table D.4
Calibration of economy-wide parameters.

Parameter	Target/source
$\beta = .995$	2 % steady-state annual interest rate R
$\sigma = 2$	Standard value
$\theta = 41.01$	0.33 steady-state total hours N
$\eta = 1/0.8$	Chetty et al. (2013)
$\xi = 0.3$	Bouakez and Rebei (2007), Sims and Wolff (2018)
$\zeta = 0.7$	Ratio of nominal value of consumption expenditures over the sum of consumption and government expenditures
$\delta = 0.025$	10 % annual depreciation rate
$\Omega = 20$	8 quarters peak response of investment
$\nu_C = 2$	Hobijn and Nechio (2019)
$\nu_I = 2$	$\nu_I = \nu_C$
$\nu_H = 0.1$	Barrot and Sauvagnat (2016), Atalay (2017), Boehm et al. (2019)
$\nu_N = 1$	Horvath (2000)
$\nu_K = 1$	$\nu_K = \nu_N$
$\epsilon = 4$	33 % steady-state mark-up
$\varphi_R = 0.8$	Clarida et al. (2000)
$\varphi_\Pi = 1.5$	Clarida et al. (2000)
$\varphi_Y = 0.2$	Clarida et al. (2000)
$\rho = 0.9$	Standard value

As for the Taylor rule, we use the estimates of Clarida et al. (2000): we set the degree of interest-rate inertia to $\varphi_R = 0.8$, and the responsiveness to changes in the inflation rate and to the output gap to $\varphi_\Pi = 1.5$ and $\varphi_Y = 0.2$, respectively.

Finally, the tables that report the parameters that vary across sectors (i.e., the contribution to the final consumption good, the contribution to the final investment good, the contribution to government spending, the entire Input–Output matrix, the factor intensities, and the degree of price rigidity) are available upon request.

D.2. Validating the calibration

We assess the empirical plausibility of our calibration strategy by evaluating the model's ability to account for the cross-industry elasticity of output to government purchases, in the spirit of Nakamura and Steinsson (2014, 2018), Beraja et al. (2019), and Jones et al. (2023).

To do so, we build a panel of sectoral value added and government defense spending at an annual frequency, from 1958 to 2018, using data from the U.S. Bureau of Economic Analysis (BEA). The panel is constructed at the same level of sectoral disaggregation considered in the model,[52] and is used to estimate the following regression:

$$\Delta \log Y_{s,t} = \beta_1 \Delta \log \tilde{G}_{s,t} + \beta_2 \Delta \log Y_{s,t-1} + \beta_3 \Delta \log \tilde{G}_{s,t-1} + \delta_s + \delta_t + \epsilon_{s,t}, \tag{D.34}$$

where the dependent variable, $\Delta \log Y_{s,t}$, is the log-change in the value added of sector s, and $\Delta \log \tilde{G}_{s,t}$ is the defense spending shock in sector s. The regression also includes lagged values of sectoral value added and government spending, as well as industry fixed effects, δ_s, and year fixed effects, δ_t.

Since sectoral defense purchases, $G_{s,t}$, could depend on the economic conditions of the recipient industry, we identify the sectoral shocks by assuming that the allocation of aggregate defense spending across sectors remains constant over time. Specifically, we closely follow Nekarda and Ramey (2011) and Acemoglu et al. (2016) and construct the series of defense spending shocks as

$$\Delta \log \tilde{G}_{s,t} = \theta_s \times \Delta \log G_t, \tag{D.35}$$

where G_t is the aggregate series of real defense spending, and θ_s is the sample average of the ratio between sectoral defense spending in sector s and sectoral total shipments, $Z_{s,t}$, that is

$$\theta_s = \frac{1}{T} \sum_{t=1}^{T} \frac{G_{s,t}}{Z_{s,t}}. \tag{D.36}$$

While the common practice of using military spending as a proxy for government expenditure relies on the premise that the U.S. does not embark on a war because national value added is low (Barro and Redlick, 2011; Ramey, 2011), our approach implies a much weaker identifying condition,

[52] More precisely, the constructed panel contains 53 sectors, whereas the baseline economy comprises 57 sectors. This difference is due to the fact that the BEA reports sectoral data at a relatively lower degree of disaggregation for the early years of the sample.

Table D.5
Estimation results: data-based versus model-based estimates.

	Dependent variable: $\Delta \log Y_{s,t}$	
	Data (1)	Model (2)
$\Delta \log \tilde{G}_{s,t}$	0.75**	0.79***
	(0.30)	(0.06)
$\Delta \log Y_{s,t-1}$	0.01	−0.01
	(0.05)	(0.03)
$\Delta \log G_{s,t-1}$	−0.10	0.03
	(0.28)	(0.06)
Industry Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
R^2	0.19	0.66
N. Obs.	2862	3078

Notes: The table reports estimates of the coefficients in Eq. (D.35) and their standard errors (in parentheses). Column (1) reports the estimates based on a panel of U.S. sectoral value added and government spending across 53 sectors, measured at an annual frequency, from 1963 to 2018. Column (2) reports the estimates based on an artificial panel of 57 sectors spanning 56 years, which is simulated using the baseline model. We closely follow Nekarda and Ramey (2011) and Acemoglu et al. (2016) by constructing the series of defense spending shocks as $\Delta \log \tilde{G}_{s,t} = \theta_s \times \Delta \log G_t$, where G_t is aggregate government spending, and θ_s is the sample average of the ratio between sectoral defense spending and sectoral total shipments. Standard errors are double-clustered at the sector-year level.

requiring that the U.S. do not embark in a war when the output of a given sector is lower than that of all the other industries. In this setting, the coefficient β_1 denotes the elasticity of the value added of sector s – relative to the elasticity of the value added of all the other industries – to a 1 % increase in real defense spending in sector s.

Using the baseline economy, we simulate – and aggregate at an annual frequency – an analogous artificial panel of sectoral value added and government defense spending, and construct a series of defense spending shocks according to Eq. (D.35). We then use the artificial data to estimate Eq. (D.34). Our validation exercise therefore consists in comparing the model-based estimate of β_1 with its data-based counterpart.

Table D.5 reports the estimation results. The model-based estimate of β_1 (0.79) is extremely close to its data-based counterpart (0.75), indicating that the model successfully accounts for the cross-industry output effects of government spending shocks as measured in the data.

Appendix E. Sectoral characteristics and the spending multiplier – additional results

This section evaluates the robustness of the relationship between sectoral characteristics and the aggregate value-added multiplier associated with sectoral spending shocks under two alternative specifications of our economy. In the first, we consider a model version in which both labor and capital are imperfectly mobile across industries. We do so by setting $\nu_N = \nu_K = 0$, so that sectoral labor equals to $N_{s,t} = \omega_{N,s} N_t$ and an analogous treatment is applied to sectoral capital, so that $K_{s,t} = \omega_{K,s} K_t$. In other words, labor and capital are allocated in fixed proportions across industries. In the second specification, we consider a constant nominal interest rate by setting a full degree of inertia in the Taylor rule, so that $\varphi_R \to 1$. This case provides an approximation of how the sectoral characteristics of the shocked sector shape the response of aggregate value added in an economy in which the zero lower bound is (permanently) binding.

To perform these robustness checks, we replicate the analysis of Section 3.3, and reproduce the patterns depicted in Fig. 1 for each of the two alternative model specifications. We do so in Fig. E.1 for the case of immobile production factors, and in Fig. E.2 for the case of constant nominal interest rate. While there are slight quantitative differences with respect to results obtained for our baseline economy, our main findings hold: the response of aggregate value added to sectoral spending shocks is larger when government spending originates in sectors with a relatively small contribution to private final demand, low markup, high labor intensity, and in those located downstream in the supply chain.

Appendix F. Aggregate effects of sectoral spending shocks - robustness checks

Below, we report the aggregate implications of sectoral spending shocks obtained from an alternative version of the baseline economy in which we assume that government spending does not enter directly into the utility function. This is achieved by assuming $\zeta = 1$. Figs. F.1–F.3 report, respectively, the value-added, consumption, and investment multipliers associated with spending shocks in each of the 57 sectors, under this assumption. The figures show that abstracting from complementarity between private consumption and government spending in preferences reduces the magnitude of the aggregate effects of sectoral spending shocks. Intuitively, when government spending no longer raises the marginal utility of consumption, labor supply increases by a smaller amount in response to an increase in public purchases, leading to a larger crowding out of private spending, and attenuating the absolute size of the aggregate multipliers. This attenuation, however, has virtually no effect on the relative size of the multipliers associated with sectoral shocks. For instance, the correlation between the aggregate value-added multipliers implied by the baseline model and the alternative economy (which abstracts from complementarity) amounts to 0.98.

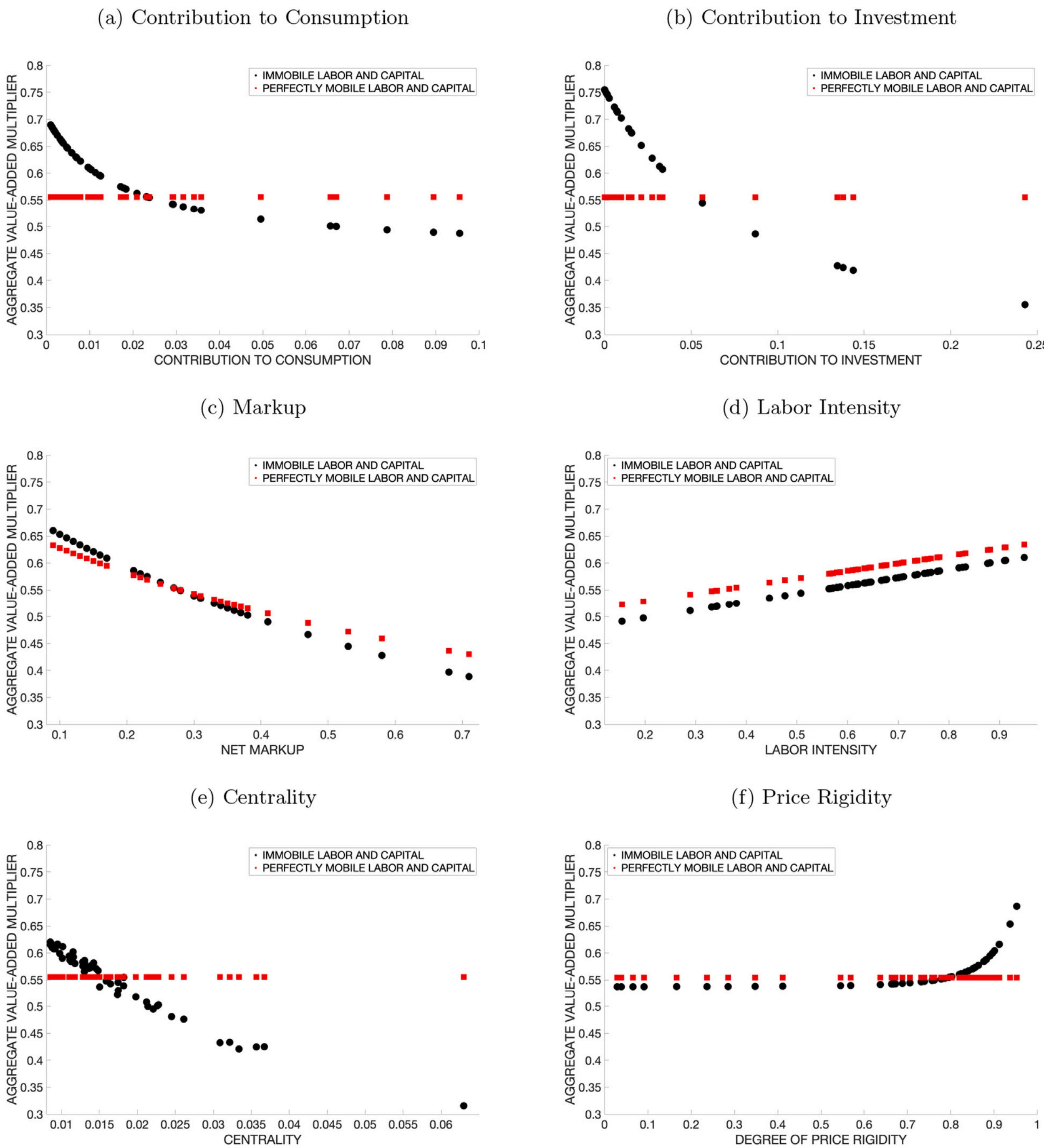

Fig. E.1. Counterfactual experiments: Model with immobile labor and capital. Notes: Similarly to Fig. 1, the figure reports the aggregate value-added multiplier in counterfactual economies in which we allow for one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the remaining sectoral attributes. In this case, we compare the two extreme cases of perfect labor and capital mobility (red squares) and total immobility (black dots). Each dot/square represents one of the 57 sectors of the economy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

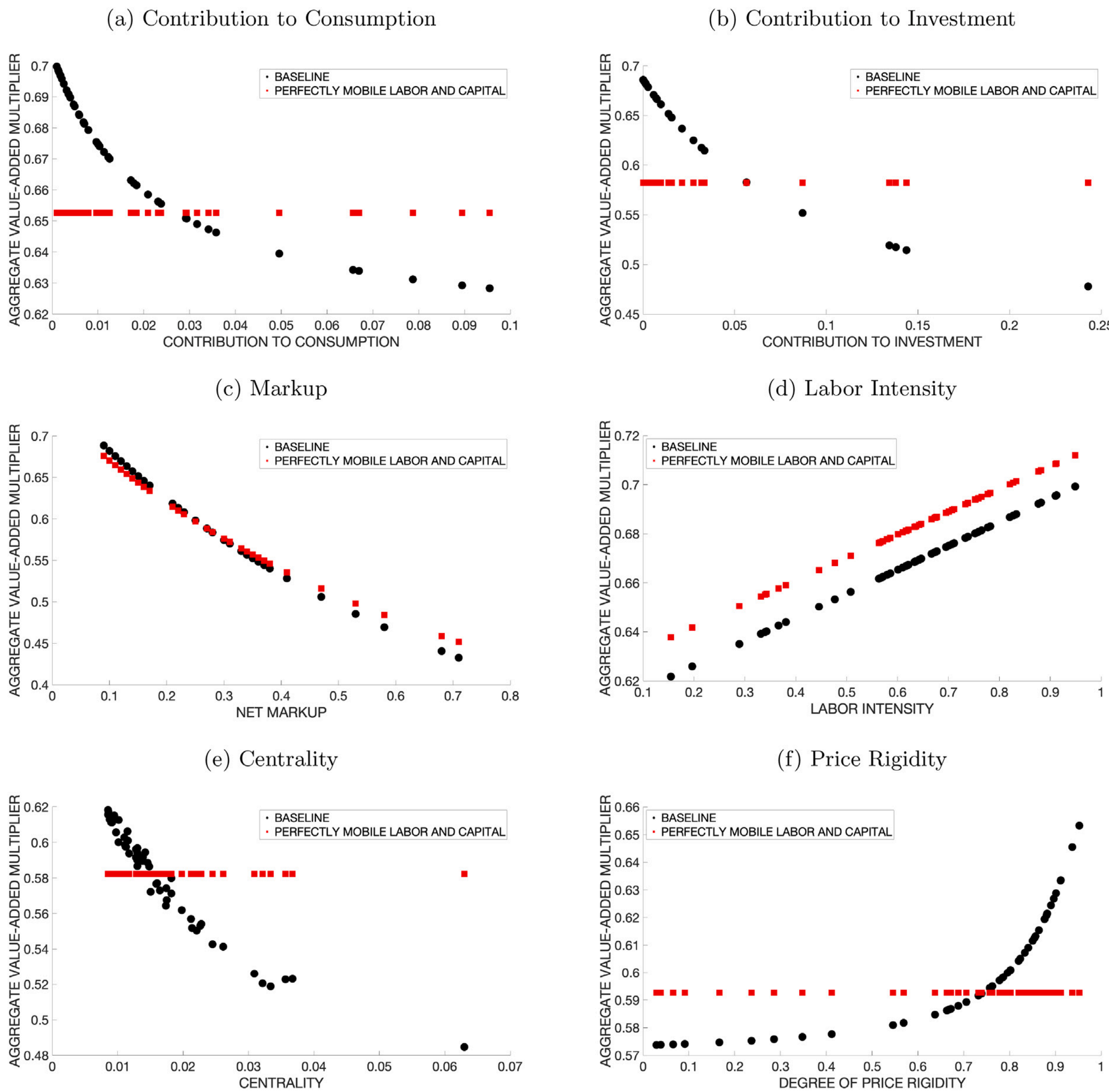

Fig. E.2. Counterfactual experiments: Model with constant nominal interest rate. Notes: Similarly to Fig. 1, the figure reports the aggregate value-added multiplier in counterfactual economies in which we allow for one dimension of sectoral heterogeneity at a time, while imposing symmetry in all the remaining sectoral attributes. In this case, we compare the case of imperfect labor and capital mobility across industries (black dots) to that of perfect mobility (red squares) in a model specification with constant nominal interest rate (i.e., $\varphi_R \to 1$). Each dot/square represents one of the 57 sectors of the economy. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

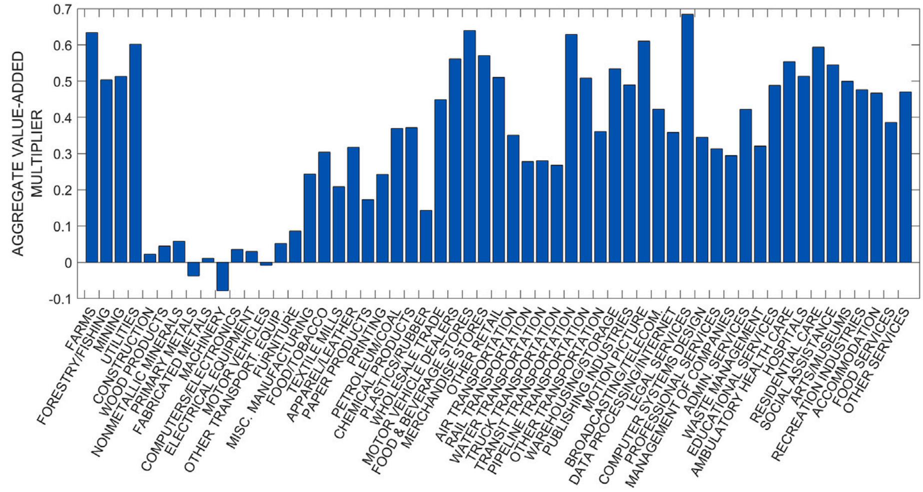

Fig. F.1. Aggregate output response to sectoral government spending shocks – No complementarity between C_t and G_t. Notes: The figure plots the aggregate value-added multiplier associated with each sectoral government spending shock, obtained from a version of the fully-heterogeneous economy in which government spending does not enter into the utility function.

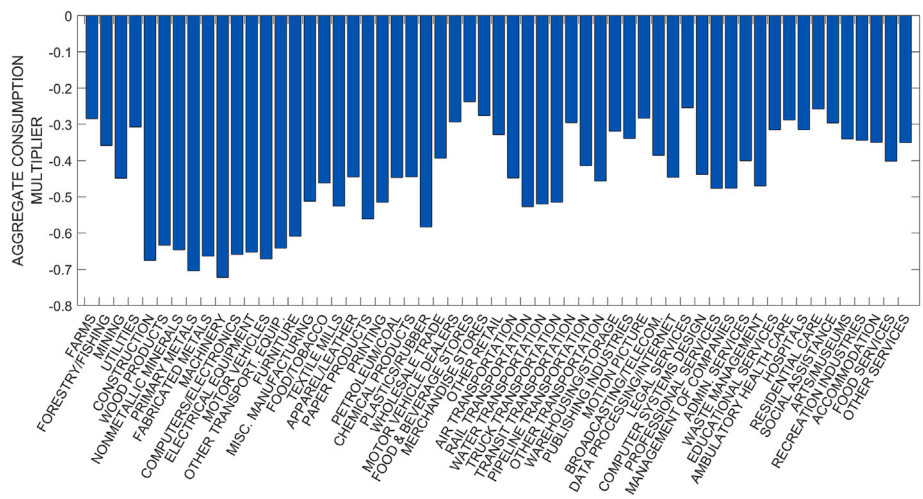

Fig. F.2. Aggregate consumption response to sectoral government spending shocks – No complementarity between C_t and G_t. Notes: The figure plots the aggregate consumption multiplier associated with each sectoral government spending shock, obtained from a version of the fully-heterogeneous economy in which government spending does not enter into the utility function.

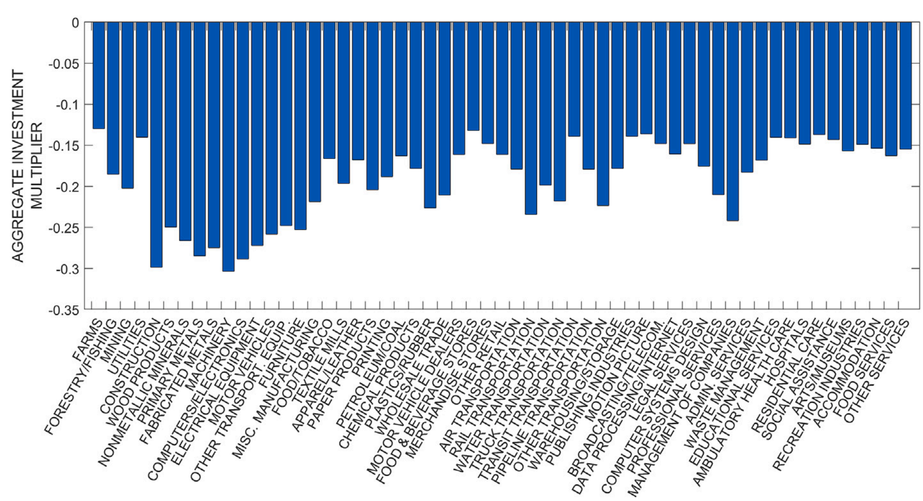

Fig. F.3. Aggregate investment response to sectoral government spending shocks – No complementarity between C_t and G_t. Notes: The figure plots the aggregate investment multiplier associated with each sectoral government spending shock, obtained from a version of the fully-heterogeneous economy in which government spending does not enter into the utility function.

Appendix G. The sectoral composition of government purchases across countries

In this section, we use the 2014 Input–Output Tables of the OECD to derive the sectoral composition of national government spending for a set of 28 countries: Austria, Belgium, Cyprus, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Latvia, Lithuania, Macedonia, the Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, and the United Kingdom. As in Section 3.4.2, we consider a sequence of economies, one for each country, that feature the same steady state (based on the U.S. economy) and differ only in the calibration of the sectoral composition of the government spending shocks. Note that because the specific blend of sectoral government spending in a given country is, to a large extent, endogenous to its economic conditions, we do not seek to measure the spending multiplier in each of the 28 countries based on the model calibrated to the U.S. economy. Instead, we would like to determine what the government spending multiplier in the U.S. would be, should the calibration reflect the sectoral composition of government spending in other advanced economies.

Allowing for variation in the sectoral composition of spending by the general government across countries leads to large differences in the size of the government spending multiplier. Figs. G.1 and G.2 respectively report the output and consumption multipliers associated with spending shocks whose sectoral split is calibrated to the U.S. and each of the 28 OECD countries we consider. The output multiplier ranges between 0.60 in the case of Slovakia and 0.92 for the United Kingdom. These differences are driven by the fact that the general government in (low-multiplier) countries such as Czech Republic, Slovakia, and Slovenia tends to concentrate its spending relatively more in manufacturing and transportation industries, whereas the general government of (high-multiplier) economies such as Croatia, Cyprus, and the United Kingdom spends relatively more on professional, educational, and health-care services. As for consumption, we observe – once again – strong heterogeneity, with both crowding-in and crowding-out effects associated with different countries/compositions of the public spending shock. The general picture emerging from this exercise is that the multiplier associated with the sectoral composition of government spending in the U.S. is lower than those implied by the sectoral composition of public purchases in at least half of the OECD countries.

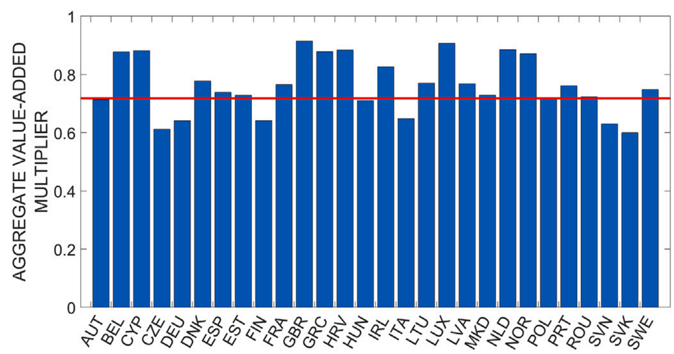

Fig. G.1. The aggregate value-added multiplier across countries. Notes: The figure reports the aggregate value-added multiplier based on the sectoral composition of general government spending in twenty-eight OECD countries. The red line corresponds to the value of the aggregate value-added multiplier in the United States. All the multipliers are obtained from otherwise identical economies that only differ in the sectoral composition of the government spending shock, which is calibrated based on the Input–Output table of each country. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

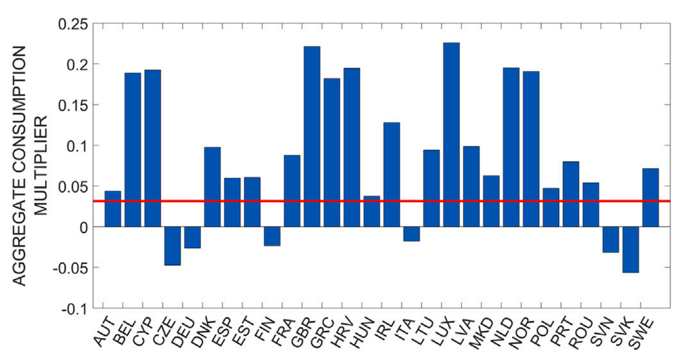

Fig. G.2. The aggregate consumption multiplier across countries. Notes: The figure reports the aggregate consumption multiplier based on the sectoral composition of general government spending in twenty-eight OECD countries. The red line corresponds to the value of the aggregate consumption multiplier in the United States. All the multipliers are obtained from otherwise identical economies that only differ in the sectoral composition of the government spending shock, which is calibrated based on the Input–Output table of each country. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Appendix H. Testing the theoretical predictions - additional results

This section provides additional details with respect to the empirical results reported in Section 4.1. Table H.1 reports the raw estimates of the coefficient β_2 in the state-level regression (23). Indeed, for ease of interpretation, Table 1 normalizes the coefficients so that they measure the percentage change in the average local spending multiplier associated with a one-standard-deviation change in each of the weighted-average sectoral characteristics.

Table H.1
Local spending multiplier and sectoral characteristics.

	Characteristics					
	Contribution to consumption (ω_C)	Contribution to investment (ω_I)	Markup (ϑ)	Labor intensity (α_N)	Centrality (c)	Price rigidity (ϕ)
Baseline	−7.116 (0.030)	−2.275 (0.125)	−0.199 (0.025)	0.198 (0.021)	−3.410 (0.010)	0.012 (0.018)
Tax control	−6.643 (0.028)	−2.769 (0.077)	−0.191 (0.031)	0.200 (0.022)	−3.249 (0.014)	0.012 (0.020)
Baseline (2001–2019)	−6.410 (0.044)	−1.832 (0.106)	−0.197 (0.035)	0.196 (0.034)	−3.237 (0.017)	0.010 (0.038)
Tax control (2001–2019)	−5.918 (0.055)	−2.176 (0.072)	−0.180 (0.051)	0.190 (0.043)	−2.964 (0.028)	0.010 (0.050)

Notes: This table reports the estimates of β_2 in Eq. (23), as well as the corresponding p-values (between parentheses). Estimates are based on a state-level panel, measured at an annual frequency, from 2001 to 2021. Standard errors are clustered at the state level. *Baseline* refers to the estimation considering the entire sample, while *Tax control* refers to the case in which we control for the contemporaneous change in the ratio of personal federal taxes over personal income. The additional label *2001–2019* refers to the estimations that exclude the years 2020 and 2021.

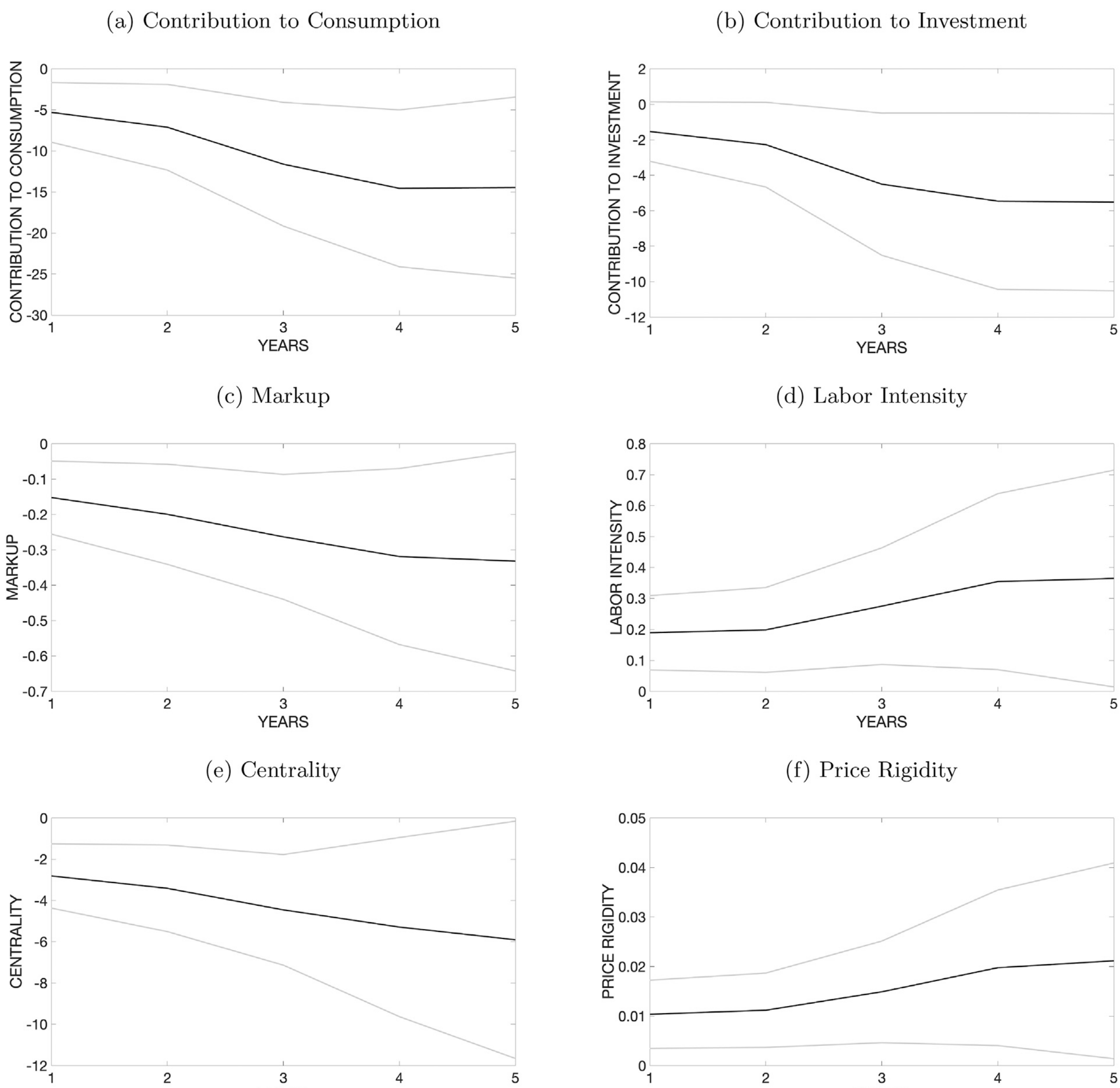

Fig. H.1. Local spending multiplier and sectoral characteristics – Different time horizons. Notes: The figure reports the estimated effects of the weighted-average characteristics and local spending shocks at different time horizon, considering 1-year, 2-year, 3-year, 4-year, and 5-year changes in local GDP. The estimates at the 2-year horizon coincide with those reported in Table H.1. The dark lines correspond to the point estimates and the gray lines delimit the 90 % confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table H.2
Aggregate spending multiplier and sectoral characteristics.

	Characteristics					
	Contribution to consumption (ω_C)	Contribution to investment (ω_I)	Markup (ϑ)	Labor intensity (α_N)	Centrality (c)	Price rigidity (ϕ)
Baseline	−0.472 (0.017)	−0.477 (0.065)	−0.712 (0.001)	0.259 (0.226)	−0.697 (0.011)	1.141 (0.000)
Tax control	−0.480 (0.030)	−0.516 (0.032)	−0.747 (0.008)	0.264 (0.210)	−0.683 (0.016)	1.866 (0.000)

Notes: The table reports the estimates of β_2 in Eq. (24), as well as the corresponding p-values (between parentheses). Estimates are based on annual data covering the period 1963–2015. *Baseline* refers to the estimation considering the entire sample, while *Tax control* refers to the case in which we control for the contemporaneous change in the ratio of personal federal taxes over personal income.

Fig. H.1 evaluates the extent to which the estimates of the coefficient β_2 vary in case we consider different time horizons when computing the response of local GDP to local government spending shocks. Recall that regression (23) considers 2-year changes following the seminal work of Nakamura and Steinsson (2014). Fig. H.1 reports how the estimates vary in case we consider 1-year, 2-year, 3-year, 4-year, and 5-year changes. We find that the magnitude of the estimated coefficients tends to increase with the time horizon, but importantly it remains statistically significant at least at the 10 % level. From this perspective, this result indicates that the key dependence of the local spending multipliers on the weighted-average sectoral characteristics holds irrespective of the time horizon over which the change in aggregate value added is computed in (23).

Finally, Table H.2 reports the raw estimates of the coefficient β_2 in the aggregate-level regressions (24). As in the case of the state-level regressions, Table 2 features normalized coefficients for ease of interpretation.

Data availability

Data will be made available on request.

References

Acemoglu, D., Akcigit, U., Kerr, W., 2016. Networks and the macroeconomy: an empirical exploration. NBER Macroecon. Annu. 30 (1), 273–335.
Altig, D., Christiano, L., Eichenbaum, M., Linde, J., 2011. Firm-specific capital, nominal rigidities and the business cycle. Rev. Econ. Dyn. 14 (2), 225–247.
Atalay, E., 2017. How important are sectoral shocks? Am. Econ. J.: Macroecon. 9 (4), 254–280.
Auerbach, A.J., Gorodnichenko, Y., 2012. Measuring the output responses to fiscal policy. Am. Econ. J.: Econ. Policy 4 (2), 1–27.
Auerbach, A.J., Gorodnichenko, Y., Murphy, D., 2020. Local fiscal multipliers and fiscal spillovers in the United States. IMF Econ. Rev. 68 (1), 195–229.
Baqaee, D.R., Farhi, E., 2018. The microeconomic foundations of the aggregate production function. J. Eur. Econ. Assoc. 17 (5), 1337–1392.
Baqaee, D.R., Farhi, E., 2019. Macroeconomics with Heterogeneous Agents and Input–Output Networks. Technical Report. Mimeo.
Baqaee, D.R., Farhi, E., 2020. Productivity and misallocation in general equilibrium. Q. J. Econ. 135 (1), 105–163.
Barattieri, A., Cacciatore, M., Traum, N., 2023. Estimating the Effects of Government Spending Through the Production Network. NBER Working Papers 31680. National Bureau of Economic Research, Inc.
Barnichon, R., Debortoli, D., Matthes, C., 2022. Understanding the size of the government spending multiplier: It's in the sign. Rev. Econ. Stud. 89 (1), 87–117.
Barro, R.J., Redlick, C.J., 2011. Macroeconomic effects from government purchases and taxes. Q. J. Econ. 126 (1), 51–102.
Barrot, J.-N., Sauvagnat, J., 2016. Input specificity and the propagation of idiosyncratic shocks in production networks. Q. J. Econ. 131 (3), 1543–1592.
Beraja, M., Hurst, E., Ospina, J., 2019. The aggregate implications of regional business cycles. Econometrica 87 (6), 1789–1833.
Bigio, S., La'O, J., 2020. Distortions in production networks. Q. J. Econ. 135 (4), 2187–2253.
Blanchard, O., Perotti, R., 2002. An empirical characterization of the dynamic effects of changes in government spending and taxes on output. Q. J. Econ. 117 (4), 1329–1368.
Boehm, C., Flaaen, A., Pandalai-Nayar, N., 2019. Input linkages and the transmission of shocks: firm-level evidence from the 2011 Tōhoku earthquake. Rev. Econ. Stat. 101 (1), 60–75.
Boehm, C.E., 2020. Government consumption and investment: does the composition of purchases affect the multiplier? J. Monet. Econ. 115, 80–93.
Bouakez, H., Cardia, E., Ruge-Murcia, F., 2009. The transmission of monetary policy in a multisector economy. Int. Econ. Rev. 50 (4), 1243–1266.
Bouakez, H., Cardia, E., Ruge-Murcia, F., 2014. Sectoral price rigidity and aggregate dynamics. Eur. Econ. Rev. 65, 1–22.
Bouakez, H., Rachedi, O., Santoro, E., 2023. The government spending multiplier in a multi-sector model. Am. Econ. J.: Macroecon. 15 (1), 209–239.
Bouakez, H., Rebei, N., 2007. Why does private consumption rise after a government spending shock? Can. J. Econ. 40 (3), 954–979.
Cardi, O., Restout, R., 2015. Fiscal shocks in a two-sector open economy with endogenous markups. Macroecon. Dyn. 19 (8), 1839–1865.
Carvalho, C., 2006. Heterogeneity in price stickiness and the real effects of monetary shocks. BE J. Macroecon. 2 (1), 23–48.
Carvalho, C., Nechio, F., 2016. Factor specificity and real rigidities. Rev. Econ. Dyn. 22, 208–222.
Chang, J., Lin, H., Traum, N., Yang, S.S., 2021. Fiscal consolidation and public wages. J. Money Credit Bank. 53 (2–3), 503–533.
Chetty, R., Guren, A., Manoli, D., Weber, A., 2013. Does indivisible labor explain the difference between micro and macro elasticities? A meta-analysis of extensive margin elasticities. NBER Macroecon. Annu. 27 (1), 1–56.
Christiano, L., Eichenbaum, M., Rebelo, S., 2011. When is the government spending multiplier large? J. Polit. Econ. 119 (1), 78–121.
Clarida, R., Gali, J., Gertler, M., 2000. Monetary policy rules and macroeconomic stability: evidence and some theory. Q. J. Econ. 115 (1), 147–180.
Coviello, D., Marino, I., Nannicini, T., Persico, N., 2022. Demand shocks and firm investment: micro-evidence from fiscal retrenchment in Italy. Econ. J. 132 (642), 582–617.
Cox, L., Müller, G., Pasten, E., Schoenle, R., Weber, M., 2024. Big G. J. Polit. Econ. 132 (10), 3260–3297.
de Loecker, J., Eeckhout, J., Unger, G., 2020. The rise of market power and the macroeconomic implications. Q. J. Econ. 135 (2), 561–644.
Devereux, M.B., Gente, K., Yu, C., 2023. Production networks and international fiscal spillovers. Econ. J. 133, 1871–1900.
Diamond, P.A., Mirrlees, J.A., 1971. Optimal taxation and public production I: production efficiency. Am. Econ. Rev. 61 (1), 8–27.
Dong, F., Wen, Y., 2019. Long and Plosser Meet Bewley and Lucas. J. Monet. Econ. 102 (C), 70–92.
Fève, P., Matheron, J., Sahuc, J.-G., 2013. A pitfall with estimated DSGE-based government spending multipliers. Am. Econ. J.: Macroecon. 5 (4), 141–178.
Finn, M.G., 1998. Cyclical effects of government's employment and goods purchases. Int. Econ. Rev. 39 (3), 635–657.
Flynn, J., Patterson, C., Sturm, J., 2024. Fiscal Policy in a Networked Economy. Technical Report. Mimeo.
Gibbons, R., Katz, L., 1992. Does unmeasured ability explain inter-industry wage differentials? Rev. Econ. Stud. 59 (3), 515–535.
Guerrieri, V., Lorenzoni, G., Straub, L., Werning, I., 2022. Macroeconomic implications of COVID-19: can negative supply shocks cause demand shortages? Am. Econ. Rev. 112 (5), 1437–1474.
Hall, R., 2009. By how much does GDP rise if the government buys more output? Brookings Papers on Economic Activity. pp. 183–231.
Hansen, G.D., 1985. Indivisible labor and the business cycle. J. Monet. Econ. 16 (3), 309–327.
Hebous, S., Zimmermann, T., 2021. Can government demand stimulate private investment? Evidence from U.S. Federal procurement. J. Monet. Econ. 118 (C), 178–194.
Hobijn, B., Nechio, F., 2019. Sticker shocks: using VAT changes to estimate upper-level elasticities of substitution. J. Eur. Econ. Assoc. 17 (3), 799–833.
Horvath, M., 2000. Sectoral shocks and aggregate fluctuations. J. Monet. Econ. 45 (1), 69–106.
Huffman, G., Wynne, M., 1999. The role of intratemporal adjustment costs in a multisector economy. J. Monet. Econ. 43 (2), 317–350.
Jones, C., Midrigan, V., Philippon, T., 2023. Household leverage and the recession. Econometrica 90, 2471–2505.
Jones, C.I., 2013. Misallocation, economic growth, and input–output economics. Adv. Econ. Econom.: Tenth World Congr. 2, 419.
Katayama, M., Kim, K.H., 2018. Intersectoral labor immobility, sectoral comovement, and news shocks. J. Money Credit Bank. 50 (1), 77–114.
Kim, T., Nguyen, Q.H., 2020. The effect of public spending on private investment. Rev. Financ. 24 (2), 415–451.

Krueger, A.B., Summers, L.H., 1988. Efficiency wages and the inter-industry wage structure. Econometrica 56 (2), 259–293.
Lanteri, A., 2018. The market for used capital: endogenous irreversibility and reallocation over the business cycle. Am. Econ. Rev. 108 (9), 2383–2419.
Lee, D., Wolpin, K., 2006. Intersectoral labor mobility and the growth of the service sector. Econometrica 74 (1), 1–46.
Leeper, E., Traum, N., Walker, T., 2017. Clearing up the fiscal multiplier morass. Am. Econ. Rev. 107 (8), 2409–2454.
Leeper, E.M., Plante, M., Traum, N., 2010. Dynamics of fiscal financing in the United States. J. Econom. 156 (2), 304–321.
Liu, E., 2019. Industrial policies in production networks. Q. J. Econ. 134 (4), 1883–1948.
Matheron, J., 2006. Firm-specific labor and firm-specific capital: implications for the Euro-Data New Phillips curve. Int. J. Cent. Bank. (7), 1–32.
Miranda-Pinto, J., Young, E.R., 2019. Comparing dynamic multisector models. Econ. Lett. 181 (C), 28–32.
Moro, A., Rachedi, O., 2022. The changing structure of government consumption spending. Int. Econ. Rev. 63 (3), 1293–1323.
Nakamura, E., Steinsson, J., 2008. Five facts about prices: a reevaluation of menu cost models. Q. J. Econ. 123 (4), 1415–1464.
Nakamura, E., Steinsson, J., 2010. Monetary non-neutrality in a multisector menu cost model. Q. J. Econ. 125 (3), 961–1013.
Nakamura, E., Steinsson, J., 2014. Fiscal stimulus in a monetary union: evidence from US regions. Am. Econ. Rev. 104 (3), 753–792.
Nakamura, E., Steinsson, J., 2018. Identification in macroeconomics. J. Econ. Perspect. 32 (3), 59–86.
Nekarda, C.J., Ramey, V.A., 2011. Industry evidence on the effects of government spending. Am. Econ. J.: Macroecon. 3 (1), 36–59.
Neumuller, S., 2015. Inter-industry wage differentials revisited: wage volatility and the option value of mobility. J. Monet. Econ. 76 (C), 38–54.
Pappa, E., 2009. The effects of fiscal shocks on employment and the real wage. Int. Econ. Rev. 50 (1), 217–244.
Proebsting, C., 2022. Market segmentation and spending multipliers. J. Monet. Econ. 128, 1–19.
Ramey, V., 2011. Identifying government spending shocks: It's all in the timing. Q. J. Econ. 126 (1), 1–50.
Ramey, V., 2019. Ten Years after the financial crisis: what gave we learned from the renaissance in fiscal research? J. Econ. Perspect. 33 (2), 89–114.
Ramey, V., Shapiro, M., 1998. Costly capital reallocation and the effects of government spending. J. Monet. Econ. 48, 145–194.
Ramey, V., Zubairy, S., 2018. Government spending multipliers in good times and in bad: evidence from us historical data. J. Polit. Econ. 126 (2), 850–901.
Sims, E., Wolff, J., 2018. The output and welfare effects of government spending shocks over the business cycle. Int. Econ. Rev. 59 (3), 1403–1435.
Slavtchev, V., Wiederhold, S., 2016. Does the technological content of government demand matter for private R&D? Evidence from US states. Am. Econ. J.: Macroecon. 8 (2), 45–84.
Uhlig, H., 2010. Some fiscal calculus. Am. Econ. Rev. 100 (2), 30–34.