Regional Government Consumption and Investment Multipliers

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Abstract

This paper is the first to use the regional fiscal multipliers framework to separately identify government consumption and investment multipliers. I run panel IV regressions on a U.S. state-level dataset, constructed from transaction-level data on U.S. federal military procurement contracts, and find that regional government consumption multipliers are larger than regional government investment multipliers. Also, spillovers are more negative from government consumption. I interpret these results with a New Keynesian DSGE model of a two-sector, two-region monetary union, with two key mechanisms: (1) investment is more intertemporally substitutable, and (2) consumption exhibits greater home bias. Finally, I estimate a quantitative model of the United States as a 51-region monetary union, to measure the effects of the 2021 Infrastructure Investment and Jobs Act (IIJA). While panel estimates of regional multipliers are larger than time-series estimates of aggregate multipliers, the quantitative model yields larger aggregate multipliers than a model that abstracts from sectoral or regional differences.

JEL Codes: E32, E62, H30, H57.

Keywords: Fiscal policy, regional fiscal multipliers, fiscal spillovers, government consumption, government investment.

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1 Introduction

There has been recent policy interest in using government investment for short-run economic stimulus, especially after the Great Recession and the COVID-19 pandemic. In November 2021, U.S. President Joe Biden signed the Infrastructure Investment and Jobs Act (IIJA), which planned to allocate up to $1.2 trillion on infrastructure investment, among other stimulus items, for the next 10 years. Earlier, the White House cited an estimate that the IIJA would generate up to 2 million jobs per year in the course of the decade.[1]

While there has been a large literature on estimating fiscal multipliers,[2] much of it assumes government purchases simply as government consumption. Given that government investment may affect the economy differently from government consumption, it is worth investigating the relative magnitudes of government consumption and government investment multipliers. Here, I define government (infrastructure) investment as in Ramey (2021), i.e. the (federal) government's purchases of goods to build and maintain public infrastructure and capital.[3] By contrast, government consumption encompasses government purchases of services and non-durable goods.

There has been a growing literature on fiscal multipliers of government consumption and investment, which has not reached an empirical consensus on their relative magnitudes. Boehm (2020) finds larger 1-year government consumption multipliers (0.8) than government investment multipliers (statistically insignificant) from a panel dataset of OECD economies, which he rationalizes through the smaller crowding-out effect of private consumption from government spending shocks than that of private investment. In contrast, Haug and Sznajderska (2024) finds smaller 4-quarter government consumption multipliers (0.16) than government investment multipliers (0.45) with U.S. time series data. Antolin-Diaz and Surico (2025) also find that government investment has a larger effect on GDP than government consumption.

I provide a new approach in resolving the empirical debate through the regional fiscal multipliers framework. This approach uses two advantages from using regional panel data across regions with a common monetary authority (Nakamura and Steinsson, 2014). First, the larger sample size of the panel dataset provides greater statistical power in estimating the effects of government purchases on incomes. Second, the use of time fixed effects in panel data regressions

[1] White House, November 6, 2021.

[2] See Ramey (2011) for a literature review.

[3] While "government spending" is a broader concept that could also include transfers and public sector wages, this paper is on government "procurements" or purchases from private contracting firms. Thus in this paper, the terms "government purchases", "government spending", and "government procurements" are used interchangeably.

differences out endogenous aggregate forces across regions, such as the effects of monetary policy across regions in a monetary union. I leverage the same insights to estimate regional government consumption and investment multipliers. Thus, this paper is unique in the intersection of the literatures on (1) regional fiscal multipliers (Auerbach et al., 2020) and (2) multipliers of government consumption and investment (Baxter and King, 1993).[4]

As emphasized by Chodorow-Reich (2019), regional government spending shocks in one region of a monetary union cause local incomes to rise, but also cause fiscal spillovers to other regions' incomes. There are two main channels of fiscal spillovers. First, the increase in local incomes stimulate demand for goods produced in other geographically close or major trading partner regions, increasing other regions' incomes. Second, the stimulative effects of regional government spending shocks lead to an endogenous tightening in aggregate monetary policy. This rise in interest rates depresses economic activity in other regions of the monetary union, leading to negative spillovers. We are ultimately concerned about the *aggregate* effects of government consumption and investment across the entire monetary union, and aggregate fiscal multipliers are a combination of regional fiscal multipliers and fiscal spillovers. Therefore, as is common in the literature (Nakamura and Steinsson, 2014; Dupor et al., 2023), I construct a theoretical model to link together regional fiscal multipliers, spillovers, and aggregate fiscal multipliers.

Empirically, I run panel IV regressions on a U.S. state-level panel dataset, constructed from transaction-level data on U.S. federal military procurement contracts. I find two empirical results. First, regional government consumption multipliers are larger than regional government investment multipliers. At the U.S. state level, the 2-year regional government consumption multiplier is approximately 2.5, while the 2-year regional government investment multiplier is statistically insignificant. Second, and uniquely from this paper, fiscal spillovers from regional government consumption shocks to the rest of the monetary union (i.e. the other 49 U.S. states) are more negative than for regional government investment shocks.

Theoretically, I construct a New Keynesian DSGE model of a 2-sector, 2-region monetary union to rationalize my empirical results. The baseline model incorporates two key mechanisms. First, investment is more intertemporally substitutable due to its longer service life than consumption (Boehm, 2020). From a (regional) government consumption shock that raises consumption-goods

[4]A similar paper to this one is Muratori et al. (2023), which looks at heterogeneous regional multipliers of government purchases in *goods versus services*. They show that government purchases of services, which come primarily from more labor-intensive industries, have larger effects on local employment and labor income than government purchases on goods.

prices, households still smooth their consumption, and thus there is little crowding out of private consumption, labor supply, and incomes. By contrast, the greater intertemporal elasticity of substitution of investment goods leads to households and firms delaying private investment until the increases in investment-goods prices from a (transitory) government investment shock dissipate. Private investment is crowded out by more in the short run from government investment shocks, and lead to a smaller net effect on labor supply and incomes, relative to from government consumption shocks. This mechanism helps to explain the first empirical result on regional fiscal multipliers, that regional government consumption multipliers are larger than regional government investment multipliers.

On a related note, the greater stimulative effects of regional government consumption shocks lead to a larger endogenous tightening in monetary policy across regions of the monetary union. The greater increase in interest rates depresses economic activity in the rest of the monetary union, which also contributes to the second empirical result on spillovers, that regional government consumption shocks lead to more negative spillovers to the rest of the monetary union than for investment shocks.

Second, uniquely from this paper, consumption exhibits greater home bias than investment. In other words, consumption goods (especially services) are produced and expended more locally than investment goods. Thus, from a regional government consumption shock, more of the resulting increase in local demand remains within its own region, while less of the increase spills over to other regions, as compared to from a regional government investment shock. This mechanism helps to further explain both the empirical results on regional fiscal multipliers and spillovers.

Finally, with the same theoretical framework, I also construct and estimate a state-level quantitative model, consisting of 2 sectors and 51 regions (50 states and the District of Columbia), to estimate the regional and aggregate effects of 2021 Infrastructure Investment and Jobs Act. The quantitative model shares an implication with the baseline model, that (1) the aggregate government consumption multiplier is larger than the aggregate government investment multiplier, and (2) the aggregate multipliers are smaller than their regional counterparts. In particular, the quantitative model implies that 2-year aggregate government consumption and investment multipliers are 0.73 and 0.22, respectively, as opposed to 1.14 and 0.44 for regional government consumption and investment multipliers. The estimated cumulative effect of the 2021 IIJA was $60 billion or a 0.23%p increase over U.S. GDP in 2022. My estimates are smaller than contemporary predictions by Zandi and Yaros (2021), an influential estimate in policy circles at the time of the passing of the

IIJA. From the quantitative model, I also estimate state-specific regional government consumption and investment multipliers.

My results have policy implications for the efficacy of regional government investment in stimulating local incomes, as anticipated by proponents of then-Treasury Secretary Janet Yellen's "modern supply-side economics".[5] If policymakers are to pursue and promote regionally targeted government investment, they should motivate it with increasing long-run supply and promoting regional economic development, rather than as a means to short-run local stimulus. As for implications to macroeconomics, the 2-sector monetary union models of this paper imply larger aggregate fiscal multipliers than special cases of my model which abstract from either multiple sectors or regions. These exercises highlight the effects of amplification of inter-state trade flows on regional and aggregate incomes (Norris, 2019).

2 Empirical Methodology

I describe the methodology commonly used in the regional fiscal multipliers literature, and then explain my specification for estimating regional government consumption and investment multipliers. I first denote some region-i variables in year-t: personal income Y_{it}, labor income Y_{it}^L, capital income Y_{it}^K, and employment N_{it}. A specification of a two-way fixed effects panel data regression that incorporates just the change in regional government spending G_{it} over h years would be as follows:

$$\frac{Y_{i,t+h} - Y_{i,t-1}}{Y_{i,t-1}} = \beta_{reg,h} \frac{G_{i,t+h} - G_{i,t-1}}{Y_{i,t-1}} + \alpha_i + \delta_t + \epsilon_{i,t} \tag{1}$$

where α_i and δ_t are region and time fixed effects respectively. $\beta_{reg,h}$ is our estimate of the h-period regional fiscal multiplier, i.e. the effect on change in regional personal income $(Y_{i,t+h} - Y_{i,t-1})$ of change in regional government spending $(G_{i,t+h} - G_{i,t-1})$. Both terms are divided by $Y_{i,t-1}$, both to normalize variables, and to directly estimate $\beta_{reg,h}$ as the regional fiscal multiplier.[6] For G_{it}, Nakamura and Steinsson (2014) compile data on state-level federal military procurement, as awarded by the Department of Defense (DoD). The assumption is, unlike many other types

[5] Treasury.gov, January 21, 2022.

[6] Simply putting the growth rate in government spending, $\frac{G_{i,t+h} - G_{i,t-1}}{G_{i,t-1}}$, in the right-hand side changes the interpretation of $\beta_{reg,h}$ into an *elasticity* of regional income growth relative to regional government spending growth. However, transforming this elasticity into a fiscal multiplier requires multiplying the elasticity estimate by the average share of government spending in income, G/Y. This is problematic if G_t/Y_t varies widely over time, as pointed out in the aggregate case (Owyang et al., 2013; Ramey, 2016), or across regions.

of government spending, national military spending by the DoD is driven by global geopolitical events, and would be orthogonal to national or regional business cycles.

However, the estimate of $\beta_{reg,h}$ may still be biased due to endogeneity issues. As Nakamura and Steinsson (2014) and others note, military spending is "notoriously political", and political factors might affect both military spending and outcome variables such as personal income and personal income per capita. Therefore, an instrumental variables approach is required. The intuition in building the instrumental variable lies in the empirical fact that military procurement in some states are more sensitive to increases in national military procurement than that in other states. The identifying assumption is that national military buildups and drawdowns respond to foreign wars and geopolitical events, which are outside the reach of and thus orthogonal to the local business cycles of any individual U.S. region. For example, the U.S. federal government does not increase national military spending simply because the state economy of Maryland is doing relatively worse than that of California. With this identifying assumption, the specification above uses the variation in responses of DoD spending across states to measure the regional fiscal multiplier.

I follow the literature by constructing a shift-share instrument Z_{it}^h for the right-hand side variable. The intuition is to utilize the difference between the actual right-hand side variable with what the region would receive given the region's average share of (the change in) national government spending. Specifically, I interact the "shift", or change in national government spending $(G_{t+h} - G_{t-1})$ as a ratio of regional personal income, with the average regional "share" of national government spending over time. For example, I specify Z_{it}^h as shown below:

$$Z_{it}^h \equiv \underbrace{\left(\frac{G_{t+h} - G_{t-1}}{Y_{i,t-1}}\right)}_{\text{Shift}} \times \underbrace{\overline{\left(\frac{G_{it}}{G_t}\right)}}_{\text{Share}} \tag{2}$$

where the (average) share component is defined as:

$$\overline{\left(\frac{G_{it}}{G_t}\right)} \equiv \frac{1}{T} \sum_{t=1}^{T} \frac{G_{it}}{G_t} \tag{3}$$

Thus, we can implement a panel IV regression, with the first stage regression being a two-way fixed effects panel regression with region and time fixed effects α_i^{first} and δ_t^{first}:

$$\frac{G_{i,t+h} - G_{i,t-1}}{Y_{i,t-1}} = \theta Z_{it}^h + \alpha_i^{first} + \delta_t^{first} + \eta_{it} \tag{4}$$

and the second stage regression using the predicted values of the right-hand side from the first stage regression.

In estimating regional government consumption (denoted as C_{it}^g) and investment (X_{it}^g) multipliers, I follow Muratori et al. (2023) and modify the specification above to include two endogenous variables. I also estimate regional government consumption and investment multipliers, $\beta_{reg,h}^c$ and $\beta_{reg,h}^x$ respectively, with the following specification:

$$\frac{Y_{i,t+h} - Y_{i,t-1}}{Y_{i,t-1}} = \beta_{reg,h}^c \frac{C_{i,t+h}^g - C_{i,t-1}^g}{Y_{i,t-1}} + \beta_{reg,h}^x \frac{X_{i,t+h}^g - X_{i,t-1}^g}{Y_{i,t-1}} + \alpha_i + \delta_t + \epsilon_{i,t} \tag{5}$$

There are now two instrumental variables, $Z_{it}^{C,h}$ and $Z_{it}^{X,h}$, constructed analogously as before:

$$Z_{it}^{C,h} \equiv \left(\frac{C_{t+h}^g - C_{t-1}^g}{Y_{i,t-1}} \right) \times \overline{\left(\frac{C_{it}^g}{C_t^g} \right)} \tag{6}$$

$$Z_{it}^{X,h} \equiv \left(\frac{X_{t+h}^g - X_{t-1}^g}{Y_{i,t-1}} \right) \times \overline{\left(\frac{X_{it}^g}{X_t^g} \right)} \tag{7}$$

With two endogenous regressors, I use the weak instrument identification test as proposed by Lewis and Mertens (2022). This test allows for multiple endogenous regressors and adjusts for heteroskedasticity and autocorrelation, as opposed to the weak instrument tests for single endogenous regressors (Stock and Yogo, 2005; Montiel Olea and Pflueger, 2013). The Lewis-Mertens test determines whether the bias of the IV estimator is less than the bias of the OLS estimator, given a relative bias threshold level. Therefore, I compute Lewis-Mertens test statistics and the corresponding critical values for each regression, the latter of which are computed at a confidence level of 95% and a Nagar's relative bias threshold of 30%.[7] Also, to account for autocorrelation across time periods and regions, I use Driscoll-Kraay standard errors (Driscoll and Kraay, 1998) whenever possible.

As prescribed by Ramey (2016) and others, I also compute the h-year cumulative fiscal multipliers, which are more policy-relevant. The cumulative fiscal multiplier in the model is the

[7] As a robustness check for weak instruments, I also use the Anderson and Rubin (1949) test and plot 95% confidence regions on a grid of possible estimates for $\beta_{reg,h}^c$ and $\beta_{reg,h}^x$.

cumulative income effect of a government consumption or investment shock at a given initial period. For a given region(state) i, the h-year cumulative multipliers for government consumption $\beta_h^{c,cumul}$ and government investment $\beta_h^{x,cumul}$ are estimated as such:

$$\sum_{j=0}^{h} \frac{Y_{i,t+j} - Y_{i,t-1}}{Y_{i,t-1}} = \beta_h^{c,cumul} \sum_{j=0}^{h} \frac{C_{i,t+h}^{g} - C_{i,t-1}^{g}}{Y_{i,t-1}} + \beta_h^{x,cumul} \sum_{j=0}^{h} \frac{X_{i,t+h}^{g} - X_{i,t-1}^{g}}{Y_{i,t-1}} + \alpha_i + \delta_t + \epsilon_{i,t} \tag{8}$$

Here, I instrument the right-hand side variables using the shift-share instruments for $h = 0$, i.e. $Z_{i,t}^{C,0}$ and $Z_{i,t}^{X,0}$. This accounts for the possibility that the initial shock in government spending at period t (or $h = 0$) is persistent over time.

To estimate regional multipliers for labor income ($Y_{i,t}^{L}$) and capital income (Y_{it}^{K}), I normalize the h-year change in region-i labor/capital income over region-i *total personal* income. In other words, the left-hand side variable for labor income regressions are $(Y_{i,t+h}^{L} - Y_{i,t-1}^{L})/Y_{i,t-1}$, and likewise for capital income ($(Y_{i,t+h}^{K} - Y_{i,t-1}^{K})/Y_{i,t-1}$). As for employment, the left-hand side variable in those regressions is $(N_{i,t+h} - N_{i,t-1})/N_{i,t-1}$, and thus I measure the elasticity of regional employment to normalized regional government consumption and investment shocks.

3 Data

I summarize the different types of government consumption and investment, and explain the methodology for constructing the state- (and MSA-)level panel dataset.

3.1 Categorizing Government Consumption and Investment

I categorize federal procurement transactions into government consumption and government gross investment for each region and year. As per Chapter 9 of the BEA NIPA Handbook, "government consumption" refers to government consumption expenditures, and "government investment" as more precisely government gross investment.

Government consumption expenditures consist of services that are provided to the public for less than the cost of providing the service (such as the postal service) or, in some cases, for free (such as the military, public safety, and education). The "value added" component of consumption expenditures can be further categorized into compensation of general government employees and consumption of general government fixed capital. Government consumption also includes intermediate goods and services purchased, deducted by own-account investment (into government-owned fixed assets) and sales to other sectors.

Government gross investment counts additions to, or replacements of, government-owned fixed assets. Such spending can be for structures (ex. highways and schools), equipment (ex. military hardware), or intellectual property products (ex. software and research and development). Federally-funded expenditures for research and development, as part of government investment, can be financed through purchases (contracts) or through grants.

The sample, based on the transaction-level dataset of federal procurements from USASpending.gov and the National Archives, includes only contracts, i.e. agreements between the federal government and the recipient to provide goods and services for a fee.[8] I use contracts data mainly for the reason that the vast majority of DoD spending occurs in the form of contracts with private firms.[9]

3.2 Sample Construction

I construct my panel dataset as follows, based on Auerbach et al. (2020) and Muratori et al. (2023):

1. I collect transaction-level data of U.S. federal government purchases for Fiscal Years 1989 to 2024. For years 2004 to 2024, I use federal military procurement data from USASpending.gov by filtering only procurements assigned by the Department of Defense. For years 1989 to 2003, I use data from the National Archives, which hosts an electronic database of DD-350 military procurement forms as mandated by the Department of Defense.

2. I classify each transaction into either government consumption or government investment based on its Product Service Code (PSC). The PSC indicates the type of good purchased by the government. Each 4-digit PSC code indicates a category of research and development (R&D), services, or goods. I identify government consumption and investment given the first letter (ex. 'Z': Maintenance, Repair, Alteration of Structures/Facilities) or first two digits (ex. 62: Lighting Fixtures and Lamps), as well as government consumption of non-durables goods, durable goods, and services.[10] In Tables A.1 and A.2 of Appendix A, I list the categorization of types of government procurement by product service code. Generally, I categorize non-durable goods, durable goods, and services spending as government

[8]Other types of government spending listed under the USASpending.gov database include grants, direct payments to individuals or firms, and loans.

[9]For example, in Fiscal Year 2019, total nominal DoD spending across the entire United States was $367.7 billion. Of this, $360.3 billion was in contracts.

[10]See the PSC Manual by the General Services Administration for more information.

Category	Mean	St. Dev.	Min	Max
Government Consumption	**2,460.3**	**4,086.7**	**12.6**	**34,895.4**
Durables	44.9	92.6	-59.5	1,102.3
Nondurables	341.4	574.1	-78.4	6,071.6
Services - Consumption	1,110.6	2,145.1	-24.9	19,285.6
Services - Structural Investment	963.5	1,692.2	-8,135.3	23,230.1
Government Investment	**2,792.0**	**4,604.5**	**-212.3**	**39,631.9**
Goods - Structural Investment	987.9	1,621.8	-247.6	25,693.8
Vehicles	1,136.6	2,717.0	-117.9	35,876.3
Research & Development	667.5	1,303.3	-149.8	13,287.7
Total	**5,252.3**	**7,933.1**	**-137.6**	**62,470.1**

Table 1: Summary statistics of government purchases summed across 50 states, 1989-2024 (1,800 observations), in billions of real US dollars (indexed at constant 2017 dollars).

consumption, and structures, equipment, vehicles, and R&D spending as government investment.

3. For each calendar year t and each state i, I sum up "federal action obligation" amounts that the U.S. federal government had procured in regional government consumption (C^g_{it}) or regional government investment (X^g_{it}) based on the action date and place of performance of the contract.

4. Finally, I use data on regional outcome variables Y_{it} from the BEA, which include annual state-level total personal income, employment, and annual state-level labor and capital income. I use state-level total wages and salaries (both in cash and in kind) as regional labor income, and dividends, interest, and rents as regional capital income. Most of this data is based on the BLS's methodology on the labor share of output.

The data sample spans over all 50 states (excluding the District of Columbia) from 1989 to 2024. All nominal variables (government spending, personal income) are converted into real variables by dividing by the BLS's national Consumer Price Index in each year. In Table 1, I show summary statistics of government consumption and investment, as well as its sub-categories. Summary statistics for the state-level dataset are in Table 1.

3.3 Comparison with National Income and Product Accounts

I compare my classification with the BEA's National Income and Product Accounts (NIPA) Table 3.11.5, "National Defense Consumption Expenditures and Gross Investment by Type". From government consumption expenditures, I exclude value added from compensation of general government employees (line 5) and consumption of general government fixed capital (line 8, i.e. capital depreciation). Also, based on my classification according to PSCs, I put together all government purchases on aircraft, missiles, ships, and vehicles as government investment. Thus, the modified national time series of U.S. military federal government consumption is composed of non-durable goods (line 17) and services (line 21), electronics (line 15), and other durable goods (line 16) of NIPA Table 3.11.5. The same for investment is composed of structures (line 30), equipment (line 31), intellectual property products (line 38), and aircraft, missiles, ships, and vehicles (lines 11-14) which are originally listed under government consumption.

In Appendix B.1, I show my measures of national federal military government purchases, consumption, and investment in Figure B.1, and the BEA's measures as adjusted above in Appendix Figure B.2. Overall, the three time series across both figures follow similar paths, including the drawdown in national military purchases in the 1990s after the Cold War, the buildup after 2001, and a second drawdown in the early 2010s.

4 Empirical Results

In this section, I list results for state-level multipliers and fiscal spillovers. I use the regional fiscal multiplier estimates at the state-level as a benchmark to contrast with the theoretical model in Section 5 and the quantitative model in Section 8, which can only be calibrated properly at the state level of geographical disaggregation. On the other hand, there are many more MSAs (356) than states (50), and thus the greater size of the MSA-level panel data provides greater statistical power. I list results for state-level results first, state-level fiscal spillovers second, then finally the MSA-level results.

4.1 Summary Statistics

In Table 2, I include summary statistics of the state-level sample from 1989 to 2024. I find that the ratio of state federal DoD purchases to state personal income ("State G / State Personal Income") has a mean value of 1.91%. The mean ratio of MSA federal DoD investment purchases

	Mean	St. Dev.	Min	Max
State Personal Income ($B)	268.07	336.49	13.35	2,732.30
State Population (Million Persons)	5.94	6.59	0.45	39.50
State G / State Personal Income (%)	1.91	1.63	-0.25	12.26
State C^g / State Personal Income (%)	1.01	1.07	0.07	8.64
State X^g / State Personal Income (%)	0.90	1.06	-0.39	8.71
State share of G_t (%)	2.00	2.86	-0.04	22.03
State share of C_t^g (%)	2.00	2.99	0.02	19.71
State share of X_t^g (%)	2.00	3.17	-0.11	27.28
Labor Income / State Personal Income (%)	51.20	4.35	37.04	62.81
Capital Income / State Personal Income (%)	19.40	2.78	13.34	36.44

Table 2: Summary statistics for state-level data, 50 states, 1989-2024 (1,800 observations).

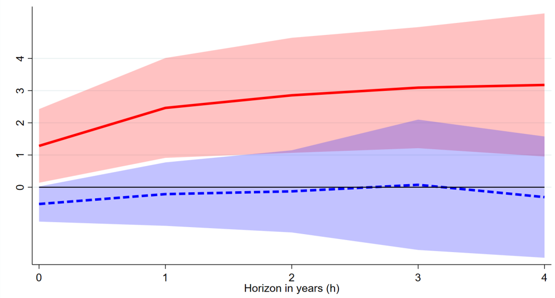
to MSA personal income ("State X^g / State Personal Income", 0.90%) is slightly less than that for consumption purchases ("State C^g / State Personal Income", 1.01%). The mean state share for all government spending types has to be the same at exactly 2%, since there are 50 states.

4.2 Results: State-level Multipliers

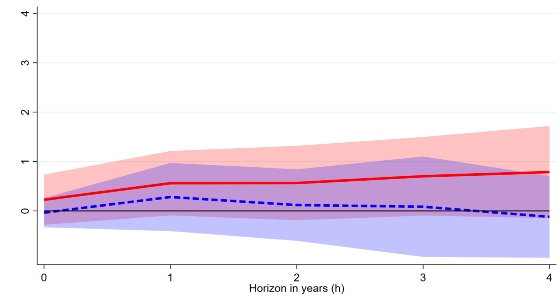
In Figure 1, I show the results of the panel 2SLS regressions for various dependent variables, and also in table form in Table C.1 of Appendix C.1. The regional government consumption multiplier $\beta^c_{reg,h}$ (red solid line) is generally larger than $\beta^x_{reg,h}$ (blue dashed line) for all regressions, and this difference is persistent over a 5-year horizon. For example, Subfigure 1a shows that the 2-year regional government consumption multiplier, corresponding to β_1^c under $h = 1$, is 2.463, while the 2-year regional government investment multiplier, β_1^x, is -0.213. Similar responses in employment (Figure 1b) and labor income (Figure 1c) imply that regional government consumption shocks increase regional incomes by more than regional government investment shocks primarily through its effects on regional labor supply, especially on the extensive margin (employment).[11] These empirical results affirm a key assertion in Boehm (2020), which empirically shows the differential crowding-out effects of private consumption and investment, but not the labor supply responses, from government spending shocks.

I show the same results in table format in Table C.1, with Wald tests for equality of coefficients. The two shift-share instruments pass the weak IV test from Lewis and Mertens (2022), and thus I generally find that the instruments are strong for $h > 0$.

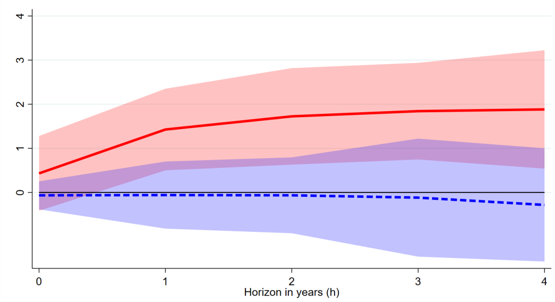
[11] This empirical finding is replicated in the baseline model in Section 6.



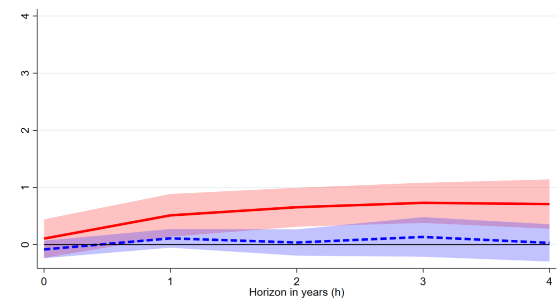
(a) Personal Income



(b) Employment



(c) Labor Income



(d) Capital Income

Figure 1: State-level regional fiscal multipliers for various dependent variables. Red: government consumption, blue: government investment. 90% confidence intervals. Each subfigure is plotted over a horizon from $h = 0$ to $h = 4$. For more details, and to see these results in tables, see Table C.1.

The estimate for the 2-year ($h = 1$) regional government consumption multiplier of 2.46 may seem unusually large, and this warrants some comparison with the headline estimate of 1.4 for the regional fiscal multiplier in Nakamura and Steinsson (2014). First, under my classification, federal military government purchases are close to evenly split between government consumption and investment (see Tables B.1 and B.2 in Appendix B.1.). The 2-year regional fiscal multiplier, as a (weighted) average of the regional government consumption and investment multipliers, is approximately 1.1.[12] Second, in that paper, the authors' baseline approach is to "instrument for state or region military procurement using total national procurement interacted with a state or region dummy", from which they get their headline estimate of 1.4. For robustness, they also estimate a state-level shift-share (Bartik) instrument, which yields a much larger estimate of around 2.5. While my paper uses shift-share instruments to avoid the many-instrument issue,[13] this choice of methodology may lead to seemingly large regional government consumption multipliers.

[12]The authors of that paper estimate within the sample period of 1966-2006, also using state-level data. Chodorow-Reich (2019) also summarizes the literature on cross-sectional multipliers up to 2019, and his "preferred" point estimate is 1.8.

[13]Given 50 states, the panel IV regression would have $50 \times 2 = 100$ instruments.

As for *cumulative* regional multipliers, I list the results in Table C.2 and Figure C.1 of Appendix C.1. As predicted, the cumulative regional government consumption multiplier $\beta_h^{c,cumul}$ is generally larger than its investment counterpart $\beta_h^{x,cumul}$.

4.3 Results: State-level Fiscal Spillovers

I also estimate fiscal spillovers of state-level government consumption and investment shocks to other states in the monetary union (i.e. the United States). In this paper, I define spillovers as the effect on the rest of the monetary union from a regional government spending shock in state i. Other papers have generally defined spillovers to neighboring regions which are geographically close to city i (Auerbach et al., 2020), or a major trading partner of state i (Dupor and Guerrero, 2017). Theoretically, a regional government spending shock raises regional incomes (and prices). Households in the affected region increase their demand for goods for their own region as well as from neighboring regions, further increasing own-region incomes and incomes in surrounding regions.

Given a state i, I denote the total personal income of regions surrounding state i as $\tilde{Y}_{it}$. I then measure fiscal spillovers from shocks in region-i government spending by running the following two-way fixed effects panel IV regression:

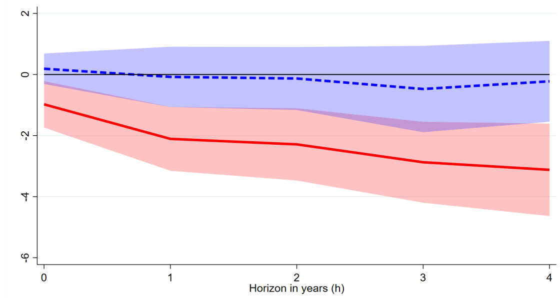
$$\frac{\tilde{Y}_{i,t+k} - \tilde{Y}_{i,t-1}}{\tilde{Y}_{i,t-1}} = \beta_{spill,h}^{c} \frac{C_{i,t+k}^{g} - C_{i,t-1}^{g}}{\tilde{Y}_{i,t-1}} + \beta_{spill,h}^{x} \frac{X_{i,t+k}^{g} - X_{i,t-1}^{g}}{\tilde{Y}_{i,t-1}} + \alpha_i + \delta_t + \epsilon_{i,t} \tag{9}$$

In this paper, I measure spillovers over $\tilde{Y}_{i,t}$, the unweighted sum of all other U.S. states $i \neq j$ between states i and j:

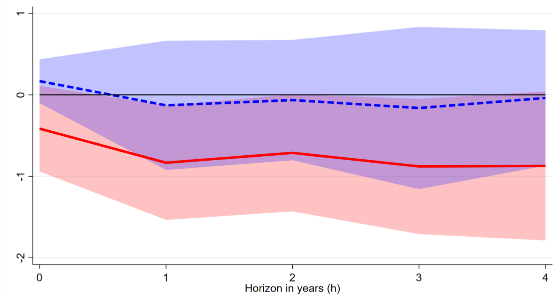
$$\tilde{Y}_{i,t} = \sum_{j \neq i} Y_{j,t} \tag{10}$$

I show the results in Figure 2, and also in table format in Table C.3 of Appendix C.1. Regional government consumption leads to more negative spillovers to the rest of the United States than regional government investment. This result holds not just for personal income (Figure 2a), but also for employment, labor income, and capital income (Figures 2b, 2c, and 2d, respectively). This is in line with Conley et al. (2020), who also find negative spillovers from U.S. regional government spending shocks.

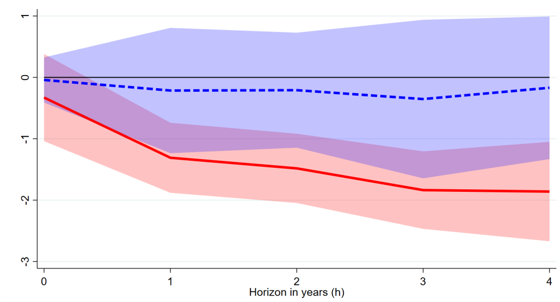
One possible explanation for the negative spillovers is due to the spatial reallocation of la-



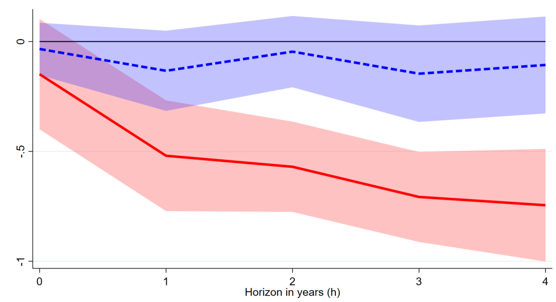
(a) Personal Income



(b) Employment



(c) Labor Income



(d) Capital Income

Figure 2: State-level regional spillovers for various dependent variables. Red: government consumption, blue: government investment. 90% confidence intervals. Each subfigure is plotted over a horizon from $h = 0$ to $h = 4$. For more details, and to see these results in tables, see Table C.3.

bor across regions due to regional government spending shocks.[14] Regions that receive greater regional government spending shocks, relative to other regions, may see an increase in labor demand that is partially fulfilled by inward labor migration from other regions. This would cause a decrease in labor supply(employment), and thus total and factor incomes, in the surrounding regions. In Figure 2b, I show some evidence that regional government consumption shocks lead to more negative spillovers in employment in the rest of the monetary union than regional government investment shocks.[15]

To demonstrate the role of the geographical scope of spillovers, I measure spillovers over $\tilde{Y}_{i,t}$, the sum of all other U.S. states $i \neq j$ weighted by inverse distances between states i and j, $dist_{ij}$:

$$\tilde{Y}_{i,t} = \sum_{j \neq i} \frac{Y_{j,t}}{dist_{ij}} \tag{11}$$

Under this specification I generally find positive spillovers from regional government con-

[14] This concern is also mentioned in Dupor and Guerrero (2017) and Chodorow-Reich (2019).

[15] While I abstract from this feature in the theoretical model in Section 5, the introduction of labor mobility in the model would amplify the negative spillovers to other regions.

sumption shocks, and generally statistically insignificant spillovers from regional government investment shocks. This illustrates how the signs of the spillovers depend on the scope of spillovers. Auerbach et al. (2020) finds positive spillovers from MSA-level government spending shocks to neighboring cities to other cities within a 100-mile radius. Empirically, the inverse distances specification may measure positive spillover effects because states closer in distance to the source state of the government spending shock are represented to a greater degree than states further away, much like the methodology and results in Dupor and Guerrero (2017). By contrast, the unweighted sums specification produces a measure of $\tilde{Y}_{it}$ that represents the entire rest of the monetary union, thereby measuring the negative spillover effects also found in Conley et al. (2020).

4.4 Results: MSA-level

For MSA-level data, there is greater possibility for outliers that can affect the results of the first-stage regression results and hence the results of the panel 2SLS regressions. Therefore, I winsorize h-year growth rates of dependent variables at the 1% and 99% levels.[16] I also drop data for MSAs which have at least one year with no recorded government spending in either federal government consumption or government investment. This leaves me with a balanced panel of 356 MSAs.

I list the MSA-level results in Appendix C.2. In Table C.7, I show summary statistics of MSA-level data for the 356 MSAs from 1989 to 2024 (to 2022 in the case of employment). Again, the ratio of MSA federal DoD purchases to MSA personal income ("MSA G / MSA Personal Income") has a mean value of 1.39%, of which investment has a slightly larger share (0.74%) of MSA personal income than consumption (0.65%) than and is more volatile (3.11%) than consumption (1.38%) across all MSA-year pairs. The mean MSA share for all government spending types is 0.28%, since there are 356 MSAs.

Table C.8 lists empirical results for MSA-level multipliers, while Table C.9 for cumulative MSA-level multipliers. The main qualitative result remains the same: regional government consumption multipliers are larger than regional government investment multipliers. Smaller regions face greater leakage of local demand to purchasing other regions' goods and services, and thus less of the income multiplier effect of regional government spending shocks remains within smaller regions (e.g. MSAs) than in larger regions (e.g. states). This mirrors an empirical finding in Nakamura and Steinsson (2014)[17] and a theoretical argument in Chodorow-Reich (2019).

[16] I find that results are qualitatively similar whether the dependent variables are winsorized or not, albeit with both smaller estimates of coefficients and smaller standard errors under winsorization.

[17] The authors of that paper compare states with census regions, or regional groups of states.

5 Generalized Model Framework and Estimation

This section provides the description for the generalized model framework and estimation procedure, in order to calibrate different versions of the model.

The first part of this section describes a generalized framework for a New Keynesian DSGE model for a J-region monetary union, where $J \geq 2$. The model is closely based on Nakamura and Steinsson (2014) and Boehm (2020). It consists of the following features: Calvo pricing frictions, a consumption-goods sector and an investment-goods sector, $J \geq 2$ regions within a monetary union with aggregate monetary policy, regional government consumption and investment shocks, and heterogeneous sectoral trade shares. The introduction of regional government investment necessitates that the monetary union has regional public capital, that serves as a public good that enters the production function of both sectors in that region (e.g. highways or waterworks in a certain state).

This generalized J-region monetary union model is then used to describe the baseline model with $J = 2$, from which I discuss theoretical mechanisms. It also describes the state-level quantitative model with $J = 51$ (including the District of Columbia), which explores the effects of the 2021 Infrastructure Investment and Jobs Act. For estimation purposes, I also construct a quantitative model with $J = 10$ at the Census division level, where each Census division is a regional group of states as defined by the U.S. Census Bureau.

The next parts of this section describe the necessary steps to explain the estimation procedure. Given the J-region model framework, I calibrate some parameters and estimate several key parameters that are important in determining regional fiscal multipliers. Section 5.2 describes the general framework for computing regional government consumption and investment multipliers, given simulated data from the 2-region model. Appendix E generalizes this procedure for the J-region monetary union model for $J > 2$. Section 5.3 describes the calibration of the externally calibrated parameters. Excluding regional shares of national income and sectoral trade shares across regions, all externally calibrated parameters are the same across all 3 model versions used in this paper.

Then, Section 5.4 describes the impulse response function (IRF) matching procedure. The IRF matching procedure is used to estimate for a subset of parameters which minimize the distance between the empirical estimates of regional fiscal multipliers (from Section 4) and the model-computed regional fiscal multipliers. A straightforward solution would be to estimate parameters in the 51-region model based on data, and using those parameter estimates to calibrate both the 2-region baseline and 51-region quantitative models. However, the 51-region model incurs heavy computational costs.[18] Therefore, I take an alternative approach that is less computationally costly, which involves the 10-region Census division-level model. The 10-region model is a compromise solution in estimation between the computational cost of the 51-region model and the relative lack of realism of the 2-region model. The parameters estimated using the 10-region model are used to calibrate the 2-region and 51-region models. The results of the baseline 2-region model are in Section 6, and those of the 51-region, state-level quantitative model are discussed in Section 7.

5.1 Model Setup

In this subsection, I list a summary of the main departures of my generalized model framework from the standard New Keynesian model. I list a full description of the J-region model in Appendix D.1, with first-order conditions (Appendix D.2) and a linearized version of the model (Appendix D.3).

There are $J \geq 2$ regions in the monetary union $\mathcal{J} = \{1, \ldots, J\}$. In the 2-region model, there are only the small Home (H) and the large Foreign (F) regions, with the latter consisting of the rest of the monetary union. In the 51-region model, each j stands for a state or the District of Columbia.

Each region $j \in \mathcal{J}$ has two sectors: a consumption-goods sector, whose variables are denoted with c, and an investment-goods sector, denoted with x. Each region has also two types of households, as in a Two-Agent New Keynesian (TANK) model (Galí et al., 2007; Bilbiie, 2020). "Ricardian" (R) households have access to savings and capital markets and thus can optimize their consumption intertemporally. "Keynesian" (K) households, who do not have access to the savings market and cannot smooth consumption, expend all their labor income in each period into consumption. Each region j has sectoral labor supply $N_{jt}^{h,c}$ and $N_{jt}^{h,x}$ from both Ricardian and Keynesian households ($h \in \{R, K\}$), sectoral capital K_{jt}^{c} and K_{jt}^{x} held by Ricardian households, and public capital K_{jt}^{g}. Regional government investment accumulates into regional public capital K_{jt}^{g}. I assume no movement of labor or capital across regions. Using these inputs, each region produces its consumption goods C_{jt} and investment goods X_{jt}. The steady-state income share of each

[18] Each iteration of solving the 51-region model, at more than 17,500 equations, takes around 2.5 hours on a personal laptop with 32GB RAM and an Intel Core i7-13620H processor.

region j is denoted as $\omega_j \in [0,1]$, where:

$$\sum_{j \in \mathcal{J}} \omega_j = 1 \tag{12}$$

There is inter-regional trade in the monetary union, in which consumption and investment goods produced in region $i \in \mathcal{J}$ are expended in region j. Each region demands a CES aggregate of consumption and investment goods produced in each region. The region-j share of demand for sector-s goods produced in region i is denoted as $\chi_j^{s,i}$, for $s \in \{c, x\}$. Region-sector trade shares sum up to 1 for each combination of s and j:

$$\sum_{i \in \mathcal{J}} \chi_j^{c,i} = 1 \; \forall j \in \mathcal{J} \tag{13}$$

$$\sum_{i \in \mathcal{J}} \chi_j^{x,i} = 1 \; \forall j \in \mathcal{J} \tag{14}$$

In the context of the baseline 2-region model, the degree of home bias in region j is simply $\chi_j^{c,j}$ for consumption goods, and $\chi_j^{x,j}$ for investment goods.

Each region-sector combination has one final goods firm and a continuum of intermediate-goods firms, with Calvo pricing frictions. Sectoral production occurs in each region, taking sector-specific private capital K_{jt}^s, labor supply N_{jt}^s, and regional public capital K_{jt}^g as inputs. For example, in the consumption-goods sector, the production function for region-j production of consumption goods is $(K_{jt}^g)^{\alpha_g}(K_{jt}^c)^{\alpha}(N_{jt}^c)^{1-\alpha}$, where $\alpha_g > 0$ is the output elasticity of public capital. Public capital, such as highways, bridges, hospitals, military bases, and other public infrastructure, are modelled as a production input that raises the marginal productivity of private capital and labor. Each firm also faces capital adjustment costs, like in Christiano et al. (2005).

As for fiscal and monetary policy, regional lump-sum taxes (T_{jt}) finance regional government consumption (C_{jt}^g) and investment (X_{jt}^g). C_{jt}^g and X_{jt}^g follow an AR(1) process, with region-specific government consumption and investment shocks.

$$C_{jt}^g = (1 - \rho_c^g)\bar{C}_j^g + \rho_c^g C_{j,t-1}^g + \epsilon_{jt}^{gc} \tag{15}$$

$$X_{jt}^g = (1 - \rho_x^g)\bar{X}_j^g + \rho_x^g X_{j,t-1}^g + \epsilon_{jt}^{gx} \tag{16}$$

Aggregate monetary policy applies to all regions of the monetary union. It is specified as a standard Taylor rule, with the nominal interest rate i_t responding to aggregate (union-wide) output and aggregate inflation.

5.2 A Framework for Model-computed Multipliers

To estimate multipliers from the model, I borrow the methodology from Nakamura and Steinsson (2014). I compute the simulated path of the endogenous variables of interest (here, income) for 190 quarters, and drop the first 50 periods to remove the effects of the initial steady state in determining the endogenous variables. Then, with the remaining 140 quarters (35 years), I take the 4-quarter average of the data to aggregate into annual frequency. Given this annualized data, I estimate and store the multipliers for that simulation. I run this procedure for 1,000 simulations. In the example below, I use the 2-region model consists of a Home region with the size of an average U.S. state ($\omega_H = 1/50 = 0.02$), and a Foreign region (F) with the size of the rest of the United States ($\omega_F = 1 - \omega_H = 0.98$).

In this exercise, I first estimate three types of responses to each type of Home government spending shock. First, there are the responses of Home income Y_{Ht}. I denote these as $\beta^{H,c}_{H,h}$ and $\beta^{H,x}_{H,h}$, the region-H response to a region-H government consumption or investment shock, where h is the time horizon of the multiplier:

$$\frac{Y_{H,t+h} - Y_{H,t-1}}{Y_{H,t-1}} = \beta^{H,c}_{H,h} \frac{C^g_{H,t+h} - C^g_{H,t-1}}{Y_{H,t-1}} + \beta^{H,x}_{H,h} \frac{X^g_{H,t+h} - X^g_{H,t-1}}{Y_{H,t-1}} + \alpha_H + \epsilon_{Ht} \tag{17}$$

Second, there are the fiscal spillovers, or the response of Foreign income Y_{Ft} to the Home government spending shocks. I denote these as $\beta^{H,c}_{F,h}$ and $\beta^{H,x}_{F,h}$, with the source (origin) region H in the superscript and the affected (destination) region F in the subscript:

$$\frac{Y_{F,t+h} - Y_{F,t-1}}{Y_{F,t-1}} = \beta^{H,c}_{F,h} \frac{C^g_{H,t+h} - C^g_{H,t-1}}{Y_{H,t-1}} + \beta^{H,x}_{F,h} \frac{X^g_{H,t+h} - X^g_{H,t-1}}{Y_{H,t-1}} + \alpha_F + \epsilon_{Ft} \tag{18}$$

From these, I define the regional fiscal multipliers as the relative regional differences in the percentage deviations of Home and Foreign outcomes (in this case, regional income), as estimated from panel data. In other words, the regional fiscal multipliers $\beta^c_{reg,h}$ and $\beta^x_{reg,h}$, are equivalent to:

$$\beta^c_{reg,h} = \beta^{H,c}_{H,h} - \beta^{H,c}_{F,h} \tag{19}$$

$$\beta^x_{reg,h} = \beta^{H,x}_{H,h} - \beta^{H,x}_{F,h} \tag{20}$$

There are also the aggregate fiscal multipliers from Home government spending shocks, or the response of aggregate income $Y_t = Y_{Ht} + Y_{Ft}$ to the Home government spending shocks. I denote these as $\beta^{H,c}_{agg,h}$ and $\beta^{H,x}_{agg,h}$, where the subscript agg represents the aggregate monetary union:

$$\frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}} = \beta^{H,c}_{agg,h} \frac{C^g_{H,t+h} - C^g_{H,t-1}}{Y_{H,t-1}} + \beta^{H,x}_{agg,h} \frac{X^g_{H,t+h} - X^g_{H,t-1}}{Y_{H,t-1}} + \epsilon_t \tag{21}$$

In Appendix E, I include a general framework for aggregating regional fiscal multipliers. In the 2-region model, the aggregate fiscal multipliers from the Home government spending shocks are approximately a weighted average of the regional fiscal multipliers and the fiscal spillovers, both from Home government spending shocks:

$$\beta^{H,c}_{agg,h} \approx \omega_H \beta^{H,c}_{H,h} + \omega_F \beta^{H,c}_{F,h} \tag{22}$$

$$\beta^{H,x}_{agg,h} \approx \omega_H \beta^{H,x}_{H,h} + \omega_F \beta^{H,x}_{F,h} \tag{23}$$

where ω_H is the ratio of the Home region's income to aggregate income, and likewise for $\omega_F = 1 - \omega_H$.[19]

5.3 Calibration

I borrow much of the quarterly-frequency calibration from Boehm (2020). I list the parameters below in Table 3. The additional parameters required are: the share of regional income shares ω_j, the degrees of sectoral trade shares from region i to region j $\chi^{c,i}_j$ and $\chi^{x,i}_j$, and the persistence of regional government consumption and investment shocks ρ^g_c and ρ^g_x.

In the 2-region model, I assume the size of the Home region to be $\omega_H = 0.02$, the income share of an average U.S. state (0.02 = 1/50). In the 51-region and 10-region models, I calibrate ω_j state/Census division shares of U.S. national income.

For sectoral home bias parameters, I calibrate $\chi^{c,H}_H = 0.80$ and $\chi^{x,H}_H = 0.25$ on the following basis. Using the Public Use File (PUF) from the 2017 Commodity Flow Survey (U.S. Depart-

[19] It is important to distinguish the aggregate fiscal multipliers $\beta^{H,c}_{agg,h}$ and $\beta^{H,x}_{agg,h}$ with those that are generally used in policy discussions, which is the response of aggregate income Y_t to the weighted average/aggregate of the regional government spending shocks. I denote these policy-relevant aggregate fiscal multipliers as $\beta^{c}_{agg,h}$ and $\beta^{x}_{agg,h}$. Appendix E shows the derivation for which:

$$\beta^{s}_{agg,h} \approx \omega_H \beta^{H,s}_{agg,h} + \omega_F \beta^{F,s}_{agg,h} \; \forall s \in \{c, x\} \tag{24}$$

ment of Transportation et al., 2020), I aggregate shipments by sector, origin state, and destination state. Since inter-state shipments data in Commodity Flow Survey (CFS) data is categorized by 2-digit NAICS codes, I classify shipments with NAICS code 33 (manufacturing of metal parts, heavy equipment, etc.) as investment goods, and all other NAICS codes as tradable consumption goods. Taking the average share, this leaves with a Home share of 40% for tradable consumption goods and 25% for investment goods, and thus $\chi_H^{x,H} = 0.25$. Following Carlino et al. (2023), I assume that consumption spending is composed of one-third tradable goods and two-thirds services. Assuming that services are produced and consumed entirely within each region, I calibrate $\chi_H^{c,H} = \frac{1}{3}(0.40) + \frac{2}{3}(1) = 0.80$. Also, the degree of home bias for the Foreign region is $\chi_F^{s,F} = 1 - (\omega_H/(1-\omega_H))\chi_H^{s,H}$.

For the persistence of regional government consumption and investment shocks, I run two panel data regressions with lagged dependent variables (Arellano and Bond, 1991), each for state-level government consumption and investment:

$$\ln S_{i,t}^{g} = \rho_{s,ann}^{g} \ln S_{i,t-1}^{g} + \alpha_i + \delta_t + \epsilon_{i,t},\ s \in \{c, x\} \tag{25}$$

Given the annual frequency of my panel data, I then calibrate into quarterly frequency by letting ρ_s^g equal the 4th root of $\rho_{g,ann}^s$, or $\rho_s^g = (\rho_{g,ann}^s)^{1/4}$. This yields $\rho_{c,ann}^g = 0.756$ and $\rho_{x,ann}^g = 0.746$, or $\rho_c^g = 0.933$ and $\rho_x^g = 0.929$.

5.4 IRF Matching Estimation with Census Division-level Model

Now I describe the IRF matching procedure, to estimate key parameters which are either important in determining the regional fiscal multipliers, or which do not have a commonly accepted calibration in the previous literature. I denote this subset of parameters $\boldsymbol{\theta}$ to be estimated via impulse response function (IRF) matching (Rotemberg and Woodford, 1997; Christiano et al., 2005). I choose five parameters for $\boldsymbol{\theta}$, for the following reasons:

1. σ, the intertemporal elasticity of substitution, and η, the inverse Frisch elasticity of labor supply: Both parameters affect the labor supply condition, the intra-temporal relationship between private consumption and labor supply (in each sector). To the extent that government spending shocks crowd out private consumption, the response of output/incomes to government spending shocks depend on the response of private consumption to government spending shocks (Aiyagari et al., 1992; Boehm, 2020).

Parameter	Value	Definition	Source
β	0.995	Discount factor	
ξ	7	Elasticity of substitution of goods within same region	
λ	0.2	Share of Keynesian ("hand-to-mouth") households	Bilbiie et al. (2023)
μ	1	Degree of labor mobility	
α	1/3	Capital share	
δ	0.025	Depreciation rate of private capital	
δ_g	0.025	Depreciation rate of public capital	
ζ	2	Capital adjustment cost parameter	
ρ_c^g	0.933	Persistence of government consumption shock	Author's calculations
ρ_x^g	0.929	Persistence of government investment shock	Author's calculations
ω_y^c	0.8	Consumption share of output	
ω_y^x	0.2	Investment share of output	
ω_c^g	0.175	Government share of consumption	
ω_x^g	0.175	Government share of investment	
θ_c	0.75	Calvo parameter for consumption goods	
θ_x	0.75	Calvo parameter for investment goods	
ϕ_π	1.5	Taylor rule coefficient for inflation	
ϕ_y	0.125	Taylor rule coefficient for output	
ω_H	0.02	Size of Home region (2-region model)	Average share of U.S. state
$\chi_H^{c,H}$	0.8	Home bias of consumption goods in Home region (2-region model)	CFS 2017
$\chi_H^{x,H}$	0.25	Home bias of investment goods in Home region (2-region model)	CFS 2017

Table 3: List of externally calibrated parameters for the baseline (2-region) model. Excluding ω_H, $\chi_H^{c,H}$ and $\chi_H^{x,H}$, all 3 versions of the model in this paper share the same values for externally calibrated parameters. Unless stated otherwise, the calibrated values of parameters are from Boehm (2020). CFS 2017: U.S. Department of Transportation et al. (2020).

2. α_g, the regional output (Y_{jt}) elasticity of regional public capital (K_{jt}^g): α_g determines the degree of public capital accumulation due to government investment shocks, and therefore the response of future output to government investment shocks. Estimating this parameter helps to differentiate the response of government *investment* multipliers from government consumption multipliers.

   Bom and Ligthart (2014) provides a meta-analysis of α_g, and reports a short-run for public capital supplied by the central government at 0.083, and an average output to public capital elasticity of 0.106. Meanwhile, Ramey (2021) and Boehm (2020) calibrate $\alpha_g = 0.05$. While Boehm (2020) emphasizes the limited quantitative effect of the size of α_g in determining short-run government investment multipliers, this parameter has a larger effect on long-run government investment multipliers.

3. ν_c and ν_x, the elasticity of substitution of consumption(c) and investment(x) goods across different regions: To discuss fiscal spillovers, I look at how much regional demand in consumption and investment goods produced in other regions are affected by regional govern-

ment consumption and investment shocks. A larger value of ν_c implies that an increase in the region-i's price of consumption goods from a region-i government consumption shock would decrease other regions' ($j \neq i$) demand of region i's consumption goods (and vice versa for ν_x). Estimating ν_c and ν_x helps to pin down the difference between *regional* government consumption and investment multipliers, separate from the difference between *aggregate* government consumption and investment multipliers.

Nakamura and Steinsson (2014) and Carlino et al. (2023) calibrate the elasticity of substitution of all goods across U.S. regions to 2. My model disaggregates those goods between consumption and investment goods, and thus I estimate for consumption and investment goods separately.

I search for the value of $\boldsymbol{\theta} = \{\sigma, \eta, \alpha_g, \nu_c, \nu_x\}$ that minimizes the value of the objective function between empirical estimates $\tilde{\boldsymbol{\beta}}_{reg}$ and model-computed multipliers $\bar{\boldsymbol{\beta}}_{reg}(\boldsymbol{\theta})$. Specifically, $\tilde{\boldsymbol{\beta}}_{reg}$ is the vector of regional government consumption multipliers and regional government investment multipliers, from $h = 0$ to $h = 4$:

$$\tilde{\boldsymbol{\beta}}_{reg} = \left[\tilde{\beta}^c_{reg,0}, \ldots, \tilde{\beta}^c_{reg,4}, \tilde{\beta}^x_{reg,0}, \ldots, \tilde{\beta}^x_{reg,4}\right]' \tag{26}$$

$\bar{\boldsymbol{\beta}}_{reg}(\boldsymbol{\theta})$ is defined similarly for model-computed multipliers.

As mentioned before, for reasons of computation cost, I use the 10-region, Census division-level model for estimation purposes. The U.S. Census Bureau divides the 50 states and the District of Columbia into four Census regions (Northeast, Midwest, South, and West), which are further disaggregated into Census divisions. Thus, I estimate parameters via IRF matching using the 10-region, Census division-level model, which takes at most seconds to solve in each iteration.

For the 10-region model, I aggregate the state-level data at the Census division level, including state-level government consumption and investment shocks from the 2021 IIJA, state shares of national income in 2021, and state-to-state trade flows of (tradable) consumption and investment goods from the 2017 Commodity Flow Survey. From the latter, I find that 37.55% of investment goods and 62.58% of tradable consumption goods originate from the same division. Again, assuming that 1/3 of private consumption and all investment goods are tradable, this implies an average division-level home bias of $1/3 \times (0.6258) + 2/3 \approx 0.875$ for all consumption goods, and 0.375 for investment goods. The other parameters are as listed in Table 3.

I list the designation of the Census divisions in Table 4. I make one alteration to the U.S. Census

Census Region	**Census Division**	States
West	Pacific	AK CA HI OR WA
West	Mountain	AZ CO ID MT NM NV UT WY
Midwest	West North Central	IA KS MN MO ND NE SD
Midwest	East North Central	IL IN MI OH WI
South	West South Central	AR LA OK TX
South	East South Central	AL KY MS TN
South	South Atlantic North	DC DE MD VA WV
South	South Atlantic South	FL GA NC SC
Northeast	Middle Atlantic	NJ NY PA
Northeast	New England	CT MA ME NH RI VT

Table 4: List of 10 Census Divisions and member states in each division.

Bureau's list of Census divisions, as in Nakamura and Steinsson (2014). I split the South Atlantic division into two regions, "South Atlantic North" (District of Columbia, Delaware, Maryland, Virginia, and West Virginia) and "South Atlantic South" (Florida, Georgia, North Carolina, and South Carolina). With this, I can construct a 10-region version of the model. Table 4 lists the Census divisions in the 10-region model.

With the calibration for the 10-region model complete, I estimate the parameters above via IRF matching. The full procedure is as follows:

1. Calibrate the 10-region, Census division-level model, and begin with an initial guess of $\boldsymbol{\theta} = \boldsymbol{\theta}_0$.

2. Compute the objective criterion as a function of the distance between the model estimates $\bar{\boldsymbol{\beta}}_{reg,i}(\boldsymbol{\theta})$ and the empirical estimates $\tilde{\boldsymbol{\beta}}_{reg}$. This is done with a 2-step iterative process, as shown below:

   (a) Estimate $\hat{\boldsymbol{\theta}}_{(1)}$, a $p \times 1$ vector where p is the number of parameters to be estimated:

   $$\hat{\boldsymbol{\theta}}_{(1)} = \arg\min_{\boldsymbol{\theta}} \left\{ \frac{1}{N_{sim}} \sum_{i=1}^{N} \bar{\boldsymbol{\beta}}_{reg,i}(\boldsymbol{\theta}) - \tilde{\boldsymbol{\beta}}_{reg} \right\}' \boldsymbol{I} \left\{ \frac{1}{N_{sim}} \sum_{i=1}^{N} \bar{\boldsymbol{\beta}}_{reg,i}(\boldsymbol{\theta}) - \tilde{\boldsymbol{\beta}}_{reg} \right\} \tag{27}$$

   $\boldsymbol{I}$ is the 10×10 identity matrix, as there are a total of 10 estimates to be matched (5 regional government consumption multipliers for horizons $h = 0, \ldots, 4$, and 5 regional government investment multipliers).

      i. Run $N_{sim} = 1{,}000$ simulations of the 10-region model given the values for $\boldsymbol{\theta}$, each simulation for $T_{sim} = 190$ periods. I truncate the first 50 periods from each simulation, leaving 140 periods(quarters) or equivalently 35 years.

ii. Compute model-computed regional government consumption and investment multipliers, $\bar{\beta}^{c}_{reg,h}$, and $\bar{\beta}^{x}_{reg,h}$, for horizons $h = 0, \ldots, 4$.

(b) Compute the 10×10 weight matrix $W\left(\hat{\boldsymbol{\theta}}_{(1)}\right)$:

$$W\left(\hat{\boldsymbol{\theta}}_{(1)}\right) = \frac{1}{N_{sim}} \sum_{i=1}^{N} \left\{\bar{\boldsymbol{\beta}}_{reg,i}(\hat{\boldsymbol{\theta}}_{(1)}) - \tilde{\boldsymbol{\beta}}_{reg}\right\}\left\{\bar{\boldsymbol{\beta}}_{reg,i}(\hat{\boldsymbol{\theta}}_{(1)}) - \tilde{\boldsymbol{\beta}}_{reg}\right\}' \tag{28}$$

(c) Finally, estimate $\hat{\boldsymbol{\theta}}_{(2)}$ given the weight matrix $W\left(\hat{\boldsymbol{\theta}}_{(1)}\right)$:

$$\hat{\boldsymbol{\theta}}_{(2)} = \arg\min_{\boldsymbol{\theta}} \left\{\frac{1}{N_{sim}} \sum_{i=1}^{N} \bar{\boldsymbol{\beta}}_{reg,i}(\boldsymbol{\theta}) - \tilde{\boldsymbol{\beta}}_{reg}\right\}' W\left(\hat{\boldsymbol{\theta}}_{(1)}\right) \left\{\frac{1}{N_{sim}} \sum_{i=1}^{N} \bar{\boldsymbol{\beta}}_{reg,i}(\boldsymbol{\theta}) - \tilde{\boldsymbol{\beta}}_{reg}\right\} \tag{29}$$

$\hat{\boldsymbol{\theta}}_{(2)}$ is the 2-step IRF-matching estimate of $\boldsymbol{\theta}$ to be used in the quantitative models.

I list the results in Table 5, which are then used to calibrate both the baseline(2-region) and the quantitative(51-region) models.

Parameter	Estimated Value	Description
σ	0.3433 (0.0273)	Intertemporal elasticity of substitution
η	0.7433 (0.0291)	Frisch elasticity of labor supply
α_g	0.0523 (0.0309)	Elasticity of output with respect to public capital
ν_c	2.2715 (0.0375)	Elasticity of substitution of consumption goods across regions
ν_x	1.9648 (0.0670)	Elasticity of substitution of investment goods across regions

Table 5: Summary of estimated parameters in the 10-region model via IRF matching. Standard errors in parentheses. See also Table 3 and main text for more details.

6 Baseline Model

Given the estimation of parameters with the 10-region model via IRF matching, I then solve the 2-region model with externally and internally calibrated parameters.

6.1 Baseline Model Results

I list model-computed multipliers in Table 6. The top panel lists consumption multipliers, while the bottom panel lists investment multipliers. Each column indicates the time horizon of the multipliers (not cumulative multipliers), from $h = 0$ to $h = 4$ years after the Home government consumption or investment shock.

The first row of each panel indicates $\beta^{H,s}_{H,h}$, the response of Home income to a sector-s Home government spending shock, where $s \in \{c, x\}$. I note that, as in standard New Keynesian DSGE models, persistent government consumption or investment shocks lead to steadily decreasing multipliers over successive time horizons h. The second row of each panel $\beta^{H,s}_{F,h}$, the response of Foreign income to the same Home government spending shock. The third row, the regional fiscal multipliers $\beta^{s}_{reg,h}$, is simply the difference between the first and second rows. As hypothesized, the regional government consumption multipliers $\beta^{c}_{reg,h}$ are larger than the regional government investment multipliers $\beta^{x}_{reg,h}$.

The fourth row indicates the response of aggregate income to the sector-s Home government spending shock, $\beta^{H,s}_{agg,h}$. The fifth row indicates the same but for the sector-s Foreign government spending shock, $\beta^{F,s}_{agg,h}$. Finally, the sixth row indicates the response of aggregate income to sector-s government spending shocks in both the Home and Foreign regions, $\beta^{s}_{agg,h}$. The multipliers in the final rows can be thought of as the aggregate fiscal multipliers from the aggregate (weighted average) of regional government spending shocks.

At both the aggregate and regional levels, government consumption multipliers are larger than government investment multipliers.[20] I also note that, because the Home region is only 2% of the monetary union, much of the aggregate multiplier $\beta^{s}_{agg,h}$ is determined by the magnitude of the responses from the government spending shocks in the larger Foreign region (98%). Finally, mainly due to the greater own-region effects and negative spillovers ($\beta^{H,s}_{F,h}$), the difference between regional government consumption and investment multipliers ($\beta^{c}_{reg,h}$ and $\beta^{x}_{reg,h}$) are larger than the difference between their aggregate counterparts ($\beta^{c}_{agg,h}$ and $\beta^{x}_{agg,h}$).

Finally, in this linearized model, I note that the aggregate government consumption and investment multipliers ($\beta^{c}_{agg,1}$ and $\beta^{x}_{agg,1}$ respectively) are not affected by the calibration of sectoral home biases. This is expected, as the degree of sectoral home biases only affects relative demand across regions but not total demand across the monetary union.

[20] The aggregate case is the main result in Boehm (2020).

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
Consumption Multipliers					
$\beta^{H,c}_{H,h}$	1.194	1.137	1.108	1.090	1.077
$\beta^{H,c}_{F,h}$	-0.013	-0.010	-0.008	-0.008	-0.008
$\beta^{c}_{reg,h}$	1.215	1.155	1.126	1.108	1.094
$\beta^{H,c}_{agg,h}$	0.011	0.013	0.014	0.014	0.014
$\beta^{F,c}_{agg,h}$	0.482	0.521	0.532	0.535	0.536
$\beta^{c}_{agg,h}$	0.492	0.532	0.542	0.546	0.547
Investment Multipliers					
$\beta^{H,x}_{H,h}$	0.343	0.347	0.375	0.404	0.429
$\beta^{H,x}_{F,h}$	-0.009	-0.011	-0.008	-0.010	-0.007
$\beta^{x}_{reg,h}$	0.307	0.315	0.348	0.380	0.410
$\beta^{H,x}_{agg,h}$	-0.002	-0.003	-0.004	-0.002	0.002
$\beta^{F,x}_{agg,h}$	0.248	0.204	0.190	0.185	0.184
$\beta^{x}_{agg,h}$	0.253	0.208	0.194	0.189	0.188

Table 6: Model-computed multipliers on incomes. Top panel lists consumption multipliers, while bottom panel lists investment multipliers. See text for details on notation.

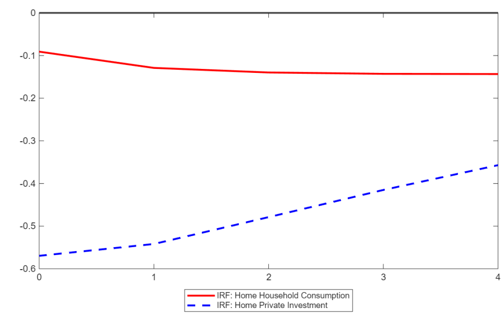
6.2 Explanation of Results

I explain the theoretical results from the 2-region model in several steps. First, I demonstrate from the model that the crowding-out effect on Home private consumption ($C^{hh}_{H,t}$) from a Home government consumption ($C^{g}_{H,t}$) shock is lesser than that of Home private investment ($X^{c}_{H,t} + X^{x}_{H,t}$) from a Home government investment ($X^{g}_{H,t}$) shock. As discussed in the introduction, this result follows from Boehm (2020). (Home) households prefer to smooth their consumption and investment has a lower intertemporal elasticity of substitution than consumption, which leads to a greater crowding out of private investment due to a transitory (Home) government investment shock that increases the price level of Home investment goods. Indeed, in Figure 3a, the crowding-out effect on Home private consumption from a Home government consumption shock equivalent to 1% of Home output (red solid line) is less negative than that on Home private investment from a Home government investment shock equivalent to 1% of Home output (blue dashed line). This translates into Figure 3b, which shows that the response of Home income is greater from the Home government consumption shock (red solid) than from the Home government investment shock (blue dashed).

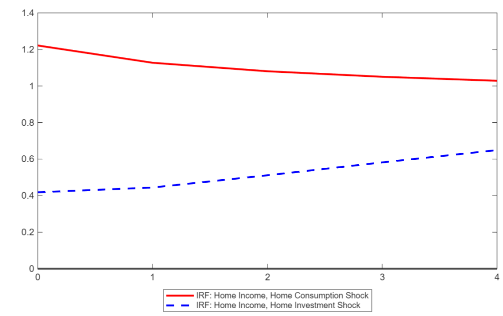
Importantly, the baseline model is able to replicate the empirical findings in Figures 1b and

1c, which show larger responses of regional labor supply from regional government consumption shocks than from investment shocks. In Figure 3c, we see the larger responses of Home labor supply from Home government consumption shocks than from Home government investment shocks.

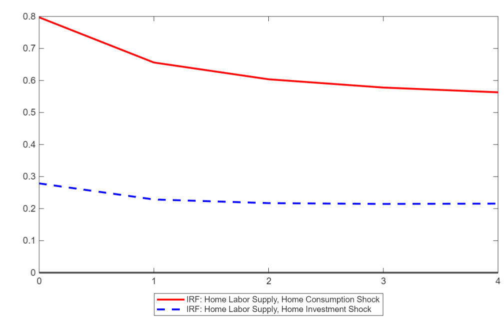
Figure 3: Response of endogenous variables to Home government consumption shock (red solid line) and Home government investment shock (blue dashed line).



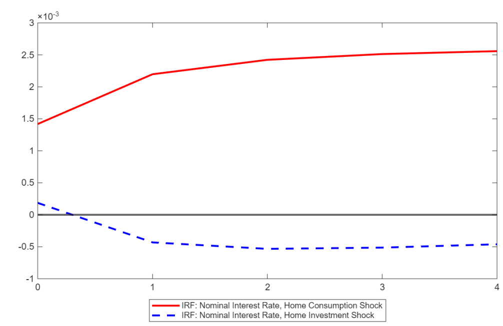
(a) Home household consumption (red) and private investment (blue)



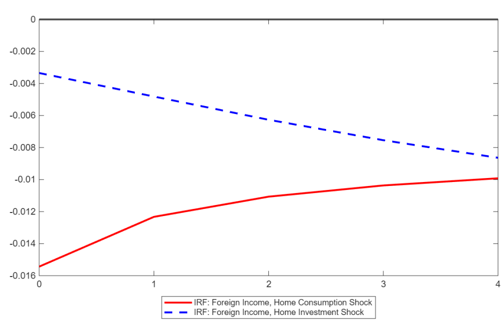
(b) Home income (red, blue)



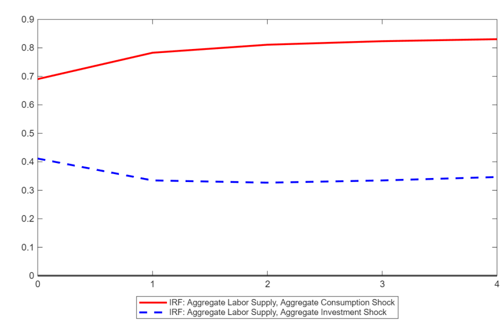
(c) Home labor supply (red, blue)



(d) Nominal interest rate (red, blue)



(e) Foreign income (red, blue)



(f) Agg. labor supply (red: agg. C^g shock, blue: agg. X^g shock)

Both shocks are equivalent to 1% of Home output. Responses of endogenous variables are measured in percentage deviations from respective steady-state values.

Second, I show the relative responses of Home and Foreign incomes to Home government spending shocks, through the expenditure-changing and aggregate monetary policy mechanisms. As explained in Chodorow-Reich (2019) for monetary unions, and more generally in international macroeconomics, an increase in Home incomes leads to an increase in the demand for goods for both Home and Foreign regions. It becomes important here that consumption goods exhibit greater home bias than investment goods in a monetary union. Given the same increase in income, the greater home bias in consumption goods leads to Home households demanding a greater share of their consumption goods produced in their own Home region, and a smaller share from the Foreign region (as compared to investment goods). From a Home government consumption shock, the own-region (Home) consumption and income responses are larger, and the spillovers to Foreign incomes are smaller, relative to a Home government investment shock of the same magnitude.

Separately, government consumption shocks have greater effects on aggregate incomes and prices, which lead to a larger endogenous response to aggregate monetary policy than government investment shocks. This is shown in Figure 3d, which shows the impulse response function of the nominal interest rate i_t in response to a Home government consumption shock (red solid) and a Home government investment shock (blue dashed). Notice that the red solid line is above the blue dashed line, indicating that the Home government consumption shock leads to a greater response in i_t than the Home government investment shock.

To summarize, the Home government consumption shock leads to a smaller expenditure-changing effect on the demand of Foreign investment goods, while having a larger negative effect on Foreign incomes separately from the stronger tightening of monetary policy, as compared to a Home government investment shock. Thus, the spillover effects from a Home government consumption shock are more negative than from a Home government investment shock, establishing the second empirical result. The second result is demonstrated in Figure 3e, which shows the responses of Foreign income to the Home government consumption (red solid) and investment (blue dashed) shocks.

When aggregating across the responses of Home and Foreign labor supplies, we still see that the response of aggregate labor supply from the aggregate of Home and Foreign consumption shocks are larger than those from the aggregate of regional investment shocks, in Figure 3e. This establishes the third result, that aggregate government consumption multipliers are larger than aggregate government investment multipliers, as consistent with the first two results.

6.3 Implications for Aggregate Fiscal Multipliers

My baseline, 2-sector, 2-region model implies larger aggregate fiscal multipliers than what previous models have implied. This is true when comparing either with a 2-sector, 1-region model as in Boehm (2020), or a 1-sector (closed economy) model as in Nakamura and Steinsson (2014).

First, comparing with a 1-region version of the 2-sector model, I find that my baseline model yields larger aggregate government consumption and investment multipliers, and thus larger aggregate fiscal multipliers. In Table 7 below, I compare aggregate government consumption (β^c_{agg}) and investment (β^x_{agg}) multipliers, as well as aggregate fiscal multipliers (β_{agg}, as a weighted average of aggregate government consumption and investment multipliers) from a TANK version of Boehm (2020)'s 2-sector model (panel (A)) and my baseline model (panel (B)). Panel (B) lists larger aggregate fiscal multipliers, due to the amplification effect of local demand via spillovers to other regions, as described in (Norris, 2019) and Chodorow-Reich (2019).[21]

	$h = 0$	1	2	3	4
Panel A: 2-sector, 1-region					
$\beta^c_{agg,h}$	0.502	0.540	0.550	0.554	0.555
$\beta^x_{agg,h}$	0.218	0.179	0.163	0.159	0.156
$\beta_{agg,h}$	0.486	0.520	0.528	0.531	0.532
Panel B: Baseline model (2-sector, 2-region)					
$\beta^c_{agg,h}$	0.772	0.830	0.846	0.850	0.852
$\beta^x_{agg,h}$	0.371	0.312	0.304	0.306	0.316
$\beta_{agg,h}$	0.695	0.732	0.744	0.749	0.753

Table 7: Comparison of aggregate consumption and investment multipliers across models: TANK version of 1-region (Boehm, 2020) vs. 2-region.

Second, comparing with a 1-sector version of the 2-region model, I find that my baseline model yields *smaller* regional fiscal multipliers (β_{reg}), but *larger* aggregate fiscal multipliers. In Table 8, I compare regional fiscal multipliers from the model in Nakamura and Steinsson (2014) with separable preferences (panel (A)) with a version of my baseline model but calibrated with $\lambda = 0$. The choice of calibration is to directly compare with a 1-sector model (Nakamura and Steinsson, 2014) that does not consider the different effects of regional government consumption and investment. I find smaller regional fiscal multipliers in panel (B), as my baseline model incorporates regional government investment, which is less stimulative than regional government consumption. How-

[21] Flynn et al. (2024) also illustrate the amplification mechanism, but for sectors and demographics with different marginal propensities to consume (MPCs).

ever, the weaker response of regional output and prices induces a weaker endogenous response from (aggregate) monetary policy, which leads to larger aggregate multipliers (β_{agg}).

	$h = 0$	1	2	3	4
Panel A: 1-sector, 2-region (RANK)					
$\beta_{reg,h}$	0.998	0.997	0.996	0.995	0.994
$\beta_{agg,h}$	0.508	0.509	0.510	0.510	0.510
Panel B: 2-sector, 2-region (TANK, $\lambda = 0$)					
$\beta_{reg,h}$	0.676	0.583	0.545	0.528	0.516
$\beta_{agg,h}$	0.698	0.734	0.745	0.750	0.753

Table 8: Comparison of regional and aggregate fiscal multipliers across models: 1-sector (Nakamura and Steinsson, 2014) vs. 2-sector.

7 State-Level Quantitative Model

Signed by President Joe Biden in November 2021, the IIJA would have allocated, from Fiscal Years 2022 to 2031, \$1.2 trillion in new government spending, of which around \$890 billion would have been in new government investment. Zandi and Yaros (2021), a contemporary brief by Moody's Analytics published also in November 2021, stated that the government investment was planned to be in the transportation sector (rail, road, airports, ports, and public transit), clean water and utilities, clean energy and electric vehicle charging stations, and telecommunications. They also estimated that there would be between 800,000 to 2.4 million more jobs at the peak of the employment impact by the mid-2020s, which was cited by other sources.[22]

In this section, I use the same estimated parameters from the 10-region model to calibrate, along with other parameters, the 51-region (state-level) quantitative model. The 51-region model consists of the 50 U.S. states and the District of Columbia. I construct the quantitative model at the state level due to data limitations. Given the role of fiscal spillovers in determining aggregate government consumption and investment multipliers, the model requires information on trade flows across regions within the monetary union. The U.S. Census Bureau's 2017 Commodity Flow Survey (U.S. Department of Transportation et al., 2020) has complete data on inter-state trade flows, but only limited data on inter-MSA trade flows for a select number of MSAs. I also assume the additional government purchases incurred by the IIJA in each state as regional government consumption and investment shocks. I then calibrate the quantitative model and specify the time

[22]See Holder and Harrison (2022) and Economic Policy Institute, November 10, 2021.

path of the regional IIJA government consumption and investment shocks.

7.1 Quantitative Model Setup, Calibration, and Shocks

Given the larger number of regions in this quantitative model of the United States, I highlight some necessary differences in calibration from the 2-region theoretical model to the 51-region quantitative model. The important differences include a full specification of trade flows across U.S. states, and the specification of the spending shocks.

To calibrate the share of state $i \in \mathcal{J}$ in each state j's basket of consumption or investment goods, I use data on inter-state flows of goods and services from the 2017 Commodity Flow Survey, as previously discussed in Section 5.5. I assume, also as before, that 2/3 of consumption (ex. services) in each state is non-tradable (Carlino et al., 2023). This result in adding onto the home bias of consumption goods. Thus, denoting each $\chi_j^{c,trade,i}$ as the share of tradable consumption goods produced in region i and consumed in (traded to) region j, I calibrate $\chi_j^{c,i} = \frac{2}{3} + \frac{1}{3}\chi_j^{c,trade,i}$ for $i = j$ and $\chi_j^{c,i} = \frac{1}{3}\chi_j^{c,trade,i}$ otherwise. I also assume that all investment goods are tradable.

For regional government spending shocks, I include all government purchases authorized via the IIJA as regional government consumption and investment shocks $\epsilon_{it}^{c,g}$ and $\epsilon_{it}^{x,g}$, for each region i in year t. An important distinction between the empirical sections and the quantitative model is that the government spending shocks are based on *all* government purchases, both military and non-military, as authorized via the IIJA.

For Fiscal Years 2022 to 2024, I aggregate transaction-level data on outlays across the 51 regions from USASpending.gov. Here, I use one more feature of the transaction-level data, on whether the transaction was authorized as part of federal emergency spending. While the federal emergency spending codes are used to indicate natural disasters, they were expanded to include the Biden Administration's stimulus since the COVID-19 pandemic, including the IIJA. Aggregating this data, USASpending.gov reports that around \$100.4 billion were spent in outlays for Fiscal Years 2022 to 2024. Of the total outlays, \$74.4 billion were spent in what this paper categorizes as government consumption, while the remaining \$26.0 billion were spent on government investment. Figures B.5 and B.6 in Appendix B.4 show the percentage ratios of state-level IIJA government consumption and investment to state personal income in 2022.

7.2 Quantitative Model: Results

In Table 9, I show the model-computed multipliers for government consumption (top panel) and investment (bottom panel) from the 51-region quantitive model. The main qualitative results from the 2-region model still hold: regional government consumption multipliers are larger than regional government investment multipliers. The regional government consumption ($\beta^c_{reg,h}$) and investment ($\beta^x_{reg,h}$) multipliers are of similar magnitude to those in Table 6 under the 2-region model. In that aspect, the 2-region model is a close approximation of the 51-region quantitative model. I also find that spillovers are generally lesser for government consumption than for government investment.

The regional government consumption multiplier $\beta^c_{reg,h}$ remains larger than its aggregate counterpart $\beta^c_{agg,h}$, and the same is true for investment multipliers ($\beta^x_{reg,h} > \beta^x_{agg,h}$). Based on the results of the quantitative model, regional government consumption has a 2-year ($h = 1$) regional multiplier effect of around 1.14 on regional income, while the combined effects of the aggregate government consumption shocks have an aggregate multiplier effect of around 0.73 on aggregate income. The same figures for investment are 0.44 (regional) and 0.22 (aggregate). Government (infrastructure) investment in the long run increases productive public capital, which increases in aggregate the productivity of labor and private capital. Even if government investment need not lead to large relative regional income differences in the short run, it can lead to increasing income multiplier effects in the long run (which is outside the scope of this paper).

I also find that the 51-region model leads to larger model-computed aggregate fiscal multipliers than a 1-region, "aggregated" version of the model. I construct a 1-region model, much in the style of Boehm (2020), with consumption- and investment-goods sectors, aggregate government consumption and investment shocks, and Ricardian and Keynesian households. I compare the model-computed aggregate multipliers from the aggregated model with those from the 51-region model. In Table D.1 of Appendix D.3, I show that the 51-region model leads to larger aggregate consumption and investment multipliers than the aggregated model. For example, the 2-year ($h = 1$) aggregate government consumption multiplier from the 51-region model is 0.73, which is larger than the corresponding value from the aggregated model (0.63). This is also true for the aggregate government investment multiplier (0.22 in the 51-region model, 0.19 in the aggregated model). Evidently, the incorporation of trade flows across the 51 regions allows for an additional multiplier effect that is omitted in the 1-region, closed-economy version of the model.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
Average Government Consumption Multipliers					
$\beta^c_{own,h}$	1.218	1.115	1.065	1.033	1.010
$\beta^c_{spill,h}$	-0.032	-0.025	-0.022	-0.020	-0.018
$\beta^c_{reg,h}$	1.250	1.140	1.086	1.053	1.029
$\beta^c_{agg,h}$	0.734	0.730	0.730	0.732	0.733
Average Government Investment Multipliers					
$\beta^x_{own,h}$	0.421	0.435	0.491	0.553	0.613
$\beta^x_{spill,h}$	-0.007	-0.008	-0.010	-0.012	-0.014
$\beta^x_{reg,h}$	0.427	0.443	0.501	0.565	0.627
$\beta^x_{agg,h}$	0.203	0.220	0.255	0.294	0.335

Table 9: Multipliers computed from quantitative model. The top panel lists government consumption multipliers, and the bottom panel government investment multipliers. Each panel contains, in order, the average own-region income response (own), the average income response of the rest of the monetary union ($spill$), the (weighted) average regional fiscal multiplier (reg), and the average aggregate fiscal multiplier (agg). See text for more details on notation.

Finally, with the quantitative model, I also compute regional government consumption and investment multipliers of each state, in contrast with the *average* of the regional fiscal multipliers across all the states in the empirical results. Assuming the model structure and calibration, I compute the effects of state j's regional sector-s government spending on state i's income, for any combination of j, s, and i, or $\beta^{s,j}_{i,h}$ for time horizon h according to the notation of Appendix E. In Figure D.1 of Appendix D.5, I show bar graphs of 2-year ($h=1$) state-level regional fiscal multipliers for government consumption (D.1a), investment (D.1b), and purchases (D.1c) respectively. I find greater variation among state-level government investment multipliers than among state-level government consumption multipliers. The states that yield the largest regional income effect from state-level government spending (combining government consumption and investment) include Vermont, North Dakota, and New Hampshire.

7.3 Quantitative Model: Comparison with Concurrent Estimates

Here, I compare my estimates of the IIJA's impact on national personal income(proxied as GDP) with Zandi and Yaros (2021)'s estimates in November 2021. Of the total outlays \$100.4 billion from the IIJA from Fiscal Years 2022-2024, \$74.4 billion were spent in government consumption and \$26.0 billion in government investment across the United States. Assuming that to be the aggregate of government spending *shocks*, the aggregate increase in U.S. GDP is $74.4\times0.730+26.0\times$

$0.220 \approx \$60$ billion over 2 years. Given that nominal U.S. GDP was \$26.0 trillion,[23] this would be equivalent to 0.23% of 2022 U.S. GDP. Zandi and Yaros (2021) estimated that the combination of the IIJA and the American Rescue Plan (ARP), as compared to the effect of only the ARP's passage, would have had an additional 0.6%p (2.9% with the IIJA and ARP, 2.3% with only the ARP) effect on U.S. GDP in 2023. My estimate of the 2-year effect is about half than their estimate. This back-of-the-envelope exercise shows the importance of considering the different stimulative effects of government investment and government consumption.

Meanwhile, it also should be noted that the original estimates of total IIJA spending were planned to be much larger: Zandi and Yaros (2021) estimated that the increase in total infrastructure spending alone would have been \$316.7 billion across Fiscal Years 2022 to 2026. A government investment shock of that size would imply an effect on aggregate incomes of \$106.1 billion over 5 years. Again using the 2022 nominal U.S. GDP figure of \$26.0 trillion, the full effect of the government investment shock would have corresponded to a 0.41%p cumulative increase in U.S. GDP after 5 years. Again, while this consideration leaves out the long-run, possibly productive effects of government investment, it highlights how it is less suitable than government consumption for short-run stimulus, regionally or nationally.

8 Conclusion

In this paper, I emphasize two main empirical findings using U.S. state-level data: first, that regional government consumption multipliers are larger than regional government investment multipliers, and second, that regional government consumption shocks lead to more negative spillovers to the rest of the monetary union than regional government investment shocks. I argue that these two empirical results can be explained through the fact that consumption goods exhibit a greater degree of home bias than investment goods. I incorporate heterogeneous sectoral trade shares into a theoretical model of a 2-region monetary union with regional government consumption and investment, and replicate the two empirical results qualitatively. Finally, I construct a quantitative model of the United States with 51 regions, and estimate the effects of the Infrastructure Investment and Jobs Act of 2021 on U.S. state and aggregate incomes.

Most importantly, the results of this paper imply that fiscal authorities should be aware of the relatively small stimulative effects of government investment in the short run. While govern-

[23] Bureau of Economic Analysis, NIPA Table 1.1.6.

ment investment can increase long-run productivity and aggregate incomes, its short-run effects on regional incomes are found to be smaller than those of government consumption. On the other hand, regional government investment shocks also lead to greater spillovers to other regions than regional government consumption. Putting together the two results in the theoretical model framework, aggregate government consumption multipliers are larger than aggregate government investment multipliers. These findings are particularly relevant for fiscal stimulus packages aimed at boosting short-term economic activity. This also means that policymakers should practice some caution on how much regional government investment can raise regional incomes, particularly in the short run. Given the focus on regional economic outcomes in "modern supply-side economics" as proposed by Janet Yellen, and more generally the arguments for "shovel-ready projects" during the Great Recession, regional government investment is better seen as a policy tool that may raise regional economic outcomes over the long run, rather than as a form of short-run economic stimulus.

Meanwhile, the modelling exercises with the quantitative model lead to other policy implications as well. First, modelling the United States as a multi-region monetary union, instead of as a single economy, incorporates (previously unconsidered) inter-state trade flows and helps to better model the effects of a fiscal stimulus package on aggregate incomes. Indeed, the multi-region monetary union version of the quantitative model predicts larger aggregate multiplier effects than the single-region, closed economy version. This implies that, if economists were to consider and model government consumption and investment only at the national level, they may still *underestimate* the aggregate effects of a fiscal stimulus package. Second, if a fiscal stimulus package is to include both government consumption and investment, the quantitative model also estimates regional fiscal multipliers for each individual state, which provides guidance on which states to target more government consumption or investment for a greater effect on aggregate(national) incomes.

References

Aiyagari, S. Rao, Lawrence J. Christiano, and Martin Eichenbaum. 1992. "The Output, Employment, and Interest Rate Effects of Government Consumption." *Journal of Monetary Economics* 30 73–86.

Anderson, T. W., and Herman Rubin. 1949. "Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations." *The Annals of Mathematical Statistics* 20 46–63.

Antolin-Diaz, Juan, and Paolo Surico. 2025. "The Long-Run Effects of Government Spending." *American Economic Review* 115 2376–2413.

Arellano, Manuel, and Stephen Bond. 1991. "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations." *The Review of Economics and Statistics* 58 297.

Auerbach, Alan, Yuriy Gorodnichenko, and Daniel Murphy. 2020. "Local Fiscal Multipliers and Fiscal Spillovers in the USA." *IMF Economic Review* 68 195–229.

Baxter, Marianne, and Robert G. King. 1993. "Fiscal Policy in General Equilibrium." *American Economic Review* 315–334.

Bilbiie, Florin O. 2020. "The New Keynesian Cross." *Journal of Monetary Economics* 114 90–108.

Bilbiie, Florin O., Giorgio Primiceri, and Andrea Tambalotti. 2023. "Inequality and Business Cycles." *NBER Working Paper*, 31729.

Boehm, Christoph E. 2020. "Government consumption and investment: Does the composition of purchases affect the multiplier?" *Journal of Monetary Economics* 80–93.

Bom, Pedro R.D., and Jenny E. Ligthart. 2014. "What Have We Learned from Three Decades of Research on the Productivity of Public Capital?" *Journal of Economic Surveys* 28 889–916.

Carlino, Gerald, Thorsten Drautzburg, Robert Inman, and Nicholas Zarra. 2023. "Partisanship and Fiscal Policy in Economic Unions: Evidence from U.S. States." *American Economic Review* 113 701–737.

Chodorow-Reich, Gabriel. 2019. "Geographic Cross-Sectional Fiscal Spending Multipliers: What Have We Learned?" *American Economic Journal: Economic Policy* 11 1–34.

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

Conley, Timothy, Bill Dupor, Mahdi Ebsim, Jingchao Li, and Peter B. McCrory. 2020. "A Local-Spillover Decomposition of the Causal Effect of U.S. Defense Spending Shocks." *Federal Reserve Bank of St. Louis Working Paper*.

Driscoll, John C., and Aart C. Kraay. 1998. "Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data." *The Review of Economics and Statistics* 80 549–560.

Dupor, Bill, and Rodrigo Guerrero. 2017. "Local and Aggregate Fiscal Policy Multipliers." *Journal of Monetary Economics* 92 16–30.

Dupor, Bill, Marios Karabarbounis, Marianna Kudlyak, and M. Saif Mehkari. 2023. "Regional Consumption Responses and the Aggregate Fiscal Multiplier." *Review of Economic Studies* 90 2982–3021.

Flynn, Joel P., Christina Patterson, and John Sturm. 2024. "Fiscal Policy in a Networked Economy." *NBER Working Paper*, 29619.

Galí, Jordi, J. David López-Salido, and Javier Vallés. 2007. "Understanding the Effects of Government Spending on Consumption." *Journal of the European Economic Association* 5 227–270.

Haug, Alfred A., and Anna Sznajderska. 2024. "Government Spending Multipliers: Is There a Difference between Government Consumption and Investment Purchases?" *Journal of Macroeconomics* 79 103584.

Holder, Michelle, and Shaun Harrison. 2022. "Why the Infrastructure Investment and Jobs Act is good economics." technical report, Washington Center for Equitable Growth.

Lewis, Daniel J., and Karel Mertens. 2022. "A Robust Test for Weak Instruments with Multiple Endogenous Regressors." *Working Paper*.

Montiel Olea, José Luis, and Carolin Pflueger. 2013. "A Robust Test for Weak Instruments." *Journal of Business & Economic Statistics* 31 358–369.

Muratori, Umberto, Pedro Juarros, and Daniel Valderrama. 2023. "Heterogeneous Spending, Heterogeneous Multipliers." *IMF Working Papers*.

Nakamura, Emi, and Jon Steinsson. 2014. "Fiscal Stimulus in a Monetary Union: Evidence from US Regions." *American Economic Review* 104 753–792.

Norris, Jordan J. 2019. "Fiscal Multipliers in Integrated Local Labor Markets." *Working Paper*.

Owyang, Michael T., Valerie A. Ramey, and Sarah Zubairy. 2013. "Are Government Spending Multipliers Greater during Periods of Slack? Evidence from Twentieth-Century Historical Data." *American Economic Review: Papers & Proceedings* 129–134.

Ramey, V.A. 2016. "Macroeconomic Shocks and Their Propagation." In *Handbook of Macroeconomics*, edited by John B. Taylor, and Harald Uhlig, Volume 2A. Chap. 2, 71–162, Elsevier Science B.V.

Ramey, Valerie A. 2011. "Can Government Purchases Stimulate the Economy?" *Journal of Economic Literature* 49 673–685.

Ramey, Valerie A. 2021. "The Macroeconomic Consequences of Infrastructure Investment." In *Economic Analysis and Infrastructure Investment*, edited by Edward L. Glaeser, and James M. Poterba, Chap. 4, 219–268, University of Chicago Press.

Rotemberg, Julio J., and Michael Woodford. 1997. "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy." *Brookings Papers on Economic Activity* 12 297–346.

Stock, James H., and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, edited by Donald W. K. Andrews, and James H.Editors Stock, 80–108, Cambridge University Press.

U.S. Department of Transportation, Bureau of Transportation Statistics, and U.S. Department of Commerce. 2020. "2017 CFS Public Use File (PUF)." https://www2.census.gov/programs-surveys/cfs/data/2017/, 2020-08.

Zandi, Mark, and Bernard Yaros. 2021. "Macroeconomic Consequences of the Infrastructure Investment and Jobs Act & Build Back Better Framework." technical report, Moody's Analytics.

A Appendix: Categorization of Product Service Codes

Product service codes are assigned according to guidelines set by the General Services Administration (GSA). All product service codes are four-digit alphanumeric codes, and begin with either a letter code for services or a two-digit code for goods. I assign the following designation for dividing all product service codes into government investment and consumption. See Tables A.1 and A.2 for the complete categorization in this paper.

1. Investment: Structural investment, vehicles, and research and development
    - Structures, Facilities, and Equipment: construction, maintenance, and repair of structures, facilities, and equipment
        - Number codes 7 (IT/telecommunications), 11, 12, and 20-67.
    - Vehicles: motor vehicles and vehicle parts/accessories
        - Number codes 14-19
    - Research and development
        - Letter code A (Research & Development)
2. Consumption: Non-durable goods (food and beverages purchased for off-premises consumption, clothing and footwear, gasoline and other energy goods, etc.), durable goods, and services (housing and utilities, health care, transportation services, recreation services, food services and accommodations, financial services and insurance, etc.)
    - Non-durable goods (food and beverages purchased for off-premises consumption, clothing and footwear, gasoline and other energy goods, etc.)
        - Number codes 13 (Ammunition), 68 (Chemicals and Chemical Products), and 75-99
    - Durable goods: furnishings and durable household equipment, recreational goods and vehicles, and other durable goods
        - Number codes 10 (Weapons), 69, and 71-74.
    - Services, excluding research & development
        - Letter codes B-Z.

PSC Category	PSC Category Name	Category	C/X?
7	INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS	Struct	X
10	WEAPONS	Struct	X
11	NUCLEAR ORDNANCE	Struct	X
12	FIRE CONTROL EQPT.	Struct	X
13	AMMUNITION AND EXPLOSIVES	Nondur	C
14	GUIDED MISSLES	Veh	X
15	AIRCRAFT/AIRFRAME STRUCTURE COMPTS	Veh	X
16	AIRCRAFT COMPONENTS/ACCESSORIES	Veh	X
17	AIRCRAFT LAUNCH/LAND/GROUND HANDLE	Veh	X
18	SPACE VEHICLES	Veh	X
19	SHIPS, SMALL CRAFT, PONTOON, DOCKS	Veh	X
20	SHIP AND MARINE EQUIPMENT	Struct	X
22	RAILWAY EQUIPMENT	Struct	X
23	MOTOR VEHICLES, CYCLES, TRAILERS	Struct	X
24	TRACTORS	Struct	X
25	VEHICULAR EQUIPMENT COMPONENTS	Struct	X
26	TIRES AND TUBES	Struct	X
28	ENGINES AND TURBINES AND COMPONENT	Struct	X
29	ENGINE ACCESSORIES	Struct	X
30	MECHANICAL POWER TRANSMISSION EQPT	Struct	X
31	BEARINGS	Struct	X
32	WOODWORKING MACHINERY AND EQPT	Struct	X
34	METALWORKING MACHINERY	Struct	X
35	SERVICE AND TRADE EQPT	Struct	X
36	SPECIAL INDUSTRY MACHINERY	Struct	X
37	AGRICULTURAL MACHINERY AND EQPT	Struct	X
38	CONSTRUCT/MINE/EXCAVATE/HIGHWY EQPT	Struct	X
39	MATERIALS HANDLING EQPT	Struct	X
40	ROPE, CABLE, CHAIN, FITTINGS	Struct	X
41	REFRIG, AIR CONDIT/CIRCULAT EQPT	Struct	X
42	FIRE/RESCUE/SAFETY; ENVIRO PROTECT	Struct	X
43	PUMPS AND COMPRESSORS	Struct	X
44	FURNACE/STEAM/DRYING; NUCL REACTOR	Struct	X
45	PLUMBING, HEATING, WASTE DISPOSAL	Struct	X
46	WATER PURIFICATION/SEWAGE TREATMENT	Struct	X
47	PIPE, TUBING, HOSE, AND FITTINGS	Struct	X
48	VALVES	Struct	X
49	MAINT/REPAIR SHOP EQPT	Struct	X
51	HAND TOOLS	Struct	X
52	MEASURING TOOLS	Struct	X
53	HARDWARE AND ABRASIVES	Struct	X
54	PREFAB STRUCTURES, FACILITIES, AND EQUIPMENT/SCAFFOLDING	Struct	X
55	LUMBER, MILLWORK, PLYWOOD, VENEER	Struct	X
56	CONSTRUCTION AND BUILDING MATERIAL	Struct	X
58	COMM/DETECT/COHERENT RADIATION	Struct	X
59	ELECTRICAL/ELECTRONIC EQPT COMPNTS	Struct	X
60	FIBER OPTIC	Struct	X

Table A.1: My classification of government consumption (C) or government investment X by Product Service Code, Part 1. "PSC Category": First two numerals (product) or first letter (services) of PSC alphanumeric code. "PSC Category Name": Official category name based on PSC Manual. "Category": My classification of each PSC category into one of Dur (Durables), Nondur (Nondurables), R&D (Research and Development), Serv (Services), Struct (Structures, Facilities, and Equipment), or Veh (Vehicles). "C/X": C, government consumption, consists of nondurables and services. X, government investment, consists of durables, R&D, structures, facilities, and equipment, and vehicles.

PSC Category	PSC Category Name	Category	C/X?
61	ELECTRIC WIRE, POWER DISTRIB EQPT	Struct	X
62	LIGHTING FIXTURES, LAMPS	Struct	X
63	ALARM, SIGNAL, SECURITY DETECTION	Struct	X
65	MEDICAL/DENTAL/VETERINARY EQPT/SUPP	Struct	X
66	INSTRUMENTS AND LABORATORY EQPT	Struct	X
67	PHOTOGRAPHIC EQPT	Struct	X
68	CHEMICALS AND CHEMICAL PRODUCTS	Nondur	C
69	TRAINING AIDS AND DEVICES	Dur	C
71	FURNITURE	Dur	C
72	HOUSEHOLD/COMMERC FURNISH/APPLIANCE	Dur	C
73	FOOD PREPARATION/SERVING EQPT	Dur	C
74	OFFICE MACH/TEXT PROCESS/VISIB REC	Dur	C
75	OFFICE SUPPLIES AND DEVICES	Nondur	C
76	BOOKS, MAPS, OTHER PUBLICATIONS	Dur	C
77	MUSICAL INST/PHONOGRAPH/HOME RADIO	Dur	C
78	RECREATIONAL/ATHLETIC EQPT	Dur	C
79	CLEANING EQPT AND SUPPLIES	Nondur	C
80	BRUSHES, PAINTS, SEALERS, ADHESIVES	Nondur	C
81	CONTAINERS/PACKAGING/PACKING SUPPL	Nondur	C
83	TEXTILE/LEATHER/FUR; TENT; FLAG	Nondur	C
84	CLOTHING/INDIVIDUAL EQPT, INSIGNIA	Nondur	C
85	TOILETRIES	Nondur	C
87	AGRICULTURAL SUPPLIES	Nondur	C
88	LIVE ANIMALS	Nondur	C
89	SUBSISTENCE	Nondur	C
91	FUELS, LUBRICANTS, OILS, WAXES	Nondur	C
93	NONMETALLIC FABRICATED MATERIALS	Nondur	C
94	NONMETALLIC CRUDE MATERIALS	Nondur	C
95	METAL BARS, SHEETS, SHAPES	Nondur	C
96	ORES, MINERALS AND PRIMARY PRODUCTS	Nondur	C
99	MISCELLANEOUS	Nondur	C
A	RESEARCH AND DEVELOPMENT	R&D	X
B	SPECIAL STUDIES/ANALYSIS, NOT R&D	Serv	C
C	ARCHITECT/ENGINEER SERVICES	Serv	C
D	ADP AND TELECOMMUNICATIONS	Serv	C
E	PURCHASE OF STRUCTURES, FACILITIES, AND EQUIPMENT/FACILITIES	Serv	C
F	NATURAL RESOURCES MANAGEMENT	Serv	C
G	SOCIAL SERVICES	Serv	C
H	QUALITY CONTROL, TEST, INSPECTION	Serv	C
J	MAINT, REPAIR, REBUILD EQUIPMENT	Serv	C
K	MODIFICATION OF EQUIPMENT	Serv	C
L	TECHNICAL REPRESENTATIVE SVCS.	Serv	C
M	OPERATION OF GOVT OWNED FACILITY	Serv	C
N	INSTALLATION OF EQUIPMENT	Serv	C
P	SALVAGE SERVICES	Serv	C
Q	MEDICAL SERVICES	Serv	C
R	SUPPORT SVCS (PROF, ADMIN, MGMT)	Serv	C
S	UTILITIES AND HOUSEKEEPING	Serv	C
T	PHOTO, MAP, PRINT, PUBLICATION	Serv	C
U	EDUCATION AND TRAINING	Serv	C
V	TRANSPORT, TRAVEL, RELOCATION	Serv	C
W	LEASE/RENT EQUIPMENT	Serv	C
X	LEASE/RENT FACILITIES	Serv	C
Y	CONSTRUCT OF STRUCTURES, FACILITIES, AND EQUIPMENT/FACILITIES	Serv	C
Z	MAINT, REPAIR, ALTER REAL PROPERTY	Serv	C

Table A.2: Continuation of Table A.1. See caption of that Table for more details.

B Appendix: Graphs of State-level Data

B.1 National DoD Spending over Time

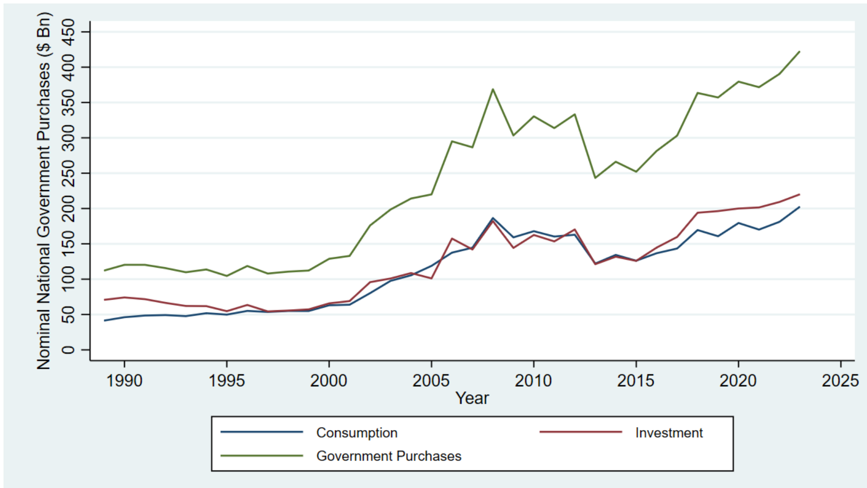


Figure B.1: Nominal national Department of Defense (DoD) spending by type, based on my criteria. Source: Author's own calculations, and DCADS data.

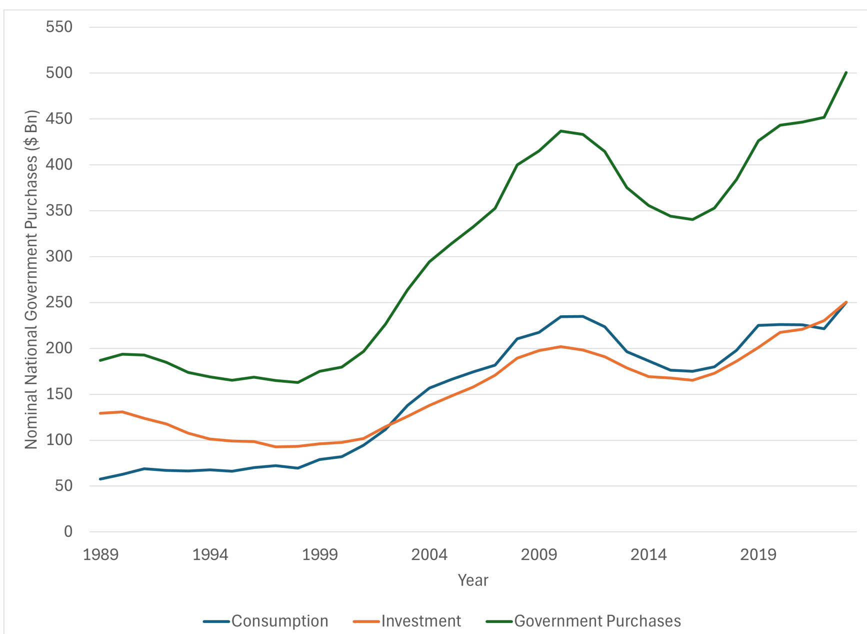


Figure B.2: Nominal national Department of Defense (DoD) government consumption and investment from BEA NIPA Table 3.11.5, adjusted to be comparable to my data. See main text for details on the construction of the time series data.

B.2 Comparison with Previous Literature

I compare nominal national military government spending from Nakamura and Steinsson (2014) and Dupor and Guerrero (2017). I find that my national data is able to track the corresponding data from the two papers fairly closely, as shown in Figure B.3.

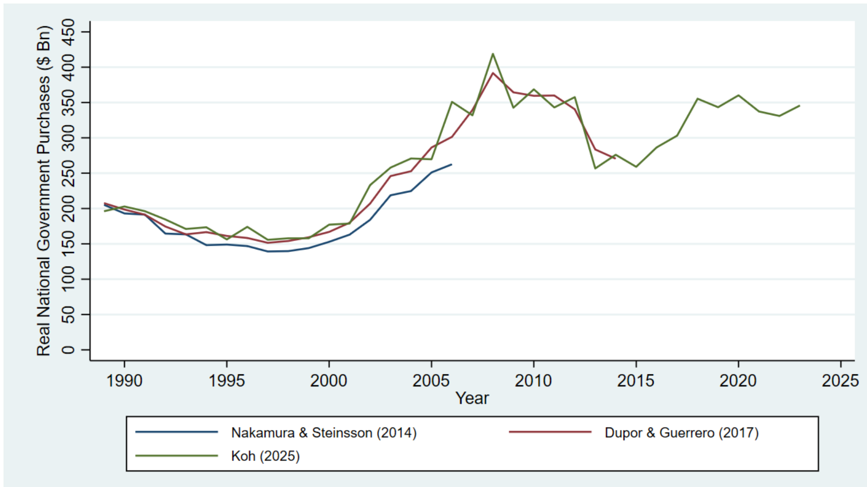
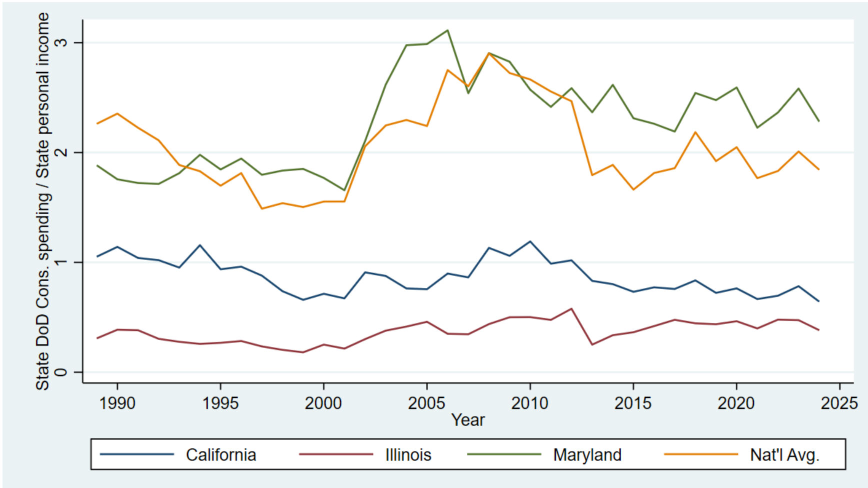


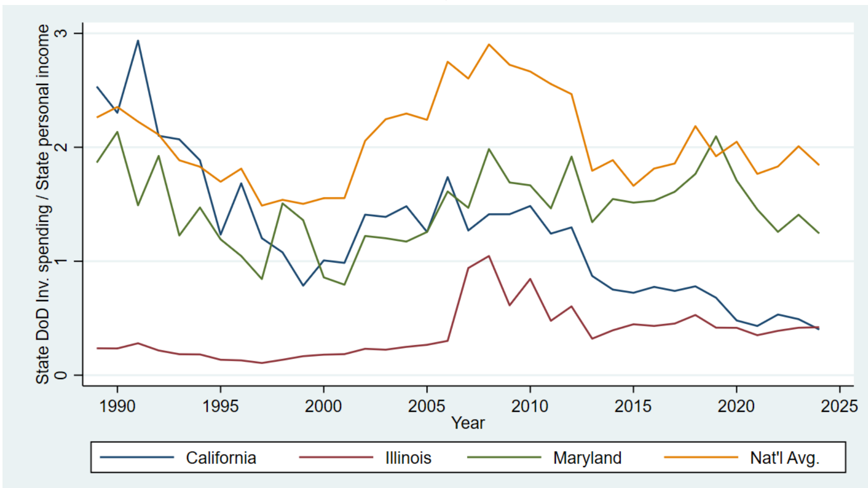
Figure B.3: Comparison of nominal national DoD spending data with other studies (Nakamura and Steinsson, 2014; Dupor and Guerrero, 2017).

B.3 State DoD Spending as a Proportion of State Personal Income

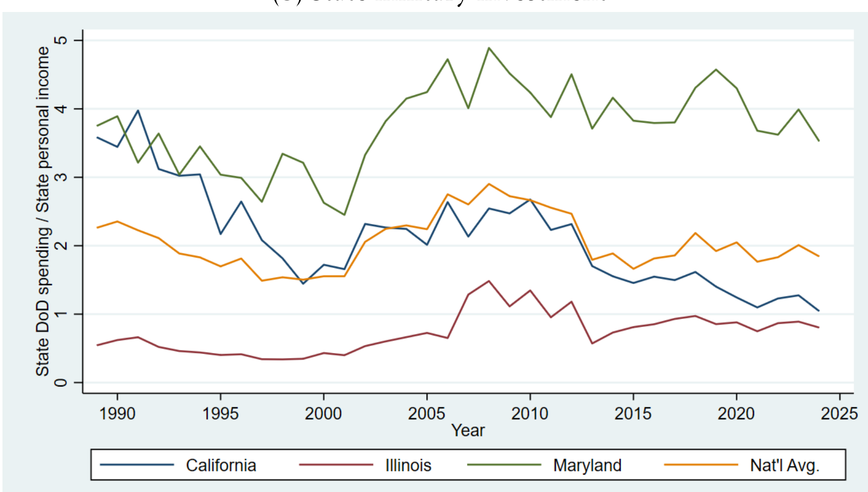
To illustrate Nakamura and Steinsson (2014)'s point on different sensitivities of state-level military spending to changes in national military spending, I compare the ratio of state military purchases, consumption, and investment for three states: California, Illinois, and Maryland. The yellow line is the national average of ratios across all 50 states. The y-axis is in percentage points.



(a) State military consumption



(b) State military investment



(c) State military purchases

B.4 State-level Distribution of IIJA Spending

I construct maps of the United States with state-level data of government consumption and investment that were allocated with the passage of the IIJA in November 2021. Here, I aggregate all spending from fiscal years 2022 to 2024.

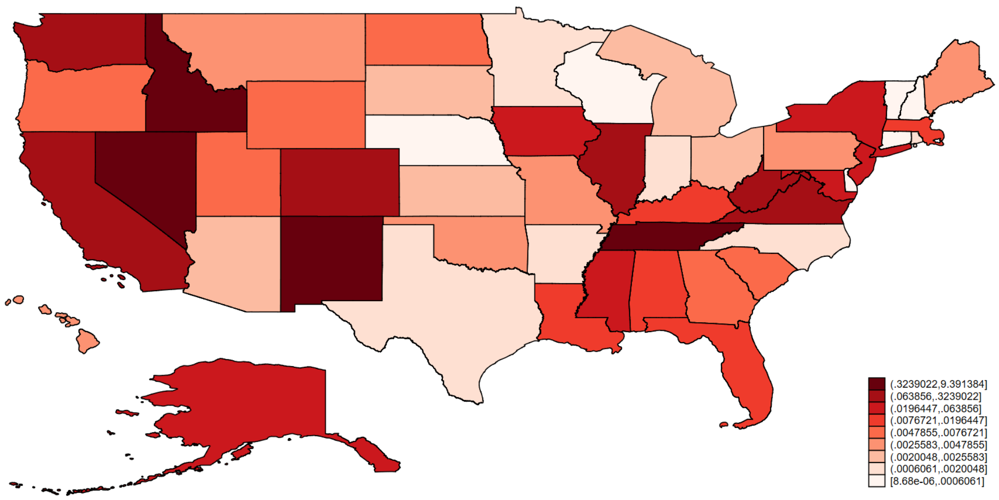


Figure B.5: Ratios of state-level government consumption expenditures, as allocated via the IIJA, to state personal income in 2022, for fiscal years 2022-2024.

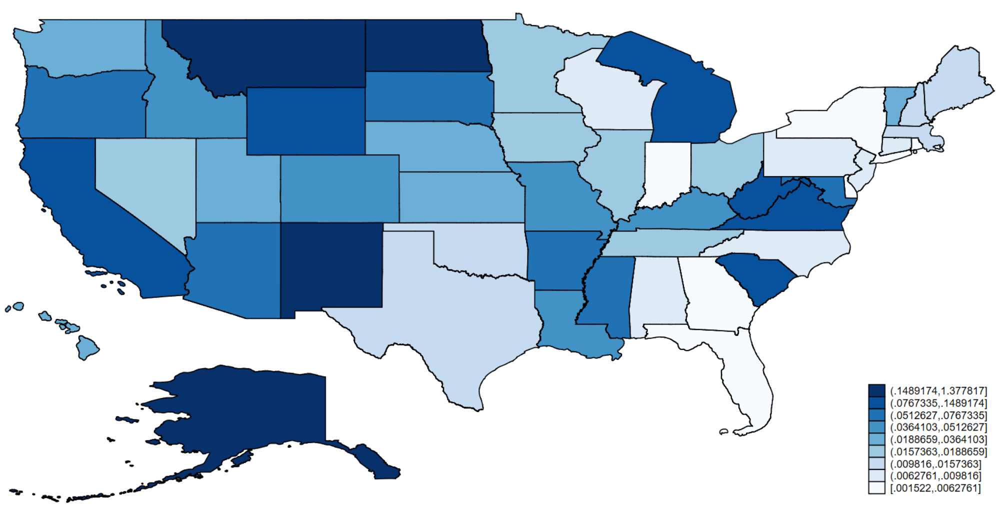
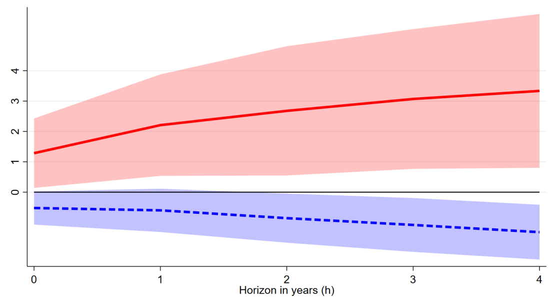


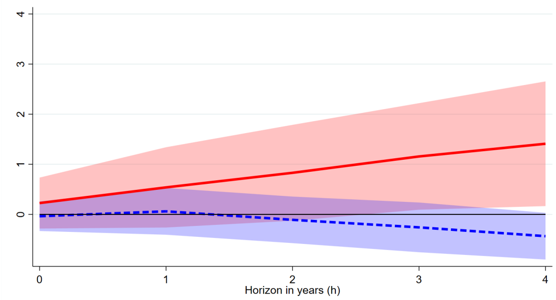
Figure B.6: Ratios of state-level government investment expenditures, as allocated via the IIJA, to state personal income in 2022, for fiscal years 2022-2024.

C Appendix: Empirical Results

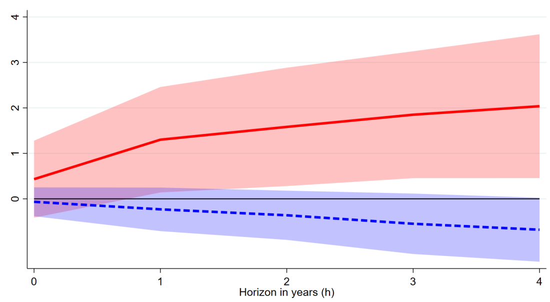
C.1 Empirical Results: State-level



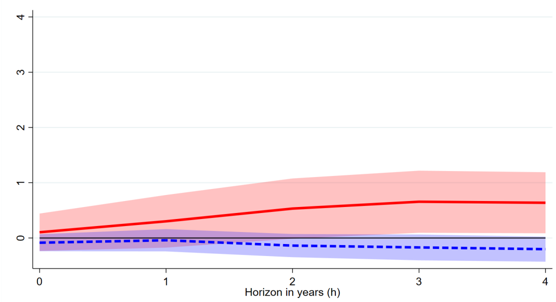
(a) Personal Income



(b) Employment



(c) Labor Income



(d) Capital Income

Figure C.1: State-level cumulative regional fiscal multipliers for various dependent variables. Red: government consumption, blue: government investment. 90% confidence intervals. Each subfigure is plotted over a horizon from $h = 0$ to $h = 4$. For more details, and to see these results in tables, see Table C.2.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
			Personal Income, State		
C^g	1.284*	2.463**	2.855**	3.093**	3.177**
	(0.695)	(0.943)	(1.086)	(1.143)	(1.351)
X^g	-0.521	-0.213	-0.128	0.076	-0.307
	(0.332)	(0.599)	(0.776)	(1.231)	(1.145)
Test $\beta_h^c = \beta_h^x$	0.049	0.058	0.097	0.189	0.148
LM Stat	6.718	26.802	13.602	24.296	15.335
LM Stat CV	14.269	13.345	13.785	12.318	13.072
			Labor Income, State		
C^g	0.432	1.426**	1.725**	1.843***	1.882**
	(0.515)	(0.562)	(0.665)	(0.666)	(0.815)
X^g	-0.065	-0.060	-0.064	-0.117	-0.283
	(0.193)	(0.462)	(0.523)	(0.813)	(0.780)
Test $\beta_h^c = \beta_h^x$	0.469	0.103	0.103	0.147	0.144
LM Stat	6.718	26.802	13.602	24.296	15.335
LM Stat CV	14.266	13.344	13.783	12.297	13.070
			Capital Income, State		
C^g	0.104	0.511**	0.653***	0.730***	0.708**
	(0.206)	(0.228)	(0.207)	(0.213)	(0.263)
X^g	-0.085	0.109	0.036	0.133	0.029
	(0.094)	(0.099)	(0.140)	(0.211)	(0.198)
Test $\beta_h^c = \beta_h^x$	0.418	0.122	0.052	0.102	0.091
LM Stat	6.718	26.802	13.602	24.296	15.335
LM Stat CV	14.267	13.386	13.806	12.333	13.112
			Employment, State		
C^g	0.226	0.561	0.565	0.702	0.787
	(0.309)	(0.396)	(0.458)	(0.484)	(0.567)
X^g	-0.037	0.282	0.119	0.085	-0.120
	(0.179)	(0.420)	(0.441)	(0.618)	(0.504)
Test $\beta_h^c = \beta_h^x$	0.525	0.647	0.540	0.488	0.295
LM Stat	6.718	26.802	13.602	24.296	15.335
LM Stat CV	14.267	13.366	13.786	12.294	13.077
Obs	1,750	1,700	1,650	1,600	1,550

Table C.1: State-level regional government consumption and investment multipliers, for various dependent variables. Each column stands for estimates of β_h^X and β_h^C, or h-year regional fiscal multipliers for C^g (government consumption) and X^g (government investment). Balanced panel consists of observations of 50 states (excluding the District of Columbia), from 1989 to 2024. Instruments are computed as stated in Section 3, over the same period. Panel 2SLS regressions, including year and state fixed effects, and Driscoll-Kraay standard errors. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively. See Section 4.2 in the main text for the description on weak identification tests from Lewis and Mertens (2022). Lewis-Mertens critical values are computed at a confidence level of 95% and Nagar's relative bias threshold of 30%.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
	Personal Income, State, Cumulative				
C^g	1.284	2.208*	2.678*	3.069*	3.335*
	(0.695)	(1.015)	(1.294)	(1.398)	(1.539)
X^g	-0.521	-0.598	-0.855	-1.079	-1.316*
	(0.332)	(0.433)	(0.491)	(0.539)	(0.548)
Test $\beta_h^c = \beta_h^x$	0.049	0.031	0.038	0.021	0.018
LM Stat	6.718	7.926	6.247	9.714	8.733
LM Stat CV	14.269	13.953	14.291	14.116	14.130
	Labor Income, State, Cumulative				
C^g	0.432	1.301	1.582	1.850*	2.037*
	(0.515)	(0.705)	(0.791)	(0.848)	(0.961)
X^g	-0.065	-0.231	-0.361	-0.548	-0.679
	(0.193)	(0.291)	(0.329)	(0.404)	(0.428)
Test $\beta_h^c = \beta_h^x$	0.469	0.106	0.070	0.040	0.038
LM Stat	6.718	7.926	6.247	9.714	8.733
LM Stat CV	14.266	13.951	14.289	14.114	14.128
	Capital Income, State, Cumulative				
C^g	0.104	0.302	0.532	0.656	0.638
	(0.206)	(0.289)	(0.331)	(0.341)	(0.336)
X^g	-0.085	-0.041	-0.138	-0.171	-0.202
	(0.094)	(0.123)	(0.127)	(0.142)	(0.138)
Test $\beta_h^c = \beta_h^x$	0.418	0.296	0.092	0.030	0.025
LM Stat	6.718	7.926	6.247	9.714	8.733
LM Stat CV	14.267	13.954	14.290	14.117	14.131
	Employment, State, Cumulative				
C^g	0.226	0.539	0.830	1.157	1.410
	(0.309)	(0.487)	(0.582)	(0.646)	(0.757)
X^g	-0.037	0.061	-0.109	-0.259	-0.435
	(0.179)	(0.284)	(0.282)	(0.302)	(0.284)
Test $\beta_h^c = \beta_h^x$	0.418	0.296	0.092	0.030	0.025
LM Stat	6.718	7.926	6.247	9.714	8.733
LM Stat CV	14.267	13.952	14.291	14.116	14.128
Obs.	1,750	1,700	1,650	1,600	1,550

Table C.2: *Cumulative* state-level regional government consumption and investment multipliers, for various dependent variables. Description is otherwise identical to that in Table C.1.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
	Personal Income, State, Spillovers				
C^g	-0.977**	-2.108***	-2.288***	-2.873***	-3.121***
	(0.462)	(0.635)	(0.719)	(0.805)	(0.920)
X^g	0.189	-0.078	-0.131	-0.475	-0.223
	(0.303)	(0.600)	(0.626)	(0.859)	(0.805)
Test $\beta_h^c = \beta_h^x$	0.088	0.042	0.060	0.081	0.040
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Labor Income, State, Spillovers				
C^g	-0.329	-1.310***	-1.482***	-1.836***	-1.860***
	(0.432)	(0.347)	(0.343)	(0.384)	(0.492)
X^g	-0.041	-0.214	-0.208	-0.353	-0.169
	(0.223)	(0.621)	(0.569)	(0.785)	(0.706)
Test $\beta_h^c = \beta_h^x$	0.637	0.141	0.084	0.097	0.071
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Capital Income, State, Spillovers				
C^g	-0.149	-0.520***	-0.570***	-0.707***	-0.745***
	(0.153)	(0.153)	(0.125)	(0.124)	(0.156)
X^g	-0.034	-0.133	-0.046	-0.146	-0.107
Test $\beta_h^c = \beta_h^x$	0.575	0.067	0.007	0.004	0.004
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Employment, State, Spillovers				
C^g	-0.415	-0.833*	-0.712	-0.879*	-0.873
	(0.319)	(0.427)	(0.437)	(0.505)	(0.556)
X^g	0.168	-0.129	-0.064	-0.162	-0.038
	(0.163)	(0.482)	(0.449)	(0.605)	(0.505)
Test $\beta_h^c = \beta_h^x$	0.130	0.208	0.296	0.360	0.275
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
Obs	1,750	1,700	1,650	1,600	1,550

Table C.3: State-level government consumption and investment fiscal spillovers, for various dependent variables. Here, $\tilde{Y}_{it}$ is the unweighted sum of all other states' (j) outcome variables. Description is otherwise identical to that in Table C.1.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
	Personal Income, State, Spillovers				
C^g	0.008*	0.008*	0.007	0.009	0.009*
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
X^g	-0.004	0.005	0.005	0.008	0.005
	(0.004)	(0.006)	(0.005)	(0.006)	(0.006)
Test $\beta_h^c = \beta_h^x$	0.134	0.800	0.837	0.967	0.667
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Labor Income, State, Spillovers				
C^g	0.002	0.004**	0.004***	0.005***	0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
X^g	-0.000	0.002	0.003	0.004	0.004
	(0.001)	(0.003)	(0.003)	(0.003)	(0.003)
Test $\beta_h^c = \beta_h^x$	0.490	0.650	0.645	0.774	0.802
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Capital Income, State, Spillovers				
C^g	0.003***	0.004***	0.004***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
X^g	-0.002	0.000	-0.000	0.000	-0.000
	(0.001)	(0.003)	(0.002)	(0.002)	(0.002)
Test $\beta_h^c = \beta_h^x$	0.049	0.230	0.109	0.080	0.024
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
	Employment, State, Spillovers				
C^g	0.001	-0.001	-0.001	-0.002	-0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
X^g	0.002	0.010**	0.009**	0.013***	0.011**
	(0.002)	(0.005)	(0.004)	(0.004)	(0.004)
Test $\beta_h^c = \beta_h^x$	0.842	0.085	0.071	0.011	0.045
LM Stat	2.242	2.137	2.115	2.211	2.220
LM Stat CV	14.062	13.873	13.884	14.044	14.012
Obs	1,750	1,700	1,650	1,600	1,550

Table C.4: State-level government consumption and investment fiscal spillovers, for various dependent variables. Here, $\tilde{Y}_{it}$ is the sum of all other states' (j) outcome variable, weighted respectively by the inverse of the distances ($dist_{ij}$) from the center of the destination state i. Description is otherwise identical to that in Table C.1.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
	Government Consumption Growth, State				
$Z^c_{i,h}$	0.935***	1.170***	1.069***	1.198***	1.204***
	(0.209)	(0.182)	(0.211)	(0.187)	(0.183)
$Z^x_{i,h}$	0.107	0.032	0.048	0.002	0.002
	(0.074)	(0.073)	(0.068)	(0.071)	(0.068)
Constant	0.004	-0.000	0.004	-0.003	-0.008
	(0.004)	(0.007)	(0.013)	(0.016)	(0.021)
F-stat	12.970	21.476	13.933	21.947	22.516
R^2	0.172	0.281	0.369	0.472	0.528
	Government Investment Growth, State				
$Z^c_{i,h}$	0.224	-0.043	-0.012	-0.054	-0.017
	(0.135)	(0.085)	(0.097)	(0.095)	(0.095)
$Z^x_{i,h}$	1.154***	1.084***	0.924***	0.753***	0.757***
	(0.386)	(0.178)	(0.233)	(0.129)	(0.179)
Constant	0.001	0.012***	0.016***	0.029***	0.035***
	(0.002)	(0.004)	(0.006)	(0.009)	(0.013)
F	11.568	18.617	9.351	16.971	9.591
R^2	0.137	0.164	0.205	0.232	0.286
Obs	1,750	1,700	1,650	1,600	1,550

Table C.5: State-level 1st-stage regressions. Balanced panel consists of observations of 50 states (excluding the District of Columbia), from 1989 to 2024. Instruments are computed as stated in Section 3, over the same period. Two-way panel data regressions with year and state fixed effects, and clustered standard errors at state level. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
			Personal Income, State		
C^g	0.107	0.334	0.267	0.383	0.452
	(0.151)	(0.206)	(0.284)	(0.369)	(0.429)
X^g	-0.003	-0.070	-0.090	-0.122	-0.202
	(0.056)	(0.086)	(0.126)	(0.167)	(0.189)
Test $\beta_h^c = \beta_h^x$	0.477	0.067	0.240	0.193	0.165
			Labor Income, State		
C^g	0.040	0.115	0.163	0.238	0.253
	(0.039)	(0.095)	(0.157)	(0.221)	(0.261)
X^g	0.005	0.003	-0.020	-0.011	-0.036
	(0.013)	(0.047)	(0.057)	(0.098)	(0.118)
Test $\beta_h^c = \beta_h^x$	0.349	0.221	0.228	0.251	0.284
			Capital Income, State		
C^g	-0.032	0.034	0.092	0.161*	0.180*
	(0.052)	(0.059)	(0.070)	(0.092)	(0.106)
X^g	0.024	0.019	0.023	0.004	0.005
	(0.024)	(0.035)	(0.051)	(0.063)	(0.062)
Test $\beta_h^c = \beta_h^x$	0.332	0.836	0.452	0.178	0.192
			Employment, State		
C^g	-0.076	-0.061	-0.115	-0.092	-0.052
	(0.048)	(0.099)	(0.139)	(0.204)	(0.254)
X^g	0.004	0.035	-0.024	-0.046	-0.048
	(0.036)	(0.071)	(0.083)	(0.140)	(0.156)
Test $\beta_h^c = \beta_h^x$	0.163	0.399	0.521	0.831	0.989
Obs	1,750	1,700	1,650	1,600	1,550

Table C.6: State-level OLS regression results, for various dependent variables. Balanced panel consists of observations of 50 states (excluding the District of Columbia), from 1989 to 2024. Constant term omitted from results. Two-way panel data regressions with year and state fixed effects, and clustered standard errors at state level. Standard errors are in parentheses. *, **, and *** represent the 10%, 5%, and 1% significance levels, respectively.

C.2 Empirical Results: MSA-level

	Mean	**St. Dev.**	**Min**	**Max**
MSA Personal Income ($M)	31,907.42	85,961.21	327.08	1,504,850
MSA Population (Persons)	684,540	1,544,416	16,184	2.01E+07
MSA G / MSA Personal Income (%)	1.39	3.62	-4.80	86.85
MSA C^g / MSA Personal Income (%)	0.65	1.38	-6.05	32.38
MSA X^g / MSA Personal Income (%)	0.74	3.11	-2.93	83.82
MSA share of G_t (%)	0.28	1.00	-0.23	20.40
MSA share of C_t^g (%)	0.28	0.98	-0.70	23.04
MSA share of X_t^g (%)	0.28	1.28	-0.06	31.45
Labor Income / MSA Personal Income (%)	50.31	8.61	14.57	88.69
Capital Income / MSA Personal Income (%)	19.06	4.71	9.11	59.18

Table C.7: Summary statistics for MSA-level data, 356 MSAs, 1989-2023 (observations: 12,460).

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
			Personal Income, MSA		
C^g	0.320**	0.527**	0.642***	0.800***	0.881***
	(0.127)	(0.234)	(0.222)	(0.215)	(0.168)
X^g	-0.011	0.020	0.029	0.072**	0.063
	(0.020)	(0.023)	(0.028)	(0.035)	(0.046)
Test $\beta_h^c = \beta_h^x$	0.012	0.046	0.016	0.004	0.000
LM Stat	56.275	61.036	87.557	73.380	103.880
LM Stat CV	28.705	28.886	28.507	28.251	28.219
			Labor Income, MSA		
C^g	0.195***	0.358***	0.448***	0.556***	0.607***
	(0.050)	(0.115)	(0.122)	(0.127)	(0.105)
X^g	0.006	0.020	0.032	0.058**	0.046
	(0.014)	(0.017)	(0.020)	(0.028)	(0.034)
Test $\beta_h^c = \beta_h^x$	0.002	0.011	0.004	0.001	0.000
LM Stat	56.275	61.036	87.557	73.380	103.880
LM Stat CV	28.754	28.884	28.506	28.253	28.222
			Capital Income, MSA		
C^g	0.071*	0.082*	0.111**	0.154***	0.173***
	(0.039)	(0.048)	(0.050)	(0.052)	(0.049)
X^g	0.004	0.009	0.011	0.007	-0.008
	(0.005)	(0.008)	(0.011)	(0.014)	(0.019)
Test $\beta_h^c = \beta_h^x$	0.110	0.153	0.073	0.016	0.003
LM Stat	56.275	61.036	87.557	73.380	103.880
LM Stat CV	28.771	28.868	28.503	28.244	28.206
Obs.	12,104	11,748	11,392	11,036	10,680
			Employment, MSA		
C^g	0.167***	0.322***	0.379***	0.475***	0.531***
	(0.051)	(0.110)	(0.112)	(0.116)	(0.092)
X^g	0.018	0.031	0.062**	0.120***	0.126***
	(0.021)	(0.028)	(0.030)	(0.036)	(0.038)
Test $\beta_h^c = \beta_h^x$	0.008	0.020	0.016	0.009	0.002
LM Stat	54.356	55.212	77.947	72.075	96.354
LM Stat CV	28.787	29.164	28.773	28.365	28.361
Obs.	11,748	11,392	11,036	10,680	10,324

Table C.8: MSA-level government consumption and investment multipliers, for various dependent variables. Each column stands for estimates of β_h^C and β_h^X, or h-year impact regional fiscal multipliers by type of government spending (C^g for government consumption, X^g for government investment). Balanced panel consists of observations of 356 MSAs, from 1989 to 2023 (Employment regressions are from 1989 to 2022). Instruments are computed as stated in Section 2. See Table C.1 for more details.

	$h=0$	$h=1$	$h=2$	$h=3$	$h=4$
	Personal Income, MSA, Cumulative				
C^g	0.331**	0.450***	0.534***	0.608***	0.689***
	(0.126)	(0.163)	(0.134)	(0.130)	(0.137)
X^g	-0.020	0.014	0.031	0.062	0.072*
	(0.025)	(0.033)	(0.033)	(0.038)	(0.036)
Test $\beta_h^c = \beta_h^x$	0.012	0.018	0.001	0.000	0.000
LM Stat	56.275	52.232	43.394	22.185	19.632
LM Stat CV	28.705	28.925	28.547	27.885	27.673
	Labor Income, MSA, Cumulative				
C^g	0.188***	0.284***	0.355***	0.405***	0.454***
	(0.055)	(0.083)	(0.072)	(0.074)	(0.080)
X^g	0.013	0.034	0.047*	0.069***	0.074***
	(0.016)	(0.024)	(0.023)	(0.024)	(0.024)
Test $\beta_h^c = \beta_h^x$	0.011	0.015	0.001	0.000	0.000
LM Stat	56.275	52.232	43.394	22.185	19.632
LM Stat CV	28.754	28.950	28.543	27.877	27.665
	Capital Income, MSA, Cumulative				
C^g	0.071*	0.086*	0.105**	0.140**	0.166**
	(0.041)	(0.043)	(0.048)	(0.054)	(0.061)
X^g	-0.001	0.004	0.005	0.006	0.007
	(0.011)	(0.015)	(0.014)	(0.013)	(0.013)
Test $\beta_h^c = \beta_h^x$	0.128	0.109	0.067	0.027	0.017
LM Stat	56.275	52.232	43.394	22.185	19.632
LM Stat CV	28.771	28.970	28.571	27.878	27.660
	Employment, MSA, Cumulative				
C^g	0.156***	0.245***	0.284***	0.321***	0.378***
	(0.055)	(0.082)	(0.071)	(0.073)	(0.085)
X^g	0.027	0.061*	0.087***	0.119***	0.129***
	(0.023)	(0.033)	(0.030)	(0.030)	(0.030)
Test $\beta_h^c = \beta_h^x$	0.050	0.065	0.020	0.012	0.007
LM Stat	54.356	48.496	42.304	22.227	21.133
LM Stat CV	28.787	29.086	28.576	27.870	27.879
Obs	12,104	11,748	11,392	11,036	10,680

Table C.9: MSA-level *cumulative* government consumption and investment multipliers, for various dependent variables. Each column stands for estimates of $\beta^C_{h,cumul}$ and $\beta^X_{h,cumul}$, or h-year cumulative regional fiscal multipliers by type of government spending (C^g for government consumption, X^g for government investment). Otherwise, see C.8 for more details.

D Appendix: Description of Quantitative Model

D.1 Description of New Keynesian Model of J-region monetary union

D.1.1 Ricardian Households

A fraction $1-\lambda$ of households in region j are Ricardian households, with access to savings and capital markets. The Ricardian household in region j chooses its household consumption C^R_{jt} and labor supply N^R_{jt} to maximize present discounted lifetime utility, by solving the following optimization problem:

$$\max_{C^R_{jt}, N^{R,c}_{jt}, N^{R,x}_{jt}, X^c_{jt}, X^x_{jt}} U^R_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{{C^R_{jt}}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \Gamma(C^g_{jt}) - \phi_n \frac{{N^R_{jt}}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right] \tag{D.1}$$

$$\text{s.t. } B_{jt} + P^c_{jt} C^R_{jt} + P^x_{jt}(X^c_{jt} + X^x_{jt}) = B_{j,t-1}(1+i_{t-1}) + \Pi_{jt} - T^R_{jt} + \sum_{s\in\{c,x\}} W^s_{jt} N^{R,s}_{jt} + \sum_{s\in\{c,x\}} \sum_{j\in\mathcal{J}} R^{k,s}_{jt} K^s_{jt} \tag{D.2}$$

$$\text{and } N^R_{jt} = \left[{N^{R,c}_{jt}}^{\frac{\eta+\mu}{\eta}} + {N^{R,x}_{jt}}^{\frac{\eta+\mu}{\eta}} \right]^{\frac{\eta}{\eta+\mu}} \tag{D.3}$$

Here, C^g_{jt} is government consumption, $N^{R,s}_{jt}$ and K^s_{jt} are the household's labor supply and capital stock specific to region $j \in \mathcal{J}$ and sector $s \in \{c, x\}$. W^s_{jt} and $R^{k,s}_{jt}$ are the corresponding wage level and return on capital. T^R_{jt} is regional lump-sum taxes paid by Ricardian households. X^c_{jt} and X^x_{jt} are, respectively, investment flows into the consumption-sector and investment-sector capital stocks. P^c_{jt} and P^x_{jt} are regional price levels of consumption and investment goods consumed in region j. Π_{jt} are firm profits.

N^R_{jt} is given as a CES aggregate of region-j sectoral labor supplies $N^{R,c}_{jt}$ and $N^{R,x}_{jt}$, where η is the Frisch elasticity of (sectoral) labor supply. $\mu \in [0,1]$ specifies the degree of labor mobility frictions across the consumption-goods and investment-goods sectors. If $\mu = 0$, labor supply is fully mobile across sectors, and is perfectly immobile if $\mu = 1$.[24]

The utility for regional government consumption C^g_{jt} is simply given as $\Gamma(\cdot)$, and is immaterial to the household's optimization problem as the household does not decide on it.

[24] Note that if $\mu = 0$, $N_{jt} = N^c_{jt} + N^x_{jt}$.

D.1.2 Keynesian Households

A fraction $\lambda \in (0,1)$ of households in region j are Keynesian households, with no access to savings and capital markets and thus consume all their labor income contemporaneously. Region-j Keynesian households are subject to their intra-temporal budget constraint, which binds in every period. Keynesian households earn labor income by providing their labor supply to both consumption- and investment-goods sectors. For simplicity, I assume that Keynesian households in region j pay lump-sum taxes T^K_{jt}, as follows:

$$\max_{C^K_{jt}, N^{K,c}_{jt}, N^{K,x}_{jt}} U^K_j = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C^{K\,1-\frac{1}{\sigma}}_{jt}}{1-\frac{1}{\sigma}} + \Gamma(C^g_{jt}) - \phi_n \frac{N^{K\,1+\frac{1}{\eta}}_{jt}}{1+\frac{1}{\eta}} \right] \tag{D.4}$$

$$\text{s.t. } P^c_{jt} C^K_{jt} = W^c_{jt} N^{K,c}_{jt} + W^x_{jt} N^{K,x}_{jt} - T^K_{jt} \tag{D.5}$$

$$\text{and } T^K_{jt} = \lambda (P^c_{jt} C^g_{jt} + P^x_{jt} X^g_{jt}) \tag{D.6}$$

Like Ricardian households, region-j Keynesian households also split their labor supply N^K_{jt} across consumption- and investment-goods sectors $N^{K,c}_{jt}$ and $N^{K,x}_{jt}$, respectively:

$$N^K_{jt} = \left[N^{K,c\,\frac{\eta+\mu}{\eta}}_{jt} + N^{K,x\,\frac{\eta+\mu}{\eta}}_{jt} \right]^{\frac{\eta}{\eta+\mu}} \tag{D.7}$$

D.1.3 Trade in Consumption Goods

I first discuss inter-regional trade in consumption goods. Consumption goods can be traded across regions. In this model, I denote C^i_{jt} as the flow of consumption goods produced in region $i \in \mathcal{J}$ and consumed in region j.[25] I also denote the steady-state share of household consumption in region j that are produced in region i as $\chi^{c,i}_j \in [0,1]$, where:

$$\sum_{i \in \mathcal{J}} \chi^{c,i}_j = 1 \ \forall j \in \mathcal{J}$$

For each household $h \in \{R, K\}$ in region $j \in \mathcal{J}$, region-j, household-h private consumption C_{jt} has two types of components: region-j expenditures of goods produced in region $i \in \mathcal{J}$, C^i_{jt}, and region-j government consumption, C^g_{jt}. C_{jt} is a CES aggregator of household consumption of

[25] In this model, all variables associated with an origin region i and a destination region j will be denoted with i as the *super*script and j as the *sub*script.

goods produced in regions $i \in \mathcal{J}$:

$$C_{jt}^{h} = \left[\sum_{i \in \mathcal{J}} (\chi_j^{c,i})^{\frac{1}{\nu_c}} (C_{jt}^{h,i})^{\frac{\nu_c - 1}{\nu_c}} \right]^{\frac{\nu_c}{\nu_c - 1}} \tag{D.8}$$

where $\nu_c > 1$ is the elasticity of substitution between different varieties of consumption goods. The first order condition for $C_{jt}^{R,i}$ is as follows:

$$C_{jt}^{h,i} = \chi_j^{c,i} C_{jt}^{h} \left(\frac{P_{jt}^{c,i}}{P_{jt}^{c}} \right)^{-\nu_c} \tag{D.9}$$

where $P_{jt}^{c,i}$ is the price index of consumption good C_{jt}^{i}, P_{jt}^{c} is the region-j price index for consumption goods.

Region-j household consumption C_{jt}^{hh} is given as the weighted average of Ricardian and Keynesian household consumption in region j:

$$C_{jt}^{hh} = \lambda C_{jt}^{R} + (1 - \lambda) C_{jt}^{K} \tag{D.10}$$

Region-j total consumption C_{jt} is given as a CES aggregate of C_{jt}^{hh} and C_{jt}^{g}:

$$C_{jt} = \left[(1 - \omega_c^g)^{\frac{1}{\nu_c}} (C_{jt}^{hh})^{\frac{\nu_c - 1}{\nu_c}} + (\omega_c^g)^{\frac{1}{\nu_c}} (C_{jt}^{g})^{\frac{\nu_c - 1}{\nu_c}} \right]^{\frac{\nu_c}{\nu_c - 1}} \tag{D.11}$$

The region-j price index of consumption goods, P_{jt}^{c}, is then given as a CES aggregator of $P_{j,t}^{c,i}$ (denoting the price of consumption goods produced in region i and consumed in region j):

$$\text{with } P_{jt}^{c} = \left[\sum_{i \in \mathcal{J}} \chi_j^{c,i} (P_{jt}^{c,i})^{1 - \nu_c} \right]^{\frac{1}{1 - \nu_c}} \quad \forall j \in \mathcal{J} \tag{D.12}$$

Equilibrium regional consumption is defined by these first-order conditions:

$$C_{jt}^{i} = \chi_j^{c,i} C_{jt}^{hh} \left(\frac{P_{jt}^{c,i}}{P_{jt}^{c}} \right)^{-\nu_c} \quad \forall i \in \mathcal{J} \; j \in \mathcal{J} \tag{D.13}$$

Finally, I assume the Law of One Price, that prices of varieties of consumption goods produced in the same region i have the same price level:

$$P_{jt}^{c,i} = P_{j't}^{c,i} \; \forall i \in \mathcal{J}, \; j, j' \in \mathcal{J} \tag{D.14}$$

D.1.4 Investment Equations

Region-j investment X_{jt} has three components: region-j investment in the consumption-goods sector X_{jt}^c, in the investment-goods sector X_{jt}^x, and region-j government investment X_{jt}^g. Each variable has steady-state shares ω_x^c, ω_x^x, and ω_x^g of X_{jt} respectively, such that $\omega_x^c + \omega_x^x + \omega_x^g = 1$:

$$X_{jt} = \left[(\omega_x^c)^{\frac{1}{\nu_x}} (X_{jt}^c)^{\frac{\nu_x - 1}{\nu_x}} + (\omega_x^x)^{\frac{1}{\nu_x}} (X_{jt}^x)^{\frac{\nu_x - 1}{\nu_x}} + (\omega_x^g)^{\frac{1}{\nu_x}} (X_{jt}^g)^{\frac{\nu_x - 1}{\nu_x}} \right]^{\frac{\nu_x}{\nu_x - 1}} \; \forall j \in \mathcal{J} \tag{D.15}$$

For sector $s \in \{c, x\}$, X_{Ht}^s is a CES aggregate of sector-s investment goods $X_{jt}^{s,i}$ produced in region i and expended in region j. Also, investment goods for each sector can also be traded across regions. I denote the steady-state share of private investment in region j that are produced in region i as $\chi_j^{x,i} \in [0,1]$, where:

$$\sum_{i \in \mathcal{J}} \chi_j^{x,i} = 1 \; \forall j \in \mathcal{J}$$

As the setup and derivation for investment goods is similar to that for consumption goods, I reproduce only the resulting investment equations here:

$$X_{jt}^{s,i} = \chi_j^{x,i} X_{jt}^s \left(\frac{P_{jt}^{x,i}}{P_{jt}^x} \right)^{-\nu_x} \; \forall s \in \{c, x\}, \; \forall i, j \in \mathcal{J} \tag{D.16}$$

$$X_{jt}^s = \left[\sum_{i \in \mathcal{J}} (\chi_j^{x,i})^{\frac{1}{\nu_x}} (X_{jt}^{s,i})^{\frac{\nu_x - 1}{\nu_x}} \right]^{\frac{\nu_x}{\nu_x - 1}} \; \forall s \in \{c, x\}, \; j \in \mathcal{J} \tag{D.17}$$

$$P_{jt}^x = \left[\sum_{i \in \mathcal{J}} \chi_j^{x,i} (P_{jt}^{x,i})^{1 - \nu_x} \right]^{\frac{1}{1 - \nu_x}} \tag{D.18}$$

$$P_{jt}^{x,i} = P_{j't}^{x,i} \; \forall i \in \mathcal{J}, \; j, j' \in \mathcal{J} \tag{D.19}$$

D.1.5 Labor Supply

Aggregation in labor supplies are as follows: given region-j, sector-s, household-h labor supply $N_{jt}^{h,s}$, sectoral aggregates N_{jt}^s are given as the weighted mean of Ricardian households' labor supply

$N_{jt}^{R,s}$ and Keynesian households' labor supply $N_{jt}^{K,s}$:

$$N_{jt}^{s} = \lambda N_{jt}^{R,s} + (1-\lambda) N_{jt}^{K,s} \tag{D.20}$$

Region-j total labor supply N_{jt} is given as the CES aggregation of sectoral labor supplies:

$$N_{jt} = \left[(N_{jt}^{c})^{\frac{\eta+\mu}{\eta}} + (N_{jt}^{x})^{\frac{\eta+\mu}{\eta}} \right]^{\frac{\eta}{\eta+\mu}} \tag{D.21}$$

D.1.6 Intermediate Goods Firms

A monopolistically competitive intermediate-goods firm of variety $l \in [0,1]$ in region i and sector $s \in \{c, x\}$ satisfies the total sectoral demand for its goods, both government and private, across all regions $j \in \mathcal{J}$.

$$C_{jt}^{g}(l) + \sum_{i \in \mathcal{J}} C_{it}^{j}(l) = (K_{jt}^{g})^{\alpha_g} (K_{jt}^{c}(l))^{\alpha} (N_{jt}^{c}(l))^{1-\alpha} \tag{D.22}$$

$$X_{jt}^{g}(l) + \sum_{i \in \mathcal{J}} (X_{it}^{c,j}(l) + X_{it}^{x,j}(l)) = (K_{jt}^{g})^{\alpha_g} (K_{jt}^{x}(l))^{\alpha} (N_{jt}^{x}(l))^{1-\alpha} \tag{D.23}$$

where α is the capital share of income and α_g is the degree of productivity of K_{jt}^{g}.

Under monopolistic competition, sector-s nominal marginal costs MC_{jt}^{s} can be implicitly expressed as such:

$$MC_{jt}^{s} = \frac{1}{(K_{jt}^{g})^{\alpha_g}} \left(\frac{R_{jt}^{k,s}}{\alpha} \right)^{\alpha} \left(\frac{W_{jt}^{s}}{1-\alpha} \right)^{1-\alpha} \tag{D.24}$$

with factor demands, i.e. real wages and returns on capital, as follows:

$$\frac{W_{jt}^{s}}{P_{jt}^{s}} = \frac{MC_{jt}^{s}}{P_{jt}^{s}} (1-\alpha) (K_{jt}^{g})^{\alpha_g} (K_{jt}^{s})^{\alpha} (N_{jt}^{s})^{-\alpha} \tag{D.25}$$

$$\frac{R_{jt}^{k,s}}{P_{jt}^{s}} = \frac{MC_{jt}^{s}}{P_{jt}^{s}} \alpha (K_{jt}^{g})^{\alpha_g} (K_{jt}^{s})^{\alpha-1} (N_{jt}^{s})^{1-\alpha} \tag{D.26}$$

For each firm l in region j and sector s, sectoral reset prices $\bar{P}_{jt}^{s}$ for intermediate goods firms that can adjust their prices under Calvo pricing are determined as follows:

$$\bar{P}_{jt}^{s} = (1-\beta\theta_s) \sum_{\tau=0}^{\infty} (\beta\theta_s)^{\tau} \mathbb{E}_t [MC_{j,t+\tau}^{s} + P_{j,t+\tau}^{s}] \tag{D.27}$$

where $\theta_s \in (0,1)$ is the sectoral Calvo pricing parameter. This leads to the New Keynesian Phillips curve for each region $j \in \mathcal{J}$ and sector $s \in \{c,x\}$:

$$\pi^s_{jt} = \frac{(1-\theta_s)(1-\theta_s\beta)}{\theta_s}\frac{\widetilde{mc}^s_{jt}}{p^s_{jt}} + \beta\mathbb{E}_t[\pi^s_{j,t+1}] \tag{D.28}$$

D.1.7 Final Goods Firm

There is one final goods firm in each region, which aggregates the output of all intermediate goods firms of the same region. For $S \in \{C,X\}$, and region $j \in \mathcal{J}$, regional production of the final good S_{jt} is defined as:

$$S_{jt} = \left[\int_0^1 S_{jt}(l)^{\frac{\xi-1}{\xi}}\,dl\right]^{\frac{\xi}{\xi-1}} \tag{D.29}$$

with associated region-j price index of sector-s good as:

$$P^s_{jt} = \left[\int_0^1 P^s_{jt}(l)^{1-\xi}\,dl\right]^{\frac{1}{1-\xi}} \tag{D.30}$$

D.1.8 Sectoral Capital

Capital K is specific to each region-sector combination, and depreciates at a rate of $\delta \in (0,1)$. In addition to sectors c and x, there is also productive public capital, denoted as K^g_{jt}, which also depreciates at rate δ. Given $s \in \{c,x\}$, sector-s capital is adjusted by sector-s investment X^s_{jt}, with an adjustment cost function of $\vartheta(X/K)$. This also happens for government investment X^g_{jt}. As is standard in the literature (Christiano et al., 2005), I assume that:

$$\vartheta\left(\frac{X}{K}\right) = \frac{X}{K},\ \vartheta'\left(\frac{X}{K}\right) = 1,\ \vartheta''\left(\frac{X}{K}\right) = -\zeta \tag{D.31}$$

Then, capital accumulation in each sector $s \in \{c,x\}$ is as follows:

$$K^s_{j,t+1} = (1-\delta)K^s_{jt} + \vartheta\left(\frac{X^s_{jt}}{K^s_{jt}}\right)K^s_{jt} \tag{D.32}$$

and public capital accumulation is as follows:

$$K^g_{j,t+1} = (1-\delta)K^g_{jt} + \vartheta\left(\frac{X^g_{jt}}{K^g_{jt}}\right)K^g_{jt} \tag{D.33}$$

D.1.9 Fiscal and Monetary Policy

I assume lump-sum taxation across both regions, that each region's (nominal) government purchases G_{jt} are paid with (nominal) regional lump sum taxes T_{jt} via a balanced budget $T_{jt} = G_{jt}$:

$$G_{jt} = P^c_{jt} C^g_{jt} + P^x_{jt} X^g_{jt} \tag{D.34}$$

$$T_{jt} = \lambda T^K_{jt} + (1-\lambda) T^R_{jt} \tag{D.35}$$

Given region-j government consumption shocks ϵ^{gc}_{jt} and investment shocks ϵ^{gx}_{jt}, I assume that regional government consumption C^g_{jt} and investment X^g_{jt} follow the following AR(1) processes:

$$C^g_{jt} = (1-\rho^g_c)\bar{C}^g_j + \rho^g_c C^g_{j,t-1} + \epsilon^{gc}_{jt} \tag{D.36}$$

$$X^g_{jt} = (1-\rho^g_x)\bar{X}^g_j + \rho^g_x X^g_{j,t-1} + \epsilon^{gx}_{jt} \tag{D.37}$$

where $\rho^g_c \in [0,1)$ and $\rho^g_x \in [0,1)$ are the persistence parameters of regional government consumption and government investment respectively, and $\bar{C}^g_j$ and $\bar{X}^g_j$ are steady-state values of C^g_{jt} and X^g_{jt}.

As for monetary policy, the central bank sets the nominal interest rate i_t via a Taylor rule given the aggregate inflation rate π_t and aggregate output gap $\tilde{y}_t$, as such:

$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t \tag{D.38}$$

where $\phi_\pi > 1$ based on the Taylor principle, and $\phi_y > 0$.

D.1.10 Market Clearing and Price Indices

Regional real GDP Y_{jt} and aggregate GDP Y_t are defined as:

$$Y_{jt} = P^c C_{jt} + P^x X_{jt} \tag{D.39}$$

$$Y_t = \sum_{j \in \mathcal{J}} Y_{jt} \tag{D.40}$$

where C_{jt} is regional consumption, X_{jt} is regional investment, and P^c and P^x are steady state values of P^c_{jt} and P^x_{jt}.

Given the regional price index for consumer goods P^c_{jt} and investment goods P^x_{jt}, the regional

GDP deflator P_{jt} is defined as such:

$$P_{jt} = \frac{P^c_{jt} C_{jt} + P^x_{jt} X_{jt}}{Y_{jt}} \tag{D.41}$$

Finally, inflation rates are defined as growth rates in price indices. For example, the region-j GDP deflator inflation π_{jt} is defined as follows:

$$\pi_{jt} = \frac{P_{jt}}{P_{j,t-1}} - 1, \text{ etc.} \tag{D.42}$$

D.2 First Order Conditions

From the household's problem, we have the following first-order conditions:

$$(C^h_{jt})^{-\frac{1}{\sigma}} = \lambda_{jt} P^c_{jt} \tag{D.43}$$

$$\phi N_{jt}^{\frac{1-\mu}{\eta}} N^{c\,\frac{\mu}{\eta}}_{jt} = \lambda_{jt} W^c_{jt} \tag{D.44}$$

$$\phi N_{jt}^{\frac{1-\mu}{\eta}} N^{x\,\frac{\mu}{\eta}}_{jt} = \lambda_{jt} W^x_{jt} \tag{D.45}$$

$$\lambda_{jt} = \beta(1+i_t)\mathbb{E}_t[\lambda_{t+1}] \tag{D.46}$$

$$P^c_{jt} = \gamma^c_{jt} \theta' \left(\frac{X^c_{jt}}{K^c_{jt}} \right) \tag{D.47}$$

$$P^x_{jt} = \gamma^x_{jt} \theta' \left(\frac{X^x_{jt}}{K^x_{jt}} \right) \tag{D.48}$$

$$\lambda_{jt}\gamma^c_{jt} = \beta \mathbb{E}_t \left[\lambda_{j,t+1} R^{k,c}_{j,t+1} + \lambda_{j,t+1}\gamma^c_{j,t+1} \left\{ (1-\delta) + \theta\left(\frac{X^c_{j,t+1}}{K^c_{j,t+1}} \right) - \theta\left(\frac{X^c_{j,t+1}}{K^c_{j,t+1}} \right)\left(\frac{X^c_{j,t+1}}{K^c_{j,t+1}} \right) \right\} \right] \tag{D.49}$$

$$\lambda_{jt}\gamma^x_{jt} = \beta \mathbb{E}_t \left[\lambda_{j,t+1} R^{k,x}_{j,t+1} + \lambda_{j,t+1}\gamma^x_{j,t+1} \left\{ (1-\delta) + \theta\left(\frac{X^x_{j,t+1}}{K^x_{j,t+1}} \right) - \theta\left(\frac{X^x_{j,t+1}}{K^x_{j,t+1}} \right)\left(\frac{X^x_{j,t+1}}{K^x_{j,t+1}} \right) \right\} \right] \tag{D.50}$$

where λ_{jt} is the Lagrangian multiplier for the household's budget constraint, and $\lambda_{jt}\gamma^s_{jt}$ is the Lagrangian multiplier for the sector-s capital accumulation process for $s \in \{c, x\}$.

Combining the households' first order conditions, we get the following:

Euler equation for consumption:

$$(C^{hh}_{jt})^{-\frac{1}{\sigma}} = \beta(1+i_t)\mathbb{E}_t \left[\frac{1}{1+\pi^c_{j,t+1}} (C^{hh}_{j,t+1})^{-\frac{1}{\sigma}} \right] \tag{D.51}$$

Investment choice:

$$1 = \frac{\gamma_{jt}^{c}}{P_{jt}^{x}}\theta'\left(\frac{X_{jt}^{c}}{K_{jt}^{c}}\right) \tag{D.52}$$

$$1 = \frac{\gamma_{jt}^{x}}{P_{jt}^{x}}\theta'\left(\frac{X_{jt}^{x}}{K_{jt}^{x}}\right) \tag{D.53}$$

Euler equations for capital:

$$\frac{\gamma_{jt}^{c}}{P_{jt}^{x}} = \mathbb{E}_t\left[\left(\frac{1+\pi_{j,t+1}^{x}}{1+i_t}\right)\left(\frac{R_{j,t+1}^{k,c}}{P_{j,t+1}^{x}} + \frac{\gamma_{j,t+1}^{c}}{P_{j,t+1}^{x}} \times \left\{(1-\delta) + \theta\left(\frac{X_{j,t+1}^{c}}{K_{j,t+1}^{c}}\right) - \theta'\left(\frac{X_{j,t+1}^{c}}{K_{j,t+1}^{c}}\right)\left(\frac{X_{j,t+1}^{c}}{K_{j,t+1}^{c}}\right)\right\}\right)\right] \tag{D.54}$$

$$\frac{\gamma_{jt}^{x}}{P_{jt}^{x}} = \mathbb{E}_t\left[\left(\frac{1+\pi_{j,t+1}^{x}}{1+i_t}\right)\left(\frac{R_{j,t+1}^{k,x}}{P_{j,t+1}^{x}} + \frac{\gamma_{j,t+1}^{x}}{P_{j,t+1}^{x}} \times \left\{(1-\delta) + \theta\left(\frac{X_{j,t+1}^{x}}{K_{j,t+1}^{x}}\right) - \theta'\left(\frac{X_{j,t+1}^{x}}{K_{j,t+1}^{x}}\right)\left(\frac{X_{j,t+1}^{x}}{K_{j,t+1}^{x}}\right)\right\}\right)\right] \tag{D.55}$$

Labor supply:

$$\phi(N_{jt})^{\frac{1-\mu}{\eta}}(N_{jt}^{x})^{\frac{\mu}{\eta}} = (C_{jt}^{hh})^{-\frac{1}{\sigma}}\frac{P_{jt}^{x}}{P_{jt}^{c}}\frac{W_{jt}^{x}}{P_{jt}^{x}} \tag{D.56}$$

$$\phi(N_{jt})^{\frac{1-\mu}{\eta}}(N_{jt}^{c})^{\frac{\mu}{\eta}} = (C_{jt}^{hh})^{-\frac{1}{\sigma}}\frac{W_{jt}^{c}}{P_{jt}^{x}} \tag{D.57}$$

D.3 Linearization of Quantitative Model

All log deviations of variables are in lower-case, tilde variables. All equations hold for all $j \in \mathcal{J}$, unless stated otherwise.

Consumption equations

$$\tilde{c}_{jt}^{h} = \sum_{i\in\mathcal{J}}\chi_j^{c,i}\tilde{c}_{jt}^{h,i},\ h \in \{R, K\} \tag{D.58}$$

$$\tilde{c}_{jt}^{g} = \sum_{i\in\mathcal{J}}\chi_j^{c,i}\tilde{c}_{jt}^{g,i} \tag{D.59}$$

$$\tilde{c}_{jt}^{hh} = \lambda\tilde{c}_{jt}^{R} + (1-\lambda)\tilde{c}_{jt}^{K} \tag{D.60}$$

$$\tilde{c}_{jt} = s_c^{g}c_{jt}^{g} + (1-s_c^{g})\tilde{c}_{jt}^{hh} \tag{D.61}$$

$$\pi_{jt}^{c} = \sum_{i\in\mathcal{J}}\chi_j^{c,i}\pi_{jt}^{c,i} \tag{D.62}$$

$$\tag{D.63}$$

Labor supply:

$$\frac{1-\mu}{\eta}\tilde{n}^h_{jt} + \frac{\mu}{\eta}\tilde{n}^{h,x}_{jt} = -\frac{1}{\sigma}\tilde{c}^h_{jt} + \left(\widetilde{\frac{p^x_{jt}}{p^c_{jt}}}\right) + \left(\widetilde{\frac{w^x_{jt}}{p^x_{jt}}}\right),\ h \in \{R, K\} \tag{D.64}$$

$$\frac{1-\mu}{\eta}\tilde{n}^h_{jt} + \frac{\mu}{\eta}\tilde{n}^{h,c}_{jt} = -\frac{1}{\sigma}\tilde{c}^h_{jt} + \left(\widetilde{\frac{w^c_{jt}}{p^c_{jt}}}\right),\ h \in \{R, K\} \tag{D.65}$$

Labor aggregator:

$$\tilde{n}_{jt} = s^c_y \tilde{n}^c_{jt} + s^x_y \tilde{n}^x_{jt},\ h \in \{R, K\} \tag{D.66}$$

$$\tilde{n}^h_{jt} = s^c_y \tilde{n}^{h,c}_{jt} + s^x_y \tilde{n}^{h,x}_{jt},\ h \in \{R, K\} \tag{D.67}$$

$$\tilde{n}^s_{jt} = \lambda n^{K,s}_{jt} + (1-\lambda) n^{R,s}_{jt},\ s \in \{c, x\} \tag{D.68}$$

Euler equation / inter-regional risk sharing equations of Ricardian Households:

$$-\frac{1}{\sigma}\tilde{c}^R_{jt} = (i_t - \mathbb{E}_t \pi^c_{j,t+1}) - \frac{1}{\sigma}\mathbb{E}_t \tilde{c}^R_{j,t+1} \text{ for given } j \in \mathcal{J} \tag{D.69}$$

$$-\frac{1}{\sigma}(\tilde{c}^R_{it} - \tilde{c}^R_{i,t-1}) + \frac{1}{\sigma}(\tilde{c}^R_{jt} - \tilde{c}^R_{j,t-1}) = \pi^c_{it} - \pi^c_{jt} \text{ for } i \in \mathcal{J}, i \neq j \tag{D.70}$$

Keynesian Households' Budget Constraint

$$s^g_y \tilde{g}_{jt} + (1 - s^g_y)\tilde{n}^K_{jt} = s^c_y \left(\frac{w^c_{jt}}{p^c jt} + \tilde{n}^{K,c}_{jt}\right) + s^x_y \left(\frac{w^x_{jt}}{p^x_{jt}} + \frac{p^x_{jt}}{p^c_{jt}} + \tilde{n}^{K,x}_{jt}\right) \tag{D.71}$$

Tradable goods:

$$(\tilde{c}^{h,i}_{jt} - \tilde{c}^{h,i}_{j,t-1}) = (\tilde{c}^h_{jt} - \tilde{c}^h_{j,t-1}) - \nu_c(\pi^{c,i}_{jt} - \pi^c_{jt}) \text{ for } i, j \in \mathcal{J}, h \in \{R, K\} \tag{D.72}$$

$$(\tilde{x}^{s,i}_{jt} - \tilde{x}^{s,i}_{j,t-1}) = (\tilde{x}^s_{jt} - \tilde{x}^s_{j,t-1}) - \nu_x(\pi^{x,i}_{jt} - \pi^x_{jt}) \text{ for } i, j \in \mathcal{J}, s \in \{c, x\} \tag{D.73}$$

Law of One Price:

$$\pi^{s,i}_{jt} = \pi^{s,j}_{jt}\ \forall i, j \in \mathcal{J}, i \neq j, s \in \{c, x\} \tag{D.74}$$

Inflation aggregation for each sector:

$$\pi^s_{jt} = \sum_{i \in \mathcal{J}} \chi^{s,i}_j \pi^{s,i}_{jt}\ \forall s \in \{c, x\} \tag{D.75}$$

Regional production of consumption and investment goods:

$$\alpha_g \tilde{k}^g_{jt} + \alpha \tilde{k}^c_{jt} + (1-\alpha)\tilde{n}^c_{jt} = \omega_j s^g_c \tilde{c}^g_{jt} + (1-s^g_c)\sum_{i\in\mathcal{J}} \omega_i \chi^{c,j}_i (\lambda \tilde{c}^{K,j}_{jt} + (1-\lambda)\tilde{c}^{R,j}_{jt}) \tag{D.76}$$

$$\alpha_g \tilde{k}^g_{jt} + \alpha \tilde{k}^x_{jt} + (1-\alpha)\tilde{n}^x_{jt} = \omega_j s^g_x \tilde{x}^g_{jt} + s^c_x \sum_{i\in\mathcal{J}} \omega_i \chi^{x,j}_i \tilde{x}^{c,j}_{jt} + s^x_x \sum_{i\in\mathcal{J}} \omega_i \chi^{x,j}_i \tilde{x}^{x,j}_{jt} \tag{D.77}$$

Investment choice:

$$\left(\widetilde{\frac{\gamma^s_{jt}}{p^s_{jt}}}\right) = \zeta\delta(x^s_{jt} - k^s_{jt}),\ s\in\{c,x\} \tag{D.78}$$

Euler equation for capital:

$$\left(\widetilde{\frac{\gamma^x_{jt}}{p^x_{jt}}}\right) + (\mathbb{E}_t r^x_{j,t+1} - r^x_{i,t}) = \mathbb{E}_t\left[(1-\beta(1-\delta))\left(\widetilde{\frac{r^x_{jt}}{p^x_{jt}}}\right) + \beta(1-\delta)\left(\widetilde{\frac{\gamma^x_{jt}}{p^x_{jt}}}\right) + \beta\zeta\delta^2(\tilde{x}^x_{j,t+1} - \tilde{k}^x_{j,t+1})\right] \tag{D.79}$$

$$\left(\widetilde{\frac{\gamma^c_{jt}}{p^c_{jt}}}\right) + (\mathbb{E}_t r^x_{j,t+1} - r^x_{i,t}) = \mathbb{E}_t\left[(1-\beta(1-\delta))\left(\widetilde{\frac{r^c_{jt}}{p^c_{jt}}}\right) + \beta(1-\delta)\left(\widetilde{\frac{\gamma^c_{jt}}{p^c_{jt}}}\right) + \beta\zeta\delta^2(\tilde{c}^c_{j,t+1} - \tilde{k}^c_{j,t+1})\right] \tag{D.80}$$

Sectoral capital accumulation:

$$\tilde{k}^s_{j,t+1} = (1-\delta)\tilde{k}^s_{i,t} + \delta\tilde{x}^s_{jt},\ s\in\{c,x,g\} \tag{D.81}$$

$$\tilde{k}^g_{j,t+1} = (1-\delta)\tilde{k}^g_{i,t} + \delta\tilde{x}^g_{jt} \tag{D.82}$$

Sectoral Phillips curves ($\widetilde{mc}^s_{jt}$ is the percentage deviation from the steady state value of MC^s_{jt}, after a linear approximation):

$$\pi^s_{jt} = \frac{(1-\theta_s)(1-\theta_s\beta)}{\theta_s}\widetilde{\frac{mc^s_{jt}}{p^s_{jt}}} + \beta\mathbb{E}_t[\pi^s_{j,t+1}],\ s\in\{c,x\} \tag{D.83}$$

Factor demands:

$$\left(\widetilde{\frac{w^s_{jt}}{p^s_{jt}}}\right) = \alpha_g\tilde{k}^g_{jt} + \alpha\tilde{k}^s_{jt} - \alpha\tilde{n}^s_{jt} + \left(\widetilde{\frac{mc^s_{jt}}{p^s_{jt}}}\right),\ s\in\{c,x\},\ j\in\mathcal{J} \tag{D.84}$$

$$\left(\widetilde{\frac{r^s_{jt}}{p^s_{jt}}}\right) = \alpha_g\tilde{k}^g_{jt} - (1-\alpha)\tilde{k}^s_{jt} + (1-\alpha)\tilde{n}^s_{jt} + \left(\widetilde{\frac{mc^s_{jt}}{p^s_{jt}}}\right),\ s\in\{c,x\},\ j\in\mathcal{J} \tag{D.85}$$

Fisher equations:

$$i_t = r_{jt}^{k,s} + \mathbb{E}_t \pi_{j,t+1}^s, \ s \in \{c, x\} \tag{D.86}$$

Monetary union-wide labor supply aggregation:

$$n_t = \sum_{j \in \mathcal{J}} \omega_j \tilde{n}_{jt} \tag{D.87}$$

Aggregation conditions:

$$\tilde{s}_t = \sum_{j \in \mathcal{J}} \omega_j \tilde{s}_{jt} \ s \in \{c, x\} \tag{D.88}$$

$$\tilde{c}_{jt} = s_c^g \tilde{c}_{jt}^g + (1 - s_c^g)(\lambda \tilde{c}_{jt}^K + (1 - \lambda)\tilde{c}_{jt}^R) \tag{D.89}$$

$$\tilde{x}_{jt} = s_x^g \tilde{x}_{jt}^g + s_x^c \tilde{x}_{jt}^c + s_x^x \tilde{x}_{jt}^x \tag{D.90}$$

$$(s_c^g s_y^c + s_x^g s_y^x)\tilde{g}_{jt} = s_x^g s_y^x \tilde{x}_{jt}^g + s_c^g s_y^c \tilde{c}_{jt}^g \tag{D.91}$$

$$\tilde{g}_t = \sum_{j \in \mathcal{J}} \omega_j \tilde{g}_{jt} \tag{D.92}$$

$$\tilde{y}_{jt} = s_y^x \tilde{x}_{jt} + s_y^c \tilde{c}_{jt} \tag{D.93}$$

$$\tilde{y}_t = \sum_{j \in \mathcal{J}} \omega_j \tilde{y}_{jt} \tag{D.94}$$

Price indices:

$$\left(\frac{p_{jt}^x}{p_{jt}^c}\right) - \left(\frac{p_{jt}^x}{p_{jt}^c}\right) = \pi_{jt}^x - \pi_{jt}^c \tag{D.95}$$

$$\pi_{jt} = s_y^x \pi_{jt}^x + s_y^c \pi_{jt}^c \tag{D.96}$$

$$\pi_t^s = \sum_{j \in \mathcal{J}} \omega_j \pi_{jt}^s \tag{D.97}$$

$$\pi_t = \sum_{j \in \mathcal{J}} \omega_j \pi_{jt} \tag{D.98}$$

Monetary and Fiscal Policy:

$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t \tag{D.99}$$

$$\tilde{t}_{j,t} = \tilde{g}_{j,t} \tag{D.100}$$

$$(s_c^g s_y^c + s_x^g s_y^x)\tilde{g}_{jt} = s_c^g s_y^c(\tilde{p}_{jt}^c + \tilde{c}_{jt}^g) + s_x^g s_y^x(\tilde{p}_{jt}^x + \tilde{x}_{jt}^g) \tag{D.101}$$

AR(1) government spending shock processes:

$$\tilde{x}_{jt}^g = \rho_x^g \tilde{x}_{j,t-1}^g + \varepsilon_{x,jt}^g \tag{D.102}$$

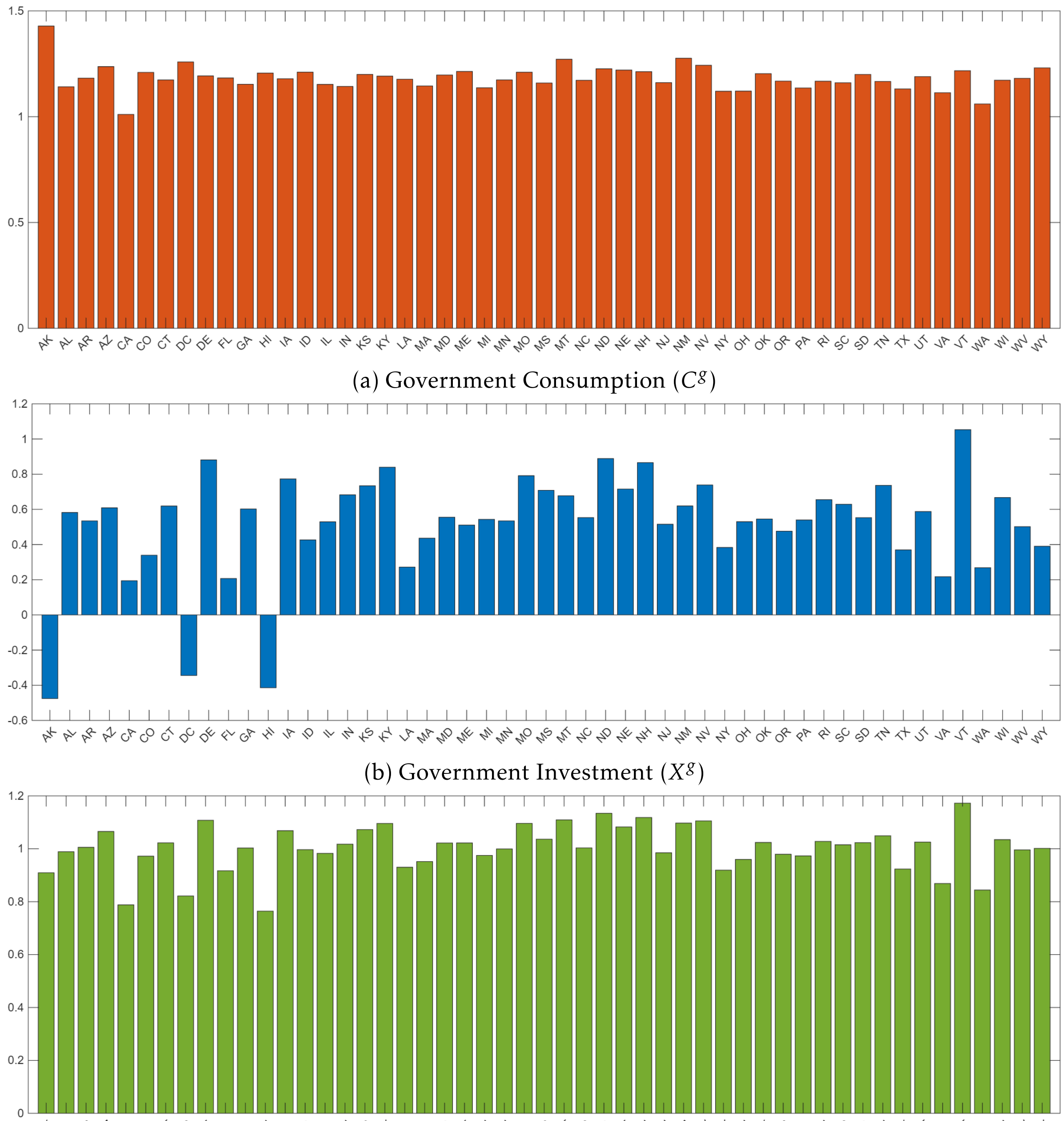
$$\tilde{c}_{jt}^g = \rho_c^g \tilde{c}_{j,t-1}^g + \varepsilon_{c,jt}^g \tag{D.103}$$

D.4 Aggregate Multipliers from Different Models

	$h = 0$	$h = 1$	$h = 2$	$h = 3$	$h = 4$
Aggregate Government Consumption Multipliers					
51-region model	0.734	0.730	0.730	0.732	0.733
Aggregated model	0.584	0.628	0.634	0.643	0.644
Aggregate Government Investment Multipliers					
51-region model	0.203	0.220	0.255	0.294	0.335
Aggregated model	0.229	0.190	0.175	0.172	0.171

Table D.1: Multipliers computed from the 51-region (state-level) and aggregated models. The top panel lists government consumption multipliers, and the bottom panel government investment multipliers. See main text in Section 8 for more details.

D.5 State-specific Regional Fiscal Multipliers



(a) Government Consumption (C^g)

(b) Government Investment (X^g)

(c) Government Purchases ($C^g + X^g$)

Figure D.1: Estimates of 2-year regional fiscal multipliers for each state, computed from state-level (51-region) quantitative model.

E Appendix: A Generalized Framework for Model-computed Multipliers

Here, I provide a framework for aggregating regional fiscal multipliers. For government consumption and investment respectively, there are three categories of multipliers to measure, in response to regional government spending shocks in region j, $\epsilon_{jt}^{s,g}$ where $s \in \{c, x\}$:

1. $\beta_{own}^{j,s}$: Change in state j's personal income Y_{jt} due to a regional government spending shock in sector s of region j

2. $\beta_{spill}^{j,s}$: Spillover effects to personal income Y_{it} of state $i \neq j$, i.e., changes in state i's personal income due to $\epsilon_{jt}^{s,g}$

3. $\beta_{agg}^{j,s}$: Total change in national personal income Y_t from the set of all regional government spending shocks $\{\epsilon_{jt}^{s,g}\}$ across all regions $j \in \mathcal{J}$

Denoting ω_j as state j's share of national income, the three types of multipliers are related thus:

$$\beta_{agg}^{j,s} = \omega_j \beta_{own}^{j,s} + \sum_{i \neq j} \omega_i \beta_{spill}^{j,s}, \tag{E.1}$$

Calibrating the model and assuming that all state-level IIJA government spending as regional government spending shocks, I can compute all three types of fiscal multipliers for both government consumption and investment. First, I provide a more general framework of thinking about region-specific regional fiscal multipliers, fiscal spillovers, and aggregate fiscal multipliers in a multiregion ($J > 2$ regions) monetary union model.

I begin with an example in the case with only one sector in government spending, two regions, and a Home government spending ($G_{H,t}$) shock. The response of Home regional income(output) to the shock is the regional fiscal multiplier, while the response of Foreign regional income is the fiscal spillover from the Home to the Foreign region. In general, let us denote the h-year response of region-i income to a region-j government spending shock as $\beta_{i,h}^{j}$. Under this notation, the region-j response from a region-j government spending shock is $\beta_{j,h}^{j}$, and the fiscal spillovers to region i as $\beta_{i,h}^{j}$. In a monetary union with only two regions (Home and Foreign), we can denote $\beta_{H,h}^{H}$ and $\beta_{F,h}^{H}$ as the Home and Foreign income responses to Home government spending shocks (normalized to Home income):[26]

$$\frac{Y_{H,t+h} - Y_{H,t-1}}{Y_{H,t-1}} = \beta^H_{H,h} \frac{G_{H,t+h} - G_{H,t-1}}{Y_{H,t-1}} \tag{E.2}$$

$$\frac{Y_{F,t+h} - Y_{F,t-1}}{Y_{F,t-1}} = \beta^H_{F,h} \frac{G_{H,t+h} - G_{H,t-1}}{Y_{H,t-1}} \tag{E.3}$$

Furthermore, let us denote the h-year response of *aggregate* income to the region-j government spending shock as $\beta^j_{agg,h}$, the aggregate fiscal multiplier. In that case, we can decompose $\beta^H_{agg,h}$ into a linear combination of $\beta^H_{H,h}$ and $\beta^H_{F,h}$ as follows:

$$\frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}} = \beta^H_{agg,h} \frac{G_{H,t+h} - G_{H,t-1}}{Y_{H,t-1}} \tag{E.4}$$

$$\begin{aligned}
\frac{Y_{t+h} - Y_{t-1}}{Y_{t-1}} &= \frac{(Y_{H,t+h} + Y_{F,t+h}) - (Y_{H,t-1} + Y_{F,t-1})}{Y_{t-1}} \\
&= \left(\frac{Y_{H,t-1}}{Y_{t-1}}\right)\left(\frac{Y_{H,t+h} - Y_{H,t-1}}{Y_{H,t-1}}\right) + \left(\frac{Y_{F,t-1}}{Y_{t-1}}\right)\left(\frac{Y_{F,t+h} - Y_{F,t-1}}{Y_{F,t-1}}\right) \\
&\approx \omega_H \left(\frac{Y_{H,t+h} - Y_{H,t-1}}{Y_{H,t-1}}\right) + \omega_F \left(\frac{Y_{F,t+h} - Y_{F,t-1}}{Y_{F,t-1}}\right) \\
&= \omega_H \left(\beta^H_{H,h} \frac{G_{H,t+h} - G_{H,t-1}}{Y_{H,t-1}}\right) + \omega_F \left(\beta^H_{F,h} \frac{G_{H,t+h} - G_{H,t-1}}{Y_{H,t-1}}\right)
\end{aligned} \tag{E.5}$$

$$\text{or } \beta^H_{agg,h} \approx \omega_H \beta^H_{H,h} + \omega_F \beta^H_{F,h} \tag{E.6}$$

where the approximation $Y_{j,t-1}/Y_{t-1} \approx \omega_j$ for $j \in \{H, F\}$ comes from the assumption that, in steady state, the ratio of region-j income $Y_{j,t-1}$ to aggregate income Y_{t-1} is equal to $\bar{Y}_j/\bar{Y} = \omega_j$.

This is easily extended into the context of a J-region monetary union with $J > 2$. $\beta^j_{spill,h}$, the *average* fiscal spillovers of a region-j government spending shock to the rest of the monetary union (all $i \neq j$) can be denoted as:

$$\begin{aligned}
\beta^j_{agg,h} &= \omega_j \beta^j_{j,h} + \sum_{i \neq j} \omega_i \beta^j_{i,h} \\
&= \omega_j \beta^j_{j,h} + (1 - \omega_j) \beta^j_{spill,h}
\end{aligned} \tag{E.7}$$

$$\text{or } \beta^j_{spill,h} = \frac{1}{1 - \omega_j} \sum_{i \neq j} \omega_i \beta^j_{i,h} \tag{E.8}$$

Now I extend this framework to a 2-sector, J-region monetary union model, with the region-

[26]For purposes of illustration, I omit the time and region fixed effects in the equations of this section.

i income response of a region-j, sector-s government spending shock denoted as $\beta_{i,h}^{j,s}$ (with an additional superscript s). Similar as before, the relationship between regional fiscal multipliers, fiscal spillovers, and aggregate fiscal multipliers of a region-j, sector-s government spending shock are derived into the following expressions:

$$\beta_{i,h}^{j} \approx s_y^c \beta_{i,h}^{j,c} + s_y^x \beta_{i,h}^{j,x} \tag{E.9}$$

$$\beta_{agg,h}^{j} \approx s_y^c \sum_{i \in \mathcal{J}} \omega_i \beta_{i,h}^{j,c} + s_y^x \sum_{i \in \mathcal{J}} \omega_i \beta_{i,h}^{j,x} \tag{E.10}$$

where $\beta_{i,h}^{j}$ is the aggregate effect across sectors of region-j government spending shocks on region-i incomes, and $\beta_{agg,h}^{j,s}$ is the aggregate effect of region-j, sector-s government spending shocks on aggregate income, i.e. across all regions $\mathcal{J}$. Consistent with the notation above, we can define the sector-s own-region multipliers $\beta_{own,h}^{j,s}$, fiscal spillovers, and aggregate fiscal multipliers as such:

$$\beta_{own,h}^{j,s} \equiv \beta_{j,h}^{j,s} \tag{E.11}$$

$$\beta_{spill,h}^{j,s} \equiv \frac{1}{1-\omega_j} \sum_{i \neq j} \omega_i \beta_{i,h}^{j,s} \tag{E.12}$$

$$\beta_{agg,h}^{j,s} = \sum_{i \in \mathcal{J}} \omega_j \beta_{i,h}^{j,s} = \omega_j \beta_{own,h}^{j,s} + (1-\omega_j) \beta_{spill,h}^{j,s}, \tag{E.13}$$

thus demonstrating the relationship at the beginning of this section.

The regional fiscal multiplier of region j and sector s, or the relative regional response of region j compared to all other regions $i \neq j$ in the monetary union, can be defined as:

$$\beta_{reg,h}^{j,s} \equiv \beta_{own,h}^{j,s} - \beta_{spill,h}^{j,s} \tag{E.14}$$

Up to this point, all the responses of variables from government spending shocks were only from region j. In policy terms, we are interested in the aggregate fiscal multiplier as the response of the aggregate of regional incomes to the aggregate of the regional government spending shocks. For that, we first need to take a weighted average of all sector-s, region-j government spending shocks across sectors $s \in \{c, x\}$ and regions $j \in \mathcal{J}$, and denote the aggregate fiscal multiplier from the aggregate of sector-s government spending shocks across all regions $j \in \mathcal{J}$ as $\beta_{agg,h}^{s}$. We can then define $\beta^s_{agg,h}$ as:

$$\beta^s_{agg,h} \approx \sum_{j \in \mathcal{J}} \omega_j \beta^{j,s}_{agg,h} = \sum_{j \in \mathcal{J}} \omega_j \left[\omega_j \beta^{j,s}_{own,h} + (1 - \omega_j) \beta^{j,s}_{spill,h} \right] \tag{E.15}$$

Finally, the aggregate fiscal multiplier $\beta_{agg,h}$, i.e. the response of aggregate income to the aggregation of all sector-s, region-j government spending shocks, can be simply approximated as:

$$\beta_{agg,h} \approx s^c_y \beta^c_{agg,h} + s^x_y \beta^x_{agg,h} \tag{E.16}$$

In a multiregion monetary union model with J symmetric regions, $\beta^{j,s}_{i,h} = \beta^{j',s}_{i',h}$ for all $i, i', j, j' \in \mathcal{J}$. However, this condition need not hold in an asymmetric model where some regions' households import or export more consumption goods from other regions due to different steady-state CES shares in their regional CES aggregator of consumption goods (Norris, 2019). These asymmetries, which determine inter-state trade flows of goods, will determine the multiplier effect of regional government consumption and investment, as well as fiscal spillovers to other states.