

MACROECONOMIC FRAMEWORKS

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Abstract: We link detailed data on defense spending, wages, hours, employment, establishments, and GDP across U.S. cities to study the effects of fiscal stimulus. Our small-open-economy empirical setting permits us to estimate key macroeconomic outcomes and elasticities, including the responses of the labor share and the labor wedge to demand shocks and the elasticity of output with respect to labor inputs. We also decompose changes in work hours into different margins (hours per worker, the employment rate, and the labor force) and examine effects on local rental prices, wages, and firm entry. We compare our findings with the predictions of macroeconomic models and propose modifications to existing theory that can accommodate our findings.

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1. Introduction

Differentiating among competing models of the macroeconomy is a central task for academics and policymakers. Despite decades of research, there remains a lack of consensus over whether neoclassical, New Keynesian, or other frameworks accurately capture the underlying sources and mechanisms of economic fluctuations. This disagreement in part reflects a variety of identification and measurement challenges. Furthermore, different metrics, such as 1) the cyclicalities of the labor share (which is typically linked to the inverse of markups), 2) the cyclicalities of the labor wedge¹, 3) the response of wages and prices to shocks, and 4) fiscal multipliers, lead to conflicting conclusions regarding the validity of different models. Because research on these metrics is typically conducted in isolation and using different empirical settings and designs, it is therefore not surprising that the discipline has yet to reach an accord on how to think about the underlying structure of the economy. Even for a specific metric (the labor share, for example), economists disagree on its cyclicalities, with even less consensus on whether the evidence to date can be reconciled with other evidence on the other metrics. In this paper we take a step toward reconciling the facts and providing a comprehensive perspective on how these “macro metrics” respond to exogenous variation in aggregate demand. By focusing on demand shocks, we are able to isolate the source of variation driving these macro metrics. To maximize statistical power and strength of our identification, we use city-level data that contain information on a range of labor-market and goods-market indicators, along with purchases by the U.S. Department of Defense (DOD), a well-measured, arguably exogenous, and economically important source of variation in demand for local markets. Our city-level analysis of DOD shocks permits a model-free assessment of how macro metrics respond to shocks. To obtain a theoretical benchmark against which to compare our empirical results, we simulate various workhorse macroeconomic models to examine the response of the macro metrics to government spending shocks.

We document that in response to a DOD-induced increase in Gross Domestic Product (GDP), the labor share falls slightly, the household labor wedge plummets, unemployment falls, nominal wages increase but local rental prices increase by more, and GDP increases by more than the increase in DOD spending. Taken as a whole, this set of facts is quite puzzling from the

¹ The labor wedge is the ratio of the marginal rate of substitution (MRS) of consumption for leisure to the marginal product of labor (MPN). It consists of two components: a firm labor wedge that is the difference between the MPN and the real wage and a household labor wedge that is the difference between the real wage and the MRS.

perspective of mainstream theories. For example, New Keynesian models that are typically used for understanding demand-driven fluctuations in the economy tend to generate procyclical labor shares. But our evidence of acyclical (mildly countercyclical) labor shares cannot be taken as supportive of the neoclassical framework because unemployment plummets along with the household labor wedge. We also document large local fiscal multipliers, contrary to the predictions of the neoclassical framework.

Our ability to jointly identify a range of macro metrics is made possible by linking a variety of city-level data sources. The primary source of our outcome data is the American Community Survey (ACS), which contains annual information on respondents' work hours, wage income, rental prices, labor force status, and employment status. We also examine city-level data on annual GDP and the GDP deflator from the Bureau of Economic Analysis (BEA), payroll data from the Quarterly Census of Employment and Wages (QCEW), establishment counts and size from the County Business Patterns Survey (CBP), and auto registrations data (a popular proxy for local consumption). Having linked these data with information on city-level DOD spending, we examine joint outcomes for relevant macro metrics within localized labor markets, a unique and novel feature our empirical analysis. Furthermore, the ability to distinguish between local consumer prices and producer prices—and hence to distinguish between real wages earned by households (“worker wages”) and real wages paid by producers (“product wages”)—is useful for disentangling the responses of labor supply and labor demand.

We first examine output multipliers to investigate whether public spending crowds out private economic activity, a robust prediction of models featuring market clearing. Consistent with prior evidence, we find a city-level GDP multiplier greater than 1, which could imply large national output multipliers (see the discussion in Auerbach, Gorodnichenko, and Murphy. 2019, henceforth AGM) that are inconsistent with mainstream neoclassical and New Keynesian models.

Textbook New Keynesian models can accommodate high (relative to neoclassical) multipliers through countercyclical markups. We therefore turn next to the cyclicalities of the inverse of the labor share, which is typically equated with markups. While the literature has agreed on the relevance of the labor share and associated markups for differentiating among macroeconomic

modeling frameworks, there has yet to be a consensus on how markups respond to shocks.² We find that the popular proxy for the markup (the inverse of the labor share) is approximately constant or mildly procyclical. When we decompose the change in the labor share into a productivity component (growth in the GDP quantity index relative to growth in hours) and a relative-price component (the growth in producer prices relative to growth in wages), we find that the productivity component moves in the opposite direction of the relative price component. A DOD spending shock that increases real value-added by 1% increases hours by only 0.57%, indicating a high elasticity of value-added with respect to hours, and thus procyclical productivity, which all else equal drives up the markup. The relative-price component, however, exhibits a reaction in the opposite direction: wages increase relative to producer prices. The net effect of the productivity component and the relative-price component is an approximately acyclical markup and acyclical labor share.

In isolation the labor share is only partially informative for distinguishing among macroeconomic frameworks. As discussed by Galí, Gertler, and Lopez-Salido (2007) and Shimer (2009), among others, the cyclicalities of the labor wedge—the ratio between the marginal rate of substitution of consumption for leisure (MRS) and the marginal product of labor (MPN)—is also an important benchmark. While prior studies have focused on aggregate data and therefore equated worker wages with product wages, our data permit us to disentangle the two and to examine more directly effects on the labor wedge.

Increases in workers' willingness to supply labor can arise from an increase in their real wage, a decrease in the markup (or wedge) between the real wage and workers' marginal rate of substitution between consumption and leisure (MRS), or a fall in consumption (equivalently, a rise in the marginal value of consumption). We measure nominal wages by dividing survey respondents' wage income by their hours worked in a year. We follow Moretti (2011) and measure real worker wages as nominal wages divided by local rental prices (a common proxy for local consumer prices, as housing accounts for approximately 40% of local expenditure). In response to a DOD-induced increase in local GDP, rental prices increase by more than wages, implying that

² For example, Nekarda and Ramey (2011) find that industry-level defense spending is associated with no detectable effect on the labor share or markups, leading them to reject the textbook New Keynesian model. On the other hand, the evidence in Bils, Klenow, and Malin (2012) is generally indicative of countercyclical markups (procyclical labor shares), consistent with the New Keynesian paradigm. Relatedly, Stroebel and Vavra (2019) and Murphy (2019) find that one component of marginal costs – the gap between nominal prices and nominal input costs – increases in response to demand shocks.

real (“worker”) wages fall.³ At the same time, the same shock results in an increase in real product wages and an increase in local consumption (proxied by auto registrations). The fact that real worker wages fall while consumption and hours increase implies a large decline in the labor wedge in response to demand shocks.

This pattern is qualitatively consistent with the countercyclical nature of the aggregate labor wedge previously documented in e.g. Shimer (2009) and has important implications for the mechanisms that can account for fluctuations in output and employment. For example, the large decline in the household labor wedge (arising from the increase in consumption and hours) is consistent with the procyclical opportunity cost of labor documented in Chodorow-Reich and Karabarbounis (2016) and poses significant challenges to classes of search and matching models based on the Mortensen-Pissarides (1994) framework. Chodorow-Reich and Karabarbounis demonstrate that models typically used for understanding the cyclical nature of the employment rate such as Hagedorn and Manovskii (2008) struggle to explain unemployment volatility in the presence of procyclical opportunity costs of work (countercyclical labor wedges).

To inform the debate on the cyclical nature of the employment rate, we decompose changes in hours into changes in hours per worker, changes in the employment rate (1 minus the unemployment rate), and changes in the labor force. We find that a DOD spending shock results in significant increases in the employment rate, with the employment rate accounting for the majority of the adjustment in hours. We also present evidence that a part of this employment increase is mediated through firm entry.

We simulate various workhorse macroeconomic models and demonstrate that, while some models can account for different aspects of our evidence, none of them can rationalize our full body of evidence. For example, frameworks that deliver large multipliers such as the model in Nakamura and Steinsson (2014) rely on a much larger response of hours (arising from preferences featuring no wealth effects on consumption) to DOD spending than what we observe in the data. Similarly, the neoclassical framework closely matches the response of real worker wages and the labor share, but it performs poorly in nearly every other dimension.

We propose an initial framework to jointly rationalize our evidence by extending the model of negligible marginal costs (NMC) in Murphy (2017). The NMC framework features price-

³ This result holds even if we scale down the increase in consumer prices by assuming that only rental prices rise and that prices for the remainder of the local consumption bundle, which we do not observe, do not increase at all.

dependent demand elasticities that have been documented in the literature (e.g., Foster, Haltiwanger and Syverson 2008), as well as flexible producer prices and the possibility of excess capacity in equilibrium. Our extended NMC framework also includes a firm entry margin, distinguishes between labor market slack and firm-level slack, and incorporates a local housing/land market. Finally, the NMC framework is consistent with the evidence in AGM that there is no detectable crowding out effect of private economic activity in response to DOD spending, as well as evidence that demand stimulus is more effective when there is excess capacity in the economy (e.g., Auerbach and Gorodnichenko (2012); AGM; Demyanyk et al. (2019)). We calibrate the extended NMC model to match the DOD share of GDP, the labor share, and the relative response of earnings to the response of GDP. We then use the model to predict the response of macro metrics to a DOD shock. The model, while stylized in many dimensions, can account for key adjustment margins, and notably can explain a large multiplier, a large increase in local land prices and consumption, a large increase in the employment rate, and a large increase in measured labor productivity.

Michaillat and Saez (2014) also propose an equilibrium framework featuring slack (idleness) that is capable of explaining many of the empirical facts that we document. We focus on the NMC framework because it can accommodate a firm entry margin through a simple model extension. The main difference between the two frameworks is that, in the NMC framework, slack arises due to fixed costs among price-setting producers. In the Michaillat-Saez model, idleness is a result of rigid prices along with search-and-matching frictions between buyers and sellers.

Our work points to a number of policy implications and avenues for future research. From a policy perspective, demand stimulus is associated with large benefits when economies operate below capacity. These benefits dissipate as workers and firms extend into regions of increasing costs. To gain more detailed insights into the relevant costs and benefits of demand stimulus, it will be important to have quantitative models that are consistent with the facts we document. We conjecture that further extending of the negligible-marginal-cost framework, including dynamic aspects, will be fruitful.

2. Macro Metrics:

In this section, we outline a framework that nests the neoclassical and New Keynesian models. We then derive macro metrics and discuss how these metrics respond to government spending shocks under alternative theoretical benchmarks.

A. Predictions from Neoclassical and New Keynesian Frameworks

Consider a small open economy in which a representative household maximizes utility, $\sum_{t=0}^{\infty} \beta^t U(C_t, H_t)$, where C is consumption, H is hours worked, and $U_C > 0, U_H < 0$. Firms produce output that is both sold locally and exported.

Households. The household's budget constraint (omitting time subscripts; primes denote next period values) is

$$CP_C + P_B B' = WH + \Pi + B$$

where P_C is the price of the consumption good, W is the nominal wage rate, Π includes non-labor sources of income (possibly including profits from owning shares in the local firm), and B is a unit discount bond priced at P_B . We will assume that the local consumption bundle consists of locally produced non-tradables and tradable goods such that the relationship between consumer prices and producer prices is

$$P_C = P^\kappa P_{IM}^{1-\kappa},$$

where P_{IM} is the price imported goods and P is the price of locally produced goods.

Firms. A representative firm hires local worker hours to produce output according to

$$Q = ZH^\beta$$

where $\beta \leq 1$ and Z includes other quasi-fixed production factors. The firm sells its output at price P .

Labor Supply. Macroeconomic models typically adopt preferences that are separable in consumption and leisure or that rule out wealth effects on labor supply, such as the generalization in Greenwood, Hercowitz, and Huffman (1988; henceforth GHH):

$$U(C, H) = \begin{cases} \log C - H^\nu / \nu & \text{separable preferences} \\ \frac{(C - H^\nu / \nu)^{1-\sigma}}{1-\sigma} & \text{GHH preferences} \end{cases}$$

where $\nu \equiv 1 + \frac{1}{\xi}$ and ξ is the Frisch elasticity of labor supply. In either case, the household's optimization problem implies that the real worker wage equals the MRS:

$$\frac{W}{P_C} = H^{\frac{1}{\xi}} I(C),$$

where $I(C) = C$ in the case of separable preferences and $I(C) = 1$ in the case of GHH preferences. Deviations of the real worker wage $\frac{W}{P_C}$ from the MRS are captured by the “household labor wedge” T^H :

$$MRS \times T^H = \frac{W}{P_C}.$$

In New Keynesian models in which workers have market power, for example, T^H captures the markup charged by households over their MRS.⁴

Production, Labor Demand, and Markups. In the simplest case of perfect competition and a homogenous good, firms will maximize profits, $PZH^\beta - WH$, with respect to H (taking product price P and wages W as given), which implies that labor demand satisfies

$$\beta \frac{Q}{H} = \frac{W}{P}.$$

Deviations of the marginal product of labor (MPN), $\beta \frac{Y}{H}$, from the real wage are captured by the “firm labor wedge” T^F :

$$MPN = \frac{W}{P} T^F \Rightarrow T^F = \beta \frac{PQ}{WH}.$$

so, that, as in New Keynesian models, T^F , which incorporates the markup over firms’ marginal cost M_F , is proportional to the inverse of the labor share of output.

Labor Wedge. The product of the household labor wedge and the firm labor wedge is “the labor wedge” T :

$$\frac{MPN}{MRS} = T^H T^F \equiv T.$$

As discussed in Shimer (2009), models with search-and-matching employment can in principle accommodate any real product wage that is less than the MPN ($T^F \geq 1$) and any real worker wage that is greater than the MRS ($T^H \geq 1$). When there is a common worker and product real wage, it

⁴ We ignore here another source of the labor wedge, namely taxes on the wage W . Although the level of such taxes may be significant, our concern here is with the cyclicity of the labor wedge, to which tax rates are unlikely to make a major contribution.

must fall between the MRS (the worker's opportunity cost) and the MPN (the firm's marginal product).

B. Macro Metrics

This setup, which nests the standard neoclassical and New Keynesian models, implies a number of restrictions on the responses of “macro metrics” in response to a DOD spending shock.

i. Ratio of output with respect to hours $\frac{Q}{H}$:

The production function implies that the elasticity of output with respect to hours is equal to β in the absence of annual adjustments in the capital input. This prediction holds in open and closed economies and well as in Neoclassical and New Keynesian frameworks. In principle, this elasticity can be greater than β because e.g. firms may vary capital utilization. However, even in this case, the elasticity cannot exceed 1 unless the production function features increasing returns to scale.

ii. Inverse of the Labor Share $\frac{PQ}{WH} \sim T^F$:

Cost minimization implies that this share is constant in the Neoclassical Framework (even in the presence of capital adjustment and monopoly power on the firm side). In the standard New Keynesian framework, this ratio equals the desired markup (or, equivalently, the firm's labor wedge) and is assumed to fall in response to a demand shock.

iii. Real product wages $\frac{W}{P}$:

In the neoclassical framework, real product wages are equal to the marginal product of labor. Because demand shocks do not directly influence productivity in this model and firms face decreasing returns to labor, this ratio falls in response to a demand shock. In the textbook New Keynesian framework, this ratio increases due to sticky prices.

iv. Real worker wages $\frac{W}{P_C} = T^H H^{\frac{1}{\xi}} I(C)$:

In the neoclassical and textbook New Keynesian frameworks, the increase in output requires that workers' real wages increase or consumption falls to induce higher work effort (or the labor wedge to fall). In neoclassical models, the labor wedge is constant. Consumption tends to fall, so real

wages can also fall. In New Keynesian models, the household labor wedge can fall if wages are sticky.

v. Fiscal Multipliers:

The neoclassical framework implies a DOD multiplier well below unity, while New Keynesian models can accommodate larger local multipliers (e.g., Nakamura and Steinsson 2014). In both cases, large multipliers rely on a large share of local products in the local household's consumption bundle and/or a strong product price response to local DOD shocks. For example, in the neoclassical model, output prices must increase so that the real product wage can fall (along with the marginal product of labor) while the real household wage increases (to induce the higher labor supply). Relative to prior state-level analyses, a city-level framework would imply lower multipliers due to a smaller share of home-produced goods in the local consumption bundle.

3. Data and Methodology

Our analysis relies on variation in DOD spending, which constitutes over half of discretionary government spending. In addition to being a significant force for fiscal stimulus, DOD spending has the advantage that it neither enters directly in households' utility function nor contributes significantly to local productive public infrastructure, thus helping to isolate the potential channels through which it can affect the economy. We use a new dataset of city-level DOD spending that allows us to overcome some of the challenges faced in previous work (e.g., limited variation in government spending). We complement government spending data with data on a wide range of economic outcomes. Table 1 summarizes these data, their sources, and available time periods. The unit of analysis is city-year, where city is defined as a core-based statistical area (CBSA).⁵

A. Government Spending Data

Our measure of government spending shocks uses data on DOD contracts, available at [USAspending.gov](https://www.usaspending.gov). This data source contains detailed information on contracts signed since 2000, including the name and location (zip code) of the primary contractor, the total contracted amount

⁵ CBSA is geographic area defined by the Office of Management and Budget that consists of one or more counties (or equivalents) anchored by an urban center of at least 10,000 people plus adjacent counties that are socioeconomically tied to the urban center by commuting.

(obligated funds), and the duration of the contract. In most cases, we also observe the primary zip code in which contracted work was performed. To extend the length of our series to begin earlier than 2000 (we are able to go back to 1997), we complement this source with the data from the Federal Procurement Data System (FPDS; www.fpds.gov).⁶

In addition to new contract obligations, the dataset also contains modifications to existing contracts, including downward revisions to contract amounts (de-obligations) that appear as negative entries. Many of these de-obligations are very large and occur subsequent to large obligations of similar magnitude. When we observe obligations and de-obligations with magnitudes within 0.5 percent of each other, we consider both elements of the pair to be null and void. This restriction removes 4.7 percent of contracts from the sample.

These data offer several advantages relative to the data used to estimate state-level local fiscal multipliers. First, the detailed location data permit us to estimate multipliers at smaller levels of economic geography. This increases the cross-sectional dimension of our study and allows us to examine localized outcome variables for which data are available for only a limited, more recent, period of time. Second, the information on the duration of each contract allows us to construct a proxy for outlays associated with each contract over time. This proxy captures the component of DOD contracts that directly affects output contemporaneously (and is thus relevant for studying crowding in and crowding out effects). Also, some of the spending is based on pre-determined contracts, which helps mitigate concerns about endogeneity.⁷

AGM and Demyanyk et al. (2019) provide further discussion of this data source and the construction of the DOD spending series.

B. Data on Output, Prices, and Labor Market Outcomes

Our measure of employee income (pre-tax earnings) comes from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW). Consistent QCEW data at the county level are available since 1984.

⁶ The FPDS is the underlying source of data for USAspending.gov; that is, USAspending.gov builds data from the FPDS and presents it in a user-friendly way. We found high consistency across the sources for overlapping observations.

⁷ To construct this spending/outlay measure by location, we derive a flow spending measure for each contract by allocating the contracted amount equally over the duration of the contract. For example, for a \$3 million contract that lasts three years we assign \$1 million in spending for each year of the contract. We then aggregate spending across contracts in a location (at each point in time) to construct local measures of DOD spending.

Our measure of output, GDP (both real, i.e., a quantity index, and nominal), and our output price series, the GDP deflator, come from the Bureau of Economic Analysis (BEA). City-level GDP data are available since 2001.

To construct series on wage rates, hours worked, and employment, we rely on the American Community Survey (ACS), which contains information on respondents' city of residence beginning in 2005. Our city-level measures of hours and employment are based on weighted sums of the hours and employment status of respondents in each city. The city-level wage measure is the average of household wages, which are equal to labor income divided by hours worked. We also examine wage residuals derived from a Mincerian regression of wages on observable respondent characteristics, including age, education, occupation, and industry.

As a proxy for local consumer prices, we construct a measure of housing rental prices (e.g., Moretti 2010). Our measure controls for variation in the quality of housing by using residuals from a regression of costs on observable housing characteristics, as in Albouy (2012) and Murphy (2018). Following Murphy (2018), we obtain the housing-cost differential for respondent j in location ℓ using a regression of gross rents, $r_{j\ell}$, on controls ($Z_{j\ell}$) for size, rooms, commercial use, kitchen and plumbing facilities, age of building, home ownership, and the number of residents per room:

$$\log(r_{j\ell}) = Z_{j\ell}\beta + \epsilon_{j\ell}.$$

Rents for homeowners are imputed using a discount rate of 7.85% (Peiser and Smith 1985). The residuals $\epsilon_{j\ell}$ are the rent differentials that represent the amount individual j pays for her apartment/home in location ℓ relative to the average cost of a similar apartment/home in the U.S. Our city-level measure of rental prices is constructed by averaging these residuals within a city.

C. Data on Consumption and Firm Entry.

We use a measure of consumption (auto registrations) that is commonly used to study consumption responses to local demand shocks (e.g., Mian, Rao, and Sufi 2013, Demyanyk et al. 2019). This data set is provided by R.L. Polk and contains the number of new automobile registrations in a zip code in a month. The zip code is based on the address of the person who purchases the automobile rather than the address of the dealership. We aggregate the zip code-month-level data to the city-year level.

Our measure of firm entry is based on growth in the number of establishments in a city. County Business Patterns at the U.S. Census provides information on the number of establishments

in each zip code. We aggregate their data to derive a series of city-level establishment growth rates. The establishment growth series contains extreme outliers (the maximum is over 90-times the size of the the 99th percentile). To remove the influence of these extreme observations, we winsorize the establishment growth rate series at the bottom and top 0.5 percent.

D. Econometric specification

We estimate several econometric specifications to achieve two goals. First, we verify that government spending shocks influence output. Second, we examine how demand-driven changes in output translate into changes in our macroeconomic metrics.

Building on AGM, we use the following specification to achieve the first goal:

$$\frac{\Delta Y_{\ell t}}{Y_{\ell, t-1}} = \beta \frac{\Delta G_{\ell t}}{Y_{\ell, t-1}} + \psi_{\ell} + \alpha_t + error_{\ell t}, \quad (1)$$

where ℓ and t index locations (CBSA) and time (year), Y is a measure of output, G is a measure of defense spending, ψ_{ℓ} and α_t are location and time fixed effects. Coefficient β measures the local DOD spending multiplier, that is, the dollar amount of output produced by a dollar of local DOD spending. As discussed in AGM, variation in government spending shocks $\frac{\Delta G_{\ell t}}{Y_{\ell, t-1}}$ could have an important “timing” component (or “wealth transfers”).⁸ AGM argue that, in this case, it is important to isolate the component of spending that is associated with actual new production and filter out wealth transfers. The Bartik instrument effectively provides such a filter: $\frac{\Delta G_{\ell t}}{Y_{\ell, t-1}}$ should be instrumented with a Bartik shock, $\frac{\widehat{\Delta G}_{\ell t}}{Y_{\ell, t-1}} \equiv \frac{s_{\ell} \times (G_t - G_{t-1})}{Y_{\ell, t-1}}$, where s_{ℓ} is the location’s average share of DOD contract spending over the relevant period and G_t is aggregate contract spending in period t . This IV approach picks up only spending-related changes in $\frac{G_{\ell, t+h} - G_{\ell, t-1}}{Y_{\ell, t-1}}$ and filters out the wealth transfers (including anticipated contracts). In addition, we report estimated specification (1) with $\frac{s_{\ell} \times (G_t - G_{t-1})}{Y_{\ell, t-1}}$ as a regressand (i.e., in the reduced form):

⁸ That is, the main source of variation may be in the timing of contracts rather than if a contract is awarded or who is going to receive a contract. For example, Boeing may know that a defense contract is coming to its Everett, WA factory but it may be uncertain when the funds will arrive. In contrast, we are interested in whether Boeing is going to get a contract when it competes with Lockheed and there is uncertainty about whether the government wants to fund a new jet at all.

$$\frac{\Delta Y_{\ell t}}{Y_{\ell, t-1}} = \beta' \frac{\widehat{\Delta G}_{\ell t}}{Y_{\ell, t-1}} + \psi_{\ell} + \alpha_t + error_{\ell t}. \quad (1')$$

Once we establish that β' is not zero, we can use the following specification to achieve the second goal:

$$\frac{\Delta X_{\ell t}}{X_{\ell, t-1}} = \gamma \frac{\Delta Y_{\ell t}}{Y_{\ell, t-1}} + \psi_{\ell} + \alpha_t + error_{\ell t}, \quad (2)$$

where X is an outcome variable of interest and $\frac{\Delta Y_{\ell t}}{Y_{\ell, t-1}}$ is instrumented with our Bartik shock $\frac{s_{\ell} \times (G_t - G_{t-1})}{Y_{\ell, t-1}}$ (specifically, (1') is the first-stage of (2)). To make our results consistent with our simulations of workhorse macroeconomic models, we will use real GDP as a measure of Y on the right-hand side of specification (2). Coefficient γ informs us about how variable X reacts to changes in output that are driven by demand-side factors.

Notice that we can use specification (2) to construct other metrics of the response to demand-driven output shocks. For example, we are interested in how variable X behaves in relation to variable W when output is raised due to a demand shock. Because γ in specification (2) gives us $\left. \frac{d \log(X)}{d \log(Y)} \right|_{\Delta demand}$, we can construct $\left. \frac{d \log(X)}{d \log(W)} \right|_{\Delta demand}$ by taking the ratio of γ with X as the regressand in specification (2) to γ with W as the regressand in specification (2), that is,

$$\left. \frac{d \log(X)}{d \log(W)} \right|_{\Delta demand} = \left. \frac{d \log(X)}{d \log(Y)} \right|_{\Delta demand} \div \left. \frac{d \log(W)}{d \log(Y)} \right|_{\Delta demand} = \frac{\gamma_X}{\gamma_W}.$$

4. Empirical Results

This section presents the effects of a local DOD shock on a range of outcomes, including the macro metrics and their components (e.g., for the household labor wedge, we examine effects on real worker wages, hours, and consumption). We begin by presenting estimates of fiscal multipliers. Our estimates are above 1, implying strong output effects of DOD spending. We then examine the various adjustment margins that contribute to the large output effect.

A. Baseline GDP and Income Multipliers

To begin our discussion of the effects of DOD spending shocks on different components of income, we show, in Table 3, the differential impact of government spending shocks on GDP. In columns (1) and (3), we use the Bartik shock as an instrument for spending. The first column of the table shows

the impact response of nominal GDP to a spending shock. The third column shows the impact on real GDP. The magnitudes of the estimated fiscal multiplier (1.05-1.10) are similar to estimates of city-level multipliers (e.g., AGM and Demyanyk et al. 2019). Columns (2) and (4) report results for reduced form regressions (1'). We find that the Bartik shock is a strong predictor of output changes.

B. Labor Share (Firm Labor Wedge) and the Output-to-Labor Ratio.

How does the earnings share respond to a demand shock relative to GDP? To assess the degree of comovement between output and earnings in response to demand shocks, we first estimate specification (2) with the change in earnings normalized by nominal GDP as the regressand and nominal GDP growth as the regressor. We find (column 2 of Table 4) that the change in earnings with respect to the change in GDP is 0.36. This estimate is below the average labor share (0.41, column 1), implying that labor shares are mildly countercyclical (markups procyclical), although we cannot reject the null hypothesis of change equal to the average labor share. We arrive at a similar conclusion when we instead use earnings growth as the regressand (column 3 of Table 4). The estimated elasticity of earnings with respect to GDP is 0.93, and we cannot reject the null of a unit elasticity. Finally, in row 1 of Table 5 we examine the response of a direct measure of the labor share to demand-driven changes in GDP. Our estimate is negative but not statistically significant from zero. Each of these estimates point to a labor share that is approximately acyclical or mildly countercyclical and hence a markup that is approximately acyclical or mildly procyclical. This finding is consistent with the industry-level evidence in Nekarda and Ramey (2011) and the time-series evidence in Hall (2009) and Karabarbounis (2014).

The marginal cost (inverse of the labor share, i.e., $\frac{PQ}{WH}$) consists of a productivity component (Q/H) and a relative-price component (P/W). In row 2 of Table 5 we use specification (2) to examine the productivity component of marginal costs. A percent increase in real GDP due to a demand shock is associated with a 0.57 percent increase in hours (or, equivalently, an elasticity of output with respect to hours of 1.75). This result suggests that labor productivity strongly increases in response to a demand shock, which all else equal drives down marginal costs (and the labor share $\frac{WH}{PQ}$) and pushes up the markup. Our evidence reinforces the evidence in Nekarda and Ramey (2011) that aggregate labor productivity increases in response to positive demand shocks, although our estimates of the productivity response are much larger, pointing to a strong increase in capital utilization rates and/or labor effort and declines in labor hoarding.

Our findings of a relatively acyclical markup along with strongly procyclical labor productivity suggests that the price-to-wage markup is countercyclical. Below (Section 4.D) we present evidence consistent with this notion. We first explore in more detail the margins that account for the response of hours.

C. Employment

To understand sources of changes in output, we now study the reaction of various labor margins. Row 2 of Table 5 reports that the estimated elasticity of hours with respect to output is 0.57. When we decompose this elasticity into the extensive margin (the number of employees) and intensive margin (the number of hours per employee), we find that the bulk of the elasticity is accounted by the extensive margin (the elasticity of the number of employees is 0.41, row3) rather than the intensive margin (the elasticity of hours per employee is not statistically different from zero, row 4), which is consistent with e.g. Blanchard and Galí (2010) and Shimer (2009).

To further explore the role for the extensive margin of employment, we decompose the change in employment into two components: changes in the labor force and changes in the employment rate:

$$N \equiv \underbrace{\frac{N}{L}}_{\text{Employment Rate}} \times \underbrace{L}_{\text{Labor Force}}.$$

Rows (5) and (6) of Table 5 show estimated elasticity for the employment rate and for the labor force. The employment rate response is economically and statistically significant. The labor force response is positive but not statistically different from zero.

We can further decompose the response of the labor force to changes in the labor force participation rate (row 7) and changes in population (row 8). We find that none of these margins has a statistically significant response to demand-driven changes in GDP. One interpretation of our evidence is that our demand shocks are insufficiently large to cause the type of labor force participation rate adjustments observed in response to the Great Recession (Erceg and Levin 2014). Furthermore, the population adjustments that have been documented to equilibrate labor markets and remove unemployment differentials over long horizons (e.g., Blanchard and Katz 1992) do not appear to occur within the annual horizon in our sample.

D. Effect on Wages and Prices

The strong response of employment to changes in GDP may trigger a reaction of wages and other prices. Using data from the American Community Survey, we use the nominal wage rate as a dependent variable in specification (2). The wage response to demand-induced changes in output are positive but not statistically different from zero (row 9 of Table 5). This “raw” wage response may be affected by changes in the composition of workers (e.g., Solon, Barsky, and Parker 1994). To address this concern, we use residual nominal wages, based on the Mincerian regression described in Section 2. The response of this composition-adjusted measure of nominal wages is larger than the “raw” wage response but also noisy (row 10).

The effect on the GDP deflator is even smaller than the effect on wages (consistent with a countercyclical price-to-wage markup) and is similarly noisy (row 12). Local rental prices, on the other hand, exhibit a strong positive response (row 11). If one assumes that the rental price response is equal to the price response of local consumption, then the real household wage falls drastically (row 13). We do not directly observe other local *consumer* prices. Since there is a strong tradable component of local consumption, an alternative bound for the real household wage response can be derived by assuming that other consumer prices remain constant, which is consistent with evidence documented in DellaVigna and Gentzkow (2019). In that case, the total price of consumption responds only by rental prices scaled by the share of rental prices in the consumption bundle. Moretti (2011) proposes that this share is bounded below at 0.4. In that case, the elasticity of real wages (with respect to GDP volume) is $0.11 - 0.4 \times 0.65 = -0.15$, a large decline. We will use this more conservative value for our theoretical exercises.

In contrast, the point estimate of product wages (nominal wages deflated with the GDP deflator) is positive and statistically significantly different from zero (row 14). Thus, the wedge between real household wages and real firm wages widens drastically in response to a demand shock. Accompanying the decline in real worker wages is a rise in consumption, as measured by auto registrations (row 15 of Table 5).⁹ The rise in consumption, along with the rise in hours (row 4) should, given standard preference assumptions, increase the marginal valuation of leisure. Hence, the substantial decline in the real wage along with the increases in consumption and hours indicate a decline in the household labor wedge.

⁹ The local consumption increase is consistent with regional evidence from government purchases in Dupor et al. (2019).

The negative labor wedge response we document is consistent with the cyclicity of the labor wedge observed in aggregate data. Shimer (2009) discusses possible explanations of the countercyclical labor wedge, including cyclical taxes policy, time-varying work disutility, and time-varying labor market power. An advantage of our setting is that (instrumented) local DOD spending is plausibly orthogonal to local preferences, market power, and taxes. Given that these factors are not responsible for the labor wedge response we document, they may also be unlikely candidates for understanding the aggregate time series cyclicity.

E. Firm Entry

How can labor productivity increase so much in response to a short-run increase in output induced by the DOD shock? Potential explanations include adjustments in labor effort (and/or a reduction in labor hoarding), increased capital utilization, and endogenous firm entry. Notably, Devereux, Head, and Lapham (1996) predict that, assuming increasing returns in production, even wasteful government spending can increase measured labor productivity (and lead to large multipliers) by inducing firm entry. We find (row 16 of Table 5) that the elasticity of the number of local establishments with respect to output is 0.15, meaning that some of increased employment occurs at new establishments. This evidence is consistent with theories that predict procyclical firm entry (e.g., Bilbiie, Ghironi, and Melitz 2012). While much of the prior theoretical literature has focused primarily on technology shocks as drivers of entry, here we document that expansionary *demand* shocks also increase firm entry. It is also consistent with prior evidence that local demand shocks induce firm entry (Campbell and Lapham 2002).¹⁰ The entry response that we estimate is relatively mild (compared to, e.g., the employment response) but nonetheless economically and statistically meaningful.

F. Comparison of Empirical Evidence to Predictions of Workhorse Macro Models.

Workhorse macroeconomic models that are typically used for policy analysis expand on the textbook New Keynesian model by introducing a number of features to match various business cycle moments. To assess whether more sophisticated models can rationalize the observed responses, we examine the effects of government spending in some of the most prominent of these “medium-scale”

¹⁰ Campbell and Lapham (2002) document strong entry responses for retail firms in response to exchange rate shocks. They note that demand-induced firm entry presents challenges for theories driven by sticky prices.

models. Models differ in their setting (e.g., open versus closed economy) and the nature of price rigidity (e.g., sticky wages versus sticky prices), among other specifications. Smets and Wouters (2007) is the basis for many of the medium-scale closed-economy models and therefore serves as our reference closed-economy model. It notably includes sticky wages, sticky prices, and variable capital utilization. We examine both the baseline medium-scale Smets-Wouters model, as well as a version of their model with flexible prices and wages and fixed capital utilization (the “neoclassical model”). Government spending in the model is similar in nature to DOD spending in that it does not enhance local productivity and it does not enter directly into the utility function.

Since our empirical setting is an open economy, we also examine open-economy models. Our baseline open-economy setting is the model in Nakamura and Steinsson (2012), which includes DOD spending across different regions bound by common monetary policy. They present a simple version of their model with only sticky prices, as well as extended versions that include GHH preferences. Our city-level empirical analysis is perhaps more analogous to a small open economy setting in that local taxes are nearly independent of local DOD spending and that a large share of local consumption is spent on imported goods. Therefore, we also examine the small-open-economy medium-scale NK model of Galí and Monacelli (2016). City-level DOD shocks are analogous to export shocks in a small-open-economy setting (in that local taxes do not finance the increased production), so we focus on the effects of export shocks in the Galí-Monacelli model.

Because none of these models has a well-defined notion of involuntary unemployment (and hence some notion of “slack”), we also use a quantitative search-and-match model of business cycles developed in Christiano, Eichenbaum, and Trabandt (2016). This medium-scale, closed-economy model has many frictions similar to those in earlier New Keynesian models (price stickiness, adjustment costs, habit in consumption, etc.). Finally, we use the FBR/US model developed by the staff of the Federal Reserve to examine whether this close-economy model heavily employed for policymaking can rationalize the empirical patterns.

Table 6 presents the effects of government spending shocks in these prominent macro models alongside our empirical estimates. Each model tends to do well by some metrics but poorly by others. For example, the Nakamura-Steinsson model with GHH preferences can match the large multiplier (row 1), but it also performs the worst in matching the increase in hours (row 2) and nominal wages (row 3). The neoclassical model best matches the decline in the real worker wage, but it performs poorly in almost every other dimension (e.g., the model predicts a massive

fall in private consumption, row 9). The Smets-Wouters model performs the best in matching the increase in labor (row 2) due to variable capital utilization. It also features a decline in the household labor wedge (due to a falling wage markup) that at least qualitatively matches the empirical estimates. But similar to the neoclassical model, it predicts a fall in private consumption. The Galí-Monacelli model performs well in matching the mild responses of wages and prices to a shock but it underpredicts the multiplier and cannot match the strong decline in the household labor wedge. The Christiano-Eichenbaum-Trabandt model is generally similar to the Smets-Wouters model and it predicts a strong response of the employment rate to a government spending shock. The FRB/US model generates a small positive response of consumption, but similar to the Nakamura-Steinsson model with GHH preferences, this model predicts a strong increase in real worker wages, which is inconsistent with the results based on our data.

To summarize, each of these models can accommodate different aspects of the data but performs poorly along other dimensions. Variable capital utilization, rather than GHH preferences alone, seems important for capturing the increase in labor productivity alongside the large multiplier. Some variation on wage rigidity appears necessary to capture the decline in the household labor wedge. A common shortcoming of many models is that they tend to predict a fall in consumption, whereas it increases in the data. A standard rationalization of a positive consumption response is to have real worker wages increase (typically alongside credit-constrained households). But we find that real wages fall due to a large increase in the cost of housing. There is no mainstream framework of which we are aware that can explain these patterns.

5. Macroeconomic Implications

In this section, we sketch a framework that can accommodate key features of our empirical results, including i) an extensive margin of employment, ii) within-firm variation in labor productivity, iii) large fiscal multipliers, and iv) a decline in real worker wages along with increases in consumption and hours. Our objective is to outline a setting that is simple yet capable of capturing these key margins of adjustment in response to a local demand shock. Therefore we include only the model elements that are necessary to capture the various adjustment margins. We evaluate the quantitative performance of the model and discuss further extensions that would improve its quantitative fit.

Our proposed setting builds on the notion of labor as a (quasi-)fixed factor (Oi 1962). Despite the treatment of labor as a marginal cost in contemporary macroeconomic models, the

field has long acknowledged the potential relevance of fixed labor. For example, studies have documented that workers often supply their labor in increments (Card 1990; Faber 2005) and that firms often operate in regions of fixed-only costs (Brown 1992; Rotemberg and Summers 1990). Murphy (2017) derives implications of “negligible marginal costs” (fixed labor) in a general equilibrium setting, and we extend this framework to include employment and firm entry margins as well as land/housing. Agents inelastically supply labor, and firms hire workers as fixed costs. Employed workers can increase output costlessly (i.e., they do not demand higher wages for additional hours or effort).

A. Model.

We extend the NMC framework of Murphy (2017) to explicitly include employment and firm entry margins. We also model different locations (cities), each of which is treated as a small open economy that exports goods to other locations and sells to the national government. In the extended model, local residents purchase tradable goods as well as a locally-endowed nontradable good that accounts for land and other immobile factors of production.

Households. The economy consists of locations (“islands”) indexed by $\ell \in [0,1]$. In each location there is a representative household that consists of a mass of N workers, indexed by $\omega_\ell \in [0, N]$. The workers seek employment with local tradable-sector firms indexed by $j_\ell \in [0, J_\ell]$. Workers remit income to the household and the household consumes.

The household in location ℓ maximizes

$$U_\ell = \sum_{t=0}^{\infty} u_{\ell t}$$

where

$$\begin{aligned} u_{\ell t} = & r \int_0^N 1(\omega_\ell) d\omega_\ell + \log \mathcal{L}_{\ell t} \\ & + \int_0^1 \int_0^{J_m} \left[\theta_{jm\ell t} q_{jm\ell t} - \frac{1}{2} \gamma q_{jm\ell t}^2 \right] dj dm, \end{aligned} \tag{3}$$

$\mathcal{L}_{\ell t}$ is a locally endowed nontradable good (“land”), and $q_{jm\ell t}$ is location ℓ ’s consumption of the perishable tradable of variety j_m produced in location m . These Melitz and Ottaviano (2008) preferences over tradables give rise to demand curves with price-dependent demand elasticities,

which is a necessary condition for equilibrium slack in the NMC framework. $1(\omega_l)$ indicates non-employment (e.g., household work), which is valued at r and captures the notion of indivisible labor as in Hansen (1985).

The household's within-period budget constraint is

$$\int_0^1 \int_0^{J_m} p_{jmt} q_{jm\ell t} dj dm + \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + T_{\ell t} = \int_0^N w_{\omega\ell t} d\omega_{\ell} + \Pi_{\ell t} + I_{\ell t}, \quad (4)$$

where $w_{\omega\ell}$ is the total wage earnings of worker ω_{ℓ} , p_{jmt} is the price of variety j_m , $T_{\ell t}$ represents lump-sum taxes, and $p_{\ell t}^{\mathcal{L}}$ is the price of the local nontradable.¹¹ $I_{\ell t}$ represents other sources of income, including from ownership of non-labor local factors of production. $\Pi_{\ell t}$ is profits from owning firms on island ℓ and other islands. We assume that land and firm ownership is diversified so that households on island ℓ derive negligible income from owning land or firms on island ℓ . Let $\lambda_{\ell t}$ be the multiplier on location ℓ 's budget constraint.

Tradable Sector Production and Demand. Each firm in the tradable sector hires workers as a fixed cost. To operate and produce, each firm requires a mass of n tasks (the input into the fixed labor cost is a Leontief technology over tasks). Each task requires an employee, and the total amount of perishable output that the n workers can produce is the capacity level $\bar{q}$, which for simplicity of aggregation is assumed to be constant across firms and is so high that it is not binding. At output levels below $\bar{q}$, output can be increased without additional costs to the firm, consistent with the notion of labor as a quasi-fixed factor (Oi 1962).

A firm's revenues depend on the demand curve it faces. Household optimization implies that demand from island ℓ for variety j_m (output produced by a firm located on island m) is

$$q_{jm\ell t}^d = \frac{1}{\gamma} (\theta_{jm\ell t} - \lambda_{\ell t} p_{jmt}). \quad (5)$$

Total private-sector demand for variety j_m is derived by integrating across locations:

$$q_{jmt}^d = \int_0^1 q_{jm\ell t}^d d\ell = \frac{1}{\gamma} (\theta_{jmt} - \lambda_t p_{jmt}),$$

¹¹ The budget constraint (4) implies that all firm profits are returned to the household as dividends each period.

where $\theta_{jmt} \equiv \int_0^1 \theta_{j\ell t} d\ell$ and $\lambda_t \equiv \int_0^1 \lambda_{\ell t} d\ell$. When firms operate below the capacity level, a firm maximizes revenues by choosing a price $p_{jmt} = \theta_{jmt}/2\lambda_t$, which implies that the quantity sold to the private sector is

$$q_{jmt}^p = \frac{\theta_{jmt}}{2\gamma} \quad (6)$$

and revenues from the private-sector are

$$R_{jmt}^p = \frac{\theta_{jmt}^2}{4\gamma\lambda_t}.$$

Nontradable Sector. The nontradable goods in each location are produced competitively using a locally endowed commodity, which represents land or other factors of production that are immobile across locations and across sectors. Therefore, local consumption of the nontradables is invariant over time and independent of tradable sector output.

Government Spending. The government purchases tradable goods from the private sector. We assume that it spends ϕ_{mt} proportion of (potential) private-sector revenues on j_m across all firms on island m , which implies that demand from the government is

$$q_{jmt}^G = \phi_{mt} R_{jmt}^p \frac{1}{p_{jmt}} \quad (7)$$

This assumption captures the fact that the DOD spends more on large firms such as Boeing than on smaller firms. Note that the government has a unit elasticity of demand and therefore it does not influence the price p_{jmt} , as variation in the firm's price has no impact on its profits from government sales. This is consistent with the fact that the government buys output at the price determined by the private market. Firms are willing to accept these extra purchases at the market price because they have spare capacity and can costlessly increase output.

Given equation (7), total firm revenues are

$$R_{jmt} = \frac{\theta_{jmt}^2}{4\gamma\lambda_t} (1 + \phi_{mt}). \quad (8)$$

Hiring. In each period, each of the tasks across firms is randomly matched with a worker. Firms employ labor locally, that is, a firm located on island ℓ can hire workers only from island ℓ . If a wage contract is agreed upon, the employment relationship lasts for the duration of the period.

There is only one opportunity to match with a firm each period, so matched workers' opportunity cost of accepting a wage offer is the reservation utility r . The benefit to the firm of agreeing on an employment contract is a firm's revenue minus the wage,

$$V_{j\ell t}^F = \lambda_t(R_{j\ell t} - w_{j\ell t}),$$

where $w_{j\ell t}$ is the wage bill paid by firm j_ℓ to each worker with which it is matched (specifically, $w_{\omega\ell t}$ equals $w_{j\ell t}$ if worker ω_ℓ is matched with firm j_ℓ). We assume that ownership of firms is distributed across all islands and therefore firms value profits at the average marginal utility of income islands, $\lambda_t = \int_0^1 \lambda_{\ell t} d\ell$.

The benefit to the worker of accepting a contract is

$$V_{j\ell t}^W = \lambda_{\ell t}(w_{j\ell t} - r).$$

where r is the value of not working. Workers value income at the local household's marginal utility of income. The household does not coordinate bargaining between firms and workers.

Workers and firms Nash bargain over the surplus. The equilibrium wage bill maximizes the product of the benefit to the worker and the benefit to the firm:

$$w_{j\ell t} = \operatorname{argmax}_{w_{j\ell t}} \left\{ \lambda_{\ell t}^\psi (w_{j\ell t} - r)^\psi \lambda_t^{1-\psi} (R_{j\ell t} - w_{j\ell t})^{1-\psi} \right\},$$

where ψ is the workers' bargaining power. At an interior optimum, the resulting wage income of a worker is

$$w_{j\ell t} = \psi[R_{j\ell t} + r] \tag{9}$$

and the total wage bill faced by the firm is $nw_{j\ell t}$.

Note that, because labor is hired as a fixed factor, workers bargain over the *wage bill* rather than the *wage rate* (compensation per hour). In other words, firms can ask employees to work more or less without adjusting the total payment to employees. Whether workers need to work more to accommodate demand shocks is unspecified in the model and likely varies according to the nature of the service provided. But, in any event, stated hours of work may not vary, to the extent that full-time work is regarded as a discrete outcome.

Firm Entry and Exit. Firms shut down if their revenues are not sufficient to cover the wage bill, $R_{j\ell t} < nw_{j\ell t}$. This occurs when

$$R_{j\ell t} < \frac{n\psi r}{(1 - n\psi)} \equiv \underline{R}.$$

In that case, no wage contract is signed, the firm shuts down, and workers matched with the firm are unemployed for the period. Equation (8) implies that surviving firms are those that face a sufficiently strong private and/or public demand for their goods:

$$\theta_{j\ell t}^2 > \frac{4\gamma\lambda_t R}{1 + \phi_{\ell t}}.$$

Equilibrium. Aggregate local outcomes in the model depend on the distribution of revenues across firms (and hence the distribution of preference parameters). We assume $\theta_{j\ell t}^2$ is distributed Pareto with a shape parameter α . Because firms exit when profits are negative, the distribution of $\theta_{j\ell t}^2$ for existing firms has a lower support equal to the break-even level of demand shifter $\underline{\theta}_{\ell t}^2 \equiv \frac{4\gamma\lambda_t R}{1 + \phi_{\ell t}}$. For simplicity of aggregation, we assume that capacity levels are infinite. Then it is straightforward to show (see appendix) that the mass of surviving firms on island ℓ is

$$J_{\ell t} = \left[\frac{4\gamma\lambda_t R}{1 + \phi_{\ell t}} \right]^{-\alpha} = [\underline{\theta}_{\ell t}^2]^{-\alpha}, \quad (10)$$

the employment rate is

$$\frac{nJ_{\ell t}}{N} = \frac{n}{N} \left[\frac{4\gamma\lambda_t R}{1 + \phi_{\ell t}} \right]^{-\alpha} = \frac{n}{N} [\underline{\theta}_{\ell t}^2]^{-\alpha},$$

and total tradable sector revenue (which is equal to GDP) is

$$R_{\ell t} = (4\gamma\lambda_t)^{-\alpha} \frac{\alpha}{\alpha - 1} \left[\frac{R}{1 + \phi_{\ell t}} \right]^{1-\alpha} (1 + \phi_{\ell t}). \quad (11)$$

Note that λ_t is endogenous, although its value is pinned down by the household's first-order condition with respect to land, along with the fact that land is endowed (exogenous). The model's numeraire is the aggregate land price (average land prices across locations), so export prices and local land prices are relative to the aggregate land price.

B. Comparative statics

Here we outline the various adjustment margins in response to an increase in local government spending $\phi_{\ell t}$ that is not financed with increased taxes in location ℓ . The expressions for these comparative statics are derived in the Appendix.

Entry and Employment Response.

One can show that the reaction of employment to a change in ϕ is given by

$$d \log Emp_{\ell t} = d \log J_{\ell t} = \frac{\alpha \phi_{\ell}}{1 + \phi_{\ell}} d \log \phi_{\ell t}.$$

Government spending causes an increase in firm entry, as the additional revenue from the government causes more firms to produce with positive profits. Since employment increases with firm entry in the model, the increase in government spending also increases employment.

Note that the model assumes that employment is mediated through firm entry, which is an extreme assumption. An alternative and less restrictive setup would be to assume that some varieties represent worker task sets rather than establishments. In that case, some of the employment increase would occur through new task sets within incumbent firms. For example, a firm can open a new conveyer line or a new shift within an existing establishment.

GDP multiplier. A dollar increase in government spending raises GDP (equal to revenue R) by

$$\frac{dR_{\ell t}}{dG_{\ell t}} = 1 + \frac{\alpha - 1}{\alpha \phi + 1}.$$

When the government spends on a tradable good produced by an incumbent firm, it increases revenues one-for-one with each dollar spent because there is no crowding out of private demand (firms have spare capacity and the marginal cost of producing extra output is negligible). The government also spends on new firms that can export both to the government and to the private sector. The additional private-sector exports from new firms imply that the local government spending multiplier in the model is strictly greater than 1. Note that the high fiscal multiplier is not driven by household income multipliers, since locally produced tradable goods are a negligible share of the consumption bundle.

Labor Share. The additional revenues generated by the government are allocated between firm owners and workers according to workers' bargaining power. In percentage terms, owners receive a slightly larger increase due to the fact that worker earnings include a reservation wage bill that does not adjust with government spending: $\frac{d \log PQ}{d \log WH} = \frac{R+r}{R}$. If the reservation wage r is small relative to firm revenues, then the share of labor income in GDP is approximately independent of demand shocks.

Prices. Firm-level export prices are independent of local government spending. This is consistent with our evidence that the effect of DOD spending on the GDP deflator is not statistically different from zero. Government spending does induce entry of some lower-value (low θ) products into the market. Land prices $p_{\ell t}^L$ increase due to the increased demand associated with increased local income. The Appendix derives the local nontradable price response around a steady state in which households balance their budget.

Local Consumption. The increase in government spending increases worker earnings, which causes them to import more tradable goods. Since the local economy is small, import prices do not increase to offset this increase in local consumption. Thus, the change in spending on imported goods is equal to the change in quantities of imported goods. We show in the Appendix that the change in the consumption of each imported good is equal to the change in spending on “land”.

Household Labor wedge. Households in the model do not experience any disutility from extra work hours or effort but rather only an opportunity cost of employment. Therefore, the model does not exhibit the traditional cost-benefit tradeoff that is captured in the household labor wedge in standard models. Nonetheless, the NMC model makes predictions about the variables (real wages, hours and consumption) that are typically used to infer the labor wedge from the data (e.g., Shimer 2009; Karabarbounis 2014). Each of these components of the household labor wedge adjusts in our model to contribute to a large fall in the measured household labor wedge.¹²

C. Calibration.

To calibrate the model, we assign one value (α) from a previous study and we infer other parameters from average DOD spending shares, average labor shares, average housing expenditure shares, and an empirical estimate from Table 4. We then use the calibrated parameters to predict the response of various macro metrics (computed around a symmetric equilibrium in which government spending is equally distributed across locations). The model’s numeraire is the average land price across locations, and we normalize the land quantity in each location to unity.

The parameter of the Pareto distribution for firm size is based on Axtell (2001): $\alpha = 1.05$. Table 7 shows the data moments that are used to calibrate other model parameters. In row (1), we

¹² The computation of the labor wedge requires elasticities of nominal wages and hours. We assume that there is no intensive margin adjustment of hours (although the model does not rule out an intensive margin adjustment) and therefore set the hours elasticity equal to the employment elasticity. The nominal wage is computed as the total local wage bill divided by local employment.

pin down the government demand parameter ϕ by matching the model-implied value of the DOD contract spending share of GDP to the average share in the U.S. during the 2000s (approximately 0.01). In row (2), we use the estimate of $\frac{dWH}{dPQ}$ from column 2 of Table 4 to pin down workers' bargaining power $n\psi$. To pin down the remaining parameters r and γ , in rows (3) and (4), we set the model-implied values of the labor share and the housing expenditure share to their counterparts in the data (both approximately 0.4).

D. Assessment of the NMC model

Table 8 compares estimated elasticities from the data with predictions from the calibrated model. The predicted multiplier and elasticity of earnings with respect to GDP are nearly identical to their empirically estimated counterparts. Other predicted metrics are reasonably close to the empirical estimates. In particular, the elasticity of employment with respect to output is well below 1, consistent with the empirical evidence that labor productivity increases in response to an expansionary demand shock. The model predicts a large (relative to existing theories) response of land prices and consumption of imports. While the predicted consumption response is less than the (large) estimated response of consumption (spending on new cars), it is in line with estimates from other studies that have examined the effect of other forms of government spending on local consumption (e.g., Dupor et al. 2019).

The model tends to over-predict the response of establishments to an increase in GDP quantities. This is a result of the strong simplifying assumption in the model that all additional employment occurs through firm entry. A straightforward modification to the model would temper the employment response while possibly enhancing the correspondence to reality: the establishment response would be muted if some export varieties represent worker task sets rather than establishments. In that case, some of the employment increase would occur through new task sets within incumbent firms.

The large response of employment (hours), along with the increase in land prices and increase in consumption, implies a large decline in the inferred household labor wedge. The model accommodates such a large fall in the measured labor wedge because additional firm-level production is costless for households (they experience no disutility) but nonetheless increases their income (and hence consumption and land prices).

Given the parsimony of the model, one should not expect the model to match all moments of the data (and indeed the model misses some moments quantitatively). However, in contrast to popular macroeconomic frameworks, the model can qualitatively match a number of empirical patterns (e.g. procyclical productivity, a strong fiscal multiplier, and a countercyclical labor wedge) observed in response a demand shock. Thus, we view the model as having sufficient potential to develop it further.

E. *Aggregate implications*

Aggregate GDP is

$$R^A = \int_0^1 R_\ell d\ell.$$

In a symmetric equilibrium $\phi_{\ell t} = \phi_{m t} = \phi_t \forall m \neq \ell$, which implies that $R^A = R_\ell$. This implies that a change in ϕ_t across islands has the same effect on national GDP as a change in local $\phi_{\ell t}$ on local GDP, and hence the national multiplier equals the local multiplier.

This result seems counterintuitive given that national DOD spending is financed with taxes across islands ($T_t = G_t$, where $G_t = \int_0^1 G_{\ell t} d\ell$ and an expression for local DOD spending $G_{\ell t}$ is provided in the appendix), whereas a location's tax does not respond to local increases in government spending. In our model, the different tax responses imply different responses for land prices and consumption, but not for GDP.

Consider first an increase in national spending that is financed by taxes on the recipients of the DOD spending. The income side of the budget constraint increases from the rise in DOD spending. Income also rises as new firms enter and sell some of their output to the private sector. Incumbent firms' sales to the private sector remain fixed (as dictated by equation (6)). On the expenditure side of the budget constraint, taxes increase (the expenditure side of the budget constraint) by an amount equal to the increase in G . Expenditure on newly available tradable goods equals the increase in private-sector income generated by the new firms. On net, national income (and expenditure) increases from government spending and, in addition, from the production of new tradable goods.

Next consider an increase in local government spending that is financed externally (and thus does not require a local tax increase). As in the prior case, the income side of the budget constraint increases from the income from the DOD. Income also rises as new firms enter and sell some of

their output to the private sector in the form of exports. External demand for incumbent varieties is independent of local government spending, so there is no increase in exports of incumbent varieties. The expenditure side of the budget constraint differs from the prior case. Here, taxes do not offset the increase in income from the DOD. Instead, the local household spends more on housing and on imports of incumbent varieties. This is possible because, while average (across locations) land prices are pinned down as the numeraire, the land price in any given locale can deviate from the national average. And, the fact that local land prices can deviate implies that the local budget multiplier $\lambda_{\ell t}$ can also deviate from the average. The deviation of $\lambda_{\ell t}$ permits local consumption of an import variety to deviate from aggregate consumption of that variety (equation (5)).

Therefore, while the consumption and land price responses differ at the local level from the national level, these responses do not affect local GDP and hence the national multiplier equals the local multiplier in this model.

Prior empirical work has found that multipliers increase with the size of the economic geography considered, reflecting positive spillovers across nearby highly localized economies (e.g., AGM, Demyanyk et al. 2019). This suggests that national multiplier might exceed local multipliers. Extensions to the model would likely increase the aggregate multiplier relative to the national multiplier. For example, the model does not feature general equilibrium income multipliers that would, in a framework with negligible marginal costs, tend to push up national multipliers.

F. Discussion and Interpretation

There is a long tradition in macroeconomics of working to make sense of the various macro metrics examined in this study. Based on challenges faced in the prior literature, researchers have called for new frameworks. For example, Hall (2009) calls for “new ideas outside the New Keynesian framework to explain the high value of the multiplier along with other mysteries of aggregate behavior.” Likewise, Shimer (2009) encourages macroeconomists to “look beyond search models for an explanation of the labor wedge.”

The NMC framework is a step in accounting for these and other macro metrics. A key feature of the NMC model is that additional firm-level production is costless (over some range of output). Therefore, labor productivity depends on firm demand. Likewise, there is no disutility from work hours or work effort (but rather a discreet opportunity cost of employment). This

implies that the opportunity cost of employment does not vary with hours or with consumption; and, as a result, workers' labor supply does not contract during expansions.

The microfoundation underlying the NMC framework is that firms face fixed, rather than marginal, labor costs.¹³ This treatment of the production process is consistent with observations of labor markets cited above and with lumpy adjustment costs. For example, it represents barbers who provide additional haircuts without incurring marginal costs, up until the point at which (s)he is working an 8-hour day (reaches capacity). The firm cannot choose a capacity level of less than a single barber because of the nature of the service provided. Because the barber supplies more labor than is demanded, the barber experiences no marginal disutility from serving additional customers. Indeed, many workers feel an intrinsic sense of value in their work that may offset the opportunity cost of leisure. They may also prefer to be busy rather than bored.¹⁴

6. Conclusion

We exploit detailed data on local DOD spending to assess the effects of government purchases on a range of "macro metrics" that are used to distinguish among macroeconomic theories. Our results indicate that, in response to an expansionary demand shock, (a) the labor share is relatively constant, (b) measured labor productivity increases drastically, and (c) the increase in hours is primarily due to adjustment on the extensive margin (employment). Furthermore, (d) the real product wage increases and (e) the real worker wage falls drastically due to a sharp increase in local rental prices. Accompanying the fall in real worker wages is (f) an increase in local consumption that, along with the increase in hours, contributes to a sharp decline in the household labor wedge.

These metrics are difficult to reconcile with mainstream models typically used for policy analysis. As a first step toward reconciling theory with the evidence, we expand a theory of negligible marginal costs to incorporate extensive margins of employment and firm entry. The model, while stylized in many dimensions, moves us closer to rationalizing observed empirical patterns, at least qualitatively.

¹³ The NMC framework is compatible with marginal costs in the form of intermediate inputs and can accommodate marginal costs for firms as long as workers provide their labor as a fixed (rather than marginal) cost. See Murphy (2017) for an extended discussion of the assumptions underlying the NMC framework.

¹⁴ Even if a firm can choose its capacity level and it can perfectly forecast demand, it may choose a level of capacity such that it experiences slack the majority of the time if demand is variable. See Fine and Freund (1990) for a general formalization of optimal capacity investment under demand uncertainty.

Our study suggests a number of fruitful avenues for future research. First, we have examined and sought to explain macro metrics in response to government expenditure shocks. It would be helpful to assess these metrics in response to other shocks, including supply-side shocks. Second, further theoretical extensions to the NMC framework or alternative frameworks such as Michaillat and Saez (2014) may prove useful for better matching the data and for welfare analysis. For example, the baseline framework presented here abstracts from income effects that can contribute to high national multipliers and large labor productivity responses.

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Table 1. Data Sources

Data	Source	First year city-level data are available, from 1998
Department of Defense spending	Federal Procurement Data System	1998
GDP	Bureau of Economic Analysis	2001
Earnings	Quarterly Census of Employment and Wages	1998
Hours, employment, and labor force	American Community Survey	2005
Wages	American Community Survey	2005
Land Prices	American Community Survey	2005
Price indices	Bureau of Economic Analysis	2009
Establishments	County Business Patterns	2003
Auto Registrations	Polk	2002

Note: A smaller subset of cities have establishment data prior to 2003. We focus on post-2003 establishment data to maintain a balanced panel.

Table 2. Model Predictions for Responses to a DOD Export Demand Shock.

	Neoclassical; reason		Textbook New Keynesian; reason	
$\frac{Q}{H}$	↓	Decreasing returns to labor	↓	Decreasing returns to labor
$\frac{W}{P}$	↓	Necessary for firms to hire more labor	↑	Sticky prices.
$\frac{W}{P_c}$	↑	Necessary for increase in H	↑	Necessary for increase in H (or large ↓ T^H)
$\frac{PQ}{WH}$	—	Constant under assumption of Cobb-Douglass production	↓	Sticky prices; Countercyclical Markups; $T^F = M \sim PQ/WH$
Output multiplier	<<1	Decreasing returns to labor	<1	Decreasing returns mitigated by countercyclical markup

Note: Column (2) shows predictions from the standard 3-equation New Keynesian model. Table 6 discusses predictions from medium-scale NK models. Directions for real worker wages W/P_c are based on the assumption that the consumption response is nonnegative.

Table 3. Response of output (GDP) to government spending shocks.

	Nominal GDP, $\Delta Y_{it}/Y_{i,t-1}$		Real GDP, $\Delta Q_{it}/Q_{i,t-1}$	
	(1)	(2)	(3)	(4)
$\Delta G_{it}/Y_{i,t-1}$	1.054** (0.508)		1.103** (0.469)	
$\widehat{\Delta G}_{it}/Y_{i,t-1}$		0.956*** (0.488)		0.996*** (0.355)
Observations	5,605	5,610	5,605	5,610
R-squared	-0.077	0.004	-0.110	0.005
1 st stage F-stat	10.18		10.18	

Notes: This table presents estimates from Specification 1. $\widehat{\Delta G}_{it}/Y_{i,t-1}$ is the Bartik instrument. Fixed effects for CBSA and year are included but not reported. Standard errors clustered by state are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Labor Share Response to DOD Shocks.

	Average Labor Share $\frac{WH}{PQ}$	Change in Earnings relative to change in GDP $\frac{dWH}{dPQ}$	Elasticity of Earnings w.r.t. GDP $\frac{d \log WH}{d \log PQ}$
	(1)	(2)	(3)
	0.41	0.360*** (0.068)	0.934*** (0.178)
N	5,984	5,610	5,595
1st-stage F-Stat		20.41	19.52

Notes: Columns (2) and (3) are based on regressions of earnings on GDP, where GDP is in growth rates and is instrumented with the Barik shock. In column (2), the change in earnings is normalized by lagged GDP (so that the coefficient captures relative changes). In column (3), the change in earnings is normalized by lagged earnings (so that the coefficient captures elasticities). In columns (2) and (3), time and city fixed effects are included but not reported. Standard errors clustered by state are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Response to demand-driven changes in output.

Row	Outcome variables	Coef. (s.e.)	1 st stage F stat	N obs
1	$dlog\left(\frac{Earnings}{GDP}\right)$, labor share	-0.066 (0.144)	17.45	5,610
2	$dlog(H)$, hours	0.571*** (0.169)	9.98	2,817
3	$dlog(E)$, employment	0.409*** (0.143)	9.98	2,817
4	$dlog\left(\frac{H}{E}\right)$, hours per employee	0.152 (0.093)	9.98	2,817
5	$dlog\left(\frac{E}{L}\right)$, employment rate	0.332*** (0.134)	9.98	2,817
6	$dlog(L)$, labor force	0.087 (0.101)	9.98	2,817
7	$dlog\left(\frac{L}{Pop}\right)$, labor force participation rate	0.012 (0.084)	9.98	2,817
8	$dlog(Pop)$, population	0.075 (0.127)	9.98	2,817
9	$dlog(wage)$, wages	0.080 (0.236)	9.98	2,817
10	$dlog(resid\ wage)$, residualized wages	0.114 (0.134)	9.98	2,817
11	$dlog(resid\ rent\ price)$, residualized rent prices	0.651** (0.295)	9.98	2,817
12	$dlog(P)$, GDP deflator	0.041 (0.046)	8.78	2,995
13	$dlog\left(\frac{wage}{P_c}\right)$, residualized real worker wages	-0.537* (0.290)	9.98	2,817
14	$dlog\left(\frac{wage}{P}\right)$, residualized real product wages	0.829* (0.461)	9.63	2,034
15	$dlog(auto)$, auto registration	4.403*** (1.005)	17.98	4,092
16	$dlog(establishments)$, firm establishments	0.151** (0.070)	10.43	4,114

Notes: This tables presents estimates based on specification (2). The regressor is growth in real GDP (instrumented by the Bartik shock). Time and city fixed effects are included but not reported. Standard errors clustered by state are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 6. Comparison of empirical and model-implied moments.

Row	Outcome	Our Empirical Results	Models						
			Closed Economy				Open Economy		
			Smets and Wouters (2007)		Cristiano et al. (2016)	FRB US	Nakamura and Steinsson (2014)		Galí and Monacelli (2016)
			Medium- scale NK	Neoclassical	Search and match	Mix	Baseline (sticky prices)	Baseline with GHH preferences	Medium- scale NK with nontradables
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Output multiplier dQ/dG	1.10	0.88	0.44	0.92	0.97	0.79	1.50	0.90
	Elasticity with respect to output:								
(2)	Hours	0.57	0.63	1.25	0.65	0.54	1.49	1.49	1.35
(3)	Nominal wages	0.11	0.14	1.74	0.25	0.87	1.35	1.57	0.05
(4)	Consumer Price Index	0.26	0.09	1.99	0.11	0.01	0.07	0.08	0.00
(5)	Real worker wage	-0.15	0.05	-0.25	0.14	0.86	1.28	1.49	0.05
(6)	Household labor wedge	-0.72	-0.56	0.00	-0.25	-0.22	0.00	0.00	0.05
(7)	GDP deflator	0.04	0.09	1.99	0.11	0.04	0.07	0.08	0.00
(8)	Employment Rate	0.33	NA	NA	0.66	0.50	NA	NA	NA
(9)	Consumption	4.40	-0.30	-1.49	-0.27	0.06	-0.77	0.87	-0.03
(10)	Firm Entry	0.15	NA	NA	NA	NA	NA	NA	NA
(11)	Capital stock	NA	-0.02	-0.12	-0.03	0.04	0.00	0.00	0.00

Notes: The neoclassical version of Smets Wouters is the version of the model with flexible wages and prices, no variable capital utilization, and no fixed output cost. In the Galí Monacelli simulation, the multiplier is with respect to an export shock (dY/dX) rather than a government spending shock (dY/dG). In the data estimate of row (5) column (1), the consumer price response is 40% of the estimated land price response (under the conservative assumption that other consumer goods prices are constant). In computing the empirical households labor wedge, we assume GHH preferences (so consumption is irrelevant) and a Frisch elasticity of 1. Separable preferences would result in a much lower household labor wedge given the strong estimated response of consumption. The empirical consumption response is based on the response of automobile purchases. The household labor wedge in the models is based each model's parameterization of the utility function. In the case of Christiano et al., labor is supplied inelastically, so there is no MRS. Therefore, we compute the "labor wedge" in that model as we do in the data (as if there were GHH preferences). All responses measure the cumulative reaction of a given variable over one year after a government spending shock, which is equal to one percent of GDP.

Table 7. Calibration

Parameter	Moment	Model-Implied Moment Value	Parameter Value
ϕ	Share of the Dept of Defense spending in GDP	$\frac{\phi}{1 + \phi}$	0.01
$n\psi$	Change in labor earnings w.r.t change in GDP, $\frac{dWH}{dPQ}$	$n\psi$	0.34
r	Housing Expenditure share	$\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + R^P}$	2.7
γ	Labor Share, $\frac{WH}{PQ}$	$\frac{n\psi[R + r]}{R}$	3.4

Note: The table shows the implications of data moments and the empirical estimates for calibrated parameters. In rows (3) and (4), R and R^P are total revenues and private-sector revenues. The model parameters listed above are the following: α is the shape parameter from the firm size distribution. ϕ is the government demand parameter. $n\psi$ is workers' bargaining power. γ is a demand curve parameter. r is the value of non-employment. Parameters r and γ are jointly derived from moments in the third and fourth rows.

Table 8. Assessment of the NMC model.

Metric	Estimate from Data	Baseline calibration	50% Increase in the value of:				
			ϕ	$n\psi$	r	γ	α
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Local Multiplier $\frac{dR}{dG}$	1.05	1.05	1.05	1.05	1.05	1.05	1.57
Elasticity with respect to GDP							
Earnings, $\frac{d \log WH}{d \log PQ}$	0.93	0.85	0.85	0.85	0.79	0.85	0.35
Elasticity with respect to GDP quantity							
Employment quantity, $\frac{d \log Emp}{d \log Q}$	0.41	0.68	0.68	0.68	0.68	0.68	0.76
Establishments, $\frac{d \log J}{d \log Q}$	0.15	0.68	0.68	0.68	0.68	0.68	0.76
Rental prices, $\frac{d \log p_{lt}^L}{d \log Q}$	0.65	0.21	0.21	0.30	0.20	0.20	0.04
Labor wedge $\frac{d \log WH - (1 + \frac{1}{\xi}) d \log Emp - 0.4 * d \log p^L - d \log q}{d \log Q}$	-0.72	-1.44	-1.44	-1.58	-1.50	-1.44	-1.71
Consumption of tradable goods $\frac{d \log pq}{d \log Q}$	4.40	0.21	0.21	0.30	0.20	0.20	0.04

Note: We report the elasticity of nominal variables (e.g., earning, land prices) with respect to nominal GDP (PQ), and we report the elasticity of real variables (e.g., employment) with respect to real GDP (Q). In the baseline calibration, $\phi = 0.01$, $n\psi = 0.34$, $r = 0.27$, $\gamma = 3.39$, $\alpha = 1.05$. ξ is calibrated at 1. The inferred labor wedge from the empirical estimates (row 6 column 1) does not take into account the response of consumption. Including our estimated consumption response would yield a substantially more negative labor wedge response.

Appendix

Here we derive expressions from the model's equilibrium as well as the response of macro metrics to increases in government spending.

Mass of Surviving Firms

Surviving firms are those for which

$$\theta_{j\ell t}^2 > \frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})}$$

Given our distributional assumption on θ^2 , this implies that the mass of surviving firms is

$$J_{\ell t} = \int_{\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})}}^{\infty} \alpha(\theta^2)^{-\alpha-1} d\theta^2 = -\infty^{-\alpha} + \left[\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})} \right]^{-\alpha} = \left[\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})} \right]^{-\alpha}$$

$$J_{\ell} = \left[\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})} \right]^{-\alpha}$$

Revenues

Total local revenues from the private sector are

$$\begin{aligned} R_{\ell t}^P &= \frac{1}{4\gamma\lambda_t} \int_{\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})}}^{\infty} \theta^2 f(\theta^2) d\theta^2 = \frac{1}{4\gamma\lambda_t} \int_{\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})}}^{\infty} \alpha(\theta^2)^{-\alpha} d\theta^2 = \frac{1}{4\gamma\lambda_t} \frac{\alpha}{1 - \alpha} (\theta^2)^{1-\alpha} \Big|_{\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})}}^{\infty} \\ &= \frac{1}{4\gamma\lambda_t} \frac{\alpha}{1 - \alpha} \left(- \left[\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})} \right]^{1-\alpha} \right) = \frac{1}{4\gamma\lambda_t} \frac{\alpha}{\alpha - 1} \left[\frac{4\gamma\lambda_t \underline{R}}{(1 + \phi_{\ell t})} \right]^{1-\alpha} \\ &= (4\gamma\lambda_t)^{-\alpha} \frac{\alpha}{\alpha - 1} \left[\frac{\underline{R}}{(1 + \phi_{\ell t})} \right]^{1-\alpha} \end{aligned}$$

Revenues from the government in a location are

$$G_{\ell t} = \phi_{\ell t} R_{\ell t}^P.$$

Total local revenues are the sum of private-sector revenues and revenues from government spending:

$$R_{\ell t} = R_{\ell t}^P + G_{\ell t} = (4\gamma\lambda_t)^{-\alpha} \frac{\alpha}{\alpha - 1} \left[\frac{\underline{R}}{(1 + \phi_{\ell t})} \right]^{1-\alpha} (1 + \phi_{\ell t}).$$

The government share of GDP in a location is $\frac{G_{\ell t}}{R_{\ell t}} = \frac{\phi_{\ell t}}{1 + \phi_{\ell t}}$.

GDP multiplier:

The multiplier is the change in total revenues for every dollar of spending from the government:

$$\frac{dR_{\ell t}}{dG_{\ell t}} = \frac{d\{(1 + \phi_{\ell t})R_{\ell t}^p\}}{d\{\phi_{\ell t}R_{\ell t}^p\}} = \frac{((1 + \phi)d(R_{\ell t}^p) + R_{\ell t}^p d\phi)}{\phi d(R_{\ell t}^p) + R_{\ell t}^p d\phi}$$

Where $d(R_{\ell t}^p) = d(4\gamma\lambda_t)^{-\alpha} \frac{\alpha}{\alpha-1} \left[\frac{R}{(1+\phi_{\ell t})} \right]^{1-\alpha} = (4\gamma\lambda_t)^{-\alpha} R^{1-\alpha} \frac{\alpha}{\alpha-1} (\alpha-1)(1+\phi_{\ell t})^{\alpha-2} d\phi$

So

$$\begin{aligned} \frac{dR_{\ell t}}{dG_{\ell t}} &= \frac{(1 + \phi)(\alpha - 1)(1 + \phi_{\ell t})^{\alpha-2} + (1 + \phi_{\ell t})^{\alpha-1}}{\phi(\alpha - 1)(1 + \phi_{\ell t})^{\alpha-2} + (1 + \phi_{\ell t})^{\alpha-1}} = \frac{(\alpha - 1) + 1}{\phi(\alpha - 1)(1 + \phi_{\ell t})^{-1} + 1} \\ &= 1 + \frac{\alpha - 1}{\alpha\phi + 1} \end{aligned}$$

(Inverse of) Labor Share:

In the model, wage income w corresponds to earnings WH in the data, and revenues R correspond to PQ (GDP). Hence, the model analogue of the inverse of labor share is

$$\frac{PQ}{WH} = \frac{R_{\ell t}}{n\psi[R_{\ell t} + r]}.$$

We examine two measures of the response of the labor share to a demand shock: the elasticity of GDP with respect to earnings, and the change in GDP relative to the change in earnings.

We first derive the elasticity of GDP with respect to earnings, $\frac{d \log PQ}{d \log WH}$, driven by a change in local government spending $\phi_{\ell t}$.

$$\begin{aligned} \frac{d \log PQ}{d \phi_{\ell t}} &= \frac{d \log R_{\ell t}}{d \phi_{\ell t}} = \frac{1}{R_{\ell t}} \frac{dR_{\ell t}}{d \phi_{\ell t}} \\ \frac{d \log WH}{d \phi_{\ell t}} &= \frac{1}{n\psi[R_{\ell t} + r]} \frac{n\psi dR_{\ell t}}{d \phi_{\ell t}} \\ \frac{d \log PQ}{d \log WH} &= \frac{R_{\ell t} + r}{R_{\ell t}}. \end{aligned}$$

Next we derive the change in revenues as a ratio of the change in earnings $\frac{dPQ}{dWH}$:

$$\frac{dPQ}{dWH} = \frac{dR_{\ell t}}{d\{n\psi[R_{\ell t} + r]\}} = \frac{dR_{\ell t}}{n\psi \times dR_{\ell t}} = \frac{1}{n\psi}$$

Elasticity of Nontradable Prices with respect to GDP

The household's first order condition relates expenditure on local nontradables to the local household's budget multiplier $\lambda_{\ell t}$:¹⁵

$$\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} = \frac{1}{\lambda_{\ell t}}.$$

To determine how this responds to an increase in government spending, we examine deviations around a steady state in which the local household's expenditure equals its income (e.g., there is balanced trade):

$$\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + \int_0^1 \int_{\underline{\theta}_{\ell t}^2}^{\infty} p_{jmt} q_{jm\ell t} dj dm + T_{\ell t} = n\psi(R_{\ell t} + r) + \Pi_{\ell t} + I_{\ell t}.$$

Totally differentiating this budget constraint with respect to locally-determined variables and dividing through by R (and assuming $\mathcal{L}$ is fixed by locally endowed production factors, $\Pi_{\ell t}$ and $I_{\ell t}$ are independent of local conditions due to diversification, $T_{\ell t}$ is independent of local DOD spending, and prices p_{jmt} are independent of local conditions due to price setting at the aggregate level), this becomes:

$$\frac{\mathcal{L}_{\ell t} dp_{\ell t}^{\mathcal{L}}}{R_{\ell t}} + \frac{1}{R_{\ell t}} \int_0^1 \int_{\underline{\theta}_{\ell t}^2}^{\infty} p_{jmt} dq_{jm\ell t} dj dm = n\psi \frac{dR_{\ell t}}{R_{\ell t}}. \quad (12)$$

Note that demand for $q_{jm\ell t}$ is given by

$$q_{jm\ell t}^d = \frac{1}{\gamma} (\theta_{jm\ell t} - \lambda_{\ell t} p_{jmt}) = \frac{1}{\gamma} \left(\theta_{jm\ell} - \frac{1}{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}} \frac{\theta_{jmt}}{2\lambda_t} \right) = \frac{\theta_{jmt}}{\gamma} \left(1 - \frac{1}{2\lambda_t \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}} \right).$$

¹⁵ $\lambda_{\ell t}$ denotes the budget multiplier for the local household while λ_t is the average multiplier across locations.

¹⁶ Note that the comparative statics at the national level would include changes in taxes. This implies that national land prices do not change in response to national spending.

Totally differentiating this expression yields

$$\begin{aligned}
dq_{jm\ell t} &= \frac{\theta_{jmt}}{\gamma 2\lambda_t} (\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}})^{-2} d(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}). \\
&= \frac{\theta_{jmt}}{\gamma 2\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}} d(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}). \\
&= \frac{\theta_{jmt}}{2\gamma} d \log(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}).
\end{aligned} \tag{13}$$

Substituting in for $dq_{jm\ell t}$ in (12) yields

$$\begin{aligned}
\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{R_{\ell t}} d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + \frac{1}{R_{\ell t}} \int_0^1 \int_{\underline{\theta}_{\ell t}}^{\infty} \frac{\theta_{jmt}}{2\lambda_t} \frac{\theta_{jmt}}{2\gamma} d \log(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}) dj dm &= n\psi \frac{dR_{\ell t}}{R_{\ell t}} \\
\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{R_{\ell t}} d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + \frac{\lambda_t}{\gamma R_{\ell t}} \int_0^1 \int_{\underline{\theta}_{\ell t}}^{\infty} \left(\frac{\theta_{jmt}}{2\lambda_t} \right)^2 d \log(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}) dj dm &= n\psi \frac{dR_{\ell t}}{R_{\ell t}} \\
d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} \left[\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{R_{\ell t}} + \frac{\lambda_t}{\gamma R_{\ell t}} \int_0^1 \int_{\underline{\theta}_{\ell t}}^{\infty} \left(\frac{\theta_{jmt}}{2\lambda_t} \right)^2 dj dm \right] &= n\psi \frac{dR_{\ell t}}{R_{\ell t}}
\end{aligned}$$

$$\text{Substitute in } \int_0^1 \int \left(\frac{\theta_{jmt}}{2\lambda_t} \right)^2 d\theta^2 dm = R_{\ell t}^P \frac{4\gamma\lambda}{4\lambda^2} = R^P \frac{\gamma}{\lambda}$$

$$d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} \left[\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{R_{\ell t}} + \frac{\lambda_t}{\gamma R_{\ell t}} R_{\ell t}^P \frac{\gamma}{\lambda_t} \right] = n\psi \frac{dR_{\ell t}}{R_{\ell t}}$$

$$\frac{d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{d \log R_{\ell t}} = \frac{n\psi}{\frac{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{R_{\ell t}} + \frac{R_{\ell t}^P}{R_{\ell t}}}$$

$$\frac{d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{d \log R_{\ell t}} = \frac{R_{\ell t} n\psi}{\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}} + R_{\ell t}^P}$$

Because in a symmetric equilibrium $\lambda_{\ell t} = \lambda_t$, it follows that

$$\frac{d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{d \log R_{\ell t}} = \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi$$

Elasticity of Consumption Response with Respect to Output

Appendix equation (13) gives the response of a variety of consumption to a change in spending on “land” $\mathcal{L}$. To turn this into an elasticity, note that $q_{jm\ell t} = \frac{\theta_{jmt}}{2\gamma}$. Then equation (13) can be written as

$$d \log q_{jm\ell t} = d \log(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}).$$

Note that the right-hand-side of this equation is the same for all j_m and therefore consumption bundle of tradable goods increases by $d \log(\mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}})$. It follows that the response of consumption to $d \log R_{\ell t}$ is given by

$$\frac{d \log q_{jm\ell t}}{d \log R_{\ell t}} = \frac{d \log q_{jm\ell t}}{d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}} \frac{d \log \mathcal{L}_{\ell t} p_{\ell t}^{\mathcal{L}}}{d \log R_{\ell t}} = 1 \times \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi = \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi$$

Elasticity of Employment with Respect to Output

Employment in the model is proportional to the number of firms: $Emp_{\ell t} = nJ_{\ell t}$. Total output is the sum of firm-level output in a location, the private-sector component of which is given by equation (6). Total private-sector output is

$$\begin{aligned} Q_{\ell t}^P &= \frac{1}{2\gamma} \int_{\frac{4\gamma\lambda_t R}{(1+\phi_{mt})}}^{\infty} \theta f(\theta^2) d\theta^2 = \frac{1}{2\gamma} \int_{\frac{4\gamma\lambda_t R}{(1+\phi_{mt})}}^{\infty} \alpha (\theta^2)^{-\frac{1}{2}-\alpha} d\theta^2 \\ &= \frac{1}{2\gamma} \frac{\alpha}{.5 - \alpha} (\theta^2)^{\frac{1}{2}-\alpha} \Big|_{\frac{4\gamma\lambda_t R}{(1+\phi_{mt})}}^{\infty} \\ &= \frac{1}{2\gamma} \frac{\alpha}{\alpha - \frac{1}{2}} \left(\frac{4\gamma\lambda_t R}{(1 + \phi_{mt})} \right)^{-(\alpha-.5)}. \end{aligned}$$

Total output is the sum of Q^P and Q^G :

$$Q = (1 + \phi_{mt}) \frac{1}{2\gamma} \frac{\alpha}{\alpha - \frac{1}{2}} \left(\frac{4\gamma\lambda_t R}{(1 + \phi_{mt})} \right)^{-(\alpha-.5)} = \frac{1}{2\gamma} \frac{\alpha}{\alpha - \frac{1}{2}} (4\gamma\lambda_t R)^{-(\alpha-.5)} (1 + \phi_{mt})^{(1+\alpha-.5)}$$

Hence

$$d \log Q = \left(\frac{1}{2} + \alpha\right) \frac{\phi}{1 + \phi} d \log \phi$$

Employment is $\frac{n}{N} \left[\frac{4\gamma\lambda_t R}{(1+\phi_{mt})} \right]^{-\alpha}$, so

$$d \log Emp = \alpha \frac{\phi}{1 + \phi} d \log \phi$$

Hence,

$$\frac{d \log Emp}{d \log Q} = \frac{\alpha}{.5 + \alpha}$$

Since $d \log J = d \log Emp$, it follows that $\frac{d \log J}{d \log Q} = \frac{\alpha}{.5 + \alpha}$.

We can also derive

$$d \log R = \alpha \frac{\phi}{1 + \phi} d \log \phi$$

Hence

$$\frac{d \log Q}{d \log R} = \frac{0.5 + \alpha}{\alpha}$$

Household labor wedge:

We can write the labor wedge in growth rates as:

$$\tau^H = w - p_c - \frac{1}{\xi} h - c$$

In our model, the wage is the same as the wagebill $n\psi(R_{\ell t} + r)$ per employee. Therefore,

$$\begin{aligned} w &= d \log n\psi(R_{\ell t} + r) - d \log Emp = d \log(R_{\ell t} + r) - d \log Emp = \frac{1}{R_{\ell t} + r} dR_{\ell t} \\ &= \frac{R_{\ell t}}{R_{\ell t} + r} d \log R_{\ell t} - d \log Emp. \end{aligned}$$

In our model, let the consumption price be

$$d\log p_{\ell t}^c = s^\mathcal{L} d\log p_{\ell t}^\mathcal{L} + (1 - s^\mathcal{L}) d\log p_{jmt},$$

where $s^\mathcal{L} = 0.4$ is the share of land expenditure in total household spending. In our model, p_{jmt} is invariant to local demand shocks. Recall also that

$$\frac{d\log \mathcal{L}_{\ell t} p_{\ell t}^\mathcal{L}}{d\log R_{\ell t}} = \frac{d\log p_{\ell t}^\mathcal{L}}{d\log R_{\ell t}} = \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi$$

Hence,

$$d\log p_{\ell t}^c = s^\mathcal{L} \times d\log p_{\ell t}^\mathcal{L} = s^\mathcal{L} \times \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi \times d\log R_{\ell t}$$

Finally we have the response of consumption of tradable goods:

$$d\log q_{\ell t} = d\log(\mathcal{L}_{\ell t} p_{\ell t}^\mathcal{L}) = \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi \times d\log R_{\ell t}$$

It follows that the response of labor wedge is

$$\begin{aligned} \tau^H &= (\text{average wage}) - p_c - \frac{1}{\xi} \text{hours} - \text{consumption} \\ &= \left(\frac{R_{\ell t}}{R_{\ell t} + r} d\log R_{\ell t} - d\log \text{Emp}_{\ell t} \right) - d\log p_{\ell t}^c - \frac{1}{\xi} d\log \text{Emp}_{\ell t} - d\log q_{\ell t} \\ &= \frac{R_{\ell t}}{R_{\ell t} + r} d\log R_{\ell t} - d\log p_{\ell t}^c - \left(1 + \frac{1}{\xi} \right) d\log \text{Emp}_{\ell t} - d\log q_{\ell t} \\ &= \frac{R_{\ell t}}{R_{\ell t} + r} d\log R_{\ell t} - s^\mathcal{L} \times \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi \times d\log R_{\ell t} - \left(1 + \frac{1}{\xi} \right) d\log \text{Emp}_{\ell t} - \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi \\ &\quad \times d\log R_{\ell t} \\ &= \frac{R_{\ell t}}{R_{\ell t} + r} d\log R_{\ell t} - (1 + s^\mathcal{L}) \times \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi \times d\log R_{\ell t} - \left(1 + \frac{1}{\xi} \right) d\log \text{Emp}_{\ell t} \end{aligned}$$

Substituting in $d\log R_{\ell t}$ for $d\log \text{Emp}_{\ell t}$, we have

$$\tau^H = \left\{ \frac{R_{\ell t}}{R_{\ell t} + r} - (1 + s^\mathcal{L}) \times \frac{\lambda_t R_{\ell t}}{1 + \lambda_t R_{\ell t}^P} n\psi - \left(1 + \frac{1}{\xi} \right) \right\} d\log R_{\ell t}.$$