Fiscal Multipliers in Integrated Local Labor Markets*

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Abstract

I reveal and analyze a spatial mechanism for generating the aggregate fiscal multiplier. Government budgets balance nationally. This permits the geographic distribution of a government spending stimulus to vary independently from the geographic distribution of the tax burden. Given asymmetric economic geography, the resulting wedge between local spending and local tax burdens can generate an increase in aggregate GDP. This effect is independent of the behavioral response to taxation, thereby providing a distinct mechanism to the canonical New Keynesian and Neoclassical models. To analyze this, I bring in techniques from the International Trade literature: I construct a tractable general equilibrium representation of the fiscal multiplier in a spatially rich framework, accounting for geographic heterogeneity and interdependence due to trade. I develop an identification strategy and structurally estimate the model by combining a government spending shift-share instrument with the general equilibrium structure. I digitize a new historical dataset on interstate trade and apply my framework to US Federal defense procurement in the late 20$^{\text{th}}$ century. I estimate that the spatial mechanism accounts for variation in the multiplier of 50% relative to canonical mechanisms, with greater increases in GDP when spending is concentrated geographically. Analogous to state-dependent fiscal multipliers, my findings suggest a meaningful analogy with *geography-dependent* fiscal multipliers.

Keywords: Fiscal Multiplier, Heteroskedastic Treatment Effects, Interregional Trade, Quantitative Trade Models, Spatial Autoregressive Models

JEL Codes: C31, E62, F12, H57, R12

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1 Introduction

In response to the 2009 recession, the US Federal Government increased expenditure by 5% ($787 billion) of US GDP and increased its fiscal deficit to levels not seen since the Second World War.[1] Governments throughout the world face a difficult decision when considering the use of fiscal policy to stimulate GDP. The induced expansion in GDP must be weighed against the already extreme levels of public debt, and the wide aversion to a tax increase. The value of the (aggregate) *fiscal multiplier* — the dollar increase in national GDP caused by a one dollar increase in government spending — is a critical metric informing and guiding policy-makers in taking these decisions.

However, there is not just one fiscal multiplier. It depends on the location of spending. The effect on national GDP will be different whether the government spends the dollar in California or Illinois or any other state. This observation itself is important for guiding the policymaker. A profound consequence is that a transfer from a low-return state to a high-return state can generate a net increase in national GDP. That is, spending the revenue in a location different to where it was raised creates a net increase in local market demand. Through standard channels, this increase in local demand generates a fiscal multiplier effect on local GDP. With asymmetric geography between the locations receiving the spending and financing the spending, the effect on aggregate GDP can also be positive. An important distinction relative to canonical New Keynesian and Neoclassical fiscal multiplier models is the initial change in market demand: there, this is achieved through income effects on households, derived from the associated tax burden. The *spatial mechanism* I describe is independent of any behavioral response to taxation

The goal of this paper is to investigate this spatial mechanism and quantify its importance relative to canonical channels. This is motivated for both the understanding of a novel explanation of fiscal multiplier magnitudes, and the measurement of a *geography-dependent* fiscal multiplier — that is, one which is heterogeneous by location of spending. Both are of importance to the economist and the policymaker, and both are mostly overlooked in the literature.

Answering this research question is challenging, as geographic asymmetry is central to the spatial mechanism. Even when abstracting from spatial considerations, identifying fiscal multipliers is difficult because government spending is endogenous with respect to GDP.[2] This is exacerbated in the current case because not only must I take account of geographic heterogeneity across states, I must also take account of geographic interdependence between

[1] The number refers to the American Recovery and Reinvestment Act.

[2] Government spending is the very definition of endogeneity. If the spending wasn't endogenous to the state of the economy, then the government is not doing its job.

them. Consider the US Federal Government making a purchase from a firm in Illinois. Not only will the output of this firm expand in response, the output of its supplier located in Wisconsin, say, will also increase as the firm in IL demands more inputs. The GDP in both IL and WI is affected from the government spending in IL. Because the US is highly integrated through its network of interstate trade, GDP in every state responds to spending in any given state.

Geographic heterogeneity makes this an identification exercise of high dimensionality: the effect on national GDP from government spending must be estimated distinctly for each state. Geographic interdependence places high requirement on exogeneity: all these effects must be estimated simultaneously, requiring a large set of full rank instruments.[3] Even given all these instruments, a parameter problem still remains: the number of parameters (the treatment effects from spending in each state on national GDP) to identify equals the size of the cross-section (the number of states); the number of observations equals the number of time periods (typically years). Even in the most ambitious studies, at best we have about 60-70 years of appropriate state-level government spending data for the US. Each parameter is therefore estimated from about one to two observations.

Solving this identification challenge is a key contribution of this paper.[4] To proceed, I restrict analysis to geographic heterogeneity and interdependence arising due to the geography of interstate trade. This is a natural focus given the deep integration of US states through trade,[5] and provides an interregional trade extension to the wide recognition of international trade being a key structural determinant of fiscal multiplier magnitudes.[6] What this restriction allows me to do is tractably parameterize the effects of spending on GDP using a general equilibrium model of trade. Two features of this solve the identification challenge. First, dimensionality is reduced. Effectively I change the identification problem from directly identifying the fiscal multiplier by each state of spending to instead identifying two structural parameters of the model (a demand and a supply elasticity) which, conditional on observable interstate trade flows and government spending shares, indirectly identify the fiscal multiplier by each state. Second, I use the general equilibrium structure to construct appropriate instruments to identify the structural parameters. Roughly, these structural

[3]In a regression of national or state GDP on state spending, it is not enough on the righthand-side to have only spending it that state. Spending in every state must be included, each entering separately with a distinct coefficient.

[4]Some papers that estimate the *local fiscal multiplier* do allow for heterogeneity interdependence, see e.g Serrato and Wingender (2016) (heterogeneity as a function of local GDP) and Dupor and Guerrero (2017). But these estimates are unable to identify the effect on national GDP. See Ramey (2011) for a survey of local fiscal multiplier papers.

[5]Looking at figure 1 the fraction of state production consumed outside the state is greater than 60% for 40 states; a similar finding is observed with imports too.

[6]See Batini et al. (2014) for a review of fiscal multiplier determinants.

instruments consist of interactions of exogenous variation in government expenditure with the trade exposure of a state.

Using a trade model to characterize the fiscal multiplier is unique in the literature, and provides some interesting insights.[7] First, in measuring the spatial mechanism, I show that I am able to be agnostic about how the spending is financed (e.g. the instrument of taxation or its timing) and what the behavioral responses to taxation are.[8] This is achieved because, by modeling the responses to first order, I can additively decompose the fiscal multiplier into the spatial channel and the taxation channel. Second, I show that the trade model jointly captures various canonical fiscal multiplier magnification mechanisms in a single reduced form, general equilibrium parameter: the supply elasticity (as alluded to above). In order for the fiscal multiplier to be greater than one, the supply elasticity must be negative, describing a downward-sloping supply. Although this sounds unorthodox, an outward-shift of the demand curve will only ever cause a more-than-proportionate response in equilibrium output if supply is downward-sloped. An insight missed in traditional macroeconomic models as a result of their complexity.[9]

What does my theoretical model predict about the effect of the spatial mechanism for the aggregate fiscal multiplier? In general, it's difficult to say as this is a problem of high-dimensionality, depending on the entire network of interstate trade flows. To get intuition, I consider a special case of two regions of equal size. I prove that, under some regularity conditions, a government expenditure transfer between the two regions (keeping aggregate expenditure and therefore taxation fixed) can generate a net increase in aggregate GDP if the region receiving the transfer is *more-closed to trade*. Furthermore, I show that the increase in aggregate GDP is *increasing* in the closedness of the receiving state. What does this suggest about the real world, in which the number of locations is many? This is the purpose of the remainder of the paper, in which I empirically quantity the model in the context of the US.

I use my framework to analyze US Federal Defense Procurement during the period 1966-2006. Military spending is the canonical source of government spending used in the estimation of fiscal multipliers as it tends to suffer from fewer identification issues than other forms of government spending, and, in the US, it is a large subset of total government spending.[10]

[7]This is not to say trade is absent from the fiscal multiplier literature (see e.g. Nakamura and Steinsson (2014)) but the spatial aspects there are very restrictive (typically only two locations), and far from modern quantitative trade models (see Redding and Rossi-Hansberg (2017) for a review).

[8]This is particularly helpful for my empirical application in defense procurement as contracts are most likely procured through deficit financing during my time period. Do taxpayers internalize the resulting future tax liabilities? I am able to remain completely silent on this.

[9]This is not to denigrate the macroeconomic models in any way, rather to be complementary. Many things are learnt from macroeconomic models which the trade model cannot speak to.

[10]To put this into context: US government spending is about 20% of US GDP; Military spending is about 5% of US GDP; defense procurement is about 2% of US GDP.

Defense procurement is a large subset of military expenditure, and I particularly focus on this as there is a large variation in its geographic distribution of spending. The data on US defense procurement is well-documented and publicly available for accountability and transparency reasons.[11] The data is at the contract level. A contract is between the federal government and a firm, with the firm producing a good or providing a service for the government. The contracts can range from the construction of aircraft carriers to wheels for tanks, to factory maintenance and catering. I aggregate the contract values to the state-year level for my analysis.

This source of spending is not free from endogeneity concerns: the state allocation of contracts is notoriously political (see, e.g., Russett et al. (1992)), and thus likely to be endogenous to state economic conditions. For example, if Illinois has a senator on the Senate Committee on Armed Services, then the senator may be able to influence the allocation of contracts and allow firms in IL to receive more in years when the economy in IL is struggling. To mitigate this concern, I follow Nakamura and Steinsson (2014) and use a Bartik (shift-share) instrumental variable for state spending. This strategy is based on two characteristics of military spending: first, national military spending is dominated by geopolitical events; second, given a rise in national expenditure, there is a differential increase in some states — such as California — relative to others — such as Illinois — consistently across the sample timeframe. The identification assumption is that the US did not embark on military buildups or drawdowns — such as those associated with the Vietnam War — to differentially benefit those states that consistently receive more of the spending (e.g. California) relative to those that consistently receive less (e.g. Illinois). A typical endogeneity concern with military spending is that the US went to war to benefit the domestic economy. With this Baritk-style identification strategy, this would not invalidate the identification assumption. What would be problematic, is if the US went to war to benefit California relative to Illinois. This violation seems less plausible.

To implement my framework, I also require data on US interstate trade flows during this period. However, the standard data source for interstate trade within the US — the Commodity Flow Survey — only began publishing data in 1993, which is towards the end of my sample timeframe.[12] Fortunately, I discovered a precursor survey — the Commodity Transportation Survey — that published interstate manufacturing trade flows for the year 1977. Perhaps a reason why this data has not been used in the literature is due to it only existing in scanned-image form on the US National Archives.[13] I transcribed this data to

[11]For the electronic database, see Record Group 330: Records of the Office of the Secretary of Defense at https://www.archives.gov/research/electronic-records/reference-report/federal-contracts.

[12]See: https://www.census.gov/programs-surveys/cfs.html.

[13]Weiss (1972) is the only paper I'm aware of. They use the much more limited 1963 iteration of the

electronic form and use this for my measure of interstate trade.

Turning to the results. To quantify the spatial mechanism, I use the model to determine how much a transfer to a state — for each state — causes national GDP to change, where the transfer is financed from all other states proportionately according to their GDP. I find large heterogeneity depending on the state receiving the transfer; for a \$1 transfer, the change in national GDP at the 5$^{\text{th}}$ and 95$^{\text{th}}$ percentiles are $-\$0.57$ (Ohio) and \$0.57 (California) respectively. The change in national GDP can be negative precisely because it is a transfer: if the receiving state is a low-return state (such as Ohio), then the reduction in GDP in the financing states outweighs the increase in GDP in the receiving state, leading to a net negative change in national GDP.

To understand this relative to canonical New Keynesian and Neoclassical mechanisms, it's helpful to consider an extreme example. Take the case where the spending is financed entirely through contemporaneous taxation, and the behavioral response of consumers is such that they reduce consumption today to exactly offset the tax burden; that is, they do not adjust hours worked or amount borrowed. The canonical mechanisms will imply that the fiscal multiplier in this scenario is zero: government consumption today has gone up by \$1, but private consumption has gone down by \$1, meaning zero net change in demand today and therefore zero change in output. However, in the same scenario, the spatial mechanism implies that if the government spends this dollar entirely in California then national GDP will in fact increase by \$0.57. This is because net (government plus private) demand in California has increased (it has received \$1 in government spending, yet private demand has gone down by $< \$1$ as the government spending is financed by all states),[14] even though national demand has not changed. The resulting increase in California's GDP caused by this increase in demand in California outweighs the decrease in GDP in all other states, such that national GDP increases.

What is the mechanism that causes national GDP to increase in response to a state, such as California, receiving a transfer? There are two elements. The first and main channel is shared with the canonical fiscal multiplier mechanisms: conditional on a net demand change, the resulting change in GDP can be magnified due to the presence of factors such as sticky prices, labor-consumption complementarities and economies of scale. Sufficient strength in either of these can cause the supply elasticity to become negative, and hence the magnification of output, as discussed earlier. My model is agnostic to the microfoundation at work, but I provide auxiliary quantitative analysis showing that my estimated value of the

survey.

[14]Of course, demand for California goods includes demand by other states, which has decreased due to the transfer. However given home bias (e.g. from trade costs), the same conclusion follows as the concentration of demand is shifted to California.

supply elasticity is easily rationalized by plausible strengths of these channels, as guided by the literature. The second channel is spillovers between states. Due to interstate trade, the increase in GDP in California results in its residents and firms increasing their consumption of goods from other states too. This attenuates the reduction in GDP in other states that would otherwise occur due their financing of the transfer to California.

What explains the heterogeneity I find across the states? Qualitatively, I find that spending in states that are smaller (in terms of GDP) and more closed to trade (import share) generates larger changes in national GDP. These both follow from the supply curve being downward-sloping (inferred from the estimated supply elasticity) and convex (assumption in the model): geographically concentrated spending results in the greatest increase in GDP. The convexity implies the returns are diminishing with size, hence smaller states having greater increases in output. If the state is open to trade, then the gains from spending percolate out to the rest of the country, and it's as if the spending is not concentrated at all, but distributed; hence states being more closed to trade tend to have greater increases in GDP.

These results depend in part on the structural assumptions imposed in the model, therefore I provide some direct evidence on my findings. It's not possible to completely validate my results, this is why I impose the structure to begin with (because of the dimensionality problem). However I am able to (approximately) non-structurally validate some statistics. In particular, I look at heterogeneity in the local fiscal multiplier: the effect on a state's GDP from spending in that state. Both structural and non-structural estimates coincide: states that are smaller and more-closed to trade exhibit greater local fiscal multipliers.

Finally, turning to the policy-relevant object of interest: the (aggregate) fiscal multiplier. The literature provides estimates of the fiscal multiplier that is unconditional on the location of spending; this is about 0.5 for the US during my time period. My estimates provide a correction to this due to the spatial mechanism that accounts for changes in the geographic distribution of spending across time, holding everything else fixed. With this correction, I find that the fiscal multiplier varies about 0.5 with a standard deviation of 0.25. This is big, 50% relative to the average. To help quantify this economically, I consider counterfactual geographic distributions of spending and find that long-run annual growth can be increased 4% relative to the factual rate.

What is the implication for policy of these findings? Historically, economists and policymakers were content with a single fiscal multiplier, the 0.5. More recently, a revolution has taken place with *state-dependent* fiscal multipliers; it is now standard to acknowledge that multipliers tend to be greater in times of recession (with values of $1.5 - 2$ not unexpected) than in booms. My results suggest an analogy with *geography-dependent* fiscal multipliers, proposing multipliers of greater magnitude are to be expected when spending is concentrated geographically.

1.1 Outline

The rest of this paper is organized as follows. I first discuss the literature in section 1.2. Then, in section 2 I develop the theoretical framework, derive the fiscal multipliers as implied by the theory and present the sufficient statistics for identification. In section 3, I present the empirical framework. I first describe the data, the empirical application and the Bartik instrument. Second, I present the structural identification methodology using the model-implied instrumental variable strategy. And third I present the structural parameter results and offer a discussion of their estimated values. In section 4, I present the main results of the paper - the fiscal multiplier estimates - provide intuition on the mechanisms in the model underlying their values, and discuss the resulting fiscal policy implications. In section 5, I conclude.

1.2 Literature

This paper relates to a large empirical literature on fiscal multipliers - see Ramey (2011) for an excellent review. In particular, mine is closest to the more recent strand that uses exogenous military variation in a regional empirical framework, notably Nakamura and Steinsson (2014) who estimate relative local fiscal multipliers.[15] Also Auerbach and Gorodnichenko (2013), who estimate the fiscal multiplier from spending in neighboring countries as function of the trade integration. One major point of departure is the research question: these papers study the average local effect from a spending transfer (the local multiplier), whereas I study the heterogenous aggregate effects from a spending transfer, allowing me to determine how the distribution of spending affects fiscal multiplier magnitudes. This question shares an analogy with Ramey and Shapiro (1998), who analyze how spending across industries affect the fiscal multiplier, and find that costly capital reallocation can magnify the multiplier.

Bridging the fiscal multiplier and trade literatures, I analyze the fiscal multiplier mechanism in a *gravity* model of trade.[16] Building off the generalized spatial framework of Allen et al. (2014), I integrate a rich - yet tractable - spatial analysis, going beyond the standard two-region small-open economy model typical in macroeconomic theory. My approach connects the fiscal multiplier mechanism to the Home Market Effect, a mechanism studied

[15] Dupor and Guerrero (2017) also study fiscal multipliers in the context of US Federal defense procurement.

[16] For seminal contributions to the gravity models of trade see Anderson (1979), Eaton and Kortum (2002), and Melitz (2003).

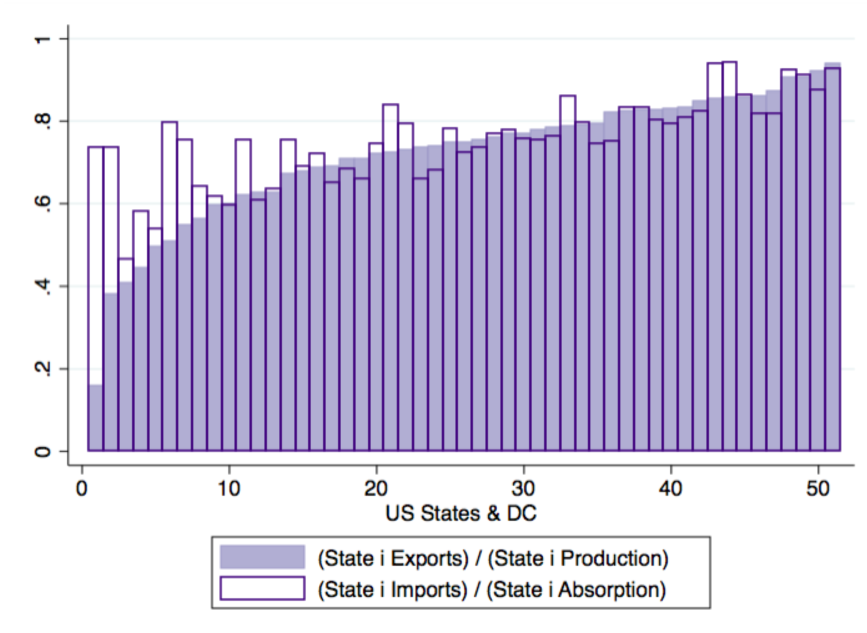


Figure 1: Measures of regional openness through trade

Notes. Manufacturing only. Absorption ≡ Production + Imports - Exports.
Datasource. Commodity Transportation Survery (1977).

extensively in trade, that generates multipliers from the interaction of scale economies and segmented spending.[17] One conceptual difference is that the fiscal multiplier mechanisms tend to focus on a temporal shift of expenditure, whereas the home market effect focuses on a spatial shift of expenditure.

My analysis more broadly relates to the study of local labor market shocks, a growing trend in the trade literature with early work by Autor et al. (2013); more recent studies take greater focus on heterogenous response - see Monte et al. (2015) - and the role of spillovers - see Adao et al. (2018) and Stumpner (2014). For a study on the aggregation of local shocks, see Carvalho et al. (2016). Similar to papers in this area, my paper utilizes the exact hat algebra as pioneered by Dekle et al. (2008), which allows one to avoid explicit estimation of many parameters of the model if one is only interested in counterfactuals in changes, rather than levels.[18] My structural identification strategy utilizing model-implied instrumental variables builds on related studies here, in particular Allen et al. (2014) and Adao et al. (2018).

[17]See Krugman (1979) and Helpman and Krugman (1985) for seminal work on the home-market effect in two-region models; see Behrens et al. (2009) and Matsuyama (2017) for many-region theoretical analysis. See Costinot et al. (2016) for an empirical test of the Home Market Effect. See Devereux et al. (1996) for a fiscal multiplier model analysis in the context of increasing returns to scale.

[18]See Adao et al. (2017) for a general framework of this.

2 Theory

In section 2.1, I present the theoretical framework used to model the spatial interactions between locations due to trade.[19] In section 2.2, I derive the fiscal multiplier in this framework and discuss the spatial implications for it. In section X, I present my theoretical results implied in this framework for the fiscal multiplier.

2.1 Theoretical Framework

The nation consists of locations $i \in \{1, ..., N\}$ and is static. In each location there is a demand equation and supply equation, trade between all locations, a federal government, and market clearing. The equilibrium can be summarized by the following conditions.

2.1.1 Demand

X_{ij} is the sum of private and public nominal (dollar) demand from location j for products produced in location i and is described by the following equation

$$X_{ij} = \underbrace{\left(\frac{p_{ij}}{P_j}\right)^{1-\phi} E_j}_{private} + \underbrace{G_i^{transfer} \cdot \mathbb{1}[i=j]}_{public} \tag{1}$$

where $\mathbb{1}[i=j]$ is indicator that is 1 if $i=j$ and 0 otherwise. Private demand is described by a constant elasticity of substitution relation where E_j is total private expenditure by from location j, p_{ij} is the consumption price faced by j for products produced in i, and $P_j \equiv \left(\sum_i p_{ij}^{1-\phi}\right)^{\frac{1}{1-\phi}}$ is the ideal price index in j. Public demand for goods produced in i is given by $G_i^{transfer}$ and is described in section 2.1.3. I refer to the unobservable parameter ϕ as the *demand elasticity*, and it is equal to the elasticity of substitution between goods produced in different locations.

2.1.2 Supply

q_i is the quantity of goods produced in location i and is described by the following equation

$$q_i = A_i \left(\frac{p_i}{P_i}\right)^{\psi} \tag{2}$$

[19] This is largely based on the *universal gravity* framework of Allen et al. (2014), extended to include a government sector.

p_i is the production price in i, and A_i is an exogenous productivity shifter. I refer to the unobservable parameter ψ as the *supply elasticity*, and it is equal to the elasticity of output with respect to the production price, holding the price index fixed.

2.1.3 Government

Each location receives a real transfer $g_i^{transfer}$ by the federal government, which is related to nominal transfers through the price index in that location by

$$g_i^{transfer} \equiv \frac{G_i^{transfer}}{P_i} \tag{3}$$

where nominal transfers are constrained to sum to zero

$$0 = \sum_i G_i^{transfers} \tag{4}$$

The exogenous shocks I consider are arbitrary real spending by each location, g_i, which I define by

$$g_i^{transfers} \equiv g_i - by_i \tag{5}$$

where $b \in \mathbb{R}$ is endogenous. This has a very natural interpretation. g_i is an arbitrary distribution of government spending. The spending is financed through transfers from each state proportionally to their GDP, equal to by_i (b takes its equilibrium value so that $g^{transfers}$ satisfies the governments budget constraint, equation (4)). The net transfer each state therefore receives is $g_i^{transfers} = g_i - by_i$.[20]

2.1.4 Geography

Trade in the product market is subject to iceberg trade costs, τ_{ij}, (with the normalization $\tau_{ii} \equiv 1$) linking the production price and consumption price as follows

$$p_{ij} = \tau_{ij} p_i \tag{6}$$

Intuitively, to consume 1 product, τ_{ij} must be shipped and $\tau_{ij} - 1$ "melts" along the way.

[20] This is done for two reasons. 1) The first is that in the empirical section, government spending is not necessarily constrained to be transfers. 2) The second is that $\{g_i^{transfers}\}_i$ is not a valid set of exogenous shocks. Due to equation (3), $0 = \sum_i G_i^{transfers} = \sum_i P_i g^{transfers}$, transfers in at least one location must be determined endogenously. A simple example is choosing $\forall i : \ g_i^{transfers} > 0$; for equation (3) to be satisfied, it must be that $P_k < 0$ for some k. Negative prices are not consistent with an equilibrium. Thus, $g_i^{transfers}$ in at least one location must be determined endogenously so that (3) is satisfied.

2.1.5 Product Market Clearing

Total (nominal) production in location i, $Y_i \equiv p_i q_i$, is equal to total demand from all locations

$$Y_i = \sum_j X_{ij} \tag{7}$$

2.1.6 Local Labor Markets

All income from production in i goes to private consumption from i, allowing for exogenous nominal trade (im)balances, TB

$$Y_i = E_i + TB_i \tag{8}$$

Walras' Law holds in this framework therefore $\sum_i TB_i = 0$.[21]

2.1.7 Price Normalization

The equilibrium is indeterminate up to scale of prices, therefore I set the normalization for some $i = u$[22]

$$p_u \equiv 1 \tag{9}$$

2.1.8 Equilibrium

Equilibrium is attained in this framework when equations (1), (2, (4), (6), (7), (8), (9) hold.

2.2 The Fiscal Multiplier in a Spatial Framework

2.2.1 Cross-Location Local Fiscal Multiplier

To derive the fiscal multiplier in this framework, I start by combining the seven equilibrium conditions of section 2.1, log-linearize, and solve for the change in real output in each location as a function of real government spending in each location, holding fixed all other exogenous variables of the model. The result is the following

$$\frac{\mathrm{d}y_i}{y_i} = \sum_{j \in \{1,...,N\}} \Lambda_{ij}^{transfers} \frac{\mathrm{d}g_j}{y_j} \tag{10}$$

[21]See appendix A.1.2 for proving Walras Law holds in this framework.

[22]All theoretical results relevant for my empirical analysis are in real terms, therefore the choosing of $u \in \{1, ..., N\}$ is inconsequential. Nonetheless, inclusion of this condition is vital for solving the model in order to derive the fiscal multiplier.

where $\mathrm{d}y_i$ is the infinitesimal change in real output, $y_i \equiv \frac{Y_i}{P_i}$, $\mathrm{d}g_j$ is the infinitesimal change in real government expenditure, g_i, and the matrix Λ is a function of all endogenous and exogenous variables of the model,

$$\Lambda^{transfers} : \Omega^{all} \rightarrow \mathbb{R}^{N^2}$$

where $\Omega^{all} \equiv \{\{y_i, p_i, b, g_i, \{A_i\}_i, \{\tau_{ij}\}_{ij}, \phi, \psi\}$. See appendix A.1 for the functional form of $\Lambda^{transfers}$ and all associated derivations.

Intuitively, the object $y_i \Lambda_{ij}^{transfers} y_j^{-1}$ gives the dollar change in i output caused by a \$1 change in j government expenditure, where the expenditure is funded by transfers from all locations proportional to their output.[23] Note that this is the natural cross-location extension of the familiar local fiscal multiplier, which in this framework is given by $y_i \Lambda_{ii}^{transfers} y_i^{-1} \equiv \Lambda_{ii}^{transfers}$, the dollar change in output in i due to \$1 spending in i.

2.2.2 Aggregate Effects of Localized Spending

The fiscal multiplier object of typical interest in macroeconomics relates how a change in spending affects aggregate output[24]

$$y_{agg} = \sum_i y_i \tag{11}$$

The relation in my framework is derived simply by inserting equation (10) into equation (11), giving

$$\mathrm{d}y_{agg} = \underbrace{\sum_{i \in \{1,\ldots,N\}, j \in \{1,\ldots,N\}} y_i \Lambda_{ij} y_j^{-1}}_{(\dagger)} \underbrace{\mathrm{d}g_j}_{(\dagger\dagger)} \tag{12}$$

This is the inner product of two objects: (†), the change in aggregate output due to location j receiving a transfer; and (††), the transfer received by j. The key implication is that even if the change in spending across all locations is zero-sum (only transfers are considered), the effect on aggregate output needn't be zero, given that (†) isn't zero.

To determine the implications of this for the aggregate fiscal multiplier, aggregate gov-

[23]The theoretical framework easily accommodates different transfer rules. For example, all spending being funded entirely by transfers from California.

[24] The definition of y_{agg} in equation (11) is by assumption. Any statement about *real* aggregate output requires an aggregate price index, which in turn requires a statement about aggregate utility. I use the definition in equation (11) as this is simple, intuitive and most immediate. In terms of aggregate utility, it corresponds to a planner with CES utility across goods produced in each location, with elasticity of substitution ϕ, and who pays P_i for goods produced in i.

ernment spending must be allowed to vary, otherwise the aggregate fiscal multiplier is ill-defined.[25]. I constrained aggregate expenditure to be zero in my theoretical framework. However, as I only consider the effects on output up to first order, a change in aggregate expenditure, $g_{agg} = \sum_j g_j$, that is spent is spent proportional across states according to their GDP, is going to enter equation (12) additively and linearly.[26]

First, looking at how this changes the relation at the local level, equation (10). Denote the effect of $\frac{\mathrm{d}g_{agg}}{y_{agg}}$ on $\frac{\mathrm{d}y_i}{y_i}$ by $\Lambda_i^{aggregate}$, then

$$\frac{\mathrm{d}y_i}{y_i} = \underbrace{\sum_{j\in\{1,\dots,N\}} \Lambda_{ij}^{transfers} \frac{\mathrm{d}g_j}{y_j}}_{(*)} + \underbrace{\Lambda_i^{aggregate} \frac{\mathrm{d}g_{agg}}{y_{agg}}}_{(**)} \tag{13}$$

What this equation shows is that the effect of a change in aggregate government spending on GDP in location i can be decomposed into two terms: $(**)$ the effect due to an increase in aggregate spending that is distributed proportionally, such that the change in local spending equals the change in the local tax burden; $(*)$ the differential effect due to spending actually being concentrated in some regions, such that some locations receiving spending beyond their local tax burden (i.e. a transfer). It is $(*)$ that is absent from single-location models (as local and aggregate are the same, and aggregate spending must equal the aggregate tax burden) and generates a novel *spatial mechanism* for fiscal multipliers. Distinctively, as only transfers are considered in $(*)$, this mechanism is independent of how the spending is financed.

Second, at the aggregate level, equation (12), this becomes

$$\frac{\mathrm{d}y_{agg}}{\mathrm{d}g_{agg}} = \underbrace{\sum_{i\in\{1,\dots,N\}, j\in\{1,\dots,N\}} y_i \Lambda_{ij}^{transfers} y_j^{-1} \frac{\mathrm{d}g_j}{\mathrm{d}g_{agg}}}_{(+)} + \underbrace{\sum_i \Lambda_i^{aggregate} \frac{y_i}{y_{agg}}}_{(++)} \tag{14}$$

This is the aggregate fiscal multiplier. Analogous to above, the term $(++)$ is the effect on aggregate GDP due to spending that is distributed proportionally; and the term $(+)$ is the differential effect due to spending actually being concentrated in some regions.

What this equation shows is that, once we go beyond a single-location model, the aggregate fiscal multiplier depends on the distribution of location (described by the vector $\left\{\frac{\mathrm{d}g_j}{\mathrm{d}g_{agg}}\right\}_j$). The term $(+)$ captures the component of the aggregate fiscal multiplier that is due to the spatial mechanism.

[25]Ramey (2011) briefly considers a multiplier due to transfers and concludes its value must be zero or infinity.

[26]I use the same aggregation as used for y_{agg}. For the same reasons discussed in footnote 24, this isn't the only option but is a natural one.

2.3 Theoretical Results

I proceed here by deriving two theoretical properties of $\Lambda^{transfers}$. The first is a sufficient statistic helpful for identifying $\Lambda^{transfers}$. The second considers an $N = 2$ special and describes how the fiscal multiplier depends on geography.

2.3.1 Sufficient Statistics

The first result is presented in the following proposition.

Proposition 1 (Sufficient Statistics)**.** *The cross-location effects of transfers on locations' outputs admit the following functional dependence on observables and unobservables*

$$\Lambda^{transfers} : (s^G, s^{Im}, s^{Ex}, \phi, \psi) :\longrightarrow \mathbb{R}^{N^2}$$

where $s_i^G \equiv \frac{G_i}{Y_i}$ *is the government spending share,* $s_{ij}^{Im} \equiv \frac{X_{ij}}{E_j}$ *is the import share and* $s_{ij}^{Ex} \equiv \frac{X_{ij}}{Y_i}$ *is the export share.*

Proof: see appendix A.2.

What this proposition says is conditional on observable government spending shares, import shares and export shares, the unobservable demand ϕ and supply ψ elasticities are sufficient statistics for identification of the full matrix $\Lambda^{transfers}$. That is, even though $\Lambda^{transfers}$ directly depends on all the variables and parameters of the model, Ω^{all}; knowledge of Ω^{all} in it's entirety is not necessary for identification.[27]

Intuitively, proposition 1 allows me to effectively change the identification problem from directly identifying $\Lambda_{ij}^{transfers}$ for all i, j pairs, to instead identifying ϕ, ψ which indirectly identify $\Lambda^{transfers}$. That is, I've reduced the number of parameters to identify down from N^2 to 2.

2.3.2 Spatial Mechanism Theoretical Predictions

What does my theoretical framework theory predict about the magnitude and sign of the fiscal multiplier spatial mechanism? In general, it's difficult to say as this is a problem of high-dimensionality, depending on the entire network of N^2 trade flows. However, to get intuition, I derive a result in the following proposition for a special case.

[27] This relates to a large literature in trade on *Exact-Hat Algebra*, with seminal work by Dekle et al. (2008). My result specifically closely follows the work of Allen et al. (2014).

Proposition 2 (Aggregate Fiscal Multiplier and Internal Geography)**.** *Let $N = 2$, fix $Y_1 = Y_2 \equiv Y$, and consider a transfer $dG_1^{transfers} + dG_2^{transfers} = 0$. The change in real aggregate GDP is given by*

$$\frac{dy_{agg}}{dg_1} = \left\{ \sum_{i=1}^{2} y_i \left(\Lambda_{i1}^{transfers} - \Lambda_{i2}^{transfers} \right) y_1^{-1} \right\}$$

Under the perturbation $\delta \equiv \{dX_{11} + dX_{12} = 0, dX_{21} = dX_{22} = 0\}$, a sufficient condition for the following

$$\frac{dy_{agg}}{dg_1} > 0$$
$$\frac{d}{dX_{11}} \frac{dy_{agg}}{dg_1} > 0$$

is

$$\psi < 0, \qquad 1 - \phi - \psi > 0, \qquad \Lambda_{11}^{transfers} - \Lambda_{12}^{transfers} > 0, \qquad X_{11} > X_{22} > \frac{Y}{2}$$

Proof. *See appendix A.3.*

This proposition says the following. Consider two locations of equal size ($Y_1 = Y_2$). Make the natural assumption that the majority of goods are sold locally ($\forall i : X_{ii} > Y/2$),[28] and assume for location 1 this is even more the case ($X_{11} > X_{22}$), i.e. location 1 is more closed in terms of trade. Under the assumption that a transfer to a location is actually locally beneficial for that location in terms of GDP ($\frac{\mathrm{d}y_i}{\mathrm{d}g_i} = \Lambda_{11}^{transfers} - \Lambda_{12}^{transfers} > 0$),[29] and given a restriction on the parameters ($1 - \phi - \psi > 0$), then a transfer to that location ($\mathrm{d}G_1^{transfers} = -\mathrm{d}G_2^{transfers}$) also increases GDP on aggregate ($\frac{\mathrm{d}y_{agg}}{\mathrm{d}g_1} > 0$).[30] Furthermore, the more closed that location 1 becomes ($\mathrm{d}X_{11} > 0$), the greater the increase in aggregate GDP ($\frac{\mathrm{d}}{\mathrm{d}X_{11}} \frac{\mathrm{d}y_{agg}}{\mathrm{d}g_1} > 0$).

This result implies that geographically concentrating spending can generate greater increases in aggregate GDP compared to spending that is distributed geographically. Moreover, and importantly, even if spending is concentrated nominally (i.e. $\mathrm{d}G_1 > \mathrm{d}G_2$), if the spending is concentrated in a location that is very open to trade ($X_{11} \not> X_{22}$), then it's as if, effectively, the spending is not concentrated geographically at all, but instead distributed across the regions (as the incidence of the spending leaks into the other location via the trade flows) and will actually lead to a reduction in aggregate GDP.

[28] This is known as *home bias* and is prevalent in the trade literature. See e.g. XX

[29] $\Lambda_{11}^{transfers} - \Lambda_{12}^{transfers} < 0$ is reflective of an unstable equilibrium in which the supply curve is more negatively-sloped than the demand curve. See appendix XX.

[30] Note that this isn't guaranteed by $\Lambda_{11}^{transfers} - \Lambda_{12}^{transfers} > 0$ as location 2 receives a negative transfer, having a negative effect on GDP there.

What does this suggest about spending in a country composed of many regions, that is, in which $N > 2$? Just like the *state-dependent* fiscal multiplier in the macroeconomic literature, in which fiscal multipliers are greater in times of recession than in normal times; proposition 2 suggests a meaningful analogy with *geography-dependent* fiscal multipliers, in which fiscal multipliers are greater when spending is concentrated geographically.

The purpose of the empirical and quantitative sections is to investigate and quantity this geography-dependence of fiscal multipliers in the context of the geography of the US.

2.4 Discussion of the Spatial Mechanism

The spatial mechanism of the fiscal multiplier described in the preceding section is best understood by making an analogy to the standard fiscal multiplier models. In order for the fiscal multiplier to be non-zero, two components are required. 1) A market must experience a net change in demand. 2) A magnification effect in output is exhibited when a net demand change is experienced.

1) Net change in market demand. Typically in macroeconomic models of the fiscal multiplier the government taxes (contemporaneously or in deficit) households and spends the revenue on firm output. Ceteris paribus, the taxation reduces private demand for output by \$1 (say), and the spending increases public demand for output by \$1. The fiscal multiplier is the description of the effect on output from the *combination* of these actions.[31] Holding everything else fixed, the change in total demand is \$0, and therefore, regardless of any magnification mechanisms being present, the fiscal multiplier is identically zero, as equilibrium output will not respond as the demand curve has not shifted.

This illustrates that, when ceteris paribus is lifted, there must be a mechanism initiated from either the taxation or spending that causes the change in total demand to be non-zero. In standard macroeconomic fiscal multiplier models, this manifests through an income effect on labor supply. When households are taxed (contemporaneously or in deficit), their lifetime income is reduced. This creates a negative income effect which, assuming leisure is a normal good, causes labor supply to increase. Therefore, private demand decreases by less than \$1, while public demand still increases by \$1 as before, creating positive net increase in total demand.

Distinctively, this change in net demand is entirely dependent on the behavioral response of agents to taxation. This is where the spatial mechanism diverges. Acknowledging that spending by the government is geographically segmented, then spending can be simulta-

[31] Although the separate effect of each may be of interest, separate identification is impossible due to accounting: the dollars spent by the government must come from somewhere.

neously increased in one region while decreased in another, so that total expenditure, and therefore taxation, is unchanged. The result is a net increase in total market demand in the first region. It's public demand increases by \$1, due to the transfer. It's private demand decreases as the second region now importing less (as it is poorer due to financing the spending but receiving none of it), but this reduction is by less than \$1, as the second region reduces spending from all regions, not just the first. The novelty here is that the net demand change is now entirely dependent on the behavioral response of agents to the spending (that is, adjustments in imports).

This generates a positive demand shift in the first region, but of course is accompanied by a negative demand shift in the second. In order for there to be a net effect on aggregate output (and create a non-zero fiscal multiplier), there must be sufficient geographic asymmetry between financing and beneficiary locations a transfer between symmetric locations will cancel out.

2) Magnification Effect. Given a net change in market demand, the demand curve shifts out. This shift is, as described above, net of taxation or reduced imports, and therefore will be less than \$1, and possibly much less. How are fiscal multipliers close to or even greater than one therefore possible? Some form of magnification mechanism is required.

In standard macroeconomic models, this is predicated on mark-ups that countercyclical.[32] Intuitively, first consider the case where, under fixed mark-ups, output increases one-for-one with the demand shift. The fiscal multiplier here will be small, as the demand shift and therefore the output increase is less than the government spending increase (and the fiscal multiplier equals $= \Delta Y/\Delta G$). If the mark-up is countercyclical, then, as output increases, the mark-up decreases. Private demand therefore increases as purchasing power has increased (mark-up is inversely related to the real wage), thus further increasing output.[33] The result is a magnification of the increase in equilibrium output, raising the value of the fiscal multiplier.

My framework naturally allows me to generalize this magnification effect beyond countercyclical mark-ups. The starting point is understanding precisely what constitutes a magnification mechanism. Given a shift in the demand curve, equilibrium output can increase by more than one-for-one only if the supply curve is downward-sloping (see figure 2). In my framework, the slope of the supply curve is controlled by the supply elasticity, ψ, with a

[32] See **?**.

[33] This is the basis of the New-Keynesian model of the fiscal multiplier, and in modern models is generated by imposing sticky prices, and can generate fiscal multipliers greater than one (see Christiano et al. (2011)). The Neo-Classical model of the fiscal multiplier does not have such a magnification mechanism, but instead can generate larger fiscal multipliers by having strong income effects so that the net change in market demand is not small (see **?**). Of course, here, the fiscal multiplier is bounded above by one.

downward-sloping curve generated with $\psi < 0$.

A downward-sloping supply curve may go against priors, but it's important to realize this is a general equilibrium supply curve (notice the absence of wages in the supply equation (2)), and therefore combines, for example, the optimal pricing conditions from production and optimal labor supply. A downward-sloping supply can be generated from, for example, countercyclical mark-ups, increasing returns to scale, and labor-consumption complementaries.[34] These are the same features that generate large multipliers in canonical fiscal multiplier models in the literature.[35]

A unique feature about my model is that I am able to nest all these magnification mechanisms in a single parameter, the single supply elasticity ψ. The allows me to be agnostic about what exactly the underlying mechanism operating is.[36] To illustrate the relation between ψ and potential underlying mechanisms, I add more structure to the model in appendix A.4 and derive the associated supply elasticity. This yields

$$\psi = \frac{1 - \sigma^{-1}}{\frac{1+\nu^{-1}-\theta}{1+\chi} + \xi - (1 - \sigma^{-1})} \tag{15}$$

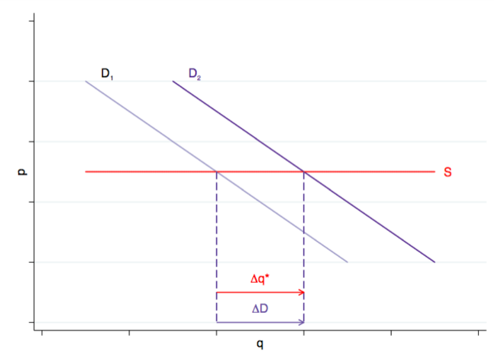
Each of the parameters on the righthand-side of equation (15) control different underlying mechanisms. See table 1 for a description of these parameters. This exercise provides insight into what underlying mechanisms are theoretically consistent with a magnification mechanism ($\psi < 0$) in, and the magnitude of, the fiscal multiplier. I undertake this exercise in section 3.5.2.

A Static Framework for Fiscal Multipliers? A final note is in order regarding the absence of dynamics from my framework. The canonical fiscal multiplier models are rich along the temporal dimension, but extremely limited along the spatial dimension (most often absent). My approach takes the opposite approach, being very rich spatially but static. The primary limitation is that I can say nothing about dynamics, and all my inference is regarding the contemporaneous *impact multiplier*. However, I'm nonetheless able to account for common magnification mechanisms, as illustrated above, and importantly, able to do so tractably. This creates a complementary framework to the macroeconomic literature, that is able to acutely probe the spatial implications for the fiscal multiplier, both theoretically,

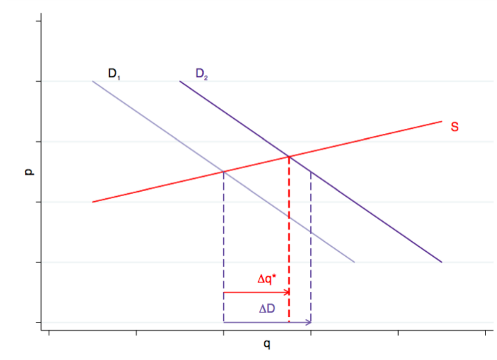
[34]On the other hand, when $\psi > 0$ (figure 2b), supply is upward-sloping, and the change in equilibrium output is less than the demand shift, leading to small multipliers. This is reflective of decreasing returns to scale in production, or inelastic labor supply; anything that makes production more costly at greater scales.

[35]See Devereux et al. (1996) for scale economies. See Nakamura and Steinsson (2014) for sticky-prices and labor-consumption complementarities.

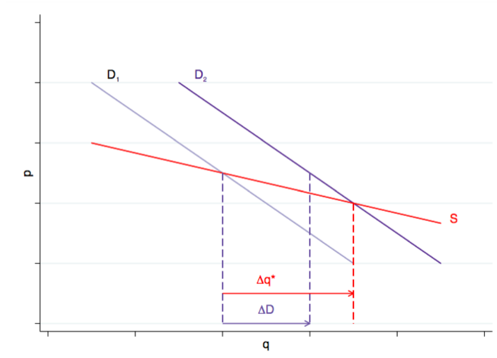
[36]Typical macroeconomic models of the fiscal multiplier have rich dynamics which preclude expression of these mechanisms via a single parameter, such as ψ in my framework.



(a) $\psi = 0$



(b) $\psi > 0$



(c) $\psi < 0$

Figure 2: Stylized response of equilibrium output to demand shock for various ψ.
Notes. 2a: the output response is equal to the size of the demand shock. 2b: the output response is less than the size the of the demand shock. 2c: the output response is greater than the size the of the demand shock.

as described here, and empirically, in section 3.

3 Empirical Framework

In this section I detail my strategy to identify the two unobservable supply and demand elasticities, ψ, ϕ, then subsequently present and discuss the estimated values. Conditional on observable spending, import and export shares, these two elasticities are sufficient to identify the $\Lambda^{transfers}$, which describes the component of the fiscal multiplier due to my spatial mechanism.

First, in section 3.1, I explain why I even require a structural approach. In section 3.2, present my structural identification strategy. In section 3.4 I describe the data sources used. Finally, in section 3.5, I present the elasticity estimation results and discussion of these.

Parameter	Name	Generate $\psi < 0$	Description
σ	Intertemporal Elasticity of Substitution	$\sigma < 1$	Income effect on labor dominates substitution effect
ν	Frisch Elasticity of Labor Supply	—	Not possible. $\nu \gg 1$ accommodates*
χ	Elasticity of (production technology) productivity with respect to labor	$\chi > 0$	Increasing returns to scale
ξ	Elasticity of the mark-up with respect to output	$\xi < 0$	Sticky prices
θ	Labor-Consumption complementarities, $\propto \partial^2$utility$/\partial L \partial c$	$\theta > 0$	Edgeworth Complements

Table 1: Microfoundations theoretically consistent with a fiscal multiplier magnification effect, $\psi < 0$

Notes. ν:* without any of the other parameter inequalities being satisfied, an arbitrary Frisch Elasticity is unable to generate $\psi < 0$; however, with one of the other inequalities satisfied, a large Frisch Elasticity makes ψ even more negative.

3.1 Why use a Structural Solution?

To understand why a structural solution is taken, and why geographic heterogeneity and interdependence are the underlying limitations, consider what the non-structural research design would require. Because of geographic heterogeneity, we need to estimate the effect on national GDP distinctly by each state of spending. Formally, the following regression[37]

$$\frac{\Delta y_{agg,t}}{y_{agg,t}} = \sum_{j=1}^{N} \tilde{\beta}_j \frac{\Delta g_{jt}}{g_{jt}} + \varepsilon_t, \qquad t \in \{1, ..., T\} \tag{16}$$

where $y_{agg,t}$ is aggregate (national) GDP and Δ indicates time differences (see sections 2.2.2 and 3.3 respectively). Now, the number of observations is the number of time periods, T; the number of parameters is the number of locations, N $(= |\tilde{\beta}|)$. To be identified, we require $T \geq N$, and ideally $T \gg N$. Typically, however, in an empirical setting we are constrained along the time dimension, resulting in a parameter problem: $T \lesssim N$.[38] Identification of $\tilde{\beta}$ is

[37] Abstracting from constants and the error structure.

[38] Even if we could use time asymptotics, a conceptual limitation arises. In reality, $\tilde{\beta}_j$ is not time invariant, and is likely to vary considerably over long time horizons. An (time-) averaged measure of this, which is what will be identified using time asymptotics, is therefore of limited value as the average is likely far from the marginal for a time period of interest.

not feasible using (16).[39]

Alternatively, we could run the regression at the state level. If there was no geographic interdependence, then it would be correct to run the following regression[40]

$$\frac{\Delta y_{i,t}}{y_{i,t}} = \tilde{\beta}_i \frac{\Delta g_{it}}{g_{it}} + \varepsilon_{it}, \qquad t \in \{1, ..., T\}, i \in \{1, ..., N\} \tag{17}$$

where $\tilde{\beta}_i$ is both the effect of spending in state i on state i's GDP, and on national GDP. In this case we would be identified, as there are N parameters, and NT observations. However, because states are interdependent, we need to account for the effect of spending in a state on the GDP of a state for all state-state pairs. This means we must modify (17) to the following

$$\frac{\Delta y_{i,t}}{y_{i,t}} = \sum_{j=1}^{N} \beta_{ij} \frac{\Delta g_{jt}}{g_{jt}} + \varepsilon_{it}, \qquad t \in \{1, ..., T\}, i \in \{1, ..., N\} \tag{18}$$

We are now back to having a parameter problem: N^2 $(= |\beta|)$ parameters, NT observations, ideally requiring $T \gg N$.

Thus, to make progress, some form of dimensionality reduction on β is required. This is where the structural solution comes in. I change the identification problem from identifying the N^2 parameters to instead only identifying two: ϕ, ψ.

3.2 Identification

In section 3.2.1, I impose an assumption common in the literature and explain why I can be agnostic about how the government finances its expenditure. In section 3.3, I take the empirical analogue of my theoretical framework. In section 3.3.1, I present my structural identification framework to recover ψ, ϕ, conditional on a source of exogenous variation in government spending. In section 3.3.2, I detail the source used.

[39] If the the (exogenous) spending in each location is uncorrelated, then instead of equation (16), one could run $\frac{\Delta y_{agg,t}}{y_{agg,t}} = \tilde{\beta}_j \frac{\Delta g_{jt}}{g_{jt}} + \varepsilon_{it}$ separately for each $j \in \{1, ..., N\}$. This would solve the parameter problem but places a very high demand on the research design: a set of N instruments for government that are uncorrelated with one another. Because the states of the US are highly integrated − politically and economically − it's much more likely that movements in spending (be them endogenous or exogenous) are correlated with one another.

[40] This is correct even if spending is correlated across states (assuming that states are not interdependent). This is also correct under the converse: uncorrelated spending and interdependent states (but the problem here is as in footnote 39).

3.2.1 Agnosticism regarding financing the Government Spending

In order to use my theoretical framework for structural identification, I must first make the following assumption

Assumption 1 (Homogeneous Aggregate Incidence)**.** *The incidence on location i from a change in aggregate government spending is constant up to some residual ν_i*

$$\Lambda_i^{aggregate} \frac{dg_{agg}}{y_{agg}} = \bar{\Lambda}^{aggregate} \frac{dg_{agg}}{y_{agg}} + \nu_i$$

where the residual ν_i is uncorrelated with $\{\frac{dg_i}{y_i}\}$.

This assumption is already widely imposed in the literature, though rarely made explicit. $\Lambda_i^{aggregate}$ is the effect of aggregate policy on local GDP. It is indexed by location i as, even though the aggregate policy is the same in all locations, the transmission of this policy to local GDP is heterogeneous, as locations themselves are heterogeneous (in their trade exposure, for example). Research designs typically impose this transmission to be homogeneous, so that it may be absorbed into a time fixed effect.[41] Assumption 1 formalizes this, and the result of which can be seen by substituting it into equation (13)

$$\frac{\mathrm{d}y_i}{y_i} = \sum_{j \in \{1,\dots,N\}} \Lambda_{ij}^{transfers} \frac{\mathrm{d}g_j}{y_j} + \underbrace{\bar{\Lambda}^{aggregate} \frac{\mathrm{d}g_{agg}}{y_{agg}}}_{(\dagger)} + \underbrace{\nu_i}_{(\dagger\dagger)} \tag{19}$$

When taking the empirical analogue of this, (†) can be absorbed into a (time) fixed effect, and (††) can be absorbed in the remaining residual of the error term. Thus, $\Lambda^{aggregate}$ is effectively differenced out in the identification of $\Lambda^{transfers}$.

A powerful implication of this assumption is that I am able to remain agnostic about how aggregate expenditure is financed.[42] This can be seen because, as described in the theory section 2.2.2, all behavioral response to taxation is contained within $\Lambda^{aggregate}$. With this absorbed into the time fixed effect, I needn't make any statement on the financing.[43]

[41] See e.g. Nakamura and Steinsson (2014): in their abstract, they say "...'differences out' these [aggregate] effects because monetary and tax policies are uniform across the nation."

[42] This is particularly helpful in my context of government procurement. The federal government finances these contracts in deficit. Does the taxpayer adjust their behavior to the increased future tax burden resulting from these contracts? Seems like the effect will be small, but then how should it be incorporated in the model? I am able to avoid this question altogether.

[43] In the quantitative section 4, I need a value for $\bar{\Lambda}^{aggregate}$ in order to present the results on the aggregate fiscal multiplier. The identification strategy outlined here does not identify $\bar{\Lambda}^{aggregate}$. However, $\bar{\Lambda}^{aggregate}$ is effectively the standard aggregate fiscal multiplier object widely identified in the literature. Therefore, I calibrate $\bar{\Lambda}^{aggregate} = 0.5$ to be consistent with the consensus in the literature. See Ramey (2011).

3.3 Empirical Analogue

Assumption 1 is imposed and the empirical analogue of the multiplier equation (19) is taken as follows

$$\frac{\Delta y_{it}}{y_{it-2}} = \sum_j \Lambda_{ij}^{transfers} \frac{\Delta g_{jt}}{y_{jt-2}} + \tilde{\alpha}_i + \tilde{\gamma}_t + \tilde{\varepsilon}_{it}; \qquad i \in \{1,..,N\}, t \in \{1,...T\} \tag{20}$$

where i represents states and t years.[44] Concretely, the comparative statics between equilibria are interpreted as transitions across time. The infinitesimal changes $\mathrm{d}x$ have been replaced by two-period time differences $\Delta x_{it} \equiv x_{it} - x_{it-2}$. $\Lambda_{ij}^{transfers}$ is assumed fixed across the sample timeframe. The fixed effects $\tilde{\alpha}, \tilde{\gamma}$ and the residual $\tilde{\varepsilon}$ are a function of contemporaneous changes in the other exogenous variables of the model (such as productivity, A and trade costs τ),[45], measurement error from assuming $\Lambda^{transfers}$ is fixed across time, and $\Lambda^{aggregate}$. When discussing identification, this implied dependence of the error term provides guidance for an instrument to satisfy the exogeneity condition.[46]

3.3.1 Identifying the Structural Supply and Demand Elasticities

In principle, an identification strategy for ψ, ϕ based directly on equation 20 is possible. $\Lambda^{transfers}$ is a highly non-linear object, but non-linear techniques could be used. In practice, however, this is problematic because $\Lambda^{transfers}$ requires a symbolic inversion of a N^2 matrix (and $N = 51$ in my setting, as detailed below). For any given value of (ψ, ϕ), it is fast to calculate $\Lambda^{transfers}$, but to calculate $\Lambda^{transfers}$ as a function of (ψ, ϕ) is very computationally costly. This is to say, even though the form of $\Lambda^{transfers}$ is known mathematically, it is not known analytically.

Therefore, I proceed somewhat indirectly. I combine the equilibrium equations of section 2.1 in an alternative fashion so that the unobservable elasticities (ϕ, ψ) appear linearly. This is formalized in the following proposition.

Proposition 3 (Linear Structural Equation)**.** *Combining the seven equilibrium equations listed in section 2.1, and imposition of assumption 1, yields the following system of equations*

[44] The non-structural analogue of this typically used in regional studies is $\frac{\Delta y_{it}}{y_{it-2}} = \beta \frac{\Delta g_{it}}{y_{it-2}} + \tilde{\alpha}_i + \tilde{\gamma}_t + \varepsilon_{it}$, with $\beta \in \mathbb{R}$. In particular, $\Lambda^{transfers}$ is assumed diagonal and homogeneous: this is the restrictive nature of the non-structural approach.

[45] In equation (19), changes in exogenous variables other than $\{g_i\}_i$ were held fixed for exposition, but of course vary in the empirical setting; see equation (40) in appendix A.1.1 for the expression including these too.

[46] Of course, this is only guidance; all possible confounding factors must be taken into account.

linear in ϕ, ψ

$$\mathcal{Y}_{it} = \psi \mathcal{X}^a_{it} + \phi \mathcal{X}^b_{it} + \alpha_i + \gamma_t + \varepsilon_{it}, \qquad i \in \{1, ..., N\}, t \in \{1, ..., T\} \tag{21}$$

where

$$\begin{aligned}
\mathcal{Y}_{it} &\equiv \sum_j (M^a + M^b + M^c)_{ij} \frac{\Delta y_{jt}}{y_{jt-2}} - \frac{\Delta g_{it}}{y_{it-2}} \\
\mathcal{X}^a &= \frac{\Delta g_{it}}{y_{it-2}} - \sum_j M^a_{ij} \frac{\Delta y_{jt}}{y_{jt-2}} \\
\mathcal{X}^b &= - \sum_j M^b_{ij} \frac{\Delta y_{jt}}{y_{jt-2}}
\end{aligned}$$

$$M^a, M^b, M^c : (s^G, s^{Ex}, s^{Im}) \to \mathbb{R}^{N^2}$$

along with the residual ε_{it}, and fixed effects α_i, γ_t.

Proof: see appendix A.5.

The power of this proposition is that $\mathcal{Y}, \mathcal{X}^a, \mathcal{X}^b$ are all observable, and the unobservable ϕ, ψ appear linearly as coefficients on the $\mathcal{X}^a, \mathcal{X}^b$. It is therefore feasible to use this as my estimation equation. There are two things note in doing so. First is that the same variables appear on both of the equation. This is expected and desirable, because the coefficients are structural: their interpretation is such that they describe this circularity (in sharp contrast to reduced-form coefficients, that require exogenous variables on the righthand-side). Second, is correlation with the error term, which is a consequence of the aforementioned circularity. In addition to usual endogeneity concerns, reverse causality is inescapable, as the lefthand-side variable is also on the righthand-side. Precisely, variation in the error term, that explains the lefthand-side variable by construction, also explains the righthand-side variables, as the same variables ($\Delta y, \Delta g$ and the constituents of the M matrices) appear in each. For example, a productivity shifter that shifts GDP Δy is going to shift both the lefthand-side and righthand-side variables simultaneously.

Identification follows from an important observation. In the derivation of equation (21), one independent variable has been accounted for, and is therefore absent from the error term: government spending. Exogenous variation in this is used to get identification. Now, government spending itself could also be correlated with other variation in the error term (e.g. the productivity shifter may simultaneously shift GDP *and* government spending). I allow for this, and assume the existence of an instrument, with the source given in section

3.3.2, formalized in the following assumption

Assumption 2 (Exogenous Variation in Regional Government Expenditure)**.** *For all* $i \in \{1, ..., N\}, t \in \{1, ..., T\}$*, there exists* z_{it} *such that*

$$\forall\, j \in \{1, ..., N\} : \qquad \mathbb{E}\left[z_{it}\varepsilon_{jt}\right] = 0$$

(the exogeneity condition), and

$$\mathbb{E}\left[z_{it}\frac{\Delta g_{it}}{y_{it-2}}\right] = 0$$

(the rank condition).

That is, conditional on including the fixed effects in equation (21), α_i, γ_t, the instrument z for government spending is valid.

Exogenous shifts in a location's government spending in turn shifts GDP in each location. The propagation of this is described by the general equilibrium structure of the model; indeed, exactly what the relation in equation (21) is describing. I use this structure to construct instruments for the righthand-side variables in equation (21), which I refer to as *model-implied instrumental variables* (MIIV), due to their similarity to such objects in the literature (see below for details). Effectively, I am using the model to predict how the composite general equilibrium variables $\mathcal{X}^a, \mathcal{X}^b$ would respond to exogenous shifts in government expenditure; and this response is my instrument for $\mathcal{X}^a, \mathcal{X}^b$.

I construct the instruments as follows

Definition 1 (Model-Implied Instrumental Variables (MIIV))**.** *Define the model-implied instrumental variables* $\mathcal{Z}^a, \mathcal{Z}^b$ *as follows*

$$\mathcal{Z}^a_{it} \equiv z_{it} - \sum_j M^a_{ij} z_{jt}$$

$$\mathcal{Z}^b_{it} \equiv - \sum_j M^b_{ij} z_{jt}$$

Notice that in definition 1 $(\mathcal{Z}^a, \mathcal{Z}^b)$ are identical to $(\mathcal{X}^a, \mathcal{X}^b)$ except that $\frac{\Delta Y_{it}}{y_{it-2}}, \frac{\Delta g_{it}}{y_{it-2}}$ have each been substituted out for z_{it}. The validity of this construction can be understood as follows. The $(\mathcal{Z}^a, \mathcal{Z}^b)$ need to be relevant for $(\mathcal{X}^a, \mathcal{X}^b)$ but exogenous with respect to ε. The only elements of $(\mathcal{Z}^a, \mathcal{Z}^b)$ are z, M^a, M^b. The MIIVs are relevant because z is predictive of $\frac{\Delta g_{it}}{y_{it-2}}$ by assumption 2, and predictive of $\frac{\Delta y_{it}}{y_{it-2}}$ indirectly through $\frac{\Delta g_{it}}{y_{it-2}}$. And of course M^a, M^b are predictive of themselves. The MIIVs are exogenous because z is exogenous by assumption, and because M^a, M^b is time-invariant, the inclusion of the state fixed effect controls for all time-invariant correlation.

The definition of MIIV in definition 1 differs from that popularized in recent papers.[47] The difference being that I replace the endogenous variable $\frac{\Delta y_{it}}{y_{it-2}}$ directly with z_{it}, rather than using the general equilibrium structure of the model to predict $\frac{\Delta y_{it}}{y_{it-2}}$ from z_{it}. I take this approach to avoid having to specify initial values of ϕ, ψ (which are needed in order to use the model to predict $\frac{\Delta y_{it}}{y_{it-2}}$), as the resulting estimates from my framework seem to be very sensitive to the choice.[48] Nonetheless, mine shares the feature that I'm using the model-implied structure of $\mathcal{X}^a, \mathcal{X}^b$ to construct the instruments $\mathcal{Z}^a, \mathcal{Z}^b$ from only exogenous variation z.

Bringing it all together, identification of (ϕ, ψ) comes from estimating equation (21) by 2SLS using the MIIV instruments defined in definition 1.

3.3.2 Exogenous Variation in Government Spending

My source of government spending is federal defense procurement, as detailed in the data section 3.4. However, the allocation of government contracts is notoriously political, therefore regional spending, Δg_{it} cannot be assumed exogenous. I allow for this by using an instrumental variable strategy, with the instruments satisfying assumption 2.

The exogeneity condition in assumption 2 requires the instrument to be orthogonal to all regional movements in the residual, not just those that are co-local. On the surface this may seem more restrictive than what is normally assumed in studies using regional analysis (only assuming that the instrument is orthogonal to co-local movements in the residual), however, those studies are already (implicitly, if not explicitly) assuming that locations are independent, therefore implying that non-local shocks are already orthogonal. Thus, taking both together, my condition is no more restrictive than what is normally assumed.

Following the strategy used in Nakamura and Steinsson (2014), I construct an instrumental variable z_{it} for government spending using a Bartik-style methodology, dating back to Bartik (1991). This strategy is based on two characteristics of military spending: first, national military spending is dominated by geopolitical events; second, given a rise in national expenditure, there is a differential increase in some states — such as California — relative to others — such as Illinois — consistently across the sample timeframe (see figure 3). The

[47] See Allen et al. (2014) and Adao et al. (2018).

[48] In the referenced papers, the MIIV is given by $\frac{\Delta \hat{y}_{it}}{\hat{y}_{it-2}} = \sum_j \Lambda_{ij} z_{it}$. This is using equation (20) replacing $\frac{\Delta g_{it}}{y_{it-2}}$ with z_{it} and setting changes in the other exogenous variables to zero, i.e. $\varepsilon_{it} = 0$. The motivation being that the predicted variation in GDP only comes from the exogenous variation in government spending. Of course, Λ depends on ψ, ϕ, which is why an initial specification of these two parameters is required. Adao et al. (2018) offer an optimal methodology for choosing these.

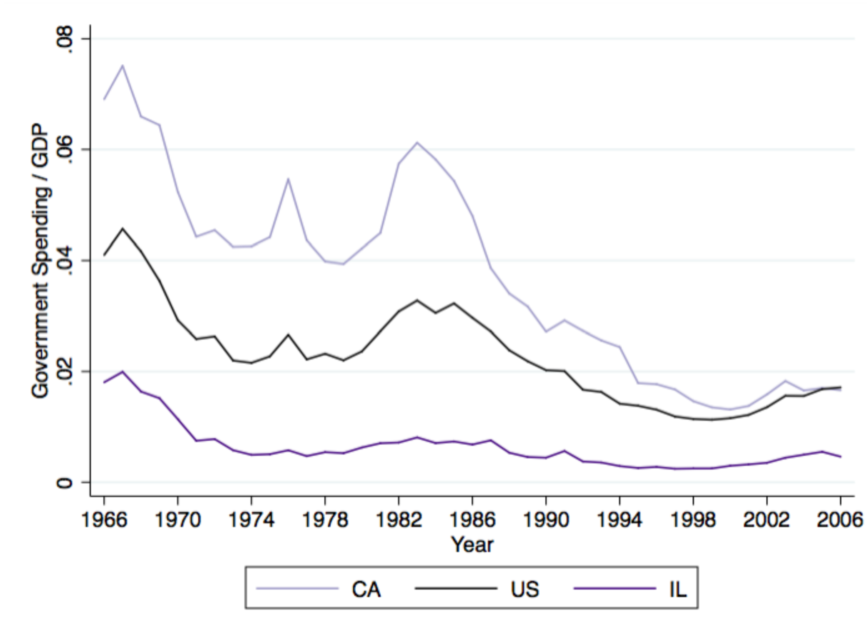


Figure 3: Prime Military Contract Spending as a Fraction of State GDP

identification assumption is that the US did not embark on military buildups — such as those associated with the Vietnam War — to differentially benefit those states that consistently receive more of the spending (California) relative to those that receive less (Illinois).[49]

Formally let b_{it} denote the Bartik-style instrument, defined as follows

$$b_{it} \equiv s_i \cdot \frac{y_{agg,t} - y_{agg,t-2}}{y_{agg,t-2}} \tag{22}$$

where $y_{agg,t} \equiv \sum_{i\in\{1,...,N\}} y_{it}$ is national, real GDP and s_i are the coefficient estimates from running the following regression separately for each i by OLS

$$\frac{g_{it} - g_{it-2}}{y_{it-2}} = s_i \cdot \frac{g_{agg,t} - g_{agg,t-2}}{y_{agg,t-2}} + \alpha_i + \gamma_t + \epsilon_{it}, \quad t \in \{1, ..., T\} \tag{23}$$

where $g_{agg,t} \equiv \sum_{i\in\{1,...,N\}} g_{it}$ is national, real military expenditure. The predicted values for $\frac{g_{it}-g_{it-2}}{y_{it-2}}$ from this regression are scaled versions of changes in national spending, allowing for heterogeneous sensitivity by state. For the identification assumption to be valid, the state shares s_i must be exogenous with respect to changes in state GDP in i across time.[50] It may well be the case that states that receive greater shares of government spending (higher s_i) exhibit greater growth in state GDP, which would violate the identification assumption.

[49] This is analogous, though weaker than the identification assumption maintained in an aggregate analysis: the US did not embark on military buildups to benefit the (aggregate) domestic economy.

[50] See Goldsmith-Pinkham et al. (2017) for details.

This is addressed by the inclusion of state fixed effect; the assumption being that the share of spending s_i can be correlated with the state GDP growth rate, but not correlated with changes in the growth rate. The inclusion of the time fixed effect controls for any confounding variation from aggregate shocks or policy (e.g. monetary policy) that is correlated with national spending and regional GDP; it is the time fixed effect that allows for the California-Illinois intuition above.[51] Mathematically, the state and time fixed effects achieve these by demeaning the regressor (Δg) and regressand (Δy) along the cross-section and time dimension respectively.

A point of departure from the standard Bartik framework (and Nakamura and Steinsson (2014)) is that I use the demeaned variation directly. That is, my instrument is

$$z_{it} \equiv b_{it} - \bar{b}_{\cdot t} - \bar{b}_{i\cdot} + \bar{b}_{\cdot\cdot} \tag{24}$$

where I denote the averages $\bar{b}_{\cdot t} \equiv \frac{1}{N}\sum_i b_{it}, \bar{b}_{i\cdot} \equiv \frac{1}{T}\sum_t b_{it}, \bar{b}_{\cdot\cdot} \equiv \frac{1}{NT}\sum_{it} b_{it}$. This is necessary because, as will become apparent in the structural identification section 3.3.1 below, the endogenous variables in the structural identification equation are operated on by matrices - see equation (21) - and therefore the fixed effects in those equations do not demean Δg or Δy. This will be returned to below.

3.4 Data

The data demanded by equation 21 are listed below with their sources and description.

3.4.1 Interstate Trade Flows

The trade flow data for $\{X_{ij}\}_{i\in\{1,\ldots,N\},j\in\{1,\ldots,N\}}$ comes from the Commodity Transportation Survey (CTS), which provides statistics on the volume and characteristics of commodity shipments by manufacturing establishments in the United States.[52] The survey began in 1963, though only began publishing statistics on the value of shipments (as opposed to just shipment weight) and with shipments disaggregated to the state-state level[53] (as opposed to just at the Census region-region level) in 1977. In this year, the survey took a stratified probability sample (across each of the 456 manufacturing SIC industries) of 19,500 manufacturing establishments from the 1977 Census of Manufactures' universe of manufacturing

[51] Subtly, this also requires s_i to be uncorrelated with state i exposure to aggregate shocks i.e. the marginal local effect in i from an aggregate shock, $\Lambda_i^{aggregate}$, as presented in section ??.

[52] For details, see https://archive.org/details/1977censusoftran03unse/page/n0. Table 1 presents the data used in this paper. Appendix B describes the sample design.

[53] All 50 states and DC.

establishments (approximately 350,000).[54] Respondents were asked to report the "net selling value" (after discounts and allowances, exclusive of freight charges and excise taxes) on a sample of their shipments. All shipments were within the scope of the sampling procedure, except classified defense materials, which were excluded. Exports are included with the destination listed as the US port of export, meaning they are indistinguishable from domestic shipments.

The import and export shares are constructed as follows

$$s_{ij}^{Ex} \equiv \frac{X_{ij}}{\sum_k X_{ik}}, \quad s_{ij}^{Im} \equiv \frac{X_{ij}}{\sum_k X_{kj}}$$

3.4.2 Military Expenditure

The government spending data for $\{G_{it}\}_{i\in\{1,\ldots,N\},t\in\{1,\ldots,T\}}$ comes from the DD-350 military procurement forms;[55] these report contracts for goods and services between the private sector and the military services agencies of the US Department of Defense with a value of $\$10,000$ or more from fiscal year 1965 to 1984, and of a value of $\$25,000$ or more from fiscal year 1983 to 2006. The forms document everything from tank wheels to aircraft carriers, form catering to military factory repairs. The forms present data by principal place of performance: manufacturing contracts are attributed to the state where the product was processed and assembled; construction and service contracts are attributed to the state where the construction or the service was performed.[56]

I aggregate the contracts to state and calendar year for 1966-2006.[57] The state government spending share is constructed as

$$s_i^G \equiv \frac{G_i}{\sum_j X_{ij}}$$

[54] 16,000 establishments responded.

[55] For the electronic database and additional details, see Record Group 330: Records of the Office of the Secretary of Defense at https://www.archives.gov/research/electronic-records/reference-report/federal-contracts.

[56] Note that the trade flow dataset only covers manufacturing, whereas GDP and military expenditure cover all sectors. Data on only manufacturing GDP for the time period is feasible, but the military data does not provide industry codes per contract during my time period. The implications of this are returned to in the discussion in section 3.5.2.

[57] An important concern is the extent of interstate subcontracting, the presence of which means the reported location of spending is not the actual location of spending. Nakamura and Steinsson (2014) present evidence showing these concerns are minimal.

3.4.3 Other Economic Data

Other economic data come from standard sources.

State GDP in the variables $\frac{\Delta y_{it}}{y_{it-2}}$, and denominator of $\frac{\Delta g_{it}}{y_{it-2}}$ come from the BEA at the state-calendar year level.

Price Index used to deflate GDP y and spending g is the national CPI taken from the BLS.

3.5 Estimation Results

Turning to the estimation, section 3.5.1 presents the results and section 3.5.2 offers a discussion.

3.5.1 Structural Elasticity Estimates

As outlined in section 3.3.1, the estimating equation is

$$\mathcal{Y}_{it} = \psi \mathcal{X}_{it}^a + \phi \mathcal{X}_{it}^b + \alpha_i + \gamma_t + \varepsilon_{it}, \quad i \in \{1, ..., N\}, t \in \{1, ..., T\}$$

using the model-implied instruments $(\mathcal{Z}^a, \mathcal{Z}^b)$ in a 2SLS specification. The results are presented in table 2. The 2SLS specification yields $\psi = -1.25$ and $\phi = 0.49$. The first stage passes the heuristic F-Stat threshold of 10. The estimate of the supply elasticity is fairly noisy with a p-value of 0.016. The demand elasticity is precisely estimated with a p-value equal to zero up to three significant figures.

3.5.2 Discussion

Supply Elasticity. The negative estimated value of $\psi = -1.25$ implies that supply is downward sloping. This may seem to go against expectation, but it is important to acknowledge that the supply equation (2) is a general equilibrium relation, combining, for example, both the partial equilibrium production optimal pricing equation and optimal labor supply.

In fact, a negative supply elasticity is actually expected in order to generate a multiplier mechanism that underlies the fiscal multiplier. As explained in section 2.2.2 and illustrated by figure 2. Only when $\psi < 0$ is the equilibrium change in output greater than the size of the demand shock (figure 2.2c); that is, only negative ψ can generate the fiscal multiplier magnification effect. In canonical macroeconomic fiscal multiplier models, the analogous supply equation is highly complex due to dynamics and as a result does not exhibit an

	OLS	2SLS
ψ (Supply)	-0.91	-1.25
	(0.09)	(0.50)
ϕ (Demand)	0.57	0.49
	(0.02)	(0.12)
First Stage F-Stat		
$\mathcal{X}^a$		17.20
$\mathcal{X}^b$		5.43
Observations	1989	1989
(i,t) fixed effects	yes	yes

Cluster (i) robust standard errors in parentheses

Table 2: Parameter Estimation

analogous constant elasticity of supply. Therefore this finding of a negative equilibrium supply elasticity is likely obscured in those models, but nonetheless present.

In order to understand the economic forces generating $\psi = -1.25$, I revisit the micro-structure underlying ψ presented in equation (15)

$$\psi = \frac{1-\sigma^{-1}}{\frac{1+\nu^{-1}-\theta}{1+\chi} + \xi - (1-\sigma^{-1})}$$

with the parameter interpretations detailed in table 1. Any mechanism that implies prices decreases at greater scales of output will push ψ towards being negative. The three present here are increasing returns to scale in production (production is more efficient at greater scales, meaning price is less) and is generated by $\chi > 0$; sticky prices, (the mark-up decreases at greater scales as wages adjust up, in response to moving up the labor supply curve, but prices are slow to adjust)[58] and is reflective of $\xi < 0$; and labor-consumption complementarities (laborers consume even more as they work more meaning equilibrium output increases by even more, leading to a multiplication effect)[59] and is reflective of $\theta > 0$.

Can $\psi = -1.25$ be rationalized by plausible magnitudes of these underlying channels? I investigate this in table 3, where I present various combinations of $(\sigma, \nu, \chi, \xi, \theta)$ that generate $\psi = -1.25$. The challenge is that the value of these parameters are very much context dependent, and even then there is not strong consensus in the literature.[60] $\psi = -1.25$ is

[58]See Christiano et al. (2011). Paraphrasing the authors: since prices are sticky, price over marginal cost falls after a rise in demand. This fall in the mark-up induces an outward shift in the labor demand curve.

[59]Intuitively, at larger scales, households are working more, therefore consume more due to the complementarity, therefore increase the scale of output even more. The complementarity can, for example, represent the extra consumption on food away from home, clothing, gas, and the like that often arises in the context of work.

[60]For σ, the literature has found values close to zero and greater than one (for a summary, see Nakamura

	σ	ν	χ	ξ	θ	ψ
$a)$	1.21	1	0.45	-1	0.5	-1.25
$b)$	1.21	0.5	0.45	-1	1.5	-1.25
$c)$	1.21	1	0.45	0	1.95	-1.25
$d)$	1.21	1	0	0	1.97	-1.25
$e)$	1.21	1	0.45	-1.34	0	-1.25
$f)$	0.1	1	0	0	0	-0.82

Table 3: Rationalizing $\psi = -1.25$ using various microfoundations.

Notes. a) is the baseline. I consider changes keeping $\sigma = 1.21$ (either around this or close to zero in literature) and $\chi = 0.45$ (somewhat consensus in literature) fixed.

b): ν, θ are substitutable in their effect on ψ. For example, a micro-level ($\nu = 0.5$) labor supply can be rationalized with high $L - c$ complementarities ($\theta = 1.5$)

c): Invariable mark-ups ($\xi = 0$) can be accommodated if L-c complementarities are higher ($\theta = 1.95$ rather than $\theta = 0.5$)

d): Invariable mark-ups ($\xi = 0$) and no scale economies ($\chi = 0$) can be accommodated if L-c complementarities are higher ($\theta = 1.97$ rather than $\theta = 0.5$)

e): no $L - c$ complementarity ($\theta = 0$) can be accommodated if the mark-ups have even greater intensity of decreasing in scale. ($\xi = -1.34$ rather than $\xi = -1$)

f) $\psi < -1$ cannot be rationalized without any of these three channels, even with income effects dominating on labor ($\sigma < 1$)

easily able to match values within the literature's range. Note that in absence of these three mechanisms, $\psi = -1.25$ is not able to be rationalized, even with income effects dominating on labor.[61]

Demand Elasticity. The estimated value of $\phi = 0.49$ implies that products from different locations are complements. Economically, this means that, given an increase in price in one location relative to another, the expenditure on that location relative to the other increases, even though the relative quantity consumed does decrease.[62]

There are at least three explanations for this finding. The first derives from the observation that the military contracts are heavily represented in both manufacturing and services (see figure 4).[63] The literature is suggestive of complements between manufacturing and

and Steinsson (2014), page 775), For ν, in microeconomic contexts it is about 0.5, in macroeconomic contexts, can be 1 or higher (Nakamura and Steinsson (2014)); for females ($\nu = 2.2$) it is much higher than males ($\nu = 0.3$) (see Greenwood et al. (1988), page 412). For χ, the Urban economics literature suggests a value in the range 0.3 to 0.6.

[61] Of course, there could be a mechanism unconsidered in this paper that rationalizes $\psi = -1.25$ without requiring increasing returns to scale, sticky prices, or labor-consumption complementarities.

[62] Such phenomenon is suggestive of necessity: the price of the good increases, but consumption of it decreases less, because the good is less substitutable. The consumption decrease is dominated by the price increase and hence expenditure still rises.

[63] Note that my data on trade flows is restricted to manufacturing. The implication of only using manufacturing trade flows is that I have measurement error in the trade flows; effectively, I am assuming that the trade flows of non-manufacturing follow the same pattern as manufacturing.

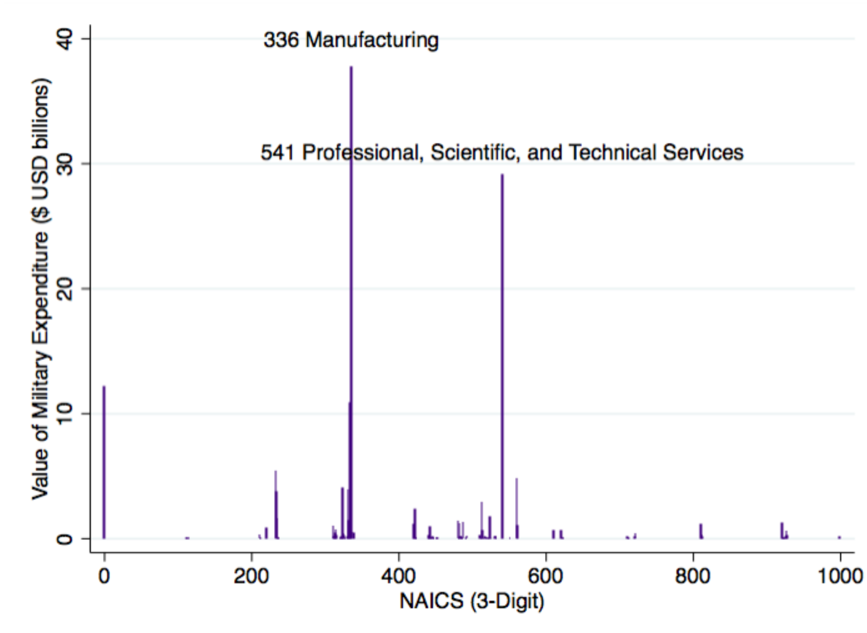


Figure 4: Industry composition of Defense Procurement.

Notes: Year 2001. Across 50 US States + DC.
Datasource: USAspending.

service industries.[64]

A second derives from industrial specialization across locations, as this can further increase the complementarity of region product aggregates.[65] Figure 5 graphs the share of military expenditure in manufacturing by state.[66] The share varies widely from 2% in Wyoming to 85% in Missouri, offering evidence in support of the specialization mechanism.[67]

The third source is due to the duration of shocks. It is intuitive that the elasticity of substitution is going to be smaller for shocks that are of shorter duration, and evidence of this has been provided in the literature.[68] The military procurement shocks are certainly of transitory nature, therefore it is certainly reasonable to consider ϕ as a short-run estimate.

[64]See e.g. Comin et al. (2015) in the context of structural change.

[65]I show this in appendix A.6 using a multi-sector nested CES model.

[66]The more recent datasource on USAspending has industry codes per contract.

[67]A story based on specialization is interesting though beyond the scope of this paper as my model is only informative about the movement of goods at the region-aggregate level. Such direction provides an avenue for future research.

[68]For short- and long-run elasticity estimates, see Alessandria and Choi (2019) for Armington elasticities, and Bentzen and Engsted (1993) for in the energy industry. Both estimate the elasticity of substitution to be less than one in the short run and greater than one in the long-run.

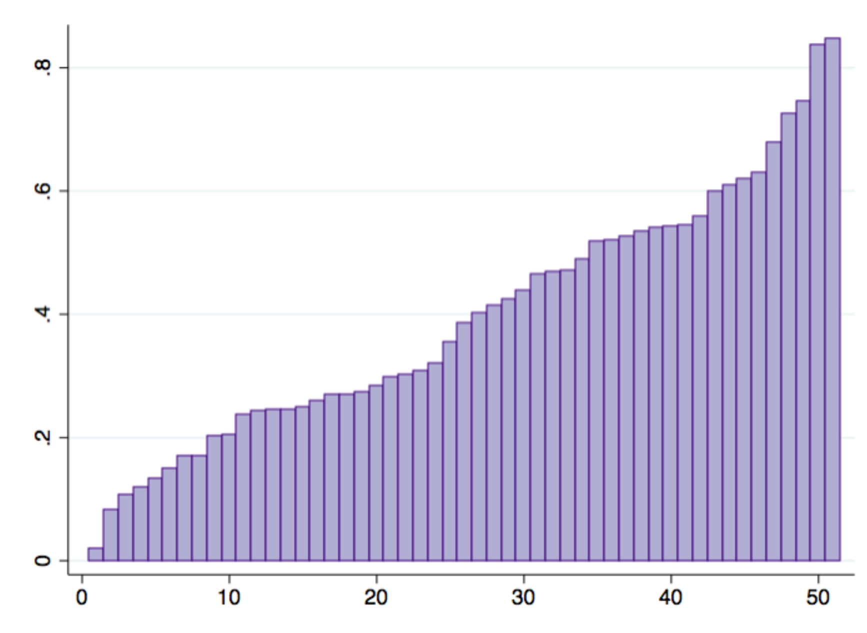


Figure 5: Share of Military Expenditure in Manufacturing, by state.

Notes: Year 2001. 50 states + DC. x-axis: states ordered by manufacturing share. *Datasource*: USAspending.

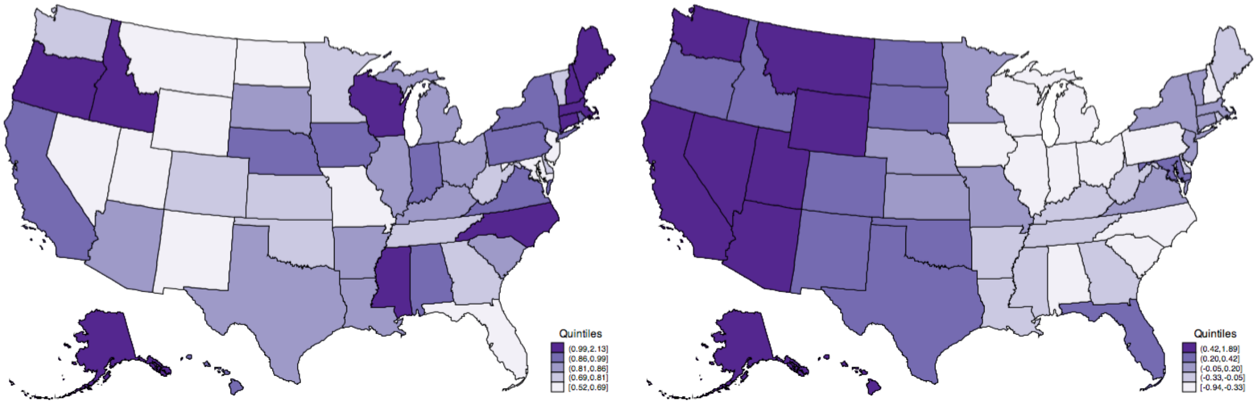
4 Inference on the Fiscal Multiplier

Given the previous section's estimates of ψ, ϕ, the object $\Lambda^{transfers}$ can now be identified, therefore allowing me to quantify the component of the fiscal multiplier due to the spatial mechanism. In section 4.1, I local at the heterogeneity by state in the effect of spending and thus quantifying the spatial mechanism. In section 4.2 I describe the factors in the model generating these results. In section 4.3, I relate my structural results to non-structural estimates. In section 4.4, I present what this implies for the typical object of interest in fiscal policy: the aggregate fiscal multiplier. In section 4.5, I look at what my findings imply for long-run growth by considering counterfactual geographic distributions of spending.

4.1 Quantifying the Spatial Mechanism

Figure 6 graphically illustrates the heterogeneity by state in the fiscal multiplier due to the spatial mechanism. Figure 6.6a displays the effect from a transfer to a state on its GDP, whereas 6.6b displays the effect on the nation's GDP (in each case, the transfer is financed by all states proportionally to their GDP). The darker the state is shaded, the greater the change in GDP.

For the local effect (figure 6.6a), the average change in a state's GDP from receiving a



(a) Local, $\left\{\Lambda_{ii}^{transfers}\right\}_{i\in\{1,\ldots,N\}}$ (b) Aggregate, $\left\{\sum_j y_j \Lambda_{ji}^{transfers} y_i^{-1}\right\}_{i\in\{1,\ldots,N\}}$

Figure 6: Change in local and aggregate GDP due to transfers by state

Notes. Calculated using interstate trade, government spending and GDP data for the year 1977.

\$1 transfer is \$0.89; the 5^{th} and 95^{th} percentiles are \$0.59 and \$1.51 respectively. Given the supply elasticity ψ is estimated to be negative, therefore implying a magnification effect due to spending (see section 2.2.2), one may wonder why the local multiplier for all of the states is not greater than one? This is because the demand elasticity ϕ is estimated to be less than one: a complementarity elasticity of substitution attenuates the resulting equilibrium change in GDP. A government transfer shifts local demand out, causing local GDP to increase. The downward-sloping supply implies that this is associated with a local price decrease. Complementarity means consumers in response increase their spending share on products from other states as prices have now become relatively more expensive there. The reduction in local spending share dampens the increase in GDP locally, hence the multiplier being less than one in some cases. The effect is heterogeneous by state as a state's trade exposure is a determinant of the level of equilibrium substitution.

For the aggregate effect, from a \$1 transfer the change in national GDP at the 5^{th} and 95^{th} percentiles are $-\$0.57$ and \$0.57 respectively. The change in national GDP can be negative precisely because it is a transfer: if the receiving state is a low-return state, then the reduction in GDP in the financing states outweighs the increase in GDP in the receiving state, leading to a net negative change in national GDP.[69]

[69] Taking the average of the aggregate effects from transfers is not a meaningful statistic. The average is taken over all possible transfers; the symmetry of the operation, with movement of spending in one transfer canceling with the converse movement of spending in another, means that the average will near zero by construction. Indeed if the average is weighted by state GDP, this is identically zero, as $\Lambda^{transfers}$ is constructed to give the multiplier relative to the distribution of spending that is proportional to state GDP.

4.2 Model Factors underlying the Spatial Mechanism

To get intuition about the estimated values of the local and aggregate effects of transfers, I explain how the supply elasticity, the demand elasticity and the economic geography affect the spatial mechanism described by $\Lambda^{transfers}$.

Supply Elasticity. Figures 7a and 13b illustrate the dependence on ψ of the local ($\Lambda_{ii}^{transfers}$) and spillover effects ($\Lambda_{i \neq j}^{transfers} + \frac{y_j}{y_{agg}}$) from transfers, respectively.[70] I graph the effects at the estimated supply elasticity, $\psi = -1.25$, along with two counterfactual supply elasticities, $\psi \in \{-1.15, -3\}$. All three are at the estimated $\phi = 0.49$.

As ψ becomes more negative, the supply curve becomes more intensely downward-sloped. A spending shock therefore decreases local prices to a greater extent, and the output response is magnified to a greater extent. Figure 7a demonstrates this: as ψ becomes more negative, the distribution $\{\Lambda_{ii}^{transfers}\}_i$ shifts right: the effect on local GDP from a transfer is greater.

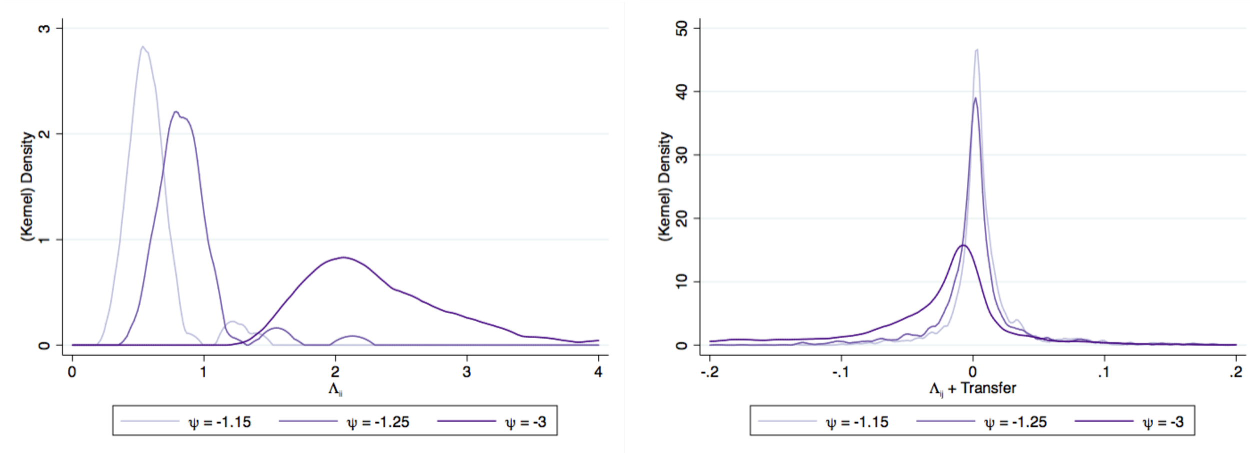
As local GDP increases, consumers and firms increase consumption of goods from all states: a positive spillover. The more negative that ψ becomes, the greater the relative decrease in local prices. Consumers therefore consume more goods locally, and less from other states; this attenuates the positive spillovers. Figure 13b illustrates this: as ψ becomes more negative, the distribution $\{\Lambda_{i \neq j}^{transfers}\}_{ij} + \frac{y_j}{y_{agg}}$ shifts left: the spillovers become less positive (and even negative).

Demand Elasticity. Figures 8a and 14b present the analogous analysis to above, except now varying the demand elasticity, ϕ.[71] I graph the effects at the estimated demand elasticity, $\phi = 0.49$, along with two counterfactual demand elasticities, $\psi \in \{0.4, 0.6\}$. All three are at the estimated $\psi = -1.25$.

As ϕ becomes more positive, the degree of substitutability between products from different states becomes greater. In response to a spending increase in j, j GDP increases and j prices relatively decrease (as supply is downward-sloping). This makes j products more attractive to consumers and firms in other states. The more substitutable the goods are, the greater the substitution towards the j goods, and the greater the increase in j GDP. Figure 8a demonstrates this: as ϕ increases, the distribution $\{\Lambda_{ii}^{transfers}\}$ shifts to the right: the

[70] Note that the mechanical decrease in GDP due to financing the transfer, $\frac{y_j}{y_{agg}}$, is included in the measure of $\Lambda^{transfers}$. As this is not normally considered part of the spillover effect, I correct for this by adding the transfer back on. In appendix figure 13 I present both uncorrected and corrected non-local effects of spending. The uncorrected effect essentially is, unsurprisingly, a leftward shift of the corrected effect. (It's important however to know that this does not mean spillovers are negative; it is the mechanical effect of financing a transfer that is creating the net-negative equilibrium change in non-local output.)

[71] And similarly, appendix figure 14 presents both uncorrected and corrected non-local effects of spending; the same conclusions follow.

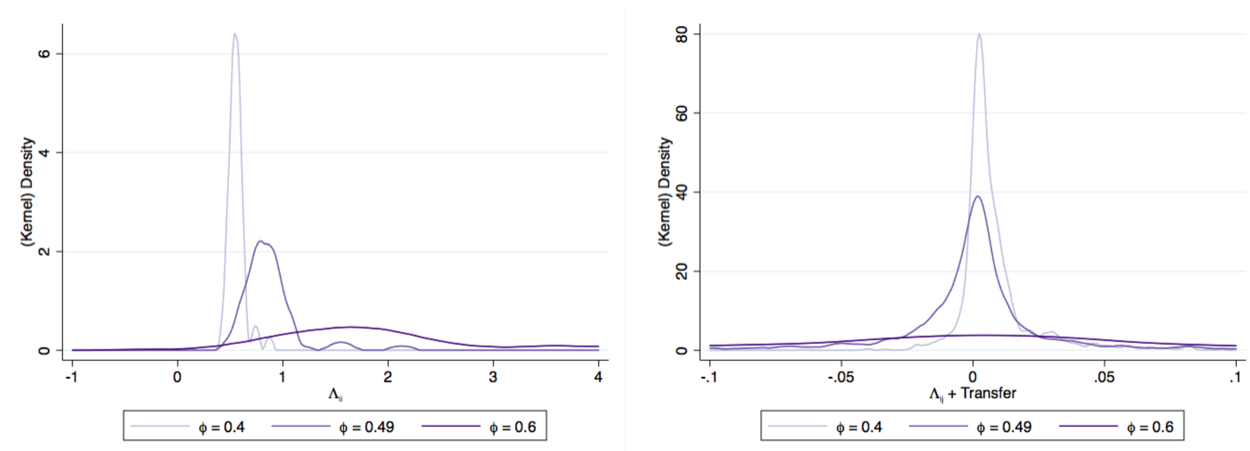


(a) Absolute Local Fiscal Multiplier from Transfers, $\forall\, i : \Lambda_{ii}$

(b) Spillovers, $\forall\, i, j : i \neq j : \Lambda_{ij} + \frac{y_j}{y_{agg}}$

Figure 7: ψ and the magnitude of $\Lambda^{transfers}$

Notes. At estimated value of ϕ.



(a) Absolute Local Fiscal Multiplier from Transfers, $\forall\, i : \Lambda_{ii}^{transfers}$

(b) Spillovers, $\forall\, i, j : i \neq j : \Lambda_{ij}^{transfers} + \frac{y_j}{y_{agg}}$

Figure 8: ϕ and the magnitude of $\Lambda^{transfers}$

Notes. At estimated value of ψ.

effect on local GDP from a transfer is greater.

Figure 14b demonstrates that the effect of an increase in substitutability (increasing ϕ) results in a slight negative shift in the distribution of spillovers, though less-pronounced. This direction is consistent with the above intuition however: the more substitutable the goods become, the more consumes and firms shift from i to j in response to a price decrease in j due to government spending in j. Locations $i \neq j$ are therefore are more negatively impacted as ϕ increases.

	Dependent variable: $\frac{\partial y_i}{\partial g_i}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
constant	0.87^{***}	0.87^{***}	0.87^{***}	0.87^{***}	0.87^{***}	0.87^{***}	0.87^{***}
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)
$\ln \bar{y}_i$		-0.02			-0.03	-0.03	-0.07^{**}
		(0.04)			(0.04)	(0.04)	(0.03)
s_i^{Im}			-1.83^{*}		-1.85^{*}		-4.16^{***}
			(0.96)		(0.97)		(0.95)
s_i^{Ex}				0.23		0.26	2.05^{***}
				(0.48)		(0.46)	(0.36)
Observations	51	51	51	51	51	51	51

Robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Dependence of Local Effect on the Economic Geography

	Dependent variable: $\frac{\partial y_{agg}}{\partial g_i}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln \bar{y}_i$	-0.13^{*}			-0.15^{***}	-0.09^{**}	-0.10^{**}
	(0.07)			(0.10)	(0.04)	(0.04)
s_i^{Im}		-3.64^{***}		-3.78^{**}		-0.79
		(1.03)		(0.91)		(1.33)
s_i^{Ex}			-3.10^{***}		-3.12^{***}	-2.66^{**}
			(1.06)		(0.48)	(0.04)
Observations	51	51	51	51	51	51

Robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Dependence of Aggregate Effect on the Economic Geography

Many locations continuing to experience positive spillovers at greater degrees of substitutability is an example of the non-monotonicity examined in the theoretical trade literature on spatial models with scale economies resulting from higher order interactions.[72] At high degrees of substitutability, the direct effect of a local spending shock in a first location on a second location, that is economically-close, is negative, causing the price in the second location to increase. However, this reduction in competitiveness in the second location from the price increase can benefit — a more positive spillover to — third location that is economically-close to the second location and is economically far from the first.

Economic Geography. The dependencies on the demand and supply elasticities describe

[72]See Matsuyama (2017) for an exploration of this in the context of the home market effect.

the mean behavior of the model but abstract from the large geographic heterogeneity in GDP response to government spending by state. The elements of the model driving the heterogeneity are the observable constituents of $\Lambda^{transfers}$: the network of interstate trade flows and government spending shares by state. This is a complex dependence due to each state being a node in a 51×51 network. To distill some helpful regularities and get some insight into the mechanism, in tables 4 and 5 I regress the local and aggregate effects of transfers, respectively, on (ln) state GDP, state import shares and state export shares. For example, in table 4 column (1), the regression equation is

$$\Lambda_{ii}^{transfers} = \beta_0 + \beta_1 \ln \bar{y}_i + \varepsilon_i$$

Although weaker for the local effects, both local and aggregate effects display a negative dependence on both state GDP and state import share. For the aggregate effect there is also a negative dependence on state export share, as is predicted in the special case of proposition 2. The mechanisms underlying these relations is as follows.

Consider the government concentrating spending in state i. Then, output and GDP of i increase. As the other states are financing this spending but directly receiving less back, their GDP initially decreases.[73] The negative supply elasticity describes a convex, downward-sloping supply curve. This means that returns to spending are greater the in initially smaller locations. If i is small relative to the financing states, then the GDP increase in i dominate the GDP decrease in the financing states, leading a increase in aggregate GDP. This explains the first result: spending in states that are smaller in terms of GDP generate greater local and aggregate effects.

How does this relate to trade? As GDP in i increases, consumers and firms in i increase their consumption of products from all states. The more closed to trade that i is, the greater the proportion of this increase in consumption that is spent locally. This magnifies the increase in i GDP; hence the negative dependence of the local effect on state import share (table 4). The relation with the aggregate effect is, theoretically, ambiguous. The more closed to trade that state i is, the greater the reduction in GDP in other states (as they don't benefit as much from increased consumption). This creates two opposing channels on the aggregate effect, and which dominates depends on the trade exposure of state i. As implied by table 5 columns (2) and (3), the increase in local GDP outweighs the decrease in non-local GDP for the economic geography of the US, resulting in a negative dependence on state import share.

At the same time, the real wage in IL increases in order to incentivize more labor to be

[73] Of course, it is all general equilibrium and everything happens simultaneously, but for exposition it is helpful to consider the process in the described order.

supplied to meet the increase in production. An increase in the real wage in IL causes a response in local (real) prices in IL due to operational costs increasing. The negative supply elasticity means that local real prices don't respond as much as real wages. The result is that consumers in IL purchase even more goods in IL further magnifying the increase in IL GDP. This magnification mechanism is common to the fiscal multiplier mechanisms in the macroeconomics literature.

4.3 Direct Evidence

The inference on the spatial mechanism in the preceding sections depend in part on the structural assumptions imposed, therefore in this section I provide some direct evidence on my findings. Because of the dimensionality problem (see section 3.1), it's not possible to completely validate my results, this is why I impose the structure to begin with. However, by following the growing literature on local fiscal multipliers, I can make progress by making an approximation.

The local fiscal multiplier literature is centered on the following regression

$$\frac{\Delta Y_{it}}{Y_{it-2}} = \beta^{NS} \frac{\Delta G_{it}}{Y_{it-2}} + \alpha_i + \gamma_t + \varepsilon_{it} \tag{25}$$

Where are all the spillover terms? Although normally not stated explicitly, the authors are imposing the assumption[74]

Assumption 3. *Homogeneous Spillovers*

$$\forall\ i \neq j : \Lambda_{ij}^{transfers} = \tilde{\Lambda}_j^{transfers}$$

Intuitively, this means that from spending in any state j, the spillover effect on GDP in state $i \neq j$ is equal for all $i \neq j$. Under this assumption, all spillover terms are absorbed into the time fixed effect and the object identified is $\beta^{NS} = \mathbb{E}_i[\Lambda_{ii}^{transfers} - \tilde{\Lambda}_i^{transfers}]$. This is the *relative* local fiscal multiplier: the effect of spending (or a transfer) on a state's GDP relative to GDP in all other states.

How does this relate to my structural results? Well, assumption 3 is refuted by my structural estimates of $\Lambda^{transfers}$. Therefore to proceed, I construct $\tilde{\Lambda}_j^{transfers}$ as the average

[74] Directly, equation (25) is concerning total state spending, not state transfers. However, under assumption 1, these both coincide. This assumption is also widely assumed in the literature, though also implicitly. For example, when Nakamura and Steinsson (2014) say "By including time fixed effects, we control for aggregate shocks and policy that affect all states at a particular point in time" (page 755), they are making this assumption. Although the policy may be homogeneous across states, the treatment of it on output need not be. Their statement and assumption 1 both constrain the incidence to homogeneous.

$$\bar{\bar{\Lambda}}_j^{transfers} = \frac{1}{N-1} \sum_{i \neq j} \Lambda_{ij}^{transfers}$$

Although subject to the approximation from assumption 3, I can now compare heterogeneity in my structural estimates for the relative local fiscal multiplier $\Lambda_{ii}^{transfers} - \bar{\bar{\Lambda}}_j^{transfers}$, with heterogeneity in the non-structural estimates β^{NS}. To do this, I run the following two regressions

$$\begin{aligned} \text{Structural :} \quad \Lambda_{ii}^{transfers} - \bar{\bar{\Lambda}}_i^{transfers} &= \beta_0 + \beta_1 \ln \bar{y}_i + \beta_2 s_i^{Im} + \varepsilon_i \\ \text{Non-Structural :} \quad \frac{\Delta Y_{it}}{Y_{it-2}} &= \left(\beta_0 + \beta_1 \ln \bar{y}_i + \beta_2 s_i^{Im}\right) \cdot \frac{\Delta G_{it}}{Y_{it-2}} + \alpha_i + \gamma_t + \varepsilon_{it} \end{aligned}$$

where $\ln \bar{y}_i, s_i^{Im}$ are demeaned,[75] and the non-structural regression is ran using 2SLS with the Bartik instrument (described in section XX) for $\frac{\Delta G_{it}}{Y_{it-2}}$. In each of these regressions, the vector of coefficients $(\beta_0, \beta_1, \beta_3)$ correspond to structural and non-structural analogues of the same objects: respectively, the average relative local fiscal multiplier (due to the demeaning), the marginal effect of GDP, and the marginal effect of state import share. The results are presented in table 6.

Looking at the table, qualitatively, there is agreement. There is insignificant dependence on state GDP, and negative dependence on state import share. Quantitatively, the magnitudes are misaligned. Interestingly, the non-structural state import share estimates suggests an even greater dependence on trade exposure than my structure accounts for.[76]

What about the difference in the average relative local fiscal multiplier estimates, which is given by the constant? The main contender is that only account for the fiscal multiplier magnification mechanism due to trade. The macroeconomics literature provides a wealth of mechanisms unrelated to interstate trade that contribute to the multiplier magnitude that my estimates do not capture. With this in mind, it's not unexpected that the magnitudes do not align more precisely.

4.4 Fiscal Multipliers from Aggregate Expenditure Changes

The object of interest for policymakers is the aggregate fiscal multiplier: the dollar change in national GDP caused by a one dollar increase in government spending. Up until now, I've only been presenting results on the component of the fiscal multiplier due to interstate transfers, which captures the spatial mechanism. This is $(*)$ in equation (14). To determine

[75] Because of the demeaning, β_0 is equal to the average of the relative local fiscal multiplier.

[76] The one disconnect is dependence on state export share in column (7).

	Dependent variable: $\frac{\partial y_i}{\partial g_i}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
constant	0.87***	0.87***	0.87***	0.87***	0.87***	0.87***	0.87***
	1.41***	1.42***	1.91***	1.73***	2.02***	1.78***	2.01***
$\ln \bar{y}_i$		−0.02			−0.03	−0.03	−0.07**
		−0.08			−0.41	−0.23	−0.41
s_i^{Im}			−1.83*		−1.85*		−4.16***
			−16.8**		−18.2**		−19.0**
s_i^{Ex}				0.23		0.26	2.05***
				−8.42		−8.86	0.80
Observations	51	51	51	51	51	51	51
	1989	1989	1989	1989	1989	1989	1989

Clustered by state robust standard errors in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Local Effect heterogeneity: Structural (first row) and Non-Structural Estimates (second row)

Notes. This is not a moment-matching exercise using simulated data. Rather, I structural estimate the parameters using the observed data.

what these results imply for the aggregate fiscal multiplier, I need to specify $(**)$ in equation (14). Therefore, I set its value to be 0.5 so that it is consistent with the consensus in the literature.[77] That is, I impose

$$\sum_i \Lambda_i^{aggregate} \frac{y_i}{y_{agg}} = 0.5 \tag{26}$$

Precisely, this implies that the fiscal multiplier from a change in aggregate spending that is geographically distributed proportionately by state GDP is 0.5.[78] Under equation (26), the aggregate fiscal multiplier in my framework is

$$\frac{\Delta y_{agg,t}}{\Delta g_{agg,t}} = \sum_{i\in\{1,\dots,N\},j\in\{1,\dots,N\}} y_{i1977} \Lambda_{ij}^{transfers} y_{j1977}^{-1} \frac{\Delta g_{j,t}}{\Delta g_{agg,t}} + 0.5 \tag{27}$$

where a similar empirical analogue to section 3.3 has been taken. Note that the real GDP y_{i1977} is evaluated at its value in 1977 in order to be consistent with $\Lambda^{transfers}$, as this is also evaluated using GDP and trade data in 1977.[79] Equation (27) models the fiscal multiplier

[77] See Ramey (2011).

[78] This can be seen by noting that (†) in equation (14) is equal to zero when government spending is distributed proportionally by state GDP.

[79] In appendix B.1, I present the results using y_{it} in equation (27) in place of y_{i1977}. In this case, the time variation in $\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}$ is due to changes in the state spending shares $\frac{\Delta g_{jt}}{\Delta g_{agg,t}}$ and state GDP y_{it}. The results are very similar.

inclusive of the spatial mechanism and therefore as a function of the geographic distribution of spending (the term $\frac{\Delta g_{j,t}}{\Delta g_{agg,t}}$). I can use this to inform how important the spatial mechanism is in determining fiscal multiplier magnitudes.

Figure 9 graphically displays equation (27) across my time period 1966-2006 for the observed changes in the geographic distribution of spending. Note that as the object $y_{i1977}\Lambda_{ij}^{transfers}y_{j1977}^{-1}$ in equation (27) is held fixed at 1977 values, the figure displays variation in the fiscal multiplier that is only coming from changes in the geographic distribution of government spending; everything else is held fixed (such as business cycle considerations). Because it is *ceteris paribus*, the deviation from 0.5 is capturing exactly the spatial mechanism. For example, in 1994 the fiscal multiplier is 0.5 whereas in 1996 it is 1.5. Because everything else is held fixed, this illustrates that we are able to increase the fiscal multiplier magnitude (in this case, from 0.5 to 1.5) simply by changing the geographic distribution of spending.

To quantify the spatial mechanism, I consider the standard deviation of the fiscal multiplier distribution across time (i.e. that graphed in figure 9). Excluding the year 1972, this value if 0.24. This implies, on average, the spatial mechanism can generate variation of 50% in the fiscal multiplier relative to the value of 0.5 from the literature.

Indeed, the mechanism can generate a much greater fiscal multiplier in a given year, with the year 1972 providing a striking example of this. A multiplier of 14.5 may seem unreasonable: how can \$1 of government spending generate an additional \$14.5 in national GDP? The reason is that the net \$1 change in government expenditure can be associated with a large redistribution of spending across states — a result missed in models that abstract from spatial considerations (and which are averaged out in time series empirical measurements). As illustrated in figure 10, in 1972 the change in aggregate expenditure is a tiny 0.005% relative to aggregate GDP, yet there are comparatively large transfers across states during this year. The median absolute transfer is 0.3% of state's GDP. The aggregate expenditure change hides the large underlying economic activity, which resulting leads to the large fiscal multiplier of 14.5.

This is the key result of this paper. When it comes to fiscal multipliers, the *geography* of spending matters a lot. The spatial mechanism — the result of distinct financing and spending locations of asymmetric geography — can generate large variation in the fiscal multiplier relative to canonical channels.

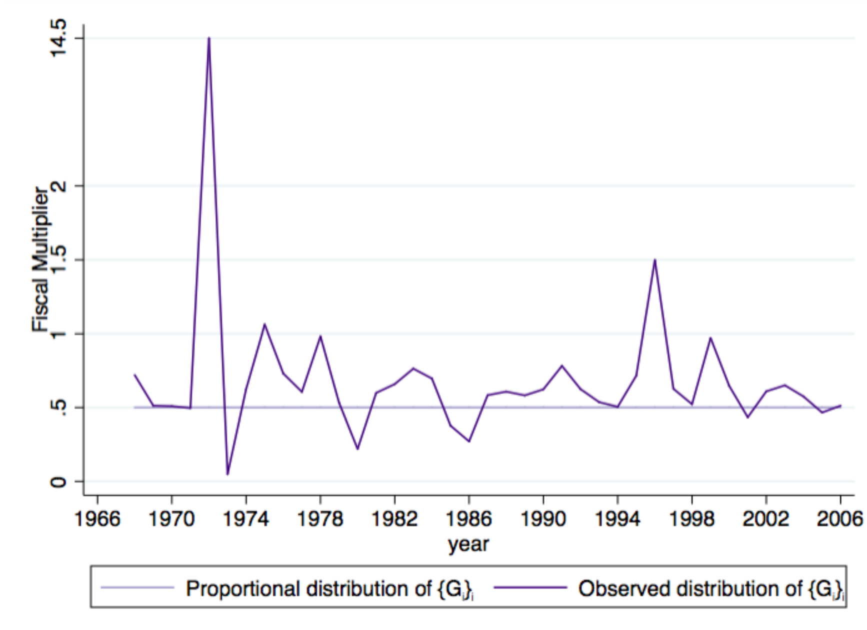


Figure 9: Aggregate fiscal multiplier from aggregate spending changes.

Notes. Calibrating: $\forall i : \Lambda_i^* = 0.5$

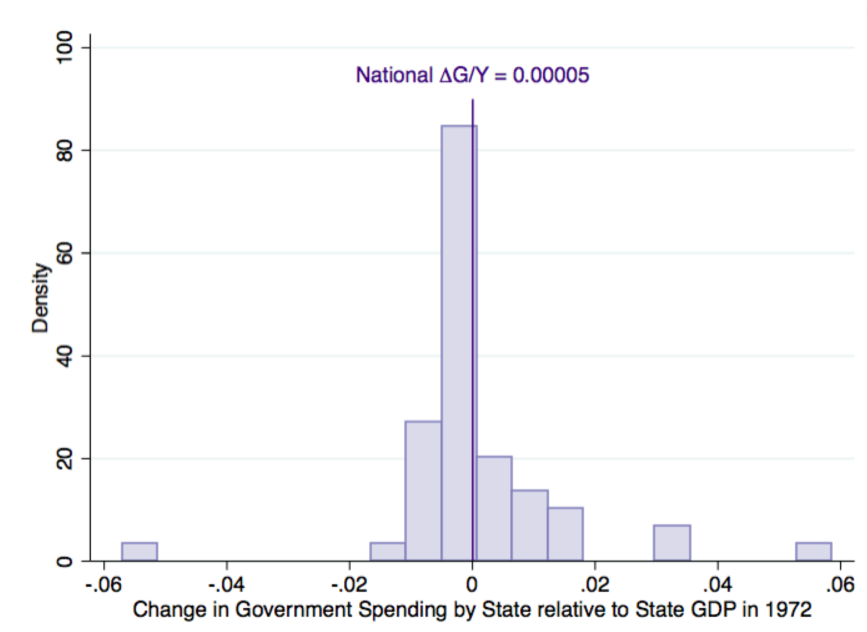


Figure 10: Change in State Government spending relative to State GDP in 1972.

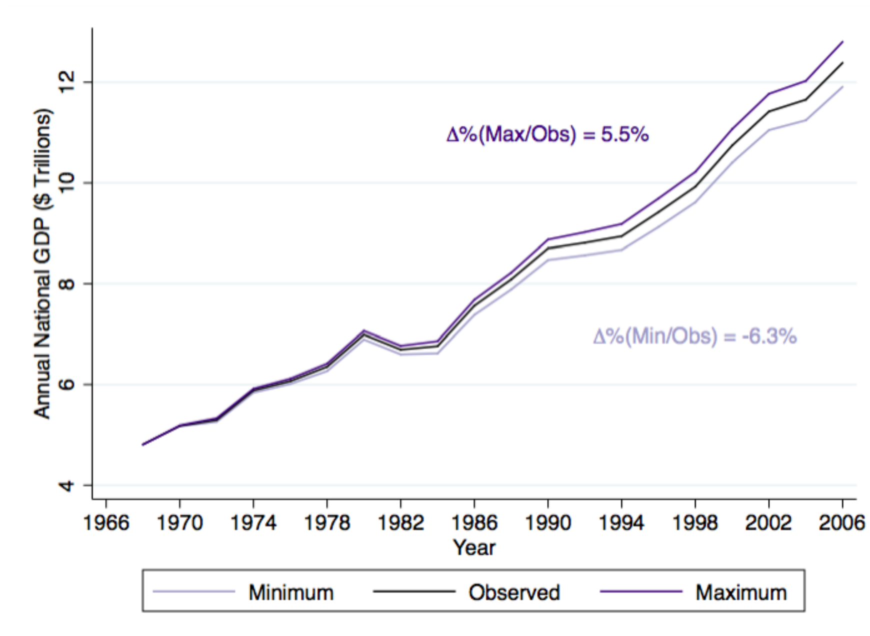


Figure 11: Long-run growth under alternative spending distributions.

Notes. Fiscal Multiplier from proportionally-distributed aggregate spending change assumed to be 0.5 i.e. $\forall i : \Lambda_i^{aggregate} = 0.5$

4.5 Implications for Long-Run Growth

Section 4.4 quantifies the contribution of the spatial mechanism to the fiscal multiplier. To more tangibly assess the implication of this for the economy, I analyze its effect on long-run growth. In figure 11, I graph the the observed US national GDP from 1968-2006, along with two counterfactual growth paths. These two counterfactuals correspond to the two counterfactual time-varying distributions of spending across the years that maximize and minimize national GDP growth of the nation, subject to the constraint that the annual aggregate expenditure is equal to the observed.[80]

The cumulative change in national GDP from 1968 to 2006 decreases by 6.3% relative to the observed in the minimum path, and increases by 5.5% in the maximum path.[81] What this says is that an increase in GDP of 5.5% from 1968 to 2006 can be achieved just by reallocating spending; no additional spending is required.[82] This large result is intuitive given the large variance in the fiscal multiplier due to the distribution of spending as found in the previous sections.

[80]See appendix B.3 for details of their construction.

[81]Converting to a per-annum rate, this is an increase by 3.5% (0.09 percentage points) in the max relative to the observed, and a decrease by 4.2% (0.11 percentage point) in the min relative to the observed.

[82]This assumes the government is able to reallocate spending. In reality, there are constraints due to e.g. technology of the location. Not all locations have the industry present to fulfill the contracts.

5 Conclusion

In this paper, I study a novel spatial mechanism generating aggregate fiscal multipliers that is orthogonal to canonical New Keynesian and Neoclassical mechanisms. In the beginning I highlight that regional heterogeneity and interdependence make this a challenging question to study, as the effect of regional spending on national GDP requires identification of all state-state treatment effects.

I develop a structural solution to address these challenges. Within a tractable gravity model of interregional trade, I derive, to first-order, the general equilibrium responses of regional GDP to regional government spending across all region-region pairs. I show that these responses can be decomposed into two channels: 1) the effect on regional GDP due to a change in aggregate government spending that is distributed proportionally by regional GDP; 2) the effect on GDP due to the redistribution of spending, while holding aggregate spending fixed. I calibrate the first channel using widely available estimates in the literature, and develop an empirical framework to identify the second. I show that it is completely identified by observable government spending and interregional trade flows, and two unobservable parameters: a supply and a demand elasticity.

Combing a Bartik instrument with a model-implied instrumental variable strategy, I develop a structural estimation framework to estimate these two elasticities. I apply this framework to study late-20^{th} century US Federal Defense Procurement. The identification assumption is that the US Federal government did not embark upon national military build-ups/downs to benefit the states that consistently receive more of the contracts differentially to the states that consistently receive fewer of the contracts.

The estimates of the supply and demand elasticities indicate downward-sloping supply and complementarity in demand between products from different state. With these, I study the implied fiscal multipliers. I illustrate that the changes in the geographic distribution of spending significantly affects their magnitude. I find that the spatial mechanism accounts for 50% of the variation in the fiscal multiplier relative to canonical mechanisms.

This is the key result of this paper. The spatial mechanism is of meaningful importance, yet largely abstracted from in the literature. Just like the advancement of state-dependent fiscal multipliers, my results suggest an analogy with geography-dependent fiscal multipliers.

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Appendices

A Theory

A.1 Deriving the Cross-Location Multiplier, equation (10)

The outline of the derivation is as follows. The first step is to construct the structural demand and supply equations of the economy. These are N-location analogues of textbook supply and demand equations; each are implicit functions of endogenous GDP y and prices p, and exogenous government spending shocks g. These structural equations are highly nonlinear, therefore, next I log-linearize. I log-linearize about the equilibrium with observed trade flows in 1977, and transfers set to zero. The final step is to invert the log-linearized structural equations to yield the reduced form equations; each are explicit functions of GDP and prices as a function of government spending shocks. The relation between GDP and government spending is precisely the cross-location multiplier, equation (10). However, the inversion is non-trivial as the set of equations is not full rank due to price being invariant up to scale. I detail all this in the following.

Structural Equations Use the local labor markets equation (8), government spending equations (3), (5), and geography equation (6) to substitute out E_i, G_i and p_{ij}, respectively, in the demand equation (1)

$$X_{ij} = \left(\frac{\tau_{ij}p_i}{P_j}\right)^{1-\phi} Y_j + P_i(g_i - by_i) \cdot \mathbb{1}[i=j]$$

Insert this equation into the product market clearing equation (7)

$$Y_i = \sum_j \left(\frac{\tau_{ij}p_i}{P_j}\right)^{1-\phi} Y_j + P_i(g_i - by_i)$$

Convert to real GDP, insert the price index dependence $P_j = P_j(\boldsymbol{p}) \equiv \left(\sum_i (\tau_{ij}p_i)^{1-\phi}\right)^{\frac{1}{1-\phi}}$ and rearrange

$$D_i(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) \equiv P_i(\boldsymbol{p})y_i - \sum_j \left(\frac{\tau_{ij}p_i}{P_j(\boldsymbol{p})}\right)^{1-\phi} P_j(\boldsymbol{p})y_j + P_i(\boldsymbol{p})(g_i - by_i) = 0 \tag{28}$$

where bolded variables denote the vector across locations, $\boldsymbol{z} \equiv \{z_i\}_{i=1}^N$. $\boldsymbol{D}(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) = \boldsymbol{0}$ form the structural demand equations. Next, multiply the supply equation (2) by p_i, convert to real GDP, insert $P_j = P_j(\boldsymbol{p})$ and rearrange to give

$$S_i(\boldsymbol{y}, \boldsymbol{p}) \equiv P_i y_i - A_i \left(\frac{p_i}{P_i(\boldsymbol{p})}\right)^{1+\psi} = 0 \tag{29}$$

$\boldsymbol{S}(\boldsymbol{y}, \boldsymbol{p}) = \boldsymbol{0}$ form the structural supply equations. The final equation needed is the government budget constraint, equation (4)

$$B(\boldsymbol{p}, \boldsymbol{g}, b) \equiv \sum_i P_i(g_i - by_i) = 0$$

Together, the complete set of structural equations for the system are

$$
\begin{aligned}
\boldsymbol{D}(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) &= \mathbf{0}\\
\boldsymbol{S}(\boldsymbol{y},\boldsymbol{p}) &= \mathbf{0}\\
B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) &= 0
\end{aligned} \tag{30}
$$

Log-linearized Structural Equations. Log-linearizing equation (30) gives

$$
\underbrace{\begin{pmatrix} \nabla_{\ln \boldsymbol{y}}\boldsymbol{D} & \nabla_{\ln \boldsymbol{p}}\boldsymbol{D} & \nabla_{b}\boldsymbol{D}\\ \nabla_{\ln \boldsymbol{y}}\boldsymbol{S} & \nabla_{\ln \boldsymbol{p}}\boldsymbol{S} & \mathbf{0}\\ \nabla_{\ln \boldsymbol{y}}B & \nabla_{\ln \boldsymbol{p}}B & \nabla_{b}B \end{pmatrix}}_{\equiv\Gamma} \begin{pmatrix} \mathrm{d}\ln \boldsymbol{y}\\ \mathrm{d}\ln \boldsymbol{p}\\ \mathrm{d}b \end{pmatrix} = \underbrace{\begin{pmatrix} -(\nabla_{\boldsymbol{g}}\boldsymbol{D})\mathbb{Y}\\ \mathcal{O}\\ -\nabla_{\boldsymbol{g}}B \end{pmatrix}}_{\equiv\tilde{\Gamma}} \frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \tag{31}
$$

where, I use the gradient notation $(\nabla_{\boldsymbol{x}}\boldsymbol{y})_{ij} \equiv \frac{\partial y_i}{\partial x_j}$; the diagonal matrix of nominal GDP $(\{\mathbb{Y}\}_{ij} \equiv Y_i \mathbb{1}[i=j]$; $(\mathbf{0})_i = 0$ for the zero vector of size $N \times 1$; $(\mathcal{O})_{ij} = 0$ is the square zero matrix of size $N \times N$; I use, with slight abuse of notation, $\left(\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}}\right)_i \equiv \frac{\mathrm{d}g_i}{y_i}$; and, finally, the matrices

$$
\begin{aligned}
\Gamma &: (\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) \to \mathbb{R}^{(2N+1)\times(2N+1)}\\
\tilde{\Gamma} &: (\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) \to \mathbb{R}^{(2N+1)\times N}
\end{aligned}
$$

This step is done in detail in appendix section XX. Equation (40) separates the endogenous variables, on the left, from the exogenous variables, on the right. This is important for the inversion in the next step.

Reduced-Form Equations. Deriving the reduced-form equation requires inverting Γ. However, a matrix inversion is not possible as, due to price normalization, the maximum rank of Γ is $2N$; it is therefore rank deficient.[83] A pseudo-inverse must be taken instead and is done so as follows.

Before inverting, the price normalization equation (9) (which in changes implies $\mathrm{d}\ln p_u \equiv 0$) must be imposed in the structural set of equations (40). This is equivalent to dropping the $(N+u)^{th}$ column in Γ as each element in this column is multiplying zero

$$
\Gamma_{.,-(N+u)} \begin{pmatrix} \mathrm{d}\ln \boldsymbol{y}\\ \mathrm{d}\ln \boldsymbol{p}_{-u}\\ \mathrm{d}b \end{pmatrix} = \tilde{\Gamma}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \tag{32}
$$

[83]Intuitively, if Γ were full rank, then equation (40) could be inverted and, for all $i \in \{1,...,N\}$, the price changes $\mathrm{d}\ln p_i$ will be determined. But this cannot be possible as one of the prices is determined by the normalization condition 9; a condition which has not anywhere been imposed in the set of structural equations (40).

where $-n$ indicates that the n^{th} element is excluded.[84] However, these structural equations can still not be inverted as $\Gamma_{.,-(N+u)}$ is no longer square. The second step is to drop one of the structural equations in (32), which drops a row in $\Gamma_{.,-(N+u)}$, so that the matrix becomes square. I exclude the $(2N+1)^{th}$

$$\Gamma_{-(2N+1),-(N+u)} \begin{pmatrix} \mathrm{d}\ln \boldsymbol{y} \\ \mathrm{d}\ln \boldsymbol{p}_{-u} \\ \mathrm{d}b \end{pmatrix} = \tilde{\Gamma}_{-(2N+1),.} \begin{pmatrix} \frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \\ \mathrm{d}t \end{pmatrix} \tag{33}$$

Even though the last equation is dropped and therefore not explicitly imposed when solving for the endogenous variables (i.e. when I soon invert), the equation is still satisfied - and therefore general equilibrium maintained - due to Walras' Law. That is, the following is true

$$\sum_i D_i(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g}) \equiv B(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) \tag{34}$$

I show this formally in appendix A.1.2. Importantly, this holds whether $\{\boldsymbol{y}, \boldsymbol{p}, b\}$ are general equilibrium values or not.[85] The implication is that when $D_i(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g}) = 0$ holds for all $i \in \{1, ..., N\}$, equation (34) implies that $B(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) = 0$ holds automatically. Thus, $\boldsymbol{S}(\boldsymbol{y}, \boldsymbol{p}) = \boldsymbol{0}$ and $\boldsymbol{D}(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g}) = \boldsymbol{0}$ are sufficient for general equilibrium; $B(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) = 0$, and therefore the $(2N+1)^{th}$ equation of (40), need not directly be imposed and can be dropped.

Inverting equation (33) yields the reduced-form equations

$$\begin{pmatrix} \mathrm{d}\ln \boldsymbol{y} \\ \mathrm{d}\ln \boldsymbol{p}_{-u} \\ \mathrm{d}b \end{pmatrix} = (\Gamma_{-(2N+1),-u})^{-1} \tilde{\Gamma}_{-(2N+1),.} \frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \tag{35}$$

The cross-location fiscal multiplier of equation (10) concerns the firs N rows of equation (35), with

$$\Lambda^{transfers} \equiv \left((\Gamma_{-(2N+1),-u})^{-1} \tilde{\Gamma}_{-(2N+1),.} \right)_{i,j}, \quad i \in \{1,,,.N\}, j \in \{1,,,.N\}$$

and where

$$\Lambda^{transfers} : \Omega^{all} \to \mathbb{R}^{N^2}$$

with $\Omega^{all} \equiv \{\{y_i, p_i, b, g_i, \{A_i\}_i, \{\tau_{ij}\}_{ij}, \phi, \psi\}$, that is, simply all variables and parameters

[84] $\boldsymbol{p}_{-u} \equiv \{x_i\}_{i \in \{1,...,u-1,u+1,...,N\}}$; $\Gamma_{.,-(N+u)} \equiv \{M_{ij}\}_{i \in \{1,...,2N+1\}, j \in \{1,...,N+u-1,N+u+1,...,2N+1\}}$.

[85] $\{\boldsymbol{y}, \boldsymbol{p}, b\}$ are general equilibrium values if equation (**??**) holds. i.e. $D_i(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g}) = 0$ and $B(\boldsymbol{y}, \boldsymbol{p}, \boldsymbol{g}, b) = 0$ in addition to $\boldsymbol{S}(\boldsymbol{y}, \boldsymbol{p}) = \boldsymbol{0}$.

of the model. No attempt has been made to simplify this dependence down — yet.

A.1.1 Log-Linearizing the structural equations

Here I in detail derive equation (40). In what follows, I use the notation: doublestroke font to denote trade share matrices: $\{\mathbb{S}^{Im}\}_{ij} \equiv s_{ij}^{Im}, \{\mathbb{S}^{Ex}\}_{ij} \equiv s_{ij}^{Ex}$; and diagonal matrices $\{\mathbb{G}^{transfers}\}_{ij} \equiv P_i g_i^{transfers} \mathbb{1}[i=j], \{\mathbb{Y}\}_{ij} \equiv Y_i \mathbb{1}[i=j], \{\mathbb{S}^G\}_{ij} \equiv s_i^G \mathbb{1}[i=j]$; for the trade cost matrix I use $\{\bar{\tau}\}_{ij} \equiv \tau_{ij}$, and for the vector of ones $\{\boldsymbol{e}\}_i \equiv 1$.

As it will be used extensively in the derivation, first the derivative of the price index

$$\mathrm{d}\ln P_i = \sum_j \left(\frac{p_{ji}}{P_j}\right)^{1-\phi} \mathrm{d}\ln p_{ji} = \sum_j s_{ji}^{Im} \mathrm{d}\ln(p_j \tau_{ji})$$

$$\iff \quad \mathrm{d}\ln \boldsymbol{P} = \mathbb{S}^{Im'} \mathrm{d}\boldsymbol{p} + (\mathbb{S}^{Im} \odot \mathrm{d}\ln \bar{\tau})' \boldsymbol{e} \tag{36}$$

where $\odot$ repesents the Hadamard product (element-wise multiplication). Now, to differentiating the structural equations.

Demand equation

$$\mathrm{d}D_i = Y_i \mathrm{d}\ln(P_i y_i) - \sum_j X_{ij} \{(1-\phi)\mathrm{d}\ln(\tau_{ij} p_i) + \phi \mathrm{d}\ln P_j + \mathrm{d}\ln y_j\} + \cdots$$

$$\cdots - G_i^{transfers} \mathrm{d}\ln P_i + bY_i \mathrm{d}\ln y_i - Y_i \frac{\mathrm{d}g_i}{y_i} + Y_i \mathrm{d}b$$

$$= \sum_j \{(1+b) Y_j \mathbb{1}[i=j] - X_{ij}\} \mathrm{d}\ln y_j + \sum_j \left\{(Y_j - G_j^{transfers})\mathbb{1}[i=j] - \phi X_{ij}\right\} \mathrm{d}\ln P_j + \cdots$$

$$\cdots - \sum_j (1-\phi) X_{ij} \mathrm{d}\ln p_i - \sum_j (1-\phi) X_{ij} \mathrm{d}\ln \tau_{ij} - Y_i \frac{\mathrm{d}g_i}{y_i} + Y_i \mathrm{d}b$$

Rewriting in matrix form, using 36 and $\sum_j X_{ij} = Y_i - G_i^{transfers}$

$$\mathrm{d}\boldsymbol{D} = \{(1+b)\mathbb{Y} - \mathbb{X}\} \mathrm{d}\ln y + \left\{\mathbb{Y} - \mathbb{G}^{transfers} - \phi \mathbb{X}\right\} \left\{\mathbb{S}^{Im'} \mathrm{d}\ln \boldsymbol{p} + (\mathbb{S}^{Im} \odot \mathrm{d}\ln \bar{\tau})' \boldsymbol{e}\right\} + \cdots$$

$$\cdots - (1-\phi)(\mathbb{Y} - \mathbb{G}^{transfers}) \mathrm{d}\ln \boldsymbol{p} - (1-\phi)(\mathbb{X} \odot \mathrm{d}\ln \bar{\tau})\boldsymbol{e} - \mathbb{Y}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} + \boldsymbol{Y}\mathrm{d}b$$

In equilibrium, $b = b^* \equiv \frac{\sum_i P_i g_i}{\sum_i P_i y_i}$, so that the government's budget is balanced. Rearranging and collecting terms

$$\mathrm{d}\boldsymbol{D} = \underbrace{\{(1+b^*)\mathbb{Y} - \mathbb{X}\}}_{\nabla_{\ln \boldsymbol{y}}\boldsymbol{D}} \mathrm{d}\ln \boldsymbol{y} + \underbrace{\left[\left\{\mathbb{Y} - \mathbb{G}^{transfers} - \phi\mathbb{X}\right\} \mathbb{S}^{Im'} - (1-\phi)(\mathbb{Y} - \mathbb{G}^{transfers})\right]}_{\nabla_{\ln \boldsymbol{p}}\boldsymbol{D}} \mathrm{d}\ln \boldsymbol{p} + \cdots$$

$$\cdots + \underbrace{-\mathcal{I}}_{\nabla_{\boldsymbol{g}}\boldsymbol{D}} \mathbb{Y}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} + \underbrace{\boldsymbol{Y}}_{\nabla_b \boldsymbol{D}} \mathrm{d}b + \cdots$$

$$\cdots + \underbrace{\left\{\mathbb{Y} - \mathbb{G}^{transfers} - \phi\mathbb{X}\right\} (\mathbb{S}^{Im} \odot \mathrm{d}\ln\bar{\tau})'\boldsymbol{e} - (1-\phi)(\mathbb{X} \odot \mathrm{d}\ln\bar{\tau})\boldsymbol{e}}_{(\nabla_{\varepsilon}\boldsymbol{D})\mathrm{d}\varepsilon} \tag{37}$$

Setting the transfers to zero at the expansion point, $\mathbb{G}^{transfers} = \mathbf{0}, b^* = 0$

$$\mathrm{d}\boldsymbol{D} = \underbrace{\{\mathbb{Y} - \mathbb{X}\}}_{\nabla_{\ln \boldsymbol{y}}\boldsymbol{D}} \mathrm{d}\ln \boldsymbol{y} + \underbrace{\left[\{\mathbb{Y} - \phi\mathbb{X}\} \mathbb{S}^{Im'} - (1-\phi)\mathbb{Y}\right]}_{\nabla_{\ln \boldsymbol{p}}\boldsymbol{D}} \mathrm{d}\ln \boldsymbol{p} + \cdots$$

$$\cdots + \underbrace{-\mathcal{I}}_{\nabla_{\boldsymbol{g}}\boldsymbol{D}} \mathbb{Y}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} + \underbrace{\boldsymbol{Y}}_{\nabla_b \boldsymbol{D}} \mathrm{d}b + \cdots$$

$$\cdots + \underbrace{\{\mathbb{Y} - \phi\mathbb{X}\} (\mathbb{S}^{Im} \odot \mathrm{d}\ln\bar{\tau})'\boldsymbol{e} - (1-\phi)(\mathbb{X} \odot \mathrm{d}\ln\bar{\tau})\boldsymbol{e}}_{(\nabla_{\varepsilon}\boldsymbol{D})\mathrm{d}\varepsilon} \tag{38}$$

Supply equation

$$\mathrm{d}S_i = Y_i \mathrm{d}\ln(P_i y_i) - Y_i \{\mathrm{d}\ln P_i + (1+\psi)(\mathrm{d}\ln p_i - \mathrm{d}\ln P_i) + \mathrm{d}\ln A_i\}$$

Converting to matrix notation

$$\mathrm{d}\boldsymbol{S} = \mathbb{Y}\mathrm{d}\ln \boldsymbol{y} - (1+\psi)\mathbb{Y}\mathrm{d}\ln \boldsymbol{p} + (1+\psi)\mathbb{Y}\mathrm{d}\ln \boldsymbol{P} - \mathbb{Y}\mathrm{d}\ln \boldsymbol{A}$$

and using 36

$$\mathrm{d}\boldsymbol{S} = \underbrace{\mathbb{Y}}_{\nabla_{\ln \boldsymbol{y}}\boldsymbol{S}} \mathrm{d}\ln \boldsymbol{y} + \underbrace{-(1+\psi)\mathbb{Y}\left(\mathcal{I} - \mathbb{S}^{Im'}\right)}_{\nabla_{\ln \boldsymbol{p}}\boldsymbol{S}} \mathrm{d}\ln \boldsymbol{p} + \underbrace{(1+\psi)\mathbb{Y}(\mathbb{S}^{Im} \odot \mathrm{d}\ln\bar{\tau})'\boldsymbol{e} - \mathbb{Y}\mathrm{d}\ln \boldsymbol{A}}_{(\nabla_{\varepsilon}\boldsymbol{S})\mathrm{d}\varepsilon} \tag{39}$$

Budget Constraint

$$\mathrm{d}B = \sum_i \left\{G_i^{transfers}\mathrm{d}\ln P_i - Y_i\frac{\mathrm{d}g_i}{y_i} - bY_i\mathrm{d}\ln y_i - Y_i\mathrm{d}b\right\}$$

In matrix form (and $b = b^*$)

$$\mathrm{d}B = \underbrace{-b^*\boldsymbol{Y}'}_{\nabla_{\ln \boldsymbol{y}} B}\mathrm{d}\ln \boldsymbol{y} + \underbrace{\boldsymbol{e}'\mathbb{G}^{transfers}\mathbb{S}^{Im'}}_{\nabla_{\ln \boldsymbol{p}} B}\mathrm{d}\ln \boldsymbol{p} + \underbrace{-\boldsymbol{Y}'}_{\nabla_{\boldsymbol{g}} B}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} + \underbrace{-\boldsymbol{e}'\boldsymbol{Y}}_{\nabla_b B}\mathrm{d}b + \underbrace{\boldsymbol{e}'\mathbb{G}^{transfers}(\mathbb{S}^{Im} \odot \mathrm{d}\ln \bar{\tau})'\boldsymbol{e}}_{(\nabla_\varepsilon B)\mathrm{d}\varepsilon}$$

Setting the transfers to zero at the expansion point, $\mathbb{G}^{transfers} = \boldsymbol{0}, b^* = 0$

$$\mathrm{d}B = \underbrace{-\boldsymbol{Y}'}_{\nabla_{\boldsymbol{g}} B}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} + \underbrace{-\boldsymbol{e}'\boldsymbol{Y}}_{\nabla_b B}\mathrm{d}b$$

Linearized Structural Equations Equation (40) is derived by inserting the above into

$$\begin{pmatrix} \mathrm{d}\boldsymbol{D} \\ \mathrm{d}\boldsymbol{S} \\ \mathrm{d}B \end{pmatrix} = \begin{pmatrix} \boldsymbol{0} \\ \boldsymbol{0} \\ 0 \end{pmatrix}$$

and rearranging to give

$$\underbrace{\begin{pmatrix} \nabla_{\ln \boldsymbol{y}}\boldsymbol{D} & \nabla_{\ln \boldsymbol{p}}\boldsymbol{D} & \nabla_b \boldsymbol{D} \\ \nabla_{\ln \boldsymbol{y}}\boldsymbol{S} & \nabla_{\ln \boldsymbol{p}}\boldsymbol{S} & \boldsymbol{0} \\ \nabla_{\ln \boldsymbol{y}}B & \nabla_{\ln \boldsymbol{p}}B & \nabla_b B \end{pmatrix}}_{\equiv \Gamma} \begin{pmatrix} \mathrm{d}\ln \boldsymbol{y} \\ \mathrm{d}\ln \boldsymbol{p} \\ \mathrm{d}b \end{pmatrix} = \underbrace{\begin{pmatrix} -(\nabla_{\boldsymbol{g}}\boldsymbol{D})\mathbb{Y} & -\nabla_\varepsilon \boldsymbol{D} \\ \mathcal{O} & -\nabla_\varepsilon \boldsymbol{S} \\ -\nabla_{\boldsymbol{g}} B & -\nabla_\epsilon B \end{pmatrix}}_{\equiv \tilde{\Gamma}} \begin{pmatrix} \frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \\ \mathrm{d}\varepsilon \end{pmatrix} \tag{40}$$

The $\mathrm{d}\varepsilon$ shows how the other exogenous shocks in the model ($\mathrm{d}\ln \boldsymbol{A}, \mathrm{d}\ln \bar{\tau}$) enter into the structural equations; I omit these for simplicity in the main text. These contribute towards the residual in the empirical framework.

A.1.2 Walras Law and equation (34)

Generally, Walras Law holds when all agents of the economy balance their budgets. The implication is that aggregate market clearing holds. Importantly, Walras Law does not require the allocation to be a general equilibrium; the first order conditions do not need to hold.[86] The consequence of Walras Law in my framework is

[86] If $(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g})$ constitute a general equilibrium, then $\forall i : D_i(\boldsymbol{y}, \boldsymbol{p}, b, \boldsymbol{g}) = 0$ (and $\forall i : S_i(\boldsymbol{y}, \boldsymbol{p}) = 0$, though this does not enter for Walras Law). However, as can be seen, this needn't be constrained to for equation 34 to hold.

$$\sum_i D_i(\boldsymbol{y},\boldsymbol{p},b,\boldsymbol{g}) \equiv B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b)$$

This holds because budget balance (equations (7) and (8) in my framework) is imposed in the construction of $D_i(\boldsymbol{y},\boldsymbol{p},b,\boldsymbol{g})$ (see section A.1). Formally, equation (34) can be shown by summing D_i over i

$$\begin{aligned}
D_i(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) &\equiv P_i(\boldsymbol{p})y_i - \sum_j \left(\frac{\tau_{ij}p_i}{P_j(\boldsymbol{p})}\right)^{1-\phi} P_j(\boldsymbol{p})y_j + P_i(\boldsymbol{p})(g_i - by_i) \\
\sum_i D_i(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) &\equiv \sum_i P_i(\boldsymbol{p})y_i - \sum_{ij} \left(\frac{\tau_{ij}p_i}{P_j(\boldsymbol{p})}\right)^{1-\phi} P_j(\boldsymbol{p})y_j + \underbrace{\sum_i P_i(\boldsymbol{p})(g_i - by_i)}_{B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b)} \\
&\equiv \sum_i P_i(\boldsymbol{p})y_i - \sum_j \frac{\sum_i(\tau_{ij}p_i)^{1-\phi}}{P_j(\boldsymbol{p})^{1-\phi}} P_j(\boldsymbol{p})y_j + B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) \\
&\equiv \sum_i P_i(\boldsymbol{p})y_i - \sum_j P_j(\boldsymbol{p})y_j + B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b) \\
&\equiv B(\boldsymbol{y},\boldsymbol{p},\boldsymbol{g},b)
\end{aligned}$$

where in going from the third to the fourth line, the identity $P_j(\boldsymbol{p}) \equiv \sum_i(\tau_{ij}p_i)^{1-\phi}$ has been used.

□

A.2 Proof of Proposition 1 (Sufficient Statistics)

Given that the $(2N+1)^{th}$ equation is dropped from $\Gamma, \tilde{\Gamma}$ before inverting to form $\Lambda^{transfers}$, Proving that the first $2N$ structural equations depend only on s^{Im}, s^{Ex}, s^G is sufficient to showing that $\Lambda^{transfers}$ only depend on s^{Im}, s^{Ex}, s^G.

First, under the assumption $Y_i \neq 0$, define

$$H \equiv \begin{pmatrix} \mathbb{Y}^{-1} & \mathcal{O} \\ \mathcal{O} & \mathbb{Y}^{-1} \end{pmatrix}$$

Then, the first $2N$ structural equations, given by

$$\begin{pmatrix} \mathrm{d}\boldsymbol{D} \\ \mathrm{d}\boldsymbol{S} \end{pmatrix} = \begin{pmatrix} \boldsymbol{0} \\ \boldsymbol{0} \end{pmatrix}$$

can be transformed without loss of generality

$$H\begin{pmatrix}\mathrm{d}\boldsymbol{D}\\ \mathrm{d}\boldsymbol{S}\end{pmatrix}=\begin{pmatrix}\mathbb{Y}^{-1}\mathrm{d}\boldsymbol{D}\\ \mathbb{Y}^{-1}\mathrm{d}\boldsymbol{S}\end{pmatrix}=\begin{pmatrix}\boldsymbol{0}\\ \boldsymbol{0}\end{pmatrix} \tag{41}$$

Noting that $\mathbb{Y}^{-1}\mathbb{X}=\mathbb{S}^{Ex}$, then

$$\begin{aligned}\mathbb{Y}^{-1}\mathrm{d}\boldsymbol{D}&=\left\{\mathcal{I}-\mathbb{S}^{Ex}\right\}\mathrm{d}\ln\boldsymbol{y}+\left[\left\{\mathcal{I}-\phi\mathbb{S}^{Ex}\right\}\mathbb{S}^{Im'}-(1-\phi)\mathcal{I}\right]\mathrm{d}\ln\boldsymbol{p}+\cdots\\ &\quad\cdots-\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}}+\boldsymbol{e}\mathrm{d}b+\left\{\mathcal{I}-\phi\mathbb{S}^{Ex}\right\}(\mathbb{S}^{Im}\odot\mathrm{d}\ln\bar{\tau})'\boldsymbol{e}-(1-\phi)(\mathbb{S}^{Ex}\odot\mathrm{d}\ln\bar{\tau})\boldsymbol{e}\\ \mathbb{Y}^{-1}\mathrm{d}\boldsymbol{S}&=\mathrm{d}\ln\boldsymbol{y}-(1+\psi)\left(\mathcal{I}-\mathbb{S}^{Im'}\right)\mathrm{d}\ln\boldsymbol{p}+(1+\psi)(\mathbb{S}^{Im}\odot\mathrm{d}\ln\bar{\tau})'\boldsymbol{e}-\mathrm{d}\ln\boldsymbol{A}\end{aligned}$$

All the partial derivatives only depend on $\mathbb{S}^{Ex}, \mathbb{S}^{Im}, \phi, \psi$. In consequence $H\Gamma_{-(2N+1),-(N+u)}, H\tilde{\Gamma}_{-(2N+1)}$ also only depend on these variables. Now, using this and the definition of $\Lambda^{transfers}$

$$\begin{aligned}\Lambda^{transfers}&\equiv(\Gamma_{-(2N+1),-u})^{-1}\tilde{\Gamma}_{-(2N+1),.}\\ &\equiv(\Gamma_{-(2N+1),-u})^{-1}H^{-1}H\tilde{\Gamma}_{-(2N+1),.}\\ &\equiv(H\Gamma_{-(2N+1),-u})^{-1}H\tilde{\Gamma}_{-(2N+1),.}\end{aligned}$$

using the trivial property that $H^{-1}H=\mathcal{I}$ in going from line one to two. Thus $\Lambda^{transfers}$ only depends on $\{s_i^G\}_i, \{s_{ij}^{Ex}, s_{ij}^{Im}\}_{ij}$.

□

A.3 Proof of Proposition 2 (Aggregate Fiscal Multiplier and Internal Geography)

To facilitate the proof, rather than consider arbitrary $\{g_i\}_i$ with endogenous b as in the main text, I instead omit b and allow $\mathrm{d}g_2$ to be endogenous. The linearized structural equations become

$$\underbrace{\begin{pmatrix}\nabla_{\ln\boldsymbol{y}}\boldsymbol{S} & \nabla_{\ln\boldsymbol{p}}\boldsymbol{S}\\ \nabla_{\ln\boldsymbol{y}}\boldsymbol{D} & \nabla_{\ln\boldsymbol{p}}\boldsymbol{D}\end{pmatrix}}_{\equiv\Gamma}\begin{pmatrix}\mathrm{d}\ln\boldsymbol{y}\\ \mathrm{d}\ln\boldsymbol{p}\end{pmatrix}=\begin{pmatrix}\mathcal{O}\\ -(\nabla_{\boldsymbol{g}}\boldsymbol{D})\mathbb{Y}\end{pmatrix}\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} \tag{42}$$

where I've written the supply equations first, then the demand equations. Given $N=2$, this matrix is of size 4×4. I drop the 4th equation, normalize the $p_2\equiv 1$, and invert. This gives the equilibrium change in output

$$\mathrm{d}\ln \boldsymbol{y} = \frac{1+\psi}{|\Gamma|}\begin{pmatrix} 1-S_{11}^{Im} \\ -S_{12}^{Im} \end{pmatrix}\frac{\mathrm{d}g_1}{y_1}$$

Note that $\frac{\mathrm{d}g_2}{y_2}$ is absent as it is now endogenous. The change in aggregate GDP is given by

$$\frac{\mathrm{d}y_{agg}}{\mathrm{d}g_1} = \sum_i y_i \Lambda_{i1}^{transfers} y_1^{-1} = \frac{1+\psi}{|\Gamma|}\underbrace{\left(1 - S_{11}^{Im} - \frac{y_1}{y_2}S_{12}^{Im}\right)}_{\equiv\Omega}$$

A.4 Isomorphisms

In this section I present some common microfoundations that isomorphic with the equilibrium in section 2.1.

A.4.1 A Simple Macroeconomic Baseline

Described here is a correspondence between the model in the main text and a stylized macroeconomic framework.

Economy

Households A representative household in each location that maximizes utility

$$\max_{\{c_{ji}\}_{j\in\{1,\ldots,N\}},L_i} \frac{c_i^{1-\sigma^{-1}}}{1-\sigma^{-1}} - \frac{L_i^{1+\nu^{-1}}}{1+\nu^{-1}}, \qquad c_i \equiv \left(\sum_j c_{ji}^{\frac{\phi-1}{\phi}}\right)^{\frac{\phi}{\phi-1}}$$

subject to the budget constraint

$$\sum_j p_{ji}c_{ji} = w_i L_i \equiv E_i \tag{43}$$

Firms A representative firm in each location maximizes profit

$$\max_{q_i,l_i} p_i q_i - w_i l_i \qquad q_i \equiv A_i l_i$$

The production technology is $q_i = A_i l_i$ with external economies of scale $A_i \equiv \bar{A}_i l_i^{\chi}$. Free entry is imposed implying zero profit.
Government (As in main text.)

Geography (As in main text.)

Product Market Clearing (As in main text.)

Labor Market Clearing Labor demand, l_i equals labor supply, L_i, in all locations:

$$l_i = L_i$$

Price Normalization (As in main text.)

Correspondence with Structural Demand and supply equations

Demand Equation, (1). The first order conditions with respect to $\{c_{ij}\}_i$ of a household in location j leads to optimal disaggregate consumption

$$c_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{-\phi} c_j$$

combining with the budget constraint

$$P_j c_j = w_j L_j = E_j$$

gives

$$p_{ij} c_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{1-\phi} E_j$$

The sum of private and public demand give the demand equation

$$X_{ij} = p_{ij} c_{ij} + G_i^{transfers} \mathbb{1}[i = j] = \left(\frac{p_{ij}}{P_j}\right)^{1-\phi} E_j + G_i^{transfers} \mathbb{1}[i = j]$$

Supply Equation, (2). The first order conditions with respect to $\{c_i, L_i\}$ of a household in location i leads to

$$L_i^{1/\nu} = c^{-1/\sigma} \frac{w_i}{P_i} \tag{44}$$

combining with the budget constraint, $P_i c_i = w_i L_i$ to solve for optimal aggregate consumption

$$c_i = L_i \frac{w_i}{P_i} \tag{45}$$

into (44) to solve for optimal labor supply in terms of the real wage[87]

$$L_i^{1/\nu+1/\sigma} = \left(\frac{w_i}{P_i}\right)^{1-1/\sigma} \tag{46}$$

Next, the optimal pricing equation from the firm's problem is

$$p_i A_i = w_i$$

Combined with the productivity definition $A_i \equiv \bar{A}_i l_i^{\chi}$ and labor market clearing $L_i = l_i$ to write labor demand

$$p_i \bar{A}_i L_i^{\chi} = w_i \tag{47}$$

Using this to substitute out wages in equation (46)

$$L^{1/\nu+1/\sigma-\chi(1-1/\sigma)} = \bar{A}_i^{1-1/\sigma}\left(\frac{p_i}{P_i}\right)^{(1-/\sigma)} \tag{48}$$

Finally, using the production function $q_i = A_i L_i$ to rewrite L_i in terms of output

$$L_i = \bar{A}_i^{\frac{1}{1+\chi}} q_i^{\frac{1}{1+\chi}}$$

and inserting this into equation (48)

$$\left(q_i \bar{A}_i\right)^{\frac{1+1/\nu}{1+\chi}-(1-1/\sigma)} = \bar{A}_i^{1-1/\sigma}\left(\frac{p_i}{P_i}\right)^{(1-/\sigma)}$$

rearranging gives the supply equation for output q_i

$$q_i = \tilde{A}_i \left(\frac{p_i}{P_i}\right)^{\psi}$$

with

$$\psi \equiv \frac{1-\sigma^{-1}}{\frac{1+\nu^{-1}}{1+\chi} - (1-\sigma^{-1})}, \qquad \tilde{A}_i \equiv \bar{A}_i^{\psi} \tag{49}$$

substituting output for real GDP, using $q_i = P_i/p_i y_i$ gives the supply equation (**??**).

The dependence of ψ on structural parameters of the microfoundation indicate under

[87] The analogous equation for consumption is $c_i^{1/\nu+1/\sigma} = \left(\frac{w_i}{P_i}\right)^{1+1/\nu}(1-t)^{\zeta+1/\nu}$.

which conditions $\psi < 0$ may arise. Looking at each parameter in turn

- $\sigma < 1$. This corresponds to the income effect in labor outweighing the substitution effect. In this case, even without scale economies, when the real wage falls, the labor supplied increases. This is what generates the magnification effect associated with negative ψ and fiscal multipliers.

- $\chi > 0$ indicates increasing returns to scale. As output rises, production becomes more efficient causing prices to fall. Consumption increase and therefore magnifying output.

- ν is the Frisch Elasticity of labor supply. This alone (i.e. without either $\chi > 0$ or $\sigma < 1$) cannot create $\psi < 0$. However, given either $\chi > 0$ or $\sigma < 1$, a greater ν makes $\psi < 0$ more likely. Intuitively, the more elastic labor supply is (the greater ν is), the more responsive output is to smaller changes in prices, thus leading to a greater magnification effect.

A.4.2 Variable Mark-Ups

An alternative microfoundation to generating $\psi < 0$ is with variable mark-ups. The definition of the mark-up is

$$\frac{p_i}{w_i/A_i} \equiv \mu_i \tag{50}$$

Consider $\mu \neq 1$ in the macroeconomic baseline microfoundation described in section A.4.1. Only the derivation of the supply equation is changes; the derivation of the demand equation is the same. With $\mu \neq 1$, profits are no longer zero. Denoting profits by Π, then

$$\Pi_i \equiv p_i q_i - w_i l_i = (\mu_i - 1) w_i l_i$$

Assuming these are transferred lump-sum to colocal consumers, then the budget constraint in equation (43) becomes

$$P_i c_i = w_i L_i + \Pi_i$$

With Π being lump-sum, the first-order conditions of the consumer are unaffected. In equilibrium, inserting Π into the budget constraint

$$P_i c_i = w_i L_i + \Pi_i = w_i L_i + (\mu_i - 1) w_i L_i = \mu_i w_i L_i$$

this is the analogy of equation (45). Using equation (44) to substitute out optimal c_i

$$L_i^{1/\sigma+1/\nu} = \mu_i^{-1/\sigma}\left(\frac{w_i}{P_i}\right)^{1-1/\sigma}$$

Using the pricing relation, equation (50),

$$L_i^{1/\sigma+1/\nu} = \mu_i^{-1}A_i^{1-1/\sigma}\left(\frac{p_i}{P_i}\right)^{1-1/\sigma}$$

Allowing for external scale economies, $A_i = \bar{A}_i L_i^{\chi}$

$$L_i^{1/\sigma+1/\nu-\chi(1-1/\sigma)} = \mu_i^{-1}\bar{A}_i^{1-1/\sigma}\left(\frac{p_i}{P_i}\right)^{1-1/\sigma}$$

Using $q_i = \bar{A}_i L_i^{1+\chi}$

$$(\bar{A}_i^{-1}q_i)^{\frac{1/\sigma+1/\nu-\chi(1-1/\sigma)}{1+\chi}} = \mu_i^{-1}\bar{A}_i^{1-1/\sigma}\left(\frac{p_i}{P_i}\right)^{1-1/\sigma}$$

Imposing that the mark-up be a function of scale,

$$\mu_i = q_i^{\xi} \tag{51}$$

for some $\xi \in \mathbb{R}$,[88] then

$$q_i = \bar{A}^{\frac{\frac{1+\nu^{-1}}{1+\chi}}{\frac{1+\nu^{-1}}{1+\chi}+\xi-(1-\sigma^{-1})}}\left(\frac{p_i}{P_i}\right)^{\frac{1-\sigma^{-1}}{\frac{1+\nu^{-1}}{1+\chi}+\xi-(1-\sigma^{-1})}}$$

That is, the microfoundation for the supply elasticity becomes

$$\psi \equiv \frac{1-\sigma^{-1}}{\frac{1+1/\nu}{1+\chi}+\xi-(1-\sigma^{-1})}$$

We are back in the baseline case of equation (49) when $\xi = 0$. Adding variable mark-ups to the microfoundation reveals an alternative channel generating $\psi < 0$: mark-ups being decreasing in scale, $\xi < 0$. In the derivation, I stipulated at a high-level that mark-ups are variable, equation (51). What underlying mechanism is consistent with $\xi < 0$? In fact a very common feature of macroeconomic models for fiscal multipliers: sticky prices. In those models, as scale increases, wages increase

[88] Formally, this is where the optimal pricing decision of the firm enters. But rather than deriving it from profit maximizing behavior, I assume it at the top-level.

A.4.3 Labor-Consumption Complementarity

Consider the modified utility

$$v(L)\frac{c^{1-1/\sigma}}{1-1/\sigma} - \frac{L^{1+1/\nu}}{1+1/\nu}$$

where $v(L) \equiv L^{\theta}$ but is not internalized by the consumer when choosing labor supply.[89][90] This specification is motivated by the concept of Edgeworth complements, which requires $\partial^2 u/\partial c \partial L > 0$.[91] Taking FOCs with respect to both labor and consumption and combining gives

$$\frac{L^{1/\nu-\theta}}{C^{-1/\sigma}} = \frac{w}{P}$$

Continuing the derivation of the supply equation yields

$$\psi = \frac{1-\sigma^{-1}}{\frac{1+\nu^{-1}-\theta}{1+\chi} - (1-\sigma^{-1})}$$

Therefore if $\theta > 1 + \nu^{-1}$, then $\psi < 0$ is possible without requiring $\chi < 0$. The intuition is that as consumers work more after the demand shock, their marginal utility of consumption increases due to labor-consumption complementarities.[92] This increase means they consume even more and therefore magnify the increase in output i.e. exactly what a negative ψ describes.

A.4.4 Investment

It has been documented theoretically that including capital can amplify the magnification effect of government spending.[93] The basic intuition can be seen from the formula for GDP

[89] An interpretation can be understood by making analogy to external economies of scale. The more that the population consumes, the greater the incentive for an individual to consume. For example, with brand status, people spend more on expensive brands, such as Apple products, the more that other people do. This shares similarity with Networks in Economics.

[90] In this example, $v(L)$ is not internalized in order to create the isomorphism. If $v(L)$ is internalized, then the functional form of the supply equation is different and is not isomorphic (there is also concern about the utility continuing to be concave for high θ).

[91] See Gliksberg (2010) for discussion of its empirical relevance; see Greenwood et al. (1988) and Nakamura and Steinsson (2014) for example applications of Edgeworth complements, particularly the latter in arguing its importance for the fiscal multiplier.

[92] The complementarity can, for example, represent the extra consumption on food away from home, clothing, gas, and the like that often arises in the context of work.

[93] See e.g. Baxter and King (1993), specifically page 323 for a summary of the short-run and long-run mechanisms of capital's effect on the fiscal multiplier.

$Y = C + I + G$ (ignoring net exports). In the neoclassical model, an increase in ΔG crowds out $\Delta C \in [0, -\Delta G]$ with the decrease being more negative the greater the income effect on C. This bounds $\Delta Y/\Delta G \in [0, 1]$ in a model without capital.

With capital, the multiplier can rise above 1. The reason is that the increase in labor supply induced by the spending pushes up the labor-capital ratio and therefore increases the MPK and thus the rental rate. This incentivizes greater investment $\Delta I > 0$. This additional positive term on the RHS on $\Delta Y = \Delta C + \Delta I + \Delta G$ is therefore able to break the $[0, 1]$ bound on the fiscal multiplier.

To see this in a simple framework, consider a Cobb-Douglas production function, $q = k^{\alpha} L^{1-\alpha}$, and non-traded capital that depreciates at rate δ. In this setting, investment is a constant share of local income, $s \equiv \frac{\alpha\delta\beta}{1-(1-\delta)\beta}$, where β is the consumer discount factor.

This only multiplicatively affects the supply equilibrium relation and therefore does not change the relation in logs (unless there is a lump sum tax, then it will appear and magnifies the neoclassical income effect channel). The demand equation is affected as follows

$$X_{ij} = \left(\frac{p_{ij}}{P_j}\right)^{1-\phi} P_j y_j (1-s) + \mathbb{1}[i=j](G_i + sP_i y_i)$$

Giving

$$(1-s)P_i y_i = \sum_j \left(\frac{p_{ij}}{P_j}\right)^{1-\phi} P_j y_j (1-s) + G_i$$

or

$$P_i y_i = \sum_j \left(\frac{p_{ij}}{P_j}\right)^{1-\phi} P_j y_j + \frac{G_i}{1-s}$$

That is, a positive share spent on investment does magnify the fiscal multiplier due to transfers. However, it's form mathematically is distinct to the how ψ enters and therefore cannot microfound $\psi < 0$ using the standard function form for investment as outlined here.

A.5 Proof of Proposition 3 (Linear Structural Equation)

First, I take the linearized structural demand equations (38) $\mathrm{d}\boldsymbol{D} = 0$ and rearrange to the following

$$((1+b^*)\mathbb{Y}-\mathbb{X})\mathrm{d}\ln\boldsymbol{y} = -\left[\left\{\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\right\}\mathbb{S}^{Im'} + (\phi-1)(\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\mathbb{S}^{Im'})\right]_{\cdot,-u}\mathrm{d}\ln\boldsymbol{p}_{-u} + \cdots$$

$$\cdots + \mathbb{Y}\left(\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} - e\mathrm{d}b\right) + \mu^D$$

where, for convenience, I've denoted the terms involving $\mathrm{d}t$ by μ^D, as this will become part of the error term. Using the structural supply equation $\mathrm{d}\boldsymbol{S} = 0$, I rearrange to solve for $\mathrm{d}\ln\boldsymbol{p}$

$$\mathrm{d}\ln\boldsymbol{p}_{-u} = \frac{1}{1+\psi}\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathrm{d}\ln\boldsymbol{y}_{-u} + \mu^S$$

with the terms involving $\mathrm{d}\varepsilon, \mathrm{d}\ln A$ collected into μ^S. Note also that here the structural equation I drop is $(N+u)^{th}$ rather than the $(2N+1)^{th}$.[94] Inserting this into the above demand equation

$$((1+b^*)\mathbb{Y}-\mathbb{X})\mathrm{d}\ln\boldsymbol{y} = \left[-\left\{\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\right\}\mathbb{S}^{Im'} + (1-\phi)(\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\mathbb{S}^{Im'})\right]_{\cdot,-u} \times \cdots$$

$$\cdots \times \frac{1}{1+\psi}\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathrm{d}\ln\boldsymbol{y}_{-u} + \mathbb{Y}\left(\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} - e\mathrm{d}b\right) + f(\mu^S, \mu^D)$$

Collecting terms

$$\Bigg\{((1+b^*)\mathbb{Y} - \mathbb{X}) + \left[\left\{\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\right\}\mathbb{S}^{Im'} - (1-\phi)(\mathbb{Y} - \mathbb{G}^{transfers} - \mathbb{X}\mathbb{S}^{Im'})\right]_{\cdot,-u} \times \cdots$$

$$\cdots \times \frac{1}{1+\psi}\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathcal{I}_{-u,-u}\Bigg\}\mathrm{d}\ln\boldsymbol{y} = \mathbb{Y}\left(\frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} - \boldsymbol{e}\mathrm{d}b\right) + f(\mu^S, \mu^D)$$

Multiplying by $\mathbb{Y}^{-1}$ to isolate $\boldsymbol{e}\mathrm{d}b$

$$\Bigg\{((1-b^*)\mathcal{I} - (\mathcal{I} - \mathbb{S}^G)\mathbb{S}^{Ex}) + \left[(\mathcal{I} - \mathbb{S}^G)\left\{\mathcal{I} - \mathbb{S}^{Ex}\right\}\mathbb{S}^{Im'} - (1-\phi)(\mathcal{I} - \mathbb{S}^{Ex})(\mathcal{I} - \mathbb{S}^{Ex}\mathbb{S}^{Im'})\right]_{\cdot,-u} \times \cdots$$

$$\cdots \times \frac{1}{1+\psi}\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathcal{I}_{-u,-u}\Bigg\}\mathrm{d}\ln\boldsymbol{y} = \frac{\mathrm{d}\boldsymbol{g}}{\boldsymbol{y}} - \boldsymbol{e}\mathrm{d}b + \tilde{f}(\mu^S, \mu^D)$$

Defining the matrices

[94] See section A.5.1 below for a discussion on the validity of this.

$$M^a \equiv (1-b^*)\mathcal{I} - (\mathcal{I} - \mathbb{S}^G)\mathbb{S}^{Ex}$$

$$M^b \equiv \left[(\mathcal{I} - \mathbb{S}^G)\left\{\mathcal{I} - \mathbb{S}^{Ex}\right\}\mathbb{S}^{Im'}\right]\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathcal{I}_{-u,-u}$$

$$M^c \equiv -\left[(\mathcal{I} - \mathbb{S}^{Ex})(\mathcal{I} - \mathbb{S}^{Ex}\mathbb{S}^{Im'})\right]_{.,-u}\left\{(\mathcal{I} - \mathbb{S}^{Im'})_{-u,-u}\right\}^{-1}\mathcal{I}_{-u,-u}$$

and, as in the main text, introducing time, taking the empirical analogue $\mathrm{d}x \to \Delta x$ and adding fixed effects $\alpha_i + \tilde{\gamma}_t + \varepsilon_{it} \equiv f_{it}(\mu^S, \mu^D)$, the above becomes

$$\sum_j \left(M^a_{ij} + \frac{1+\phi}{1+\psi}M^b_{ij} + \frac{1}{1+\psi}M^c_{ij}\right)\frac{\Delta y_{jt}}{y_{jt}} = \frac{\Delta g_{it}}{y_{it}}\underbrace{-\mathrm{d}b_t + \tilde{\gamma}_t}_{\equiv \gamma_t} + \alpha_i + \varepsilon_{it}$$

Note that $\mathrm{d}b_t$ is absorbed into the time fixed effect $\gamma_t \equiv \tilde{\gamma}_t - \mathrm{d}b_t$. This is a really important step as $\mathrm{d}b_t$ is endogenous; if it was pre-multiplied by any i=specific term, then fixed effects could not account for it and this would violate the exogeneity condition. Next, multiply by $(1+\psi)$ and rearrange to get the form in the proposition.

□

A.5.1 Inversion without Walras Law

In the derivation of the linear structural equations, as detailed in section A.5, I drop the $(N+u)^{th}$ equation. This corresponds to the supply equation, $\mathrm{d}S_u = 0$. Yet, Walras Law only implies that a demand equation (e.g. $\mathrm{d}D_u = 0$) can be dropped, conditional on the budget constrain $\mathrm{d}B = 0$ being imposed.

The reason it is valid for me to do this is because in section A.5 I am not solving for $\mathrm{d}\ln y$. In fact, the resulting linear structural equations are indeterminate for $\mathrm{d}\ln y$ precisely because the dropped supply equation is not imposed. Rather, the purpose of the linear structural equations is to provide an identifying equation for ϕ, ψ, conditional on $\mathrm{d}\ln y$ already being known. And $\mathrm{d}\ln y$ is known because I match it to the data.[95]

A.6 Specialization Depressing the Regional Elasticity of Substitution

Here I show how the regional demand elasticity of substitution, ϕ, depends on the regional industry concentration, in addition to structural preference parameters. To do this, I consider a multi-industry extension of my single-industry model, and derive the effective ϕ. This parameter is a partial equilibrium concept and therefore I only need consider the demand

[95] Of course, an implicit assumption is that I am assuming the real world operates according to my model.

side.

Consider a nested CES with the outer layer being an aggregation across industries $k \in \{1, ..., K\}$ and the inner layer being an aggregation across industry varieties, one from each region $i \in \{1, ..., N\}$. For simplicity I assume all regions produce in the same set of industries, and consumers in all regions have the same preferences. Consumption in region j is given by

$$C_j = \left[\sum_k C_{kj}^{\frac{\omega-1}{\omega}} \right]^{\frac{\omega}{\omega-1}}$$

where ω is the elasticity of substitution between industries. Consumption in region j of industry k goods from all regions

$$C_{kj} = \left[\sum_i C_{kij}^{\frac{\alpha-1}{\alpha}} \right]^{\frac{\alpha}{\alpha-1}}$$

where α is the elasticity of substitution within industries. Optimal consumption in region j of industry k goods from region i is

$$C_{kij} = \frac{1}{P_{kij}} \left(\frac{P_{kij}}{P_{kj}} \right)^{1-\alpha} \left(\frac{P_{kj}}{P_j} \right)^{1-\omega} P_j C_j$$

where the P_{kij} is the price faced in region i of industry k goods from region i. The aggregate price indexes are

$$P_{kj} = \left[\sum_i P_{kij}^{1-\alpha} \right]^{\frac{1}{1-\alpha}}$$

$$P_j = \left[\sum_k P_{kj}^{1-\omega} \right]^{\frac{1}{1-\omega}}$$

In order to relate to the object ϕ in the single-industry framework in the main text, I need the aggregate price $\ln P_{ij}$.: the cost faced by consumers in location i of a bundle of all industry goods in location j. Moreover, as everything regarding counterfactuals in the main text is in changes, I only need this price in changes, that is $\mathrm{d} \ln P_{ij}$. In the single industry framework, this is related to $\mathrm{d} \ln P_j$ by

$$\mathrm{d} \ln P_j = \sum_i s_{ij} \mathrm{d} \ln P_{ij}$$

where s_{ij} is the share of goods from i consumed in j. This is related to the many-industry model by $s_{ij} \equiv \frac{\sum_k P_{kij} C_{kij}}{P_j C_j}$. This can be written in terms of $\mathrm{d}\ln P_{kij}$ by noting the following

$$\mathrm{d}\ln P_j = \sum_k s_{kj} \mathrm{d}\ln P_{kj} = \sum_{ki} s_{kij} \mathrm{d}\ln P_{kij} = \sum_i s_{ij} \underbrace{\sum_k \frac{s_{kij}}{s_{ij}} \mathrm{d}\ln P_{kij}}_{\equiv \mathrm{d}\ln P_{ij}}$$

where the first equality can be derived by totally differentiating P_j, and $s_{kj} \equiv \frac{P_{kj} C_{kj}}{P_j C_j}$, $s_{kij} \equiv \frac{P_{kij} C_{kij}}{P_j C_j}$.. Thus comparing the above equations gives

$$\mathrm{d}\ln P_{ij} \equiv \sum_k \frac{s_{kij}}{s_{ij}} \mathrm{d}\ln P_{kij}$$

With this, the regional elasticity of substitution is

$$1 - \phi \equiv \frac{\partial \ln(s_{ij}/s_{i'j})}{\partial \ln(P_{ij}/P_{i'j})}$$

However this isn't well-defined; because preferences are not CES across locations, the response of the shares vary depending on which industry prices in i, i' are changing. I first consider the case where $\mathrm{d}\ln P_{k^*ij} \neq 0$, and all other price changes are zero, and then discuss how this result generalizes. Formally

$$1 - \phi_{ij,k=k^*} \equiv \left. \frac{\partial \ln(s_{ij}/s_{i'j})}{\partial \ln(P_{ij}/P_{i'j})} \right|_{\forall k \neq k^*, i, j : \mathrm{d}\ln P_{kij} = 0}$$

Differentiating the shares

$$\mathrm{d}\ln(s_{ij}/s_{i'j}) = (1-\alpha) \sum_k \left(\frac{s_{kij}}{s_{ij}} \mathrm{d}\ln P_{kij} - \frac{s_{kij'}}{s_{i'j}} \mathrm{d}\ln P_{ki'j} \right) + (\alpha - \omega) \sum_k \left(\frac{s_{kij}}{s_{ij}} - \frac{s_{ki'j}}{s_{i'j}} \right) \mathrm{d}\ln P_{kj}$$

Using that only $\mathrm{d}\ln P_{k^*ij} \neq 0$ and noting $\mathrm{d}\ln P_{ij} = \frac{s_{k^*ij}}{s_{ij}} \mathrm{d}\ln P_{k^*ij}$ and

$$\mathrm{d}\ln P_{k^*j} = \sum_i \frac{s_{k^*ij}}{s_{k^*j}} \mathrm{d}\ln P_{k^*ij} = \frac{s_{k^*ij}}{s_{k^*j}} \mathrm{d}\ln P_{k^*ij} = \frac{s_{ij}}{s_{k^*j}} \mathrm{d}\ln P_{ij}$$

into the above

$$\mathrm{d}\ln(s_{ij}/s_{i'j}) = (1-\alpha) \mathrm{d}\ln P_{ij} + (\alpha - \omega) \left(\frac{s_{k^*ij}}{s_{ij}} - \frac{s_{k^*i'j}}{s_{i'j}} \right) \frac{s_{ij}}{s_{k^*j}} \mathrm{d}\ln P_{ij}$$

Thus

$$\phi_{ij,k=k^*} - 1 = \alpha - 1 + \underbrace{(\omega - \alpha)\left(\frac{s_{k^*ij}}{s_{ij}} - \frac{s_{k^*i'j}}{s_{i'j}}\right)\frac{s_{ij}}{s_{k^*j}}}_{(\dagger)} \tag{52}$$

The difference to the single industry case is the addition of the term (†). Take the presumptive case where varieties within-industries are more substitutable than across-industries, $\sigma > \omega$. Then, (†) is negative, and therefore reduces the effective substitutability between regions if $\frac{s_{k^*ij}}{s_{ij}} > \frac{s_{k^*i'j}}{s_{i'j}}$. This inequality being satisfied means that for consumers in j, industry k^* forms a greater share of your consumption from i than it does from i'; that is, location i is relatively specialized in the production of industry k^* goods from the perspective of consumers in j. The greater this concentration, the more negative the term (†) is. Intuitively, if a lot of your consumption for an industry comes from a single location, and if your preferences are not strongly substitutable across industries, then you do not substitute away from that location as much when the price of those industry goods in that location rise.

For this mechanism to push ϕ to become complements, it must be that $\omega < 1$ as $\left(\frac{s_{k^*ij}}{s_{ij}} - \frac{s_{k^*i'j}}{s_{i'j}}\right)\frac{s_{ij}}{s_{k^*j}} > 1$ is not possible. Intuitively, if all varieties are substitutes including between industries, then the effective regional substitutability has to be substitutes too.

Generally, it there will not be only a single industry price changing in location i. Qualitatively, the same mechanism results. Consider the other extreme where all industry prices in location i shift equally $\forall k : \mathrm{d}\ln P_{kij} \equiv \mathrm{d}\ln p$. Denote the regional elasticity of substitution in this case

$$1 - \phi_{ij,\forall k} \equiv \left.\frac{\partial \ln(s_{ij}/s_{i'j})}{\partial \ln(P_{ij}/P_{i'j})}\right|_{\forall i'' \neq i,k,j:\mathrm{d}\ln P_{ki''j}=0}$$

In this case, the equivalent of equation (52) becomes

$$\phi_{ij,\forall k} - 1 = \alpha - 1 + \underbrace{(\omega - \alpha)\sum_k \left(\frac{s_{kij}}{s_{ij}} - \frac{s_{ki'j}}{s_{i'j}}\right)\frac{s_{kij}}{s_{kj}}}_{(\dagger\dagger)}$$

As in the case of only a single price shifting, the regional substitutability is reduced when (††) is negative. and this occurs if region i is specialized e.g. consider the extreme example where $s_{kij} \neq 0$ only for $k = k^*$ then (††) $= (\omega - \alpha)\left(\frac{s_{k^*ij}}{s_{ij}} - \frac{s_{k^*i'j}}{s_{i'j}}\right)\frac{s_{k^*ij}}{s_{k^*j}}$, which, like before, is negative if $\frac{s_{k^*ij}}{s_{ij}} > \frac{s_{k^*i'j}}{s_{i'j}}$; that is, if region i is relatively specialized in k^*.

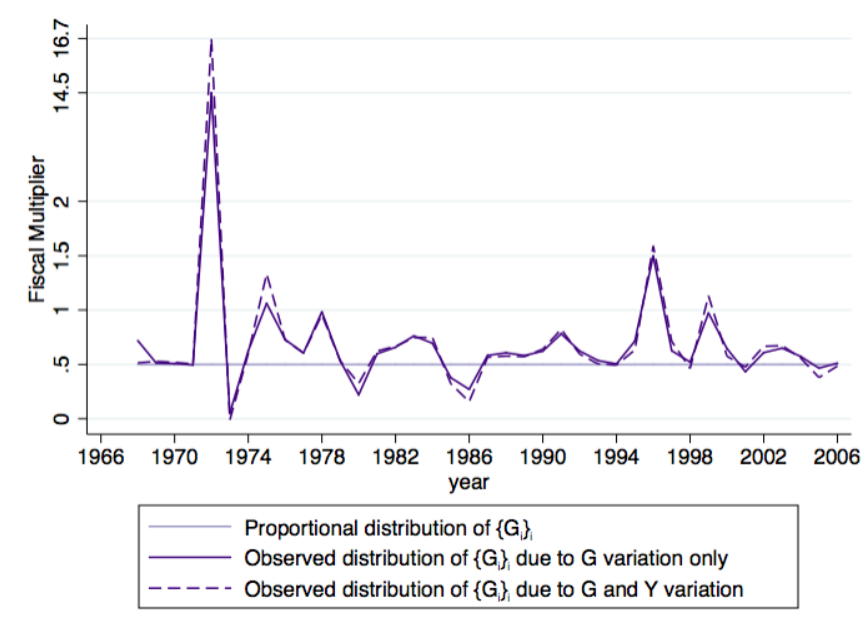


Figure 12: Aggregate fiscal multiplier from aggregate spending changes.

Notes. Calibrating: $\forall i : \Lambda_i^* = 0.5$

For general price movements, the degree of substitutability will be depressed the more these price movements are concentrated in the specialized industries.

In summary, the effective regional elasticity of substitution can exhibit complementarity even though intraindustry goods are substitutes. A necessary condition is that interindustry goods do exhibit complementarity. This result of regional complementarity is more likely to occur when the exogenous shocks analyzed are concentrated within the specialized industry-locations.

B Results

B.1 Fiscal Multiplier variation due to variation in G_{it} and Y_{it}

In this section I present the analysis of section **??** without fixing y_{it} to y_{i1977}; the resulting estimates give the value of the fiscal multiplier due to changes in the state spending shares $\frac{\Delta g_{jt}}{\Delta g_{agg,t}}$ and state GDP y_{it}. Figure 12 is equivalent to figure 9 but with this additional variable included by the dashed line. It turns out allowing y_{it} to vary also doesn't change the resulting prediction substantially. Excluding the year 1972, the standard deviation in the fiscal multiplier is 0.28.

	(1)	(2)	(3)	(4)
$\frac{\Delta G_{it}}{Y_{it}}$	0.48	0.53	0.48	0.94
	(0.05)	(0.95)	(0.05)	(0.94)
$\ln \bar{y}_i \cdot \frac{\Delta G_{it}}{Y_{it}}$		-0.002		-0.02
		(0.038)		(0.04)
$s_i^{Im} \cdot \frac{\Delta G_{jt}}{Y_{jt}}$			-0.75	-0.82
			(0.51)	(0.48)
Observations	1887	1887	1887	1887
First-Stage F-Stat (CD)	542	181	268	118

Cluster (i) robust standard errors in parentheses.

Table 7: Non-structural estimates: heterogeneity in the aggregate fiscal multiplier.

Notes. All columns are ran using 2SLS and include state fixed effects. Each column allows for progressively more heterogeneity in the estimates. Column (2) allows for heterogeneity due to state GDP, column (3) due to state import share, and column (4) due to both. Note that the coefficients should not be interpreted as dollar changes. For example, in column (1) row one, this means that for every one dollar increase in spending in i relative to GDP in i, national GDP increases by \$0.48 relative to national GDP.

B.2 Direct Evidence: Heterogeneity in the Aggregate Fiscal Multiplier

To investigate the heterogeneity in the aggregate fiscal multiplier as a function of which location receives the spending, an analogy of equation XX can be ran with change in national GDP on the lefthand-side, and no time fixed effect

$$\frac{Y_{agg,t} - Y_{agg,t-2}}{Y_{agg,t-2}} = (\beta_0 + \beta_1 \cdot W_i) \cdot \frac{G_{it} - G_{it-2}}{Y_{it-2}} + \alpha_i + \varepsilon_{it} \tag{53}$$

where W_i represents either the log of a states' average GDP $\ln \bar{y}_i$, own-import share s_i^{Im}, or a vector of both. The regression is ran using 2SLS with the Bartik instrument (same as used in XX) interacted with W_i The results of this regression are presented in table **??**. Note that the signs of all coefficients agree with the structural results, though the magnitudes differ, and significantly more noisy.

B.3 Construction of Counterfactual Growth Paths

First, for each year I construct the rate of national GDP growth that world occur in the absence of no changes in government spending, $\frac{\Delta y_{agg,t}}{y_{agg,t}}\Big|_{\Delta \boldsymbol{g}=\mathbf{0}}$. I do this by subtracting my estimated change in GDP from government spending, $\frac{\Delta y_{agg,t}}{y_{agg,t}}\Big|_{\text{Fiscal Multiplier}}$ from the observed rate of growth:

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\Delta \boldsymbol{g}=\mathbf{0}} = \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{observed}} - \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Fiscal Multiplier}}$$

My estimated change in GDP from government spending is

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Fiscal Multiplier}} \equiv \left(0.5 + \frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}\right) \cdot \frac{\Delta g_{agg,t}}{y_{agg,t}}$$

where $\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}$ is the quantity in equation (27). I then construct the two counterfactual growth rates in each year as follows

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Min}} \equiv \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\Delta \boldsymbol{g}=\mathbf{0}} + \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Min Fiscal Multiplier}}$$

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Max}} \equiv \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\Delta \boldsymbol{g}=\mathbf{0}} + \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Max Fiscal Multiplier}}$$

The counterfactual growth rates due to government spending are

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Min Fiscal Multiplier}} \equiv \left(0.5 + \left.\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}\right|_{\text{Min Fiscal Multiplier}}\right) \cdot \frac{\Delta g_{agg,t}}{y_{agg,t}}$$

$$\left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Max Fiscal Multiplier}} \equiv \left(0.5 + \left.\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}\right|_{\text{Max Fiscal Multiplier}}\right) \cdot \frac{\Delta g_{agg,t}}{y_{agg,t}}$$

The counterfactual fiscal multipliers are constructed by

$$\left.\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}\right|_{\text{Min Fiscal Multiplier}} \equiv \sum_i \left\{\min_j [y_{it}\Lambda_{ij}y_{jt}] \cdot \mathbb{1}[\Delta g_{agg,t} > 0] + \max_j [y_{it}\Lambda_{ij}y_{jt}] \cdot \mathbb{1}[\Delta g_{agg,t} < 0]\right\}$$

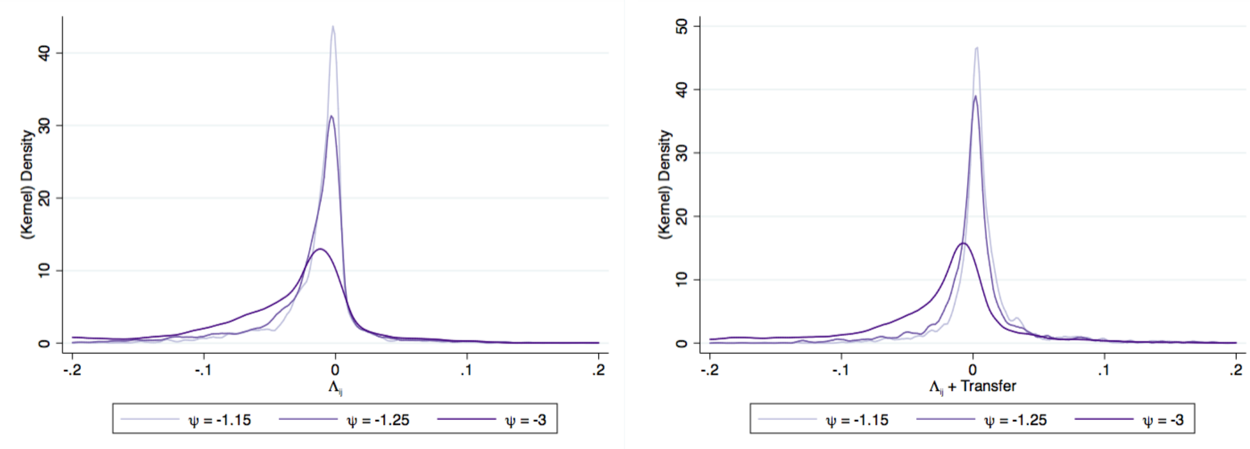
$$\left.\frac{\Delta \hat{y}_{agg,t}}{\Delta g_{agg,t}}\right|_{\text{Max Fiscal Multiplier}} \equiv \sum_i \left\{\max_j [y_{it}\Lambda_{ij}y_{jt}] \cdot \mathbb{1}[\Delta g_{agg,t} > 0] + \min_j [y_{it}\Lambda_{ij}y_{jt}] \cdot \mathbb{1}[\Delta g_{agg,t} < 0]\right\}$$

The counterfactual paths of annual GDP are then given by

$$y^{Min}_{agg,1966} = y_{agg,1966}$$

$$y^{Max}_{agg,1966} = y_{agg,1966}$$

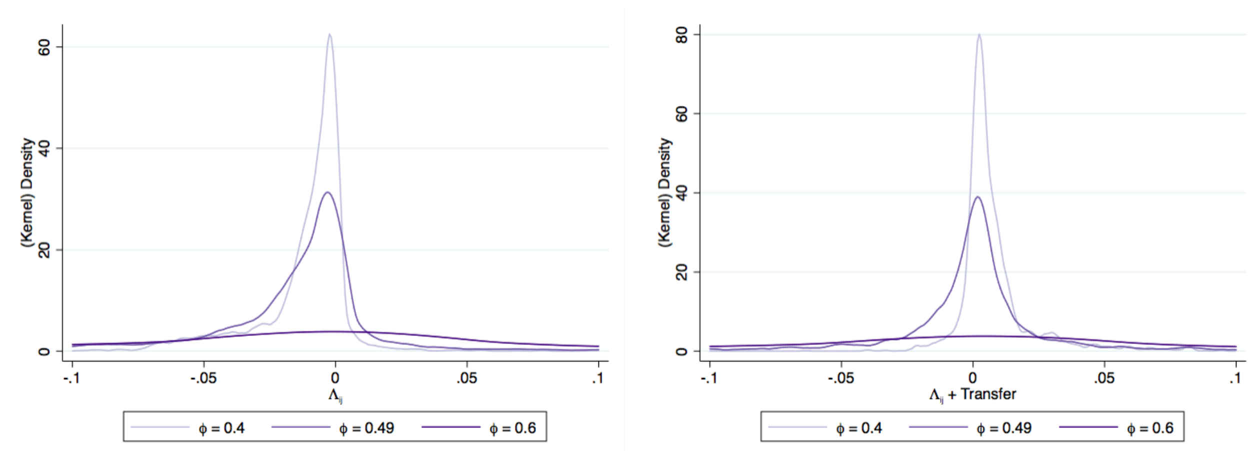
$$t \in \{1966, 1968, 2004\} : \quad y^{Min}_{agg_t+2} = \left(1 + \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Min}}\right) \cdot y^{Min}_{agg,t}$$



(a) Off-Diagonal, $\forall\, i, j : i \neq j : \Lambda_{ij}^{transfers}$ (b) Spillovers, $\forall\, i, j : i \neq j : \Lambda_{ij}^{transfers} + \frac{y_j}{y_{agg}}$

Figure 13: ψ and the magnitude of $\Lambda^{transfers}$ (ancillary graphs)

Notes. At estimated value of ϕ. This figure compares the effect of spending in state i on GDP in state $j \neq i$. Figure 13a shows the equilibrium change in i GDP inclusive of the mechanical effect from the transfer from i to j, while figure 13b is corrected to be exclusive of this.



(a) Off-Diagonal, $\forall\, i, j : i \neq j : \Lambda_{ij}^{tranfers}$ (b) Spillovers, $\forall\, i, j : i \neq j : \Lambda_{ij}^{transfers} + \frac{y_j}{y_{agg}}$

Figure 14: ϕ and the magnitude of $\Lambda^{transfers}$ (ancillary graphs)

Notes. At estimated value of ψ. This figure compares the effect of spending in state i on GDP in state $j \neq i$. Figure 13a shows the equilibrium change in i GDP inclusive of the mechanical effect from the transfer from i to j, while figure 13b is corrected to be exclusive of this.

$$t \in \{1966, 1968, 2004\} : \quad y_{agg_t+2}^{Max} = \left.\frac{\Delta y_{agg,t}}{y_{agg,t}}\right|_{\text{Max}} \cdot y_{agg,t}^{Max}$$

$y_{agg,1966}^{Min}, y_{agg,1966}^{Max}$ are the two counterfactual objects graphed along with the observed $y_{agg,t}$ on figure 11.