# The Government Spending Multiplier in a Multi-Sector Economy

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*We study the effects of aggregate government spending shocks in a production-network economy where sectors differ in their price rigidity, factor intensities, use of intermediate inputs, and contribution to final demand. The model implies an aggregate value-added multiplier that is 75 percent (and 0.32 dollars) larger than that obtained in the average one-sector economy. This amplification is mainly driven by input-output linkages and – to a lesser extent – sectoral heterogeneity in price rigidity. Aggregate government spending shocks also lead to heterogeneous responses of sectoral value added, which are larger among upstream industries. We present novel empirical evidence supporting this prediction.*
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The production apparatus of advanced economies typically consists of highly heterogeneous sectors that are interconnected through the exchange of intermediate inputs. What do sectoral heterogeneity and interactions through the production network imply for the transmission of government spending? While the effects of fiscal policy have witnessed a formidable resurgence of interest since the Great Recession, and continue to be topical in the current Covid-19 crisis, the extant literature has been mostly relying on one-sector models (e.g., Hall, 2009; Woodford, 2011; Leeper, Traum and Walker, 2017). The widespread practice of picturing the economy as a single sector, however, may well distort the conclusions one can draw about the overall impact of government purchases, in addition to concealing their potentially relevant sectoral effects.

In this paper, we build and calibrate a highly disaggregated multi-sector model to study the effects of aggregate government spending shocks, which correspond to a common increase in government purchases from all sectors. We pursue two

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objectives: the first is to determine how and to what extent sectoral heterogeneity and input-output interactions alter the aggregate effects of a change in government spending relative to the average one-sector economy; the second is to unveil the degree of heterogeneity in sectoral output responses to the shock, and investigate the factors that account for it, with a special focus on the role of the production network.

To capture the vast heterogeneity across industries observed in the data, our model allows sectors to differ in their price rigidity, factor intensities, use of intermediate inputs, and contribution to final demand. The economy consists of 57 sectors, which roughly correspond to the three-digit level of the North American Industry Classification System (NAICS) codes, and is calibrated based on the actual Input-Output matrix of the U.S. economy, as well as on available estimates of sectoral price rigidity. Despite its complexity, our model represents a natural extension of the standard New Keynesian economy, which is nested as a limiting case.

Our results indicate that the present-value aggregate value-added multiplier associated with an aggregate government spending shock financed by lump-sum taxes is 75 percent larger in the baseline multi-sector economy (0.74) than in the average one-sector model (0.42). This amplification holds for the two components of private spending (consumption and investment), under various monetary policy rules, and in a variety of alternative specifications of the baseline economy.

Counterfactual experiments show that input-output interactions are key to the amplification of the spending multiplier. Abstracting from them lowers the multiplier in the multi-sector economy by roughly 70 percent. Importantly, sectoral heterogeneity in the use of intermediate inputs does not yield further amplification of the multiplier over and beyond what one would obtain by assuming a roundabout production structure. In other words, it is the presence of intermediate inputs *per se* rather than the heterogeneity in the entries of the Input-Output matrix that matters for amplification. We also find that sectoral heterogeneity in price rigidity magnifies the multiplier, though to a much lesser extent. Imposing symmetric price rigidity across sectors reduces the multiplier by roughly one-fourth. While Pasten, Schoenle and Weber (2020) find that heterogeneity in price rigidity outweighs input-output linkages in amplifying the aggregate effects of monetary policy shocks, our analysis indicates that this ranking is reversed when it comes to amplifying the government spending multiplier.

To shed light on the mechanisms underlying this amplification, we provide some analytical insights based on a stripped-down version of the model, which isolates the role of intermediate inputs and sectoral heterogeneity in price rigidity. Both features raise the size of the government spending multiplier by acting as sources of real rigidity that amplify the extent of nominal rigidity. Together, they flatten the economy-wide Phillips curve and lower its intercept, thus dampening the response of aggregate inflation to the spending shock, in equilibrium. Under an active monetary-policy stance, this translates into a smaller increase in the real interest rate, and a larger response of aggregate output.

The same logic whereby a more muted inflation response leads to a larger multiplier when monetary policy is active, however, implies the opposite outcome when monetary policy is passive. This suggests that when the zero lower bound (ZLB) on the nominal interest rate binds, the multi-sector model should deliver a smaller multiplier than does the average one-sector model. Our results confirm this conjecture. At the ZLB, the one-sector model implies a multiplier of 1.98, much in line with the results reported in the literature (e.g., Christiano, Eichenbaum and Rebelo, 2011), whereas the corresponding number is 1.07 in the multi-sector economy. Thus, although the ZLB amplifies the multiplier in both economies, the multi-sector model implies that this amplification is not as striking as what the one-sector model might suggest, a prediction that is consistent with the empirical evidence reported by Ramey and Zubairy (2018*b*).

In the second part of the paper, we study the sectoral implications of an aggregate government spending shock. We start by documenting significant heterogeneity in the response of sectoral value added to the shock, with the service industries being the most responsive. In fact, the value-added multiplier of a single service industry such as professional services is similar in magnitude to that of the manufacturing sector as a whole. Together, the service-producing sectors have a multiplier that is more than three times larger than that of all the manufacturing industries combined.

The dispersion in the sectoral value-added multipliers is mainly driven by the sectors' position in the production network, while being virtually unrelated to other sectoral characteristics. More specifically, the model implies a strong positive correlation between the value-added multiplier of an industry and its centrality, where the latter measures the industry's upstreamness in the production chain. Intuitively, when the government demands more goods from all the industries, sectors located upstream raise their production to meet not only the higher demand from the government, but also the additional demand for intermediate goods from their customer industries. The value added of upstream sectors therefore rises more than that of downstream sectors, *ceteris paribus*.

As an empirical validation of our multi-sector model, we test in a panel of U.S. industries the positive relationship between a sector's degree of upstreamness and the response of its value added to an aggregate government spending shock. We confirm that the value-added multiplier of a given sector increases with its centrality. Interestingly, the magnitude of this relationship is remarkably similar to the one implied by the baseline model, whereas it is severely underestimated by a counterfactual economy that abstracts from price stickiness, and impossible to account for by a roundabout production structure, in which – by construction – sectors do not differ in their position in the production network. These observations highlight the importance of heterogeneity in the use of intermediate inputs in explaining the effects of spending shocks, and – more generally – lend credence to the quantitative model used in this paper.

**Related literature.** The first work on the effects of government purchases within a multi-sector model is Ramey and Shapiro (1998), which shows that a two-sector flexible-price economy with costly capital reallocation improves upon the one-sector model in accounting for the aggregate effects of government spending. Our paper considers a richer framework to evaluate – at a granular level of disaggregation – the role of sectoral heterogeneity and input-output interactions in amplifying the government spending multiplier,[1] and in shaping the sectoral effects of aggregate spending shocks. From this perspective, we relate to the literature that emphasizes the implications of sectoral heterogeneity for the degree of monetary non-neutrality (e.g., Carvalho, 2006; Nakamura and Steinsson, 2010; Bouakez, Cardia and Ruge-Murcia, 2014; Pasten, Schoenle and Weber, 2020), and to the work on the relevance of production networks for aggregate fluctuations (e.g., Horvath, 1998, 2000; Bouakez, Cardia and Ruge-Murcia, 2009, 2011; Acemoglu et al., 2012, 2016; Carvalho and Tahbaz-Salehi, 2019; Petrella, Rossi and Santoro, 2019).[2]

While this paper focuses on the effects of aggregate spending shocks, in a companion paper (Bouakez, Rachedi and Santoro, 2020), we consider a complementary approach by studying the aggregate implications of sector-specific government spending shocks. More specifically, we map the aggregate value-added multipliers of sectoral government purchases into the characteristics and position in the production network of the sectors in which those purchases originate.

Finally, we complement the literature that examines the implications of heterogeneity across households for fiscal multipliers (e.g., Galí, López-Salido and Vallés, 2007; Brinca et al., 2016; Hagedorn, Manovskii and Mitman, 2019). While we retain the convenience of the representative-household framework, we highlight the role of heterogeneity on the production side of the economy.

**Structure of the paper.** The rest of this paper is organized as follows. Section I presents the model. Section II discusses the calibration. Section III studies the role of sectoral heterogeneity and input-output interactions in amplifying the government spending multiplier. Section IV documents the heterogeneity in the response of sectoral value added to aggregate government spending shocks, and studies its determinants. Section V concludes.

## I. Model

We build a multi-sector New Keynesian model with physical capital, intermediate inputs, and government consumption spending. The economy consists of households, a government, and firms uniformly distributed across $S$ sectors. We

[1] Cox et al. (2021) corroborate our findings about the amplification of the aggregate spending multiplier in the context of a two-sector model that abstracts from input-output linkages.

[2] Relatedly, a recent strand of the literature takes a structural-change perspective, showing that secular changes in the Input-Output matrix of the U.S. economy during the post-WWII period have contributed to the flattening of the Phillips curve (e.g., Galesi and Rachedi, 2019; Höynck, 2020; Rubbo, 2020).

sketch below the most relevant features of the model, and refer the reader to Section A of the Online Appendix for further details.

### A. Households

An infinitely lived representative household has preferences over aggregate consumption, $C_t$, aggregate government spending, $G_t$, and aggregate labor, $N_t$, so that its expected lifetime utility is

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

where

$$\tilde{C}_t = \left[ \zeta^{\frac{1}{\mu}} C_t^{\frac{\mu-1}{\mu}} + (1-\zeta)^{\frac{1}{\mu}} G_t^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}.$$

In expression (1), $\beta$ denotes the subjective time discount factor, $\sigma$ is the degree of risk aversion, $\theta$ is a preference shifter that affects the disutility of labor, and $\eta$ is the inverse of the Frisch elasticity of labor supply. As in Bouakez and Rebei (2007), we allow preferences to be non-separable in consumption and government services, with $\zeta$ denoting the weight of private consumption in the effective consumption aggregator, $\tilde{C}_t$, and $\mu$ the elasticity of substitution between private consumption and government spending.

The household trades one-period nominal bonds, $B_t$, and owns the stock of physical capital, $K_t$. Every period, it purchases consumption goods at price $P_{C,t}$ and investment goods, $I_t$, at price $P_{I,t}$. The accumulation of physical capital is subject to convex adjustment costs whose magnitude is governed by the parameter $\Omega$. The household receives total labor income, $W_t N_t$, where $W_t$ is the nominal aggregate wage; total capital income, $R_{K,t} K_t$, where $R_{K,t}$ is the nominal aggregate rental rate of capital; and the gross return on nominal bonds, $R_{t-1} B_t$, where $R_{t-1}$ is the gross nominal risk-free interest rate. Finally, the household pays a nominal lump-sum tax, $T_t$, and earns firms' nominal profits, $D_t$. Its budget constraint is therefore given by

$$P_{C,t} C_t + P_{I,t} I_t + B_{t+1} + T_t = W_t N_t + R_{K,t} K_t + B_t R_{t-1} + D_t. \tag{2}$$

As in Huffman and Wynne (1999), Horvath (2000), and Bouakez, Cardia and Ruge-Murcia (2009), we posit that the total amount of labor provided by the household is a CES function of the labor supplied to each sector, that is

$$N_t = \left[ \sum_{s=1}^{S} \omega_{N,s}^{-\frac{1}{\nu_N}} N_{s,t}^{\frac{1+\nu_N}{\nu_N}} \right]^{\frac{\nu_N}{1+\nu_N}}, \tag{3}$$

where $\omega_{N,s}$ is the weight attached to labor provided to sector $s$, and $\nu_N > 0$ is the (absolute value of the) elasticity of substitution of labor across sectors. Analogously, aggregate capital, $K_t$, is a CES aggregator of sectoral capital services, $K_{s,t}$, where the corresponding weights and (absolute value of the) elasticity of substitution are denoted by $\omega_{K,s}$ and $\nu_K$, respectively. The labor and capital aggregators imply that the aggregate wage and rental rate of capital are themselves CES aggregators of sectoral wages and rental rates, respectively (see Section A of the Online Appendix) for more details).

The elasticities of substitutions $\nu_N$ and $\nu_K$ govern the degree of labor and capital mobility across sectors. When $\nu_N, \nu_K \to \infty$, these factors are perfectly mobile and both nominal wages and rental rates of capital are equalized across sectors. Instead, when $\nu_N, \nu_K < \infty$, labor and capital are imperfectly mobile and both wages and rental rates of capital can differ across sectors. Finite values of $\nu_N$ and $\nu_K$ enable us to capture in a parsimonious way the sluggish reallocation of labor and capital across sectors in response to shocks, as documented in the empirical literature (e.g., Eisfeldt and Rampini, 2006; Lee and Wolpin, 2006; Lanteri, 2018).

### *B. Firms*

In each sector, there is a continuum of producers that 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 wholesaler. The goods produced by the $S$ representative wholesalers are then purchased by retailers, who assemble them into consumption and investment bundles sold to households, a government-consumption bundle sold to the government, and intermediate-input bundles sold to producers.

PRODUCERS AND WHOLESALERS. — In sector $s$, a continuum of monopolistically competitive producers, indexed by $j \in [0, 1]$ , produce differentiated varieties using the Cobb-Douglas technology

$$Z_{s,t}^j = \left( {N_{s,t}^j}^{\alpha_{N,s}} {K_{s,t}^j}^{1-\alpha_{N,s}} \right)^{1-\alpha_{H,s}} {H_{s,t}^j}^{\alpha_{H,s}}, \tag{4}$$

where $Z_{s,t}^j$ is the gross output of the variety of producer $j$, while $N_{s,t}^j$, $K_{s,t}^j$, and $H_{s,t}^j$ denote, respectively, labor, capital, and the bundle of intermediate inputs used by this producer. The factor intensities $\alpha_{N,s}$ and $\alpha_{H,s}$ correspond to, respectively, the share of labor in value added and the share of intermediate inputs in gross output. We allow these intensities to be sector-specific. Producers hire labor, rent capital, and buy intermediate inputs at prices $W_{s,t}$, $R_{K,s,t}$, and $P_{H,s,t}$, respectively. They face price-setting frictions that give rise to nominal price stickiness. More specifically, producers reset their prices according to a Calvo-type mechanism, with $\phi_s$ being the sector-specific probability of not changing prices.

Producers in each sector sell their varieties to a perfectly competitive wholesaler, which bundles them into a single final good $Z_{s,t}$ by means of a CES production technology. The elasticity of substitution across varieties is $\epsilon$. In a Calvo-pricing model, this parameters vanishes in the log-linearization of the model around the steady-state. Thus, the assumption of a symmetric elasticity of substitution across sectors is inconsequential for our results.

Finally, the $S$ wholesalers sell their goods to retailers that assemble them into bundles destined for consumption, investment, government consumption, and intermediate-input use. Summing up the demand from the different retailers for the good produced by sector $s$ yields the following sectoral resource constraint:

$$Z_{s,t} = C_{s,t} + I_{s,t} + G_{s,t} + \sum_{x=1}^{S} H_{x,s,t}, \tag{5}$$

where $C_{s,t}$ is the demand of the consumption-good retailers, $I_{s,t}$ is the demand of the investment-good retailers, $G_{s,t}$ is the demand of the government-consumption-good retailers, and $H_{x,s,t}$ is the demand of retailers producing the intermediate-good bundle used by sector $x$.

Retailers. — Perfectly competitive consumption-good retailers purchase $C_{s,t}$ from the wholesalers of each sector and assemble them into a bundle $C_t$ sold to households at price $P_{C,t}$. The representative consumption-good retailer uses the following CES technology:

$$C_t = \left[ \sum_{s=1}^{S} \omega_{C,s}^{\frac{1}{\nu_C}} C_{s,t}^{\frac{\nu_C - 1}{\nu_C}} \right]^{\frac{\nu_C}{\nu_C - 1}}, \tag{6}$$

where $\nu_C$ 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, a final investment bundle is assembled by perfectly competitive investment-good retailers according to the CES technology

$$I_t = \left[ \sum_{s=1}^{S} \omega_{I,s}^{\frac{1}{\nu_I}} I_{s,t}^{\frac{\nu_I - 1}{\nu_I}} \right]^{\frac{\nu_I}{\nu_I - 1}}, \tag{7}$$

where $I_{s,t}$ is the investment good purchased from sector $s$, $\nu_I$ is the elasticity of substitution of investment across sectors, and $\omega_{I,s}$ denotes the weight of good $s$ in the investment bundle, which is sold to households at price $P_{I,t}$.

To produce the final government-consumption bundle, $G_t$, perfectly competitive retailers purchase goods from the wholesalers of each sector, and assemble them with the Cobb-Douglas technology

$$G_t = \prod_{s=1}^{S} G_{s,t}^{\omega_{G,s}}, \tag{8}$$

where $G_{s,t}$ is the government-consumption good purchased from sector $s$, and $\omega_{G,s}$ denotes the weight of good $s$ in the government-consumption bundle, which is sold to the government at price $P_{G,t}$. As we explain in the subsequent section, restricting the elasticity of substitution between the different goods in the government-consumption bundle to be equal to 1 allows us to focus on the case in which a percentage increase in the value of purchases from each sector translates into the same percentage increase in the total value of government spending.

Finally, in each sector $s$, there is an intermediate-input retailer that aggregates sectoral intermediate inputs $H_{s,x,t}$ into an intermediate-input bundle $H_{s,t}$ using

$$H_{s,t} = \left[ \sum_{x=1}^{S} \omega_{H,s,x}^{\frac{1}{\nu_H}} H_{s,x,t}^{\frac{\nu_H - 1}{\nu_H}} \right]^{\frac{\nu_H}{\nu_H - 1}}, \tag{9}$$

where $H_{s,x,t}$ is the purchase of intermediate goods from sector $x$, $\nu_H$ is the elasticity of substitution of intermediate inputs across sectors, and $\omega_{H,s,x}$ denotes the weight of good produced by sector $x$ in the bundle of intermediate inputs used by producers in sector $s$, which they buy at price $P_{H,s,t}$. Given sectoral prices $P_{s,t}$, the parameters $\omega_{H,s,x}$ determine the Input-Output matrix of the economy.

### *C. Government*

The government consists of a monetary and a fiscal authority. The monetary authority follows a standard Taylor rule whereby the nominal interest rate, $R_t$, reacts to the aggregate output gap and to aggregate inflation, which is computed using the GDP deflator. The rule also features interest-rate smoothing. The fiscal authority purchases goods $G_t$ from the representative government-consumption-good retailer at price $P_{G,t}$. Government purchases are determined by the autoregressive process

$$\log G_t = (1-\rho) \log G + \rho \log G_{t-1} + u_t, \tag{10}$$

where $G$ defines the steady-state amount of government spending,[3] $\rho$ measures the persistence of the process, and the government spending shock, $u_t$, is a zero-

[3]Throughout the text, variables without a time subscript denote steady-state values.

mean normally distributed innovation. The government finances its purchases by levying lump-sum taxes on households,[4] which implies the following government budget constraint:

$$P_{G,t}G_t = T_t. \tag{11}$$

Together, Equation (10) and the demand functions that derive from Equation (8) imply that an aggregate shock raising the value of total government spending by 1 percent leads to an equal percentage increase in the value of government purchases from each sector. As a result, aggregate government spending exhibits the same sectoral composition in and outside the steady state.[5] In this way, we can compute the multiplier associated with an 'average' government spending shock; that is, a shock that reflects the historical sectoral composition of public expenditure, rather than the composition of some specific fiscal package.[6]

Focusing on *composition-preserving* spending shocks allows for a meaningful comparison with the one-sector model, which – by construction – abstracts from variation in the sectoral composition of government purchases. At the same time, our approach permits a closer mapping between the aggregate spending multipliers implied by the model and those estimated based on time-series data (e.g., Blanchard and Perotti, 2002; Ramey, 2011; Ramey and Zubairy, 2018*b*). Existing empirical studies typically exploit the exogenous time-variation in aggregate government spending, and estimate the response of aggregate output by averaging out over the time-series dimension. In Section IV.B, we use a similar strategy to empirically estimate the average response of sectoral output to a change in aggregate government purchases.

## II. Calibration

We consider an economy with $S = 57$ sectors, which correspond to the three-digit level of the NAICS codes, after excluding the financial and real estate services. The complete list of sectors to which we calibrate the model is listed in Section B of the Online Appendix. A period in the model corresponds to a quarter.

We fix the elasticity of substitution of consumption to the value of $\nu_C = 2$, in line with the estimates of Hobijn and Nechio (2019) based on data at the same of level of disaggregation considered in this paper.[7] Analogously, we set

[4]The sensitivity analysis carried out in Section F of the Online Appendix considers a version of the model in which government spending is financed with distortionary labor-income taxes.

[5]In other words, a dollar change in total government purchases is allocated across sectors in accordance with their steady-state shares in total public spending.

[6]In Bouakez, Rachedi and Santoro (2020), instead, we study the aggregate implications of changes in the sectoral composition of public purchases.

[7]The literature on structural change, which focuses on the reallocation of economic activity across sectors in the long run, tends to set this elasticity to lower values, usually below 1. Our calibration is consistent with the literature that uses multi-sector models to study aggregate dynamics at business-cycle

the elasticity of substitution of investment to $\nu_I = 2$. We set the elasticity of substitution of intermediate inputs to $\nu_H = 0.1$, which generates a strong degree of complementarity of inputs across industries, in line with the empirical evidence of Barrot and Sauvagnat (2016), Atalay (2017), and Boehm, Flaaen and Pandalai-Nayar (2019).

We choose the sectoral weights $\omega_{C,s}$, $\omega_{I,s}$, $\omega_{H,s,x}$, and $\omega_{G,s}$ based on the contribution of each sector to aggregate consumption, aggregate investment, the use of intermediate inputs supplied by all other industries, and aggregate government consumption, respectively.[8] To this end, we rely on the entries of the Input-Output matrix of the U.S. Bureau of Economic Analysis, averaged over the period 1997–2015.[9] We normalize the nominal amount of government spending, $P_{G,t}G_t$, to be 20 percent of aggregate value added in the steady state, and set the autocorrelation coefficient of the process determining government spending to $\rho = 0.90$.

To calibrate the factor intensities, $\alpha_{N,s}$ and $\alpha_{H,s}$, we rely on the information provided by the Input-Output matrix on gross output, value added, labor compensation, and intermediate inputs. Our assumption of a constant-return-to-scale Cobb-Douglas production function for gross output allows us to interpret $\alpha_{H,s}$ as the sectoral share of intermediate inputs in gross output. Analogously, we can interpret $\alpha_{N,s}$ as the sectoral share of the compensation of employees in value added.[10] To determine the sectoral Calvo probabilities, $\phi_s$, we match our sectors with those analyzed by Nakamura and Steinsson (2008) and Bouakez, Cardia and Ruge-Murcia (2014), and convert their estimates of the sectoral durations of price spells into probabilities.

We set the (absolute value of the) elasticity of substitution of labor across sectors to $\nu_N = 1$, in line with Horvath (2000), and assign a similar value to $\nu_K$. The weights of sectoral labor and capital, $\omega_{N,s}$ and $\omega_{K,s}$, are set such that the model features equal sectoral wages and rental rates at the steady state. To do so, we set $\omega_{N,s} = \frac{N_s}{N}$ and $\omega_{K,s} = \frac{K_s}{K}$.

As for the parameters that affect households' utility function, we set both the time discount factor and the risk-aversion parameter to the standard values of $\beta = 0.995$ and $\sigma = 2$, respectively. We set $\eta = 1.25$ so that the Frisch elasticity is 0.8, in line with the estimate of Chetty et al. (2013), and choose $\theta = 41.01$ such that the steady-state level of total hours, $N$, equals 0.33. In line with the estimates of Bouakez and Rebei (2007) and Sims and Wolff (2018), we fix the

frequencies, such as Carvalho (2006), Bouakez, Cardia and Ruge-Murcia (2009), Pasten, Schoenle and Weber (2020), Carvalho, Lee and Park (2021).

[8]The calibration of the sectoral weights $\omega_{C,s}$, $\omega_{I,s}$, and $\omega_{H,s,x}$ is conditional on the values of the elasticities $\nu_C$, $\nu_I$, and $\nu_H$.

[9]Aggregate consumption equals personal consumption expenditures, aggregate investment is the sum of nonresidential private fixed investment in structures and in equipment, and aggregate government spending is the sum of purchases of goods and services by the federal, state, and local governments.

[10]The sectoral shares in the production function are based on a measure of sectoral gross output that excludes taxes, subsidies, and markups.

elasticity of substitution between private and public consumption to $\mu = 0.3$.[11] The relative weight of consumption is set $\zeta = 0.7$, which corresponds to the ratio of consumption expenditures to the sum of consumption and government expenditures.

We set the depreciation rate of physical capital to the standard quarterly value of $\delta = 0.025$, and calibrate the adjustment-cost parameter, $\Omega$, such that the model predicts that the response of aggregate investment to a government spending shock reaches a trough after 8 quarters, consistently with the empirical evidence reported by Blanchard and Perotti (2002). Accordingly, we set $\Omega = 20$.[12] The elasticity of substitution across varieties within sectors is calibrated to $\epsilon = 4$ so that the implied 33 percent steady-state mark-up is in line with firm-level estimates.

Finally, we calibrate the Taylor-rule parameters following the estimates of Clarida, Gali and Gertler (2000), setting the degree of interest-rate smoothing to $\varphi_R = 0.8$, and the inflation and output-gap feedback parameters to $\varphi_\Pi = 1.5$ and $\varphi_Y = 0.2$, respectively.

## III. The Government Spending Multiplier in a Multi-Sector Economy

In this section, we study how and to what extent sectoral heterogeneity and inter-sectoral linkages affect the government spending multiplier, defined as the dollar change in total value added that results from a dollar increase in government spending. We do so by comparing the multiplier obtained from our multi-sector model with those implied by a series counterfactual nested economies. We also study the sensitivity of our results to alternative parameter values and modelling assumptions, and then provide some intuition based on a stripped-down version of the model.

### A. *Quantifying the multiplier*

We start by measuring the degree to which the aggregate value-added multiplier in the multi-sector economy differs from its counterpart in the average one-sector model. The latter corresponds to an economy without intermediate inputs, where the value-added-based labor and capital intensities are computed based on aggregate variables, and the Calvo parameter, $\phi$, equals the average of the sectoral values, $\phi_s$.[13] The purpose of this comparison is to reveal to what extent approximating the economy with a single aggregate sector – which implies

[11]Our calibration implies that consumption and government spending are Edgeworth complements in utility. This is consistent with the empirical evidence reported by Fève, Matheron and Sahuc (2013) and Leeper, Traum and Walker (2017).

[12]This choice allows a version of the model that features an aggregate TFP shock to generate a relative volatility of investment that is consistent with the data.

[13]To nest the one-sector economy, we additionally impose that all sectoral shares (of labor, capital, consumption, investment, and government spending) are set symmetrically across sectors.

discarding all sources of heterogeneity and linkages across industries – can bias the measurement of the output effects of government spending shocks.

We evaluate the effects of changes in government spending on aggregate value added using the present-value spending multiplier, which is given by

$$\mathcal{M} = \frac{\sum_{j=0}^{\infty} \beta^j \mathbb{E}_t \left( Y_{t+j} - Y \right)}{\sum_{j=0}^{\infty} \beta^j \mathbb{E}_t \left( Q_{G,t} G_{t+j} - Q_G G \right)}, \tag{12}$$

where $Q_{G,t} = \frac{P_{G,t}}{P_t}$ is the relative price of government spending relative to the numeraire, the GDP deflator.[14] The multiplier, therefore, reports the dollar change in aggregate output associated with a temporary shock that raises aggregate government purchases by one dollar. The consumption and investment multipliers are computed analogously. Table 1 reports the results.[15]

Table 1—: Aggregate Spending Multipliers - Multi-Sector vs. One Sector.

| Spending Multiplier | Average One-Sector Economy (1) | Multi-Sector Economy (2) | $\Delta$ % (3) | $\Delta$ \$ (4) |
|---|---|---|---|---|
| Value Added | 0.4247 | 0.7444 | +75.3% | 0.3198 |
| Consumption | -0.0854 | 0.0453 | +153.0% | 0.1307 |
| Investment | -0.4899 | -0.3009 | +38.6% | 0.1891 |

Note: The table reports the multipliers of aggregate value added, aggregate consumption, and aggregate investment for the baseline "Multi-Sector Economy" in Column (1) and the "Average One-Sector Economy" in Column (2). The latter corresponds to a standard one-sector model without intermediate inputs, where the value-added-based labor and capital intensities are computed based on aggregate variables, and the degree of price rigidity is the average value over the sectoral price-rigidity parameters. Column (3) reports the difference in percentage terms between the multipliers of the "Multi-Sector Economy" and those of the "Average One-Sector Economy", whereas Column (4) reports the difference in absolute values.

In the one-sector economy, the value-added multiplier is 0.42. This value may

[14]We solve all the model versions studied in the paper by taking a first-order approximation of the equilibrium conditions around the zero-inflation steady state. Then, we back out the variables in levels to compute the multiplier.

[15]Section C of the Online Appendix reports the impulse-response functions of key aggregate variables obtained both from the one-sector and multi-sector economies.

seem low compared with those reported in some earlier studies (e.g., Galí, López-Salido and Vallés, 2007 and Hall, 2009). However, it is important to keep in mind that these studies typically focus on impact and/or peak multipliers, whereas we focus on the present-value multiplier.[16]

The results also indicate that the multi-sector model delivers a larger multiplier than the one-sector economy. Specifically, moving from the one-sector model to the multi-sector one raises the aggregate value-added multiplier by 75 percent, from 0.42 to 0.74. In other words, the multi-sector economy implies that a dollar increase in government spending leads to an additional \$0.32 increase in aggregate value added relative to the one-sector framework.

Table 1 also reports analogous statistics for the aggregate consumption and aggregate investment multipliers, respectively. The consumption multiplier features a larger amplification, in relative terms, than that of the investment multiplier (153 versus 39 percent). However, in absolute terms, the increase in the consumption multiplier represents only about 40 percent of the additional increase in aggregate value added (\$0.13) obtained in the multi-sector economy, relative to the one-sector model; the remaining 60 percent (\$0.19) being attributed to the increase in the investment multiplier.

### *B. Sources of amplification*

Which features of the multi-sector economy are the most important in accounting for the amplification of the value-added multiplier? To answer this question, we take the baseline model as a starting point and exclude – one at a time – various defining features of the multi-sector economy, producing five counterfactual economies. More specifically, the first economy abstracts from intermediate inputs in production (i.e., $\alpha_{H,s} = 0$); the second abstracts from heterogeneity in price rigidity across sectors (i.e., $\phi_s = \phi$, $\forall s$); the third abstracts from heterogeneity both in consumption and investment shares (i.e., $\omega_{C,s} = \omega_{I,s} = 1/57$, $\forall s$); the fourth imposes homogeneity in factor intensities (i.e., $\alpha_{N,s} = \alpha_N$ and $\alpha_{H,s} = \alpha_H$, $\forall s$); the fifth abstracts from heterogeneity in the use of intermediate inputs and assumes instead a roundabout production structure, represented by a diagonal Input-Output matrix (i.e., $\omega_{H,s,s} = 1$, $\forall s$).

Panel A of Table 2 reports the value-added multiplier across the different model economies, while Panel B shows the contribution of the excluded feature to the multiplier implied by the baseline model. The results reveal that input-output linkages and, to a lesser extent, differences in the degree of price rigidity across industries are the two ingredients that contribute the most to amplifying the re-

[16]See, for instance, Zubairy (2014), who reports an impact multiplier of 1.07 but a present-value multiplier of 0.70. Note that the impact multiplier is very close to that implied by our one-sector model (1.20). Ramey (2019) points out the value of the multiplier may critically depend on the horizon over which it is calculated, adding that "the multiplier must take into account both the multi-year effects of the fiscal plan on the government budget, in order to count the costs fully, as well as the multi-year effects on GDP, in order to count the benefits fully"; hence our focus on the present-value multiplier.

Table 2—: Sources of Amplification of the Aggregate Value-Added Multiplier.

| Multi-Sector Economy | Counterfactual Multi-Sector Economies | | | | |
|---|---|---|---|---|---|
| | Excluding Input-Output Matrix | Excluding Heterogeneity in Price Rigidity | Excluding Heterogeneity in Consumption & Investment Shares | Excluding Heterogeneity in Factor Intensities | Excluding off-Diagonal Elements of I-O Matrix |
| (1) | (2) | (3) | (4) | (5) | (6) |
| Panel A: Aggregate Value-Added Multiplier | | | | | |
| 0.7444 | 0.2372 | 0.5691 | 0.6890 | 0.7962 | 0.8703 |
| Panel B: Marginal Contribution of the Excluded Feature | | | | | |
| - | 68.1% | 23.6% | 7.5% | -7.0% | -16.9% |

Note: Panel A reports the aggregate output multipliers in the baseline model (i.e., the "Multi-Sector Economy" in Column 1) and in five alternative versions of the model (i.e., the "Counterfactual Multi-Sector Economies"). Panel B reports the difference in the multiplier (in percentage terms) between the value obtained in the baseline economy and that implied by each of the counterfactual economies.

sponse of aggregate value added. In particular, excluding inter-sectoral linkages through trade in intermediate goods reduces the spending multiplier by 68 percent, from 0.74 to 0.24, whereas abstracting from heterogeneity in price rigidity reduces the spending multiplier by 24 percent, down to 0.57. Instead, heterogeneity in either the consumption and investment shares or in factor intensities has a negligible impact on the size of the multiplier. As we show in Section F of the Online Appendix, the prevalence of input-output linkages as the main source of amplification of the spending multiplier is robust across a very wide range of modelling assumptions and parameter values.

It is also important to note that it is the presence of intermediate inputs *per se* rather than the heterogeneity embedded in the actual Input-Output matrix that matters as a source of amplification. The spending multiplier implied by a counterfactual version of the model with a diagonal Input-Output matrix amounts to 0.87. This figure is larger than the value of 0.74 obtained from the baseline model, suggesting that sectoral heterogeneity in the use of intermediate inputs is in fact 'counterproductive' in amplifying the multiplier. However, as we show in Section IV, accounting for this heterogeneity is crucial to understand the sectoral implications of aggregate spending shocks.

Interestingly, while our analysis indicates that input-output linkages play a larger role than heterogeneity in price rigidity in amplifying the spending multiplier, Pasten, Schoenle and Weber (2020) determine that the latter feature accounts for the bulk of amplification of the aggregate effects of monetary policy shocks. We confirm this observation in the context of our model. When appending the Taylor rule with a monetary policy shock, we find that the cumulative output effect of a 100 basis-point monetary policy innovation is 163 percent larger than in the average one-sector economy, and that around 68 percent of this amplification is attributed to heterogeneity in price rigidity. We emphasize, however, that despite the fact that government spending and monetary policy shocks are both demand disturbances, they propagate differently and, more importantly, in a way that prevents one from drawing unambiguous conclusions about the relative importance of input-output linkages and heterogeneity in price rigidity as sources of amplification.[17] In the absence of an exact theoretical underpinning, this issue becomes a quantitative one that can only be addressed in the context of realistically parametrized models. In light of our robustness analysis, we can safely conclude that the amplification of the spending multiplier is chiefly due to input-output linkages.

### C. *Sensitivity analysis*

As is well known from the literature on fiscal policy, two key factors that shape the propagation of government spending shocks are the conduct of monetary policy (e.g., Nakamura and Steinsson, 2014) and the persistence of the spending shocks (e.g., Baxter and King, 1993). In what follows, we study the sensitivity of our results along these two dimensions. More specifically, (i) we vary the values of the Taylor-rule parameters $\varphi_\Pi$ and $\varphi_R$, and consider alternative monetary policy rules that correspond to strict inflation targeting, price-level targeting, and nominal-GDP targeting, as well as a variant in which the output gap is replaced with output growth; (ii) we consider i.i.d., moderately persistent, and highly persistent spending shocks. Table 3 reports the results,[18] and the next section provides analytical insights that help clarify the intuition behind some of our findings.

Increasing the value of $\varphi_\Pi$ from 1.5 to 15 lowers the aggregate multiplier both in the one-sector and multi-sector economies, and yields an amplification of 38 percent, that is, half of what we obtain under the baseline calibration. On the other hand, lowering the smoothing parameter $\varphi_R$ raises the multiplier and the degree of amplification. In the limiting case where $\varphi_R = 0$, the multiplier is 100 percent larger in the multi-sector economy than in the one-sector model. Among the alternative monetary-policy rules listed above, price-level targeting

[17]In a similar vein, Rubbo (2020) shows that the relative importance of input-output interactions and heterogeneity in price rigidity in flattening the economy-wide Phillips curve may vary across model specifications. See Section E of the Online Appendix for further discussion of the amplification of the aggregate effects of monetary policy and government spending shocks.

[18]We report in Tables F.1–F.4 of the Online Appendix further results on the sources of amplification of the spending multipliers in all of these cases.

Table 3—: Value-Added Multipliers - Multi-Sector vs. One Sector - Sensitivity.

| Average One-Sector Economy (1) | Multi-Sector Economy (2) | Δ % (3) | Δ $ (4) |
|---|---|---|---|
| Panel A: Taylor-rule Parameter $\varphi_{\Pi} = 15$ | | | |
| 0.3482 | 0.4806 | +38.02% | 0.1324 |
| Panel B: Taylor-rule Parameter $\varphi_R = 0$ | | | |
| 0.4417 | 0.8871 | +100.8% | 0.4454 |
| Panel C: Taylor-rule Parameter $\varphi_R = 0.4$ | | | |
| 0.4332 | 0.8428 | +94.6% | 0.4096 |
| Panel D: Strict Inflation Targeting ($\varphi_Y = 0$ and $\varphi_R = 0$) | | | |
| 0.4492 | 1.2020 | +167.6% | 0.7527 |
| Panel E: Price-level Targeting | | | |
| 0.3500 | 0.4635 | +32.4% | 0.1136 |
| Panel F: Nominal GDP Targeting | | | |
| 0.2984 | 0.5618 | +88.2% | 0.2633 |
| Panel G: Output Growth in Taylor Rule | | | |
| 0.4336 | 0.9641 | +122.3% | 0.5305 |
| Panel H: Autocorrelation of Government Spending $\rho = 0$ | | | |
| 1.1948 | 1.3856 | +16.0% | 0.1908 |
| Panel I: Autocorrelation of Government Spending $\rho = 0.45$ | | | |
| 0.9842 | 1.2644 | +28.5% | 0.2802 |
| Panel J: Autocorrelation of Government Spending $\rho = 0.95$ | | | |
| 0.4949 | 0.9394 | +89.8% | 0.4445 |

Note: The table reports the multipliers of aggregate value added, aggregate consumption, and aggregate investment for the baseline "Multi-Sector Economy" in Column (1) and the "Average One-Sector Economy" in Column (2). The latter corresponds to a standard one-sector model without intermediate inputs, where the value-added-based labor and capital intensities are computed based on aggregate variables, and the degree of price rigidity is the average value over the sectoral price-rigidity parameters. Column (3) reports the difference in percentage points between the multipliers of the "Multi-Sector Economy" and those of the "Average One-Sector Economy", whereas Column (4) reports the difference in absolute values.

yields the lowest multiplier and the smallest degree of amplification in the multi-sector economy, whereas strict inflation targeting yields the highest multiplier and the largest amplification.

In the second experiment, we consider the following alternative values of the parameter $\rho$: 0, 0.45, and 0.95. As $\rho$ increases, the value of the spending multiplier falls while the amplification due to sectoral heterogeneity and input-output linkages rises. With i.i.d. spending shocks ($\rho = 0$), the multiplier is 1.19 in the one-sector model and 1.38 in the multi-sector economy, a difference of roughly 16 percent. In contrast, when $\rho = 0.95$, the multiplier falls to 0.49 in the one-sector model and 0.93 in the the multi-sector economy, implying an amplification of about 90 percent. Since aggregate government spending shocks are usually estimated to be very persistent (e.g., Leeper, Traum and Walker, 2017; Kormilitsina and Zubairy, 2018; Sims and Wolff, 2018), however, we believe that the amplification of the aggregate spending multiplier due to sectoral heterogeneity and input-output interactions is more likely to be sizable.

In Section F of the Online Appendix, we extend our sensitivity analysis to several other features of the model. First, we abstract from the complementarity between private and public consumption. Second, we assume that additional government spending (in excess of its steady-state level) is financed through distortionary labor-income taxes, instead of lump-sum taxes. Third, we consider a model with sticky wages à la Erceg, Henderson and Levin (2000), in which differentiated labor-service varieties are supplied monopolistically by households to unions. Fourth, we consider alternative values of the parameters $\nu_I$ and $\nu_K$. Finally, we alter the way in which we calibrate price stickiness in the one-sector model.

### D. *Some intuition*

The results reported in Table 2 underline the prominent role of input-output interactions and – to a lesser extent – sectoral heterogeneity in price rigidity in amplifying the aggregate output effects of government spending shocks. To provide some intuition for the mechanisms underlying this amplification, we rely on a simplified version of the model presented in Section I. More specifically, we make the following assumptions:

- (*i*) no government spending in the utility function (i.e., $\zeta = 1$ );
- (*ii*) a logarithmic utility (i.e., $\sigma = 1$);
- (*iii*) no capital in production and symmetric sectoral production technologies displaying constant returns to scale (i.e., $\alpha_{N,s} = 1$ and $\alpha_{H,s} = \alpha_H$, $\forall s$);
- (*iv*) a unit elasticity of substitution of consumption and intermediate inputs across sectors (i.e., $\nu_C = \nu_H = 1$);
- (*v*) equal consumption shares across sectors (i.e., $\omega_{C,s} = 1/S$, $\forall s$);
- (*vi*) equal split of government spending across sectors (i.e., $\omega_{G,s} = 1/S$, $\forall s$);
- (*vii*) a diagonal Input-Output matrix (i.e., $\omega_{H,s,s} = 1$, $\forall s$);

$(viii)$ a Taylor rule that neither reacts to the output gap (i.e., $\varphi_Y = 0$) nor allows for interest-rate smoothing (i.e., $\varphi_R = 0$);

$(ix)$ the steady-state distortion due to mark-up pricing is neutralized via a constant production subsidy financed via lump-sum taxes.

Together, these assumptions imply that $P_{C,t} = P_{G,t} = P_t$, and $P_{s,t} = P_{H,s,t}$, $\forall s$.[19] Moreover, this simplified economy features only one dimension of heterogeneity across sectors, that is, variation in the degree of price rigidity $\phi_s$.

Define $Q_{s,t} = \frac{P_{s,t}}{P_{C,t}}$ and $\pi_{s,t} = \frac{P_{s,t}}{P_{s,t-1}} - 1$ as, respectively, the relative price and the inflation rate in sector $s$, and let $v_t$ denote the log-deviation of a generic variable $V_t$ from its steady-state value, $V$. Log-linearizing the equilibrium conditions around a symmetric steady state, we obtain the following system of $1 + 2 \times S$ equations, which determines $c_t$, $\pi_{s,t}$, and $q_{s,t}$ autonomously:

$$c_t = \mathbb{E}_t c_{t+1} - \left(\varphi_\Pi \pi_t - \mathbb{E}_t \pi_{t+1}\right), \tag{13}$$

$$\pi_{s,t} = \beta \mathbb{E}_t \pi_{s,t+1} + \kappa_s \left(1 - \alpha_H\right) \left(\Theta q_{s,t} + \Xi c_t + \Psi g_t\right), \tag{14}$$

$$q_{s,t} = \pi_{s,t} - \pi_t + q_{s,t-1}, \tag{15}$$

where $\pi_t = \frac{1}{S} \sum_s \pi_{s,t}$ defines aggregate inflation. The composite parameter $\kappa_s = \frac{(1-\phi_s)(1-\beta\phi_s)}{\phi_s}$ is a decreasing function of the Calvo probability $\phi_s$. Hence, heterogeneity in the Calvo parameter $\phi_s$ maps into heterogeneity in the composite parameter $\kappa_s$. For analytical tractability, we use the parameter $\kappa_s$ to characterize the degree of price rigidity in the remainder of this section. Finally, the composite parameters $\Theta$, $\Xi$, and $\Psi$ are given by

$$\begin{aligned} \Theta &= -\frac{1 - \gamma + \nu_N}{\nu_N} < 0, \\ \Xi &= 1 + \eta \left(1 - \gamma\right) > 0, \\ \Psi &= \eta\gamma > 0, \end{aligned}$$

where $\gamma$ is the steady-state share of total government spending in aggregate value added.

Equation (13) represents the standard dynamic IS curve. Equation (14) represents the New Keynesian Phillips curve of sector $s$, in which the forcing variable (i.e., the sectoral real marginal cost of production) depends on the sector's relative price, $q_{s,t}$, aggregate consumption, $c_t$, and the spending shock, $g_t$. Finally, Equation (15) defines the relative price of sector $s$.

THE ROLE OF INTERMEDIATE INPUTS. — We first examine the implications of intermediate inputs for the size of the government spending multiplier. For this

[19] Section D of the Online Appendix describes the system of non-linear equations resulting from assumptions $(i) - (ix)$.

purpose, we abstract from sectoral heterogeneity in price rigidity and assume that $\kappa_s = \kappa$, $\forall s$. As the model becomes perfectly symmetric in this case, $q_{s,t} = 0$ and $\pi_{s,t} = \pi_t$, $\forall s$, and one can solve for the equilibrium paths of aggregate consumption and inflation using the following two-equation system:

$$c_t = \mathbb{E}_t c_{t+1} - (\varphi_\Pi \pi_t - \mathbb{E}_t \pi_{t+1}), \tag{16}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa (1 - \alpha_H) (\Xi c_t + \Psi g_t). \tag{17}$$

Since there are no endogenous state variables, under the assumption of an active monetary policy (i.e., $\varphi_\Pi > 1$), the unique rational expectations solution for consumption takes the form

$$c_t = \xi g_t. \tag{18}$$

Using the method of undetermined coefficients, one can show that the response of aggregate consumption to the government spending shock is given by

$$\xi = -\frac{(\varphi_\Pi - \rho)(1 - \alpha_H)\kappa\Psi}{(1-\rho)(1-\beta\rho) + (\varphi_\Pi - \rho)(1-\alpha_H)\kappa\Xi}. \tag{19}$$

Consequently, the value-added multiplier is given by

$$\mathcal{M} = 1 + \frac{1-\gamma}{\gamma}\xi.$$

Equation (19) has two important implications. First, for a finite $\kappa$ and a strictly positive $\eta$, the response of aggregate consumption to government spending is strictly increasing in the share of intermediate inputs in gross output, that is, $\frac{\partial \xi}{\partial \alpha_H} > 0$. Thus, as long as prices are rigid and the Frisch elasticity is finite, the aggregate value-added multiplier is strictly larger in a model that allows for input-output linkages than in the benchmark one-sector economy. Second, the cross partial derivative of the response of consumption to government spending with respect to the share of intermediate inputs and the inverse of the degree of price rigidity is negative, that is, $\frac{\partial^2 \xi}{\partial \alpha_H \partial \kappa} < 0$. This means that price stickiness acts as a catalyst that strengthens the role of inter-sectoral linkages in amplifying the consumption response, and thus the value-added multiplier.

Intuitively, the fact that the gross product in each industry is both consumed and used in the production of all the other goods in the same industry gives rise to strategic complementarity in price setting among monopolistically competitive firms (see Basu, 1995). This feature reduces the sensitivity of real marginal cost to changes in aggregate demand. In this respect, the presence of intermediate inputs acts as a source of real rigidity that amplifies the overall degree of nominal rigidity. The resulting dampening of the response of aggregate inflation translates into a larger response of aggregate output.

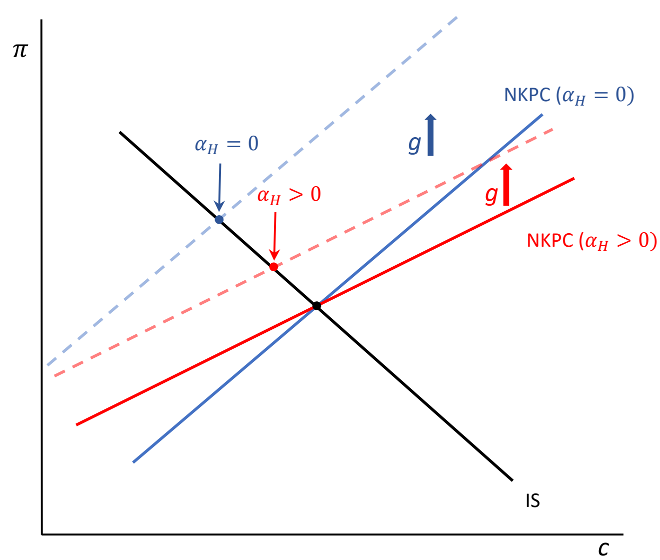
It is instructive to illustrate this mechanism graphically, which will also help understand the implications of key ingredients of the model for the multiplier. The absence of endogenous state variables implies that $E_t c_{t+1} = \rho c_t$ and $E_t \pi_{t+1} = \rho \pi_t$, allowing us to write system (16)–(17) as

$$\pi_t = -\frac{1-\rho}{\varphi_\Pi - \rho} c_t, \tag{20}$$

$$\pi_t = \frac{\kappa\,(1-\alpha_H)}{1-\beta\rho}\left(\Xi c_t + \Psi g_t\right). \tag{21}$$

This system can be represented in the ($c$,$\pi$) plan. The IS curve, representing equation (20), is downward sloping, whereas the NKPC, representing equation (21), is upward sloping. The two curves are depicted in Figure 1.

Figure 1. : Graphical Representation.




To the extent that $\eta > 0$, an increase in $g_t$ shifts the NKPC leftward. One can easily see that, when $\kappa$ is finite, a strictly positive value of $\alpha_H$ flattens the NKPC and lowers its intercept (compared with the case $\alpha_H = 0$), such that a given increase in $g_t$ translates into a milder increase in inflation and a larger response (smaller crowding-out) of aggregate consumption. This amplification of the consumption response if larger the smaller the value of $\kappa$, as more rigid prices reduce the slope of the NKPC. In the limiting case where $\kappa \to \infty$, the multiplier converges to its lower limit of

$$\mathcal{M}^f = 1 - \frac{\eta(1-\gamma)}{1+\eta(1-\gamma)}.$$

This expression holds both in the one-sector and multi-sector economies. In other words, the roundabout production structure is irrelevant for the multiplier because real rigidity becomes immaterial when prices are fully flexible. Graphically, when $\kappa \to \infty$, the NKPC becomes vertical, regardless of the value of $\alpha_H$. On the other hand, if $\eta = 0$, $g_t$ does not affect the NKPC, as the resource-constraint effect of government purchases is neutralized (see Bouakez, Rachedi and Santoro, 2020). In this case, consumption and inflation do not change and the multiplier is equal to 1.

How does the Taylor-rule parameter $\varphi_\Pi$ affect the multiplier? From Equation (19), it is straightforward to show that $\frac{\partial \xi}{\partial \varphi_\Pi} < 0$. That is, the more aggressively monetary policy responds to inflation, the smaller the response of aggregate consumption, and the lower the multiplier, in conformity with the numerical results reported in Section III.C. The reason is that a higher value of $\varphi_\Pi$ implies a larger increase in the real interest rate ($\varphi_\Pi \pi_t - \mathbb{E}_t \pi_{t+1}$), which reduces the consumption response. Graphically, a higher value of $\varphi_\Pi$ flattens the IS curve, such that a increase in $g_t$ translates into smaller inflation and consumption responses. However, with a higher value of $\varphi_\Pi$, whether there is more or less amplification (of the consumption response) resulting from the presence of intermediate inputs is ambiguous and depends on the values of the structural parameters.

In the limiting case where $\varphi_\Pi \to \infty$, the multiplier converges to $\mathcal{M}^f$. Because monetary policy fully stabilizes prices, it eliminates the distortion stemming from price rigidity, thus replicating the flexible-price allocation. Graphically, when $\varphi_\Pi \to \infty$, the IS curve becomes horizontal, while the NKPC becomes vertical, so that the parameters $\kappa$ and $\alpha_H$ are irrelevant for the equilibrium level of $c_t$. In this case, an increase in government spending leaves inflation unchanged and raises aggregate output by an identical amount in the one-sector and multi-sector economies, just as under fully flexible prices ($\kappa \to \infty$).

While the stylized model considered in this section assumes a very simple monetary policy rule, it can help build the intuition for some of the sensitivity-analysis results discussed in Section III.C. For instance, a monetary policy rule that targets the price level stabilizes prices more aggressively than the alternative rules, bringing the equilibrium allocation closer to its flexible-price counterpart, and implying a lower multiplier. On the other hand, the interest rate response to the output-gap tends to reinforce the increase in real interest rate following an increase in government spending. Because strict inflation targeting abstracts from the output gap, it implies a larger spending multiplier than a standard Taylor rule.[20]

[20]Interest-rate smoothing dampens the rise in the long-term real interest rate while raising its persis-

Finally, from Equation (19), it is easy to show that $\frac{\partial \xi}{\partial \rho} < 0$ as long as $\varphi_{\Pi} > 1$, which is the necessary condition for the determinacy of the rational expectations equilibrium. In other words, the more persistent the increase in government spending, the lower the multiplier, as is also found in the sensitivity analysis discussed in Section III.C. Intuitively, because consumers are forward looking, a more persistent shock generates a higher inflation response. Since the nominal interest rate rises more than one-for-one with inflation, this translates into a larger increase in the real interest rate and, thus, a lower multiplier. Graphically, a higher value of $\rho$ flattens the IS curve while steepening the NKPC and raising its intercept. For given values of the remaining parameters, an increase in $g_t$ results in a larger inflation response and a larger reduction in consumption. But again, the way in which the value of $\rho$ affects the extent of amplification stemming from the presence of intermediate inputs cannot be pinned down unambiguously, as $\alpha_H$ and $\rho$ exert opposite effects on the slope of the NKPC.

The role of sectoral heterogeneity in price rigidity. — Once symmetry in the degree of price rigidity across sectors is relaxed, even the stripped-down version of the model represented by Equations (13)–(15) no longer has a tractable closed-form solution for the multiplier. Nonetheless, useful insights into the role of heterogeneity in price rigidity in amplifying the value-added multiplier can be gained by aggregating the sectoral New Keynesian Phillips curves. To simplify the analysis, let us abstract from intermediate inputs (i.e., $\alpha_H = 0$). Taking a weighted average of both sides of Equation (14) across sectors yields

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \bar{\kappa} \left( \Xi c_t + \Psi g_t \right) + \frac{\Theta}{S} \sum_s \kappa_s q_{s,t}, \tag{22}$$

where $\bar{\kappa} = \frac{1}{S} \sum_s \kappa_s$. This equation nests the one obtained in a model with symmetric price rigidity (i.e., Equation (17) with $\kappa = \bar{\kappa}$) as a special case in which the last term on the right-hand side of the equality vanishes.

When sectors exhibit different degrees of price rigidity, aggregate inflation depends negatively on an endogenous shift term that is proportional to the sum of sectoral relative prices, weighted by (the inverse of) the sectoral degrees of price rigidity (recall that $\Theta$ is negative). Assume, without loss of generality, that there are only two sectors, and consider a common increase in government spending. The sector with lower price rigidity (larger $\kappa$) experiences an increase in its relative price, while the relative price of goods produced by the other sector drops by an equal amount. However, the former receives a larger weight in the shift term.

tence, following an increase in government spending. In a model without capital or when investment is costless to adjust, this translates into a larger increase in the present-value of consumption and investment and, thus, a larger multiplier. On the other hand, when there are investment-adjustment costs, as in our calibrated model, interest-rate smoothing implies that investment remains low for a prolonged period of time, ultimately resulting in a smaller present-value output multiplier, as we report in Table 3.

Thus, changes in relative prices imply a smaller response of aggregate inflation relative to the case of a symmetric economy with the same average degree of price rigidity. By lowering the intercept of the economy-wide Phillips curve, changes in relative prices act as a further source of real rigidity that amplifies the extent of nominal rigidity and, hence, the multiplier.

To substantiate our intuition regarding the role of intermediate inputs and heterogeneity in price stickiness as sources of real rigidity, Figure 2 reports the response of aggregate inflation (Panel a) and the response of aggregate value added (Panel b) to a 1 percent increase in the value of government spending, both in the baseline multi-sector model and in the average one-sector economy. In accordance with our analytical results, the baseline model yields a more muted response of aggregate inflation, which is accompanied by a larger response of aggregate value added. In this regard, taking into account sectoral heterogeneity and inter-sectoral linkages brings the model closer to matching the empirical evidence regarding the inflation response to government spending shocks, which is often found to be weak (e.g., Mountford and Uhlig, 2009; Ramey, 2016; Ricco, Callegari and Cimadomo, 2016).

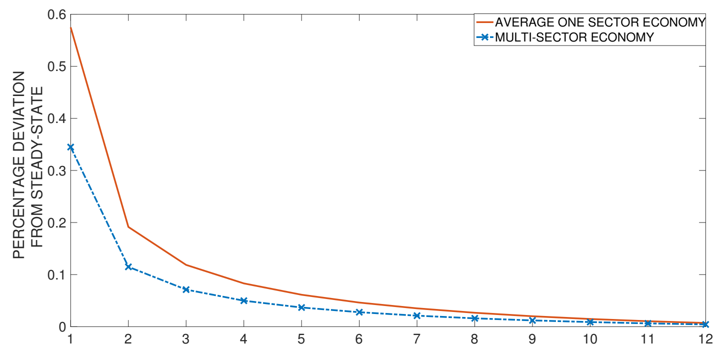
### *E. The spending multiplier at the ZLB*

In the context of one-sector New Keynesian models, a relatively large literature has shown that the government spending multiplier can become substantially large when monetary policy is constrained to keep the nominal interest rate constant, as it would be the case when the zero lower bound (ZLB) on the policy rate becomes binding. Underlying this result is the fact that inflation expectations rise following an increase in government expenditure, leading the real interest rate to fall and stimulating private spending. Typically, the literature reports a spending multiplier that is 3 to 4 times larger at the ZLB than in 'normal times', an expression commonly used to describe situations in which monetary policy is unconstrained (e.g., Christiano, Eichenbaum and Rebelo, 2011).

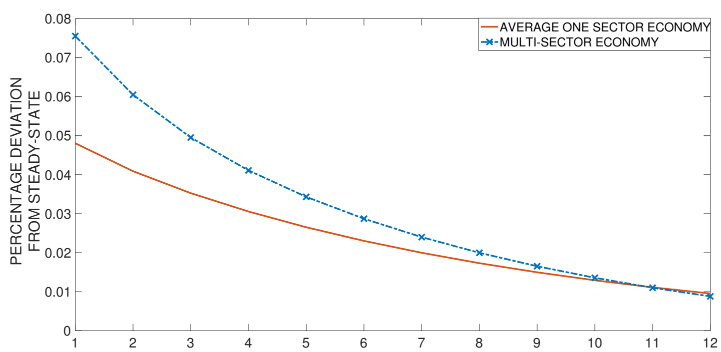
Given that the adjustment of aggregate inflation is directly impacted by input-output interactions and sectoral heterogeneity, it is natural to ask whether and to what extent this result is altered in the context of our multi-sector economy. To address this question, we subject the model to a liquidity-preference shock that raises households' appetite for safe and liquid assets, inducing them to cut consumption and investment and to save in riskless bonds.[21] We consider a realized sequence of the shock that is large enough to drive the nominal interest rate to zero. More specifically, the shock generates a ZLB episode of 8 quarters, and is associated with a cumulative output drop of 10 percent. To evaluate the spending multiplier at the ZLB, we consider a constant increase in government spending throughout the ZLB episode, such that the cumulative fiscal expansion

[21]For a discussion of the microfoundation of this shock and its macroeconomic effects, see Bouakez, Guillard and Roulleau-Pasdeloup (2020) and the references therein.

Figure 2. : The Response of Aggregate Inflation and Value Added to a Government Spending Shock.




(a) Aggregate Inflation




(b) Aggregate Value Added

Note: Panel (a) reports the response of aggregate inflation in the first 8 quarters following a 1 percent increase in the value of government spending in the "Average One-Sector Economy" (continuous black line) and in the baseline "Multi-Sector Economy" (crossed red line). Panel (b) reports the analogous responses for aggregate value added.

amounts to 5 percent of steady-state aggregate value added. The multiplier is then computed by evaluating the difference between the output response conditional on both shocks and its response conditional on the preference shock only. To maintain comparability with the average one-sector model, we subject it to the same treatment.

The spending multiplier implied by the one-sector model rises from 0.42 in normal times to 1.98 when the ZLB constraint is binding, in line with the results reported in the literature cited above. On the other hand, the multiplier delivered by the multi-sector model rises from 0.74 in normal times to 1.07 when the ZLB binds. Thus, while the multiplier is larger at the ZLB in both economies, it is smaller and less amplified in the multi-sector model than in the one-sector economy. As discussed above, input-output interactions and heterogeneity in price rigidity flatten the economy-wide Phillips curve and lower its intercept, so that aggregate inflation is less responsive to spending shocks in the multi-sector model than in the one-sector economy. While these features amplify the multiplier in normal times, they dampen it when the ZLB binds: a milder increase in expected inflation translates – under constant nominal interest rates – into a smaller fall in the real rate of interest and thus a lower multiplier than in the one-sector economy.[22]

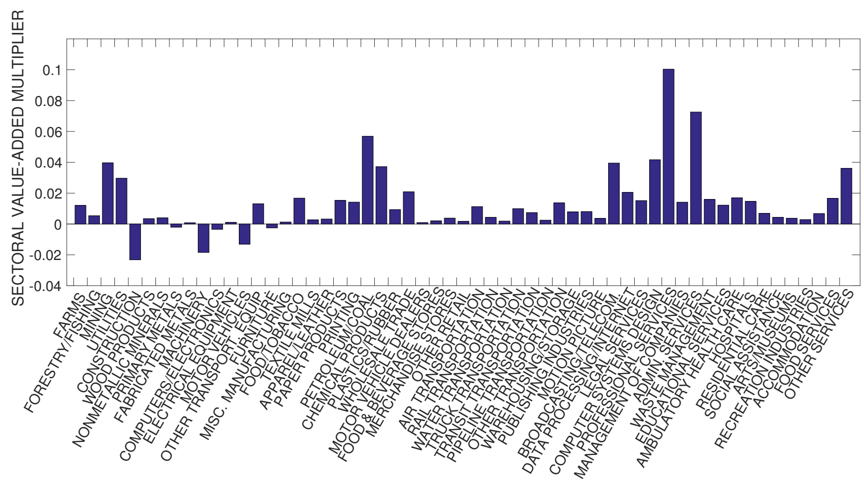
To our knowledge, this paper is the first attempt to evaluate the spending multiplier at the ZLB in the context of a quantitative multi-sector economy. Our key insight is that the amplification of the multiplier due to the ZLB is not as striking as what the one-sector model might suggest, a prediction that is consistent with the empirical evidence reported by Ramey and Zubairy (2018*b*).

## IV. Sectoral Implications: Winners and Losers

What distinguishes our framework from standard macroeconomic models used to study fiscal policy is that we can leverage its structure to derive the sectoral implications of government spending. Measuring the sectoral responses to an aggregate spending shock helps identify which industries are winning and which are losing in terms of value added or employment following an increase in government purchases from all sectors. Furthermore, we can exploit the richness of our model to isolate the features that are most relevant in accounting for the observed heterogeneity in the sectoral responses. We show below that the factor that best explains a sector's response to an aggregate government spending shock is its position in the production network, and provide novel empirical evidence supporting this prediction.

[22]An interesting implication of this analysis is that, even though the *price-flexibility paradox* affects our multi-sector economy – lower nominal rigidity makes the ZLB more costly (Eggertsson and Krugman, 2012) – the tempered response of aggregate inflation to demand shocks makes this paradox less acute than in the one-sector model.

Figure 3. : The Response of Sectoral Value Added.




Note: The graph reports the value-added multiplier for each of the 57 sectors.

### *A. Sectoral value-added multipliers*

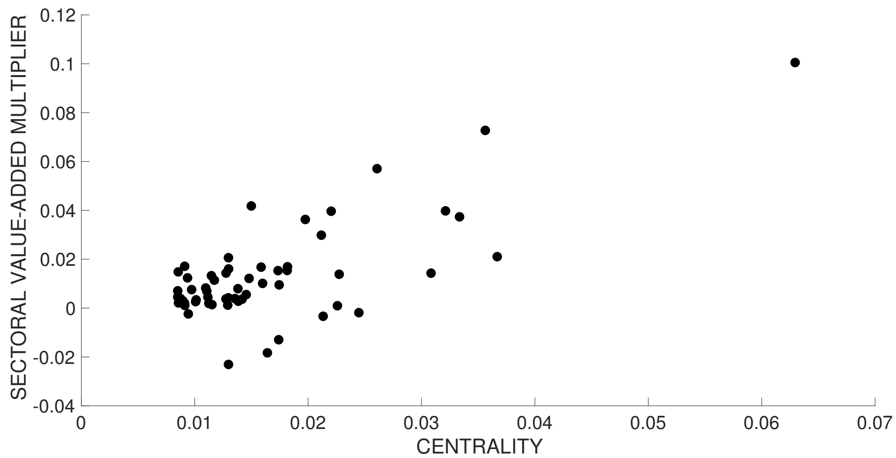
Figure 3 reports the value-added multiplier for each of the 57 sectors of the model.[23] Note that, by construction, the sectoral multipliers sum up to 0.74 – representing the aggregate value-added multiplier. The figure shows substantial heterogeneity in the sectoral value-added effects of an aggregate government spending shock: industries such as professional services and administrative services are associated with a multiplier of 0.10 and 0.07, respectively, whereas industries such as construction and machinery manufacturing have negative multipliers of around $-0.02$. By and large, the output effects of government spending are tilted towards the service industries, whose overall value-added multiplier is more than three times larger than that of the manufacturing sector.[24]

To appreciate the quantitative implications of this heterogeneity in the sectoral value-added multipliers, let us consider a shock that raises government spending from 20 to 21 percent of aggregate value added. Given the size of U.S. GDP as of the end of 2019, this stimulus would increase government spending by \$215 billion. In our model, a government spending shock of this size would lead aggregate value added to surge by \$215 billion $\times$ 0.7444 = \$160 billion. This number implies that, on average, the value added of each of the 57 industries we consider would increase by \$3 billion. However, the results depicted in Figure 3 indicate that the value added of a single industry such as professional services would increase by \$215

[23]Figure G.1 in Section G of the Online Appendix reports a similar plot for sectoral employment.

[24]The sectoral value-added multiplier in services relative to that in manufacturing is disproportionately larger than the size of the service sector relative to the manufacturing sector. In 2015, the value added of the service-producing industries was 78 percent larger than that of manufacturing industries.

Figure 4. : The Response of Sectoral Value Added and Centrality.




Note: The graph reports a scatter that links the value-added multiplier of each sector (measured on the y-axis) to its centrality in the Input-Output matrix (measured on the x-axis).

billion $\times$ 0.10 = \$22 billion, therefore accounting for almost 15 percent of the rise in aggregate output generated by the fiscal expansion. This amount roughly corresponds to the increase in the value added of the entire manufacturing sector (which in our model is split in 19 industries).

The heterogeneity in the responses of sectoral value added to a change in government spending is mainly due to the industries' position in the production network. To see this, Figure 4 shows a scatter plot of the sectoral value added multiplier and the Katz-Bonacich measure of centrality. A high value of centrality means that a sector is located upstream in the production network, and is therefore a relevant provider of intermediate inputs to all other industries. Instead, a low value of centrality is associated with a downstream sector, which demands intermediate inputs from other industries to produce mainly final goods. The figure shows that there is a correlation of about 0.7 between the sectoral multiplier and centrality, suggesting that sectors that are located upstream in the production chain tend to experience a relatively large increase in their value added in response to an aggregate government spending shock.[25] In contrast, Figures G.2–G.5 in Section G of the Online Appendix show that sectoral multipliers are virtually unrelated to the other dimensions of sectoral heterogeneity.

Intuitively, when the government demands more goods from all sectors, both downstream and upstream sectors increase their production. This requires all industries to increase their usage of intermediate inputs, but relatively more up-

[25]In fact, the relatively larger response of services can be rationalized by the fact that the top-3 upstream industries in the economy are professional services, administrative services, and wholesale trade.

stream industries experience higher pressure to expand production, so as to meet higher demand both for their final products (from the government) and for intermediate inputs (from their customer industries).[26]

### *B. Testing the theoretical prediction*

As a validation of our multi-sector model, we test empirically the theoretical prediction of a positive relationship between the sectoral multiplier and centrality. To do so, we need to identify exogenous shocks to aggregate government spending. The empirical literature has produced two leading identification strategies: (*i*) the VAR-based approach proposed by Blanchard and Perotti (2002) and (*ii*) the narrative approach advocated by Ramey and Shapiro (1998) and Ramey (2011). Blanchard and Perotti (2002) identify government spending shocks in a structural VAR framework as the orthogonalized innovations to total public expenditure. This purely statistical scheme implies that government spending is predetermined with respect to economic activity within the quarter. Ramey (2011), however, argues that changes in government spending are subject to legislation and implementation lags that make them predictable by economic agents. In this case, the VAR-based shocks are likely to miss the timing of the announced spending policies. She extends Ramey and Shapiro (1998)'s work by using narrative evidence to construct a defense news variable, which measures changes in the expected present value of U.S. defense spending. Ramey and Zubairy (2018*b*) combine the two approaches by using both the Blanchard and Perotti (2002) shocks and the Ramey (2011) news measure as instruments to derive a series of U.S. government spending shocks. The constructed series is used to compute the aggregate spending multiplier based on the local projection method of Jordà (2005).

Our methodology builds on Ramey and Zubairy (2018*b*), which we adapt in two ways to test our theoretical prediction. First, we focus on the sectoral output response to an aggregate government spending shock, rather than on that of aggregate output. Second, we allow the response of output in a given sector to depend on its position in the network. For this purpose, we construct a panel of sectoral real value added, aggregate real government purchases of goods and services, and real tax proceeds at an annual frequency from 1963 to 2015. More specifically, we complement the data constructed by Ramey and Zubairy (2018*a*) with measures of sectoral value added (source: U.S. Bureau of Economic Analysis, 1963-2015*a*) and government purchases of goods and services from the private sector (source: U.S. Bureau of Economic Analysis, 1963-2015*b*).[27] Given the

[26]The high correlation between sectoral multipliers and centrality is not merely driven by the fact that in the data government spending tends to be concentrated in upstream industries. Indeed, the correlation equals 0.4 in a version of the model in which government spending is homogeneously distributed across industries.

[27]Ramey and Zubairy (2018*b*) measure government spending as the sum of government consumption and investment expenditures. To be consistent with our theoretical model, we restrict our attention to

stability of the production network structure (e.g., Acemoglu et al., 2012), we compute a cross-sectional measure of centrality based on the average entries of the Input-Output Table over the same sample period. To maintain comparability with the theoretical results, we consider sectors at the level of disaggregation of the model. However, going back to 1963 allows us to recover information only on 53 of the 57 industries to which we calibrate the model.[28]

We then estimate the following regression

$$\sum_{t=0}^{T}\frac{Y_{s,t}}{Y_t^{\star}} = \beta_1\sum_{t=0}^{T}\frac{G_t}{Y_t^{\star}} + \beta_2\sum_{t=0}^{T}\frac{G_t}{Y_t^{\star}} \times \text{Centrality}_s + \text{Controls}_{s,t} + \epsilon_{s,t}, \tag{23}$$

where $Y_{s,t}$ is real value added in sector $s$, $G_t$ is real aggregate government purchases of goods and services, $Y_t^{\star}$ is the series potential output derived by Ramey and Zubairy (2018*b*) as a polynomial trend of real aggregate value added, and $\text{Controls}_t$ include lagged values of both sectoral value added and aggregate government spending, as well as real tax proceeds, linear and quadratic time trends, and time fixed effects.[29] Importantly, to test our theoretical prediction, we interact aggregate government spending with sectors' centrality. In this way, the estimate of $\beta_2$ informs to what extent the response of sectoral value added to an aggregate government spending shock depends on the industry's position in the production network.[30]

As in Ramey and Zubairy (2018*b*), the estimation is carried out by (*i*) introducing sectoral value added and government purchases in levels and scaling them by potential aggregate output, (*ii*) cumulating all variables over a time horizon $T$, and (*iii*) instrumenting government spending with both the Blanchard and Perotti (2002) shock and the Ramey (2011) news series. We also consider as instruments the interaction of these two variables with the Katz-Bonacich measure of centrality.[31]

Table 4 reports the results of the panel regression, in which we set $T = 10$ years.

the portion of government consumption expenditures that consists in purchases of goods and services from the private sector. Moro and Rachedi (2021) describe how these different measures of government spending are related in the National Accounts.

[28]For instance, there is no detailed disaggregated information on the industries composing the retail trade sector up to 1997.

[29]Ramey and Zubairy (2018*b*) discuss how the use of variables in levels – and scaled by potential output – is a necessary condition for the correct estimation of the government spending multiplier.

[30]In a related paper, Acemoglu, Akcigit and Kerr (2016) study how the *partial-equilibrium* response of sectoral output to *sectoral* spending shocks depends on whether the shocks originate downstream or upstream in the production network. Our empirical exercise differs from theirs in that we study the way in which centrality in the production network correlates with the sectoral output response to *aggregate* government spending shocks. In doing so, our estimation uncovers the *general-equilibrium* response of sectoral output.

[31]Ramey and Zubairy (2018*b*) show that the combination of the Blanchard and Perotti (2002) shock and the the Ramey (2011) news series represents a strong instrument for government spending. This is also evident in our setting: the F-statistics of the first-stage regressions are substantially larger than the 5 percent confidence-level thresholds. This observation remains true even when we consider the more conservative thresholds proposed by Olea and Pflueger (2013), which are robust to serially correlated errors.

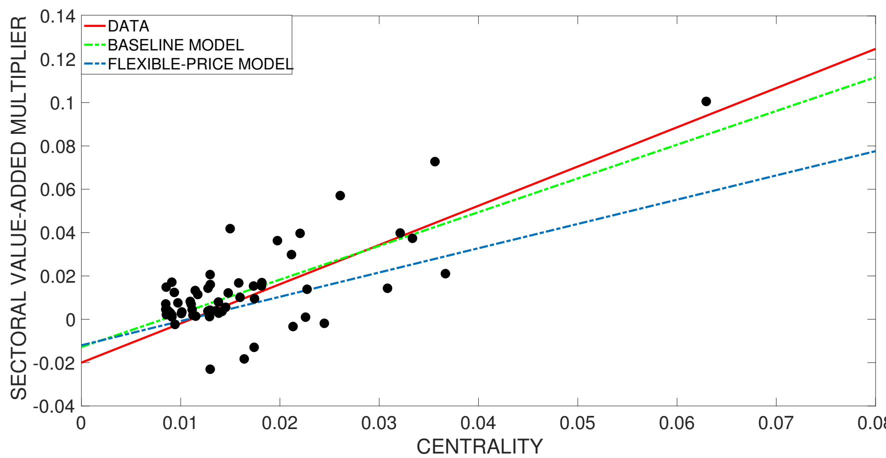
Table 4—: Estimation Results.

| Dependent Variable: $\sum_{t=0}^{10} \frac{Y_{s,t}}{Y_t^\star}$ | | | | |
|---|---|---|---|---|
| $\sum_{t=0}^{10} \frac{G_t}{Y_t^\star}$ | -0.0141<br>(0.0180) | -0.0167<br>(0.0180) | -0.0167<br>(0.0180) | - |
| $\sum_{t=0}^{10} \frac{G_t}{Y_t^\star} \times$ Centrality$_s$ | 1.7475<br>(0.7312) | 1.7472<br>(0.7313) | 1.8275<br>(0.4794) | 1.7456<br>(0.7317) |
| Lagged Values $\sum_{t=0}^{10} \frac{Y_{s,t}}{Y_t^\star}$ | YES | YES | YES | YES |
| Lagged Values $\sum_{t=0}^{10} \frac{G_t}{Y_t^\star}$ | YES | YES | YES | NO |
| Tax Control | NO | YES | YES | NO |
| Time Trends | NO | NO | YES | NO |
| Time Fixed Effects | NO | NO | NO | YES |
| N. Observations | 2226 | 2226 | 2226 | 2226 |

Note: The table reports the estimates of a panel regression where the dependent variable, $\sum_{t=0}^{10} \frac{Y_{s,t}}{Y_t^\star}$, is the 10-year cumulative change in sectoral value added (scaled by aggregate real potential output), and the two main independent variables, $\sum_{t=0}^{10} \frac{G_t}{Y_t^\star}$ and $\sum_{t=0}^{10} \frac{G_t}{Y_t^\star} \times$ Centrality$_s$, are the 10-year cumulative change in aggregate real government purchases of goods and services and its interaction with sector centrality in the Input-Output matrix of the economy, respectively. The panel ranges from 1963 to 2015, at an annual frequency. In all cases, government spending is instrumented with the Blanchard and Perotti (2002) shock and the Ramey (2011) news variable, and their interaction with sector centrality. Column (1) also controls for the lagged values of sectoral value added and aggregate government spending, Column (2) introduces real taxes as a control, Column (3) introduces a linear and a quadratic time trend, and Column (4) introduces time fixed effects. Standard errors clustered at the sector level are reported in brackets.

We consider settings that sequentially saturate the regression with sectoral controls, time trends, and time fixed effects. Column (1) reports the estimates of a plain regression of sectoral value added on government spending, its interaction with sector centrality, and the lagged value of both sectoral value added and government spending. Column (2) introduces real taxes as an additional control, Column (3) introduces a linear and a quadratic time trend, whereas Column (4) introduces a time fixed effect. The time fixed effect absorbs the effect of government spending, as well as those of the tax and trend controls. The results indicate that the real value-added multiplier of a given industry increases

Figure 5. : The Response of Sectoral Value Added and Centrality: Model vs. Data.




Note: The graph reports a scatter that links the value-added multiplier of each sector (measured on the y-axis) to its centrality in the Input-Output matrix (measured on the x-axis), together with the estimated regression line in dashed green. The crossed blue line represents the regression line implied by a counterfactual version of the model with flexible prices. The solid red line represents the regression line estimated from the data.

with its centrality, as the estimate of the parameter associated with the interaction between government spending and sector centrality is highly statistically significant and rather stable across specifications, ranging between 1.7 and 1.8. To our knowledge, this evidence of a positive relationship between the sectoral value-added multiplier and centrality is new.

To gauge the model's goodness of fit along this dimension, we report in Figure 5 the estimated regression line between the sectoral multiplier and centrality, both in the data and in the model. The model-based regression line is remarkably similar to that implied by the data, both in terms of slope and intercept. Figure 5 also depicts the regression line obtained from a counterfactual economy with fully flexible prices. While the relationship between the sectoral value added multiplier and centrality is still positive, the slope of the regression line is significantly smaller than that estimated from the data, pointing to a weaker correlation. Importantly, such a positive relationship would be impossible to account for by a roundabout production structure, in which – by construction – sectors do not differ in their position in the production network. A similar observation holds when we take into account the interaction of the aggregate government spending shock with the product of a sector's centrality and degree of price rigidity, a term that Pasten, Schoenle and Weber (2020) refer to as the "identity effect".

These results highlight the relevance of the interaction between the production network and price stickiness. An economy that features an Input-Output matrix but abstracts from either rigid prices or heterogeneity in the use of intermediate inputs yields a misleading portrait of the sectoral implications of government spending. This in turn lends credence to the quantitative multi-sector model developed in this paper, showing that it can be an appropriate laboratory for studying the aggregate and sectoral effects of government spending shocks.

## V. Concluding Remarks

This paper has studied the macroeconomic effects of government spending through the lens of a highly disaggregated multi-sector model calibrated to the U.S. economy. Our results show that the aggregate value-added multiplier is substantially larger than that obtained from the benchmark one-sector model typically considered in the literature, and that the bulk of this amplification is due to input-output interactions and – and to a lesser extent – sectoral heterogeneity in price rigidity.

We also find that the output effects of aggregate government spending shocks are heterogeneously distributed across industries, and are tilted towards the service-producing sectors. This heterogeneity is primarily driven by the industries' position in the production network, with the response of sectoral value added being larger in upstream industries. Importantly, this prediction is strongly supported by the data, and the model-based correlation between the sectoral value-added multiplier and centrality is remarkably close to that estimated empirically.

These findings suggest that taking seriously sectoral heterogeneity and production networks improves our understanding of the effects of government spending shocks and their transmission, which can be crucial when measuring the overall output effects of spending-based stimulus or consolidation plans.

Finally, while this paper has focused on public consumption purchases, a natural extension of our work would be to develop a multi-sector framework that allows to study the effects of public investment. Public investment has the specificity that it can alter the productive capacity of the economy, but is unlikely to affect all sectors uniformly. Some industries are indeed more heavily dependent on public infrastructure than others, which may lead to interesting sectoral and aggregate implications of public investment shocks. We leave this extension for future research.

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