Tradable Spillovers of Fiscal Policy: Evidence from the 2009 Recovery Act

Peter B. McCrory[*]

January 13, 2021
[Most Recent Draft]

Abstract

I generalize a textbook currency union model to incorporate trade in intermediates among labor markets in order to study the local, spillover, and aggregate effects of government spending. The spillover effects of government spending mediated by trade in intermediates represents a novel and understudied mechanism by which local fiscal multiplier estimates likely represent a lower bound on the aggregate, Zero Lower Bound (ZLB) fiscal multiplier. In my framework, there is both a local and a spillover (relative) multiplier of government spending. Theoretically, summing both multipliers together yields an approximate lower bound on the aggregate, ZLB fiscal multiplier. Using geographic variation in government spending under the 2009 Recovery Act and import-export linkages between states from the 2007 Commodity Flow Survey, I estimate a local relative multiplier of 1.46 and a spillover relative multiplier of 1.33. Adding both together yields an approximate lower bound on the aggregate, ZLB fiscal multiplier of 2.8, nearly doubling the lower bound implied by the local multiplier estimate alone. A sectoral decomposition of both estimated multipliers strongly corroborates the trade in intermediates spillover mechanism.

Keywords: Fiscal Policy, Spillovers, Great Recession, Recovery Act, Currency Union
JEL Codes: E62, E3, F4

Policymakers frequently rely upon government spending and other forms of fiscal policy to stabilize economies in distress. In such settings, a key policy parameter is the size of the aggregate fiscal multiplier; however, given that recessions occur relatively infrequently, there is limited aggregate variation available for estimating this policy-relevant, aggregate multiplier directly. An alternative approach for studying the effects of fiscal policy is to rely upon subnational, regional variation in government spending. This, however, introduces a potential inconsistency since the so-called local fiscal multiplier identified using geographic variation is conceptually distinct from—albeit related to—the aggregate fiscal multiplier.

In this paper, I argue theoretically and empirically for the economic significance of trade in intermediate goods used in final production—an understudied mechanism in the literature— for mapping the local multiplier to the aggregate multiplier.[1] To argue this point formally, I generalize a textbook currency union model to incorporate trade in intermediates among labor markets.

In my model, because of roundabout production between states, local government spending has both a local component and a spillover component. This, in turn, implies two distinct, state-level, output multipliers: (i) The cumulative multiplier on home-state output of home-state government spending, which I refer to as the local (relative) multiplier and (ii) The cumulative multiplier on home-state output of government spending in the region in which the home-state is located, which I refer to as the spillover (relative) multiplier.[2] Summing both multipliers together yields an approximate lower bound on the aggregate, fiscal multiplier when monetary policy is constrained by the Zero Lower Bound (ZLB).[3]

---

[1] In reviewing the local multiplier literature, Chodorow-Reich (2019) emphasizes four other mechanisms by which the aggregate closed economy multiplier may differ from the local multiplier: (i) the response of monetary policy, (ii) relative price changes and expenditure switching across regions, (iii) income and wealth effects, and (iv) factor mobility. Chodorow-Reich (2019) argues that, on balance, the externally financed, local multiplier provides an approximate lower bound on the closed economy, zero-lower bound, aggregate multiplier.

[2] Note that these multipliers are, both empirically and theoretically, defined as *relative* multipliers since they represent effects on the home state relative to the currency union as a whole.

[3] This argument relies upon the equivalence of the region-aggregated system and the standard model without roundabout production. Regarding the approximate lower bound result, see arguments and discussion in Farhi and Werning (2016) and Chodorow-Reich (2019).

A simple example helps to illustrate how local fiscal multpliers depend upon the trade in intermediates among local labor markets. Consider an economy comprised of N local labor markets, each of equal size. Local production uses labor and a bundle of intermediates sourced symmetrically from each N local labor markets with cost share θ_N, which is in turn dependent on N ($\theta_N \to 1$ as $N \to \infty$, so that there is essentially zero local payments to labor). With rigid prices, zero profits and a mechanical marginal propensity to consume (mpc) in terms of local production, one dollar of local government spending increases local income by $\frac{1-\theta_N}{1-\frac{1}{N}\theta_N^2}\frac{1}{1-mpc}$. Thus, as the size of the local economy becomes small relative to entire economy ($N \to \infty$)—and the importance of intermediates sourced from the rest of the economy becomes large—the observed local relative multiplier tends towards zero even though the total government spending multiplier is constant at $\frac{1}{1-mpc}$.[4] This is the basic force by which the local multiplier, all else equal, tends to understate the total effect of government spending when there is trade in intermediates among labor markets. In this example, relative prices are held fixed. This serves to illustrate that trade in intermediates among labor markets is conceptually *distinct* from other trade-related sources of spillovers— as mediated by relative price adjustments—previously emphasized in the literature (e.g. degree of home bias in consumption and expenditure switching motives).

Guided by the theory, I use state-level data to estimate the local and spillover multipliers arising from the American Recovery and Reinvestment Act (ARRA; Recovery Act) of 2009.[5] I follow the literature in estimating the local multiplier. To estimate the spillover multiplier, I use pre-recession trade-linkages from the 2007 Commodity Flow Survey (CFS) to calculate the extent to which each U.S. state was differentially exposed to Recovery Act spending elsewhere in the country.[6] I calculate spillover exposure for each state as the weighted sum of ARRA spending in the rest of the country, where bilateral weights are determined

---

[4]For each dollar of local purchases either from the government or from private consumers, local income in this simple example increases by $(1-\theta) + \frac{\theta^2}{N}(1-\theta) + \frac{\theta^4}{N^2}(1-\theta) + \cdots = (1-\theta)/(1-\frac{\theta^2}{N})$.

[5]The Recovery Act had an estimated budgetary impact of $830 b illion (see https://www.cbo.gov/publication/45122).

[6]The CFS is useful for thinking about this channel since, as reported in Hillberry and Hummels (2003), most shipments between states are between manufacturers and wholesalers.

by import shares from the spillover-exposed state. I then use local projection methods to estimate the extent to which this exposure affected state-level economic outcomes such as output, employment, and unemployment. I have three key empirical findings.[7]

My first finding is an estimate of the spillover multiplier: all else equal, each additional \$1 of government spending in a given state increased output in the rest of the country by \$1.33 (SE: 0.16) over two years. As far as I know, this is the first paper to document cross-state output spillovers of fiscal policy arising from the Recovery Act and the first to emphasize the importance of trade in intermediate goods as the underlying mechanism of such spillovers.

Given that my estimate of the local multiplier is \$1.46 (SE: 0.43) over two years, the implied approximate lower bound on the aggregate multiplier from the Recovery Act was roughly 2.80 (SE: 0.48). That is, accounting for trade in intermediate inputs between U.S. states roughly *doubles* the implied lower bound on the aggregate, ZLB fiscal multiplier relative to relying upon the local multiplier estimate alone.

My second set of findings relate to the labor market. Again using local projection methods, I find that 6.7 (SE: 0.92) job-years were created/saved in the rest of the country over two years for every \$1 million of Recovery Act spending. I extend this analysis to unemployment and find a quantitatively similar drop in unemployment relative to the rise in employment. My estimated spillover effects in the labor market are comparable to the direct effects previously estimated in the literature (see Chodorow-Reich (2019)). This provides further evidence that, at least in the case of the Recovery Act, local multipliers understate the aggregate effect of government spending.

Third, I decompose the spillover effects on output by broad industry grouping. I find that the composition of direct and spillover effects differ from one another in ways remarkably consistent with the spillover effects being mediated through the trade in intermediate goods

---

[7]Identifying the spillover effects of the Recovery Act requires that policymakers did not select, intentionally or unintentionally, a *distribution* of spending in response to current or anticipated economic conditions among states indirectly exposed to such spending. Since a large portion of ARRA spending was allocated through pre-recession formulary rules, this seems to be a reasonable assumption. Nevertheless, I present evidence in support of this identifying assumption with an event-study style specification in Appendix C.

between manufacturers and wholesalers. For example, the bulk of the spillover effect is concentrated in the manufacturing sector, with no discernible local effect on manufacturing.

Taken together, my results have clear policy implications, both in terms of the local effects and the aggregate effects of government spending. Most immediately, to the extent that the sum of the local and spillover multipliers represents a rough lower bound on the aggregate, liquidity-trap fiscal multiplier, then my estimates imply a near doubling of the corresponding aggregate multiplier. When monetary policy is constrained, fiscal policy appears to be effective in combatting economic downturns in the aggregate.

Second, the trade in intermediate goods between labor markets is a source of leakage by which local interventions may possibly fail to have predominantly local effects. If the goal of policymakers is to improve economic conditions in labor markets in distress, then spending in industries with a high share of value-added production from other labor markets may ultimately undermine that objective. Conversely, if the goal is to support a broad-based economic recovery, a sensible strategy may be to spend in sectors with a high share of intermediate inputs sourced from elsewhere in the country.

Related Literature

This paper is most closely connected to the local fiscal multiplier literature, which uses plausibly exogenous geographic variation to study the effects of government spending on the economy. In the case of the Recovery Act of 2009, researchers have typically relied upon the institutional details for how aid was allocated to identify its local effects.[8] Extending this literature, I document that government spending under the Recovery Act had large, positive spillovers that extended well beyond the labor markets in which the spending took place.

A subset of this local multiplier literature uses cross-sectional variation in government

---

[8]See, for example, Chodorow-Reich et al. (2012), Wilson (2012), Dube et al. (2018), and Feyrer and Sacerdote (2012). Dupor and McCrory (2018) documents spillover effects from the Recovery Act between counties rather than between labor markets propagated by trade in intermediates. See Chodorow-Reich (2019) for a broader review of the literature, including non-ARRA papers.

spending and economic outcomes to further discipline general equilibrium models, which can then be used to study the aggregate fiscal multiplier. For example, Nakamura and Steinsson (2014) estimate the relative output multiplier on government spending, identified from differential state-level exposure to military build-ups and drawdowns. Dupor et al. (2018) perform a similar exercise in the context of the Recovery Act, using instead the local county-level consumption multiplier to discipline their model. In both instances—and this is typical of this literature—in the empirical analysis, there is considerable trade in intermediate goods between geographic units. As I show in both theory and application below, it is important to account for trade in intermediates between regions when mapping estimates to the implied aggregate multiplier.[9]

While informative, credibly identified local fiscal multipliers differ conceptually from the policy-relevant, aggregate, closed economy multiplier. The second literature to which my results relate is that studying the aggregate effects of fiscal policy in a closed economy.[10] This literature has experienced a resurgence in the last decade in the wake of the global recession and the fact that many countries turned to fiscal policy in order to stimulate their weakened economies. Ramey (2019) reviews this literature and argues that the deficit-financed fiscal multiplier on output tends to be between 0.6 and 1.[11] While valuable for studying the typical response of the economy to government spending, this literature tends to lack sufficient statistical power to estimate the aggregate fiscal multiplier when monetary policy is constrained by the ZLB or when there excess capacity in the economy.

Yet, such circumstances are exactly when policymakers tend to be most interested in

---

[9]Dupor et al. (2018) allow for trade in intermediates between regions but rely upon within-state, between-county variation to estimate the local consumption response. The model, calibrated to the estimated positive county-level consumption response, yields an aggregate consumption multiplier twice that of the county-level estimate—consistent with my finding of a large spillover multiplier. In contrast to their paper, I illustrate the importance of such roundabout spillovers between, rather than within, labor markets.

[10]See, for example, Blanchard and Perotti (2002), Hall (2009), Mountford and Uhlig (2009), and Ramey and Zubairy (2018).

[11]Of course, the multiplier is not a universal constant. It varies depending, for example, upon the composition of government spending (e.g. consumption versus infrastructure spending), how it is financed, the responsiveness of monetary policy, and the differential impact the spending has on households of varying levels of financial constraints. In general, frictionless dynamic general equilibrium models tend to predict output multipliers lower than 1 (See, for example, Baxter and King (1993)).

implementing countercyclical fiscal policy. My finding of large, positive fiscal policy spillovers between U.S. states implies that counteryclical fiscal policy is effective in stimulating the economy when monetary policy is constrained by the ZLB.

A third literature to which this paper is related is work on the effects of fiscal policy in an open economy. (e.g. Auerbach and Gorodnichenko (2013), Ilzetzki et al. (2013), Gali and Monacelli (2008), Nakamura and Steinsson (2014) and Farhi and Werning (2016)). Empirically, Ilzetzki et al. (2013) show that the estimated effects of fiscal policy shocks are larger among closed economies than among open economies.[12] Wilson (2012), an early paper studying the effects of the Recovery Act, takes this as evidence that the estimated local multiplier may indeed be a lower bound on the aggregate multiplier, writing: "To the extent that subnational regions within the United States are more open than the national economy, this result suggests that the local multiplier estimated for these regions may indeed be a lower bound for the national multiplier" (p. 253). As far as I know, my paper is the first to present empirical evidence in support of this claim that local multipliers understate the aggregate multiplier.

Finally, my paper is related to the rapidly growing production network literature, which emphasizes the role that trade in intermediate goods has in propagating and amplifying idiosyncratic shocks.[13] This is relevant, since Hillberry and Hummels (2003) present evidence that the flows between states reported in the Commodity Flow Survey are predominantly between manufacturers and wholesalers. This trade in intermediate goods suggests parallels with the production network literature.[14]

---

[12]Sheremirov and Spirovska (2019) similarly find multipliers are larger in relatively closed economies and smaller among more open economies.

[13]See, for example, Hulten (1978), Acemoglu et al. (2012), Baqaee (2018), and Baqaee and Farhi (2019). Stumpner (2019) uses the CFS to study the geographic spread of the housing boom-bust cycle in the lead up to the Great Recession.

[14]For example, in a stylized production network model, Acemoglu et al. (2016) show that, with limited relative price changes, the upstream propagation of demand shocks is larger than the downstream effects. Consistent with this prediction, I also show there are limited spillover effects from the recipient state to those states to which it ships goods.

I Open Economy Currency Union Model with Roundabout Production

The currency union model presented in this section generalizes the complete-markets model developed in Farhi and Werning (2016). Specifically, I introduce a notion of roundabout production in which states source intermediate goods produced by other states within a common area, which I refer to as a region.

I.1 Households

There is a continuum of states that comprise a currency union of measure one. Let $i \in [0, 1]$ denote the typical state. The currency union is further partitioned into equally sized regions with measure $\mu > 0$. With slight abuse of notation, let $\mu(i)$ denote the region in which state i is located. As constructed, each state i is small relative to the region in which it is located and as such does not have an effect on region-wide outcomes. Figure 1 illustrates the conceptual distinction between states, regions, and the currency union as a whole.

Figure 1: Diagram of States, Regions, and Currency Union
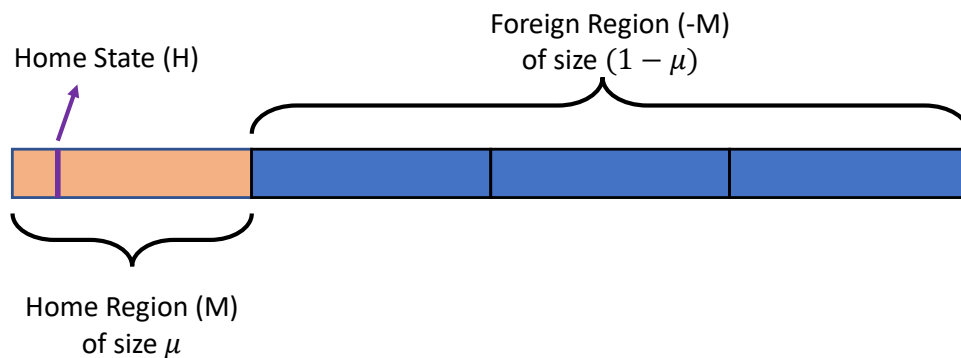
Let H denote a particular state, which I will refer to as the home state. I will refer to the home region, denoted by $M \equiv \mu(H)$, as the region in which the home state is located. All foreign states in the home-region are treated symmetrically throughout the analysis. All other states/regions in the currency union are treated symmetrically. I collectively refer to

the remaining foreign regions with $-M$. $-M$ has measure $1 - \mu$.

Following Farhi and Werning (2016), I assume that the economy is initially in steady state and all uncertainty is resolved at time $t = 0$, at which point the future values of shocks are known to the agents in the economy. This allows for a characterization of the dynamics of the economy as deterministic functions of each of the forcing variables in the various systems of differential equations.

In each state, there is a representative household with preferences:

$$\int_0^\infty e^{-\rho t} \left[\frac{C_t^{1-\sigma}}{1-\sigma} + \zeta \frac{G_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi} \right] dt,$$

with N_t representing locally supplied labor, G_t representing government purchases of goods produced in the home state, and C_t representing the household's consumption index of home-state and imported goods:

$$C_t = \left((1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}},$$

where $C_{H,t}$ is a CES aggregator of varieties produced in the home state, which I will henceforth refer to as home-produced goods except where there is likely to be some confusion:

$$C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}.$$

$j \in [0,1]$ refers to a particular good's variety produced in the home state. $C_{F,t}$ is a composite of imported goods from the rest of the currency union:

$$C_{F,t} = \left(\int_0^1 C_{i,t}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}},$$

with $C_{i,t}$ as a CES aggregater of state i-produced goods, defined in an equivalent way to $C_{H,t}$. This implies that foreign-produced goods enter symmetrically into the home-state

household's consumption. α determines the degree of home-bias in consumption.

When $\alpha \to 0$, all consumption is of goods produced within the home state. In the absence of externally sourced intermediate goods, this scenario would refer to a closed, regional economy with little to no trade with the rest of the currency union. With roundabout production, the home state may nevertheless trade considerably with the rest of the currency union even if, on the household side, all consumption is in terms of home-produced goods.[15] In that case, observed trade flows between states would entirely represent trade in intermediate goods. Because most within-state flows are over short-distances and cross-state flows are between manufacturers and wholesalers[16], a relatively low α may be the empirically relevant scenario; regardless, the model is analyzed under an arbitrary value of α.

The home-state household maximizes utility subject to the sequence of budget constraints for $t \geq 0$:

$$\dot{D}_t = r_t^* D_t - \int_0^1 P_{H,t}(j) C_{H,t}(j) dj - \int_0^1 \int_0^1 P_{i,t}(j) C_{i,t}(j) dj di + W_t N_t + \Pi_t + T_t,$$

with $P_{i,t}(j)$ being the price of state i variety j. W_t is the nominal wage, Π_t is nominal profits and T_t is a nominal lump sum transfer, all expressed in the common currency. Bond holdings are D_t and r_t^* is the union interest rate.

I.2   Government

Government consumption of home-produced goods is determined by a CES aggregator of home varieties:

$$G_t = \left(\int_0^1 G_t(j)^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

which it sources at minimum cost given prices of each j variety: $P_{H,t}(j)$. The government finances its spending through lump-sum taxes on the home-state households. Because of

---

[15]For example, consider a classic non-tradable industry: restaurants. Even though the consumption is highly local, restaurants often source ingredients from all over the country.

[16]See Hillberry and Hummels (2003).

Ricardian equivalence, the timing of taxation is irrelevant.[17]

In general, I will let G_t refer to government spending in the home state. I will let G_t^M refer to government spending in the representative (foreign) state in the home-region. G_t^{-M} refers, in turn, to spending in a representative state in the foreign regions.

I.3 Firms

I.3.1 Production with Region-Sourced Intermediates

Dropping i subscripts except where necessary, the typical firm in each state produces a differentiated good using a Cobb-Douglas production function:

$$Y_t(j) = A_{i,t} N_t(j)^{1-\theta} M_t(j)^{\theta},$$

where the intermediates used in production, $M_t(j)$ is a composite of goods imported from other states within the region:

$$M_t(j) = \left(\int_{\mu(i)} M_{s,t}(j)^{\frac{\gamma-1}{\gamma}} ds \right)^{\frac{\gamma}{\gamma-1}},$$

where s indexes states within the region. $M_{s,t}(j)$, in turn, is a composite of state s-produced varieties k:

$$M_{s,t}(j) = \left(\int_0^1 M_{s,t}(j,k)^{\frac{\epsilon-1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}}.$$

In the analysis presented below, the only shocks I consider are home state and home-region government spending. As such, without loss of generality let $A_{i,t} = A_{H,t} = A$ for all $t \geq 0$. Additionally, following Farhi and Werning (2016), I introduce a constant input tax

---

[17]The assumption of complete markets implies that the distribution of taxation across states does not matter for implications of the model. In this sense, it does not matter if the government is local or federal. See Farhi and Werning (2016) for a discussion on this point.

$(1 + \tau)$, so that real marginal cost in terms of the home-state producer price index (PPI) is

$$MC_t = \left(\frac{P_t^M}{\theta}\right)^\theta \left(\frac{W_t}{1-\theta}\right)^{1-\theta} \frac{1+\tau}{A} \frac{1}{P_{H,t}} \propto \frac{W_t^{1-\theta} P_t^{M\theta}}{P_{H,t}},$$

where P_t^M refers to the price index of home-region produced intermediates.[18]

I.3.2   Price-Setting

The Law of One Price holds so that the price of varieties in terms of the shared currency is identical regardless of where the variety is purchased.

Firms are subject to Calvo price-setting frictions. In particular, in each period a random flow of firms, ρ_δ, are allowed to change their price, they do to maximize discounted future profits. When $\rho_\delta \to \infty$, prices are fully flexible; when $\rho_\delta \to 0$, prices are rigid and no firm is able to update its price. Each firm's problem is to choose P_t^{reset} to solve the standard price-reset problem:

$$\max_{P_t^{reset}} \int_0^\infty e^{-\rho_\delta s - \int_0^s r_{t+z}^* dz} \left(P_t^{reset} \tilde{Y}_{t+s|t} - P_{H,t+s} MC_{t+s} \tilde{Y}_{t+s|t} \right) ds,$$

where $\tilde{Y}_{t+k|t} = \left(\frac{P_t^{reset}}{P_{H,t+k}}\right)^{-\epsilon} \tilde{Y}_{t+k}$. $\tilde{Y}_{t+k}$ refers to *total* demand for goods produced in the home state in period $t+k$, including the production of intermediate goods. Note that $P_{H,t+s} MC_{t+s}$ refers to nominal marginal costs. Firms take sequences of W_t, $\tilde{Y}_t$, and $P_{H,t}$ as given. The wage W_t adjusts flexibly each period.

---

[18]The employment tax is set to be $\tau = -\frac{1}{\epsilon}$, which offsets the monopoly distortion in steady state and simplifies the derivation without altering the main result.

I.3.3   Equilibrium Conditions

For a typical firm j in the home state, demand for intermediates and labor are related to one another by the firm's intratemporal first order condition:

$$M_t(j) = \frac{\theta}{1-\theta} \frac{W_t}{P_t^M} N_t(j)$$

We can thus write labor demand by firm j simply in terms of total gross production by firm j:

$$N_t(j) = \tilde{Y}_t(j) \frac{1}{A} \left(\frac{\theta}{1-\theta}\right)^{-\theta} \left(\frac{W_t}{P_t^M}\right)^{-\theta}$$

where again $\tilde{Y}_t(j)$ represents total gross production by firm j, which can further be written as

$$\tilde{Y}_t(j) = \left(\frac{P_t(j)}{P_{H,t}}\right)^{-\epsilon} \tilde{Y}_t$$

with $\tilde{Y}_t = \tilde{C}_t + G_t + \tilde{X}_t$. Total gross production in the home state and is comprised of demand for home-produced goods by union-wide consumers, the government, and firms in the home-region that use home-state goods as intermediates.

As is standard, we integrate over all home-state firms to get home-state labor demand:

$$N_t = \int_0^1 N_t(j) dj = \tilde{Y}_t \frac{1}{A} \left(\frac{W_t}{P_t^M}\right)^{-\theta} \Delta_t$$

where $\Delta_t = \left(\frac{\theta}{1-\theta}\right)^{-\theta} \int_0^1 \frac{P_t(j)^{-\epsilon}}{P_{H,t}} dj$ is the standard measure of price dispersion.

Demand for home-produced intermediates is determined by the terms of trade between the home state and the rest of the region in which it is located

$$\tilde{X}_t = \left(\frac{P_{H,t}}{P_t^M}\right)^{-\gamma} X_t^M$$

where X_t^M is total intermediates demanded by all firms within the home-region.

By assumption, except for the home state, all states within the home-region are identical,

13

each of which have producer price index P_t^M. Following the same logic as in the derivation of labor demand for the home state, integrating over firms in the typical foreign state in the home region (and recalling that the home region has mass μ) yields

$$X_t^M = \mu \tilde{Y}_t^M \frac{1}{A} \left(\frac{W_t^M}{P_t^M} \right)^{1-\theta} \Delta_t^M$$

where previously undefined variables are analogous to those for the home state.

Under complete markets[19] and because households face the same sequence of interest rates, consumption in the home state is linked to consumption in the foreign states (in the home region and in a typical foreign region) by

$$C_t = C_t^M \left(\frac{P_{M,t}}{P_t} \right)^{\frac{1}{\sigma}} = C_t^{-M} \left(\frac{P_{-M,t}}{P_t} \right)^{\frac{1}{\sigma}} = \mu C_t^M \left(\frac{P_{M,t}}{P_t} \right)^{\frac{1}{\sigma}} + (1-\mu) C_t^{-M} \left(\frac{P_{-M,t}}{P_t} \right)^{\frac{1}{\sigma}},$$

where $P_{M,t}$ is the CPI of the typical state in the home region and $P_{-M,t}$ is the CPI of the typical state in the foreign region.

The Euler equation takes the usual form

$$\frac{\dot{C}_t}{C_t} = \frac{1}{\sigma}(r_t^* - \pi_t - \rho)$$

with $\pi_t = \dot{P}_t/P_t$ as CPI inflation.

I.4   State, Region, and Currency-Union Multipliers

Following Farhi and Werning (2016), I log-linearize the model around a symmetric steady state with zero trend inflation, denoting deviations in terms of (total) private consumption of

---

[19]Complete financial markets means that households in the currency union trade in financial securities prior to the resolution of risk at $t = 0$ so as to perfectly share risk. I assume complete markets for tractability. In general, weakening this assumption with incomplete markets—so that households only have access to a one-period bond—would require us to also keep track of the home state's net foreign asset position; however, under complete markets the path of NFA_t is pinned down by other variables in the system along with the initial condition that $C_0 = C_0^*$. See Farhi and Werning (2016) for a discussion of this more general setting.

home-produced goods, total consumption of home-produced goods, and public consumption of home-produced goods as

$$\tilde{c}_t = (1 - \mathcal{G})(\log(Y_t - G_t) - \log(Y - G)) \approx \frac{Y_t - G_t - (Y - G)}{Y},$$

$$y_t = \log Y_t - \log Y \approx \frac{Y_t - Y}{Y}, \quad g_t = \mathcal{G}(\log G_t - \log G) \approx \frac{G_t - G}{Y},$$

where $Y_t = \tilde{C}_t + G_t$ represents final consumption of home-produced goods.[20] $\mathcal{G} = \frac{G}{Y}$ is the share of government spending in final consumption of home-produced goods in the typical state. Thus, up to a first-order approximation: $y_t = \tilde{c}_t + g_t$. In log-deviations, union-wide consumption is given by $c_t^* = \mu \tilde{c}_t^M + (1 - \mu)\tilde{c}_t^{-M}$.

I.4.1 State Equilibrium System

In Appendix A.1.1, I show that the log-linearized equilibrium can be reduced to a system of differential equations characterizing the path of consumption of home-produced goods and home PPI:

$$\dot{\tilde{c}}_t = \hat{\sigma}^{-1}(r_t^* - \pi_{H,t} - \rho) - \alpha(\omega - 1)\dot{c}_t^* \tag{1}$$

$$\dot{\pi}_{H,t} = \rho\pi_{H,t} - \rho_\delta(\rho_\delta + \rho)(1 - \theta)\left[\beta_{\tilde{c}}\tilde{c}_t + \beta_g g_t + \beta_{g^M} g_t^M + \beta_{c^*} c_t^* + \beta_{cM} \tilde{c}_t^M\right], \tag{2}$$

and an initial condition (as a result of complete markets) that consumption of home-produced goods be equal (on impact) to consumption in the rest of the currency union: $\tilde{c}_0 = c_0^*$.

The coefficients in the Euler equation are related to primitives of the model according to $\omega = \sigma\gamma + (1 - \alpha)(\sigma\eta - 1)$, $\hat{\sigma} = \frac{\sigma}{(1-\alpha+\alpha\omega)(1-\mathcal{G})}$ and $\tilde{\theta} = \frac{\epsilon-1}{\epsilon}\theta$; the coefficients $\{\beta_{\tilde{c}}, \beta_g, \beta_{g^M}, \beta_{c^*}, \beta_{cM}\}$ in the New Keynesian Philips Curve (NKPC) are derived and defined in Appendix A.1.1.

Because the Euler equation follows from the assumption of complete markets and the specification of household preferences, the degree of trade in intermediates (θ) does not show

---

[20]Note: This is not value added in the home-state since a portion of value added of home-produced goods is attributed to labor income in states in the rest of the home-region.

up. Of course, θ does appear in the NKPC since roundabout production induces strategic complementarities in price setting behavior à la Basu (1995).[21]

Relative to the baseline model presented in Farhi and Werning (2016), the introduction of trade in intermediates between states within a region introduces two new *forcing variables* into the state-level system[22]: (i) government spending in the rest of the region in which the home-state is located (g_t^M) and (ii) the path of consumption of goods produced by the home-region ($\tilde{c}_t^M$).[23] That the path of the state economy depends upon government spending in the rest of the region is unsurprising since firms in the rest of the region source intermediate goods from the home state to furnish goods purchased by the government. The latter force arises in general equilibrium because region-wide government spending itself alters the path of consumption of goods in the rest of the region.

In partial equilibrium, with the feedback from consumption of region-produced goods held constant, government spending in the home state and government spending in the home region enter the system with coefficients that are both proportional to and sum to $\phi \times \frac{(1-\tilde{\theta})}{(1+\theta\phi)(1-\tilde{\theta})-(1-\theta)\tilde{\theta}\phi}$—the inverse of the Frisch elasticity scaled down a term that is strictly less than one. As will be seen in the next subsection, this term is important for determining the observational equivalence between the region-aggregated system and the model developed in Farhi and Werning (2016).

I.4.2 Region Equilibrium System

To aggregate the model to the region-wide system, recall that the home state is small relative to the region. Thus, when spending in the home state is equal to what is spent in all other states in the region (i.e. $g_t = g_t^M$), it has to be the case that consumption of home-produced

---

[21]Note that trade in intermediates between states is *distinct* from the degree of home-bias in preferences. In particular, when $\sigma = \eta = \gamma = 1$, so that the Cole and Obstfeld (1991) holds, the system is *independent* of the degree of home-bias as parameterized by α but is *not* independent of the cost-share of intermediates θ.

[22]This dynamic system nests Farhi and Werning (2016) when $\theta = 0$.

[23]Recall that I assume that region-wide government spending is the same for all states except for the home-state, which is small relative to the region in which it's located. From the perspective of the home-state, region-wide variables are exogenously determined.

16

goods is the same as consumption of region produced goods for the typical state within the region (i.e. $\tilde{c}_t = \tilde{c}_t^M$ for all $t \geq 0$.)

Thus, combining coefficients where appropriate yields the (unchanged) Euler equation and the region-wide NKPC:

$$\dot{\tilde{c}}_t^M = \hat{\sigma}^{-1}(r_t^* - \pi_t^M - \rho) - \alpha(\omega - 1)\dot{\tilde{c}}_t^* \tag{3}$$

$$\dot{\pi}_t^M = \rho \pi_t^M - \rho_\delta(\rho_\delta + \rho) \frac{(1 - \tilde{\theta})(1 - \theta)}{(1 + \theta\phi)(1 - \tilde{\theta}) - (1 - \theta)\tilde{\theta}\phi} \left[(\hat{\sigma} + \phi)\tilde{c}_t^M + \phi g_t^M + \hat{\sigma}\alpha(\omega - 1)c_t^* \right], \tag{4}$$

where I have also plugged in the coefficient definition for the loading on c_t^* in the NKPC to ease exposition. These two equations are observationally equivalent to equations (5) and (6) in Farhi and Werning (2016). The only difference is the introduction of trade in intermediates which flattens out the NKPC by the scaling down the price-rigidity term $\rho_\delta(\rho_\delta + \rho)$ by $\frac{(1 - \tilde{\theta})(1 - \theta)}{(1 + \theta\phi)(1 - \tilde{\theta}) - (1 - \theta)\tilde{\theta}\phi} < 1$. Otherwise, the systems are the same.

I.4.3 Aggregate Equilibrium System

In the model, all foreign regions are treated symmetrically. Since the region dynamic system above is the same for the foreign regions after relabeling, to get union-wide outcomes we simply take a weighted average of the home region and foreign regions with weights μ and $1 - \mu$. After rearranging and recalling that $\hat{\sigma}^{-1}/(1 + \alpha(\omega - 1)) = \frac{1-\mathcal{G}}{\sigma}$, we get:

$$\dot{c}_t^* = \hat{\sigma}_*^{-1}(r_t^* - \pi_t^* - \rho) \tag{5}$$

$$\pi_t^* = \rho \pi_t^* - \chi(\theta)\kappa(c_t^* + (1 - \xi)g_t^*), \tag{6}$$

where $\lambda = \rho_\delta(\rho_\delta + \rho)$, $\kappa = \lambda(\hat{\sigma} + \phi)$, $\xi = \frac{\hat{\sigma}}{\hat{\sigma} + \phi}$, $\chi(\theta) \equiv \frac{(1 - \tilde{\theta})(1 - \theta)}{(1 + \theta\phi)(1 - \tilde{\theta}) - (1 - \theta)\tilde{\theta}\phi}$, and $\hat{\sigma}_* \equiv \frac{\sigma}{1 - \mathcal{G}}$. As with the region-wide system, at the currency level, the introduction of trade in intermediates

---

[24]Proposition 2 in Farhi and Werning (2016) states the result formally that the aggregate fiscal multiplier at the ZLB is decreasing in price rigidity.

between regions serves only to flatten out the NKPC by a factor $\frac{(1-\tilde{\theta})(1-\theta)}{(1+\theta\phi)(1-\tilde{\theta})-(1-\theta)\tilde{\theta}\phi}$. As an implication, the ZLB fiscal multiplier for the currency union as a whole is lower with roundabout production, since θ serves to flatten out the aggregate NKPC.[24]

I.4.4 Home-Region Local and Spillover Multipliers

For the purposes of defining state-level relative multipliers I consider deviations of $\{g_t, g_t^M\}$ around a symmetric steady state with zero inflation in which $c_t^* = 0$ for all $t \geq 0$. This is the model analog to estimating relative multipliers (either direct or spillover) relying upon cross-sectional variation—the dependence upon c_t^* of state (region-wide) outcomes is absorbed by the time fixed effects.

At the state-level, I consider three separate experiments. In each experiment, I let $\mu \to 0$ so that the size of each region is small relative to the union. This simplifies the exposition by implying that union-wide consumption deviations are always zero. (i.e., $c_t^* = 0$ for all $t \geq 0$).

Experiment 1: State Spending Only In the first experiment, I set $g_t^M = 0$ for all $t \geq 0$, so that the only forcing variable in the home-state system is home-state government spending. Coupled with the initial condition $\tilde{c}_0 = c_0^* = 0$, the path of consumption of home-produced goods is given by

$$\tilde{c}_t = \int_{-t}^{\infty} \alpha_s^{d,t} g_{t+s} ds, \tag{7}$$

where, as an implication of Proposition 3 in Farhi and Werning (2016), $\alpha_s^{d,t} \leq 0$. The exact formula for each $\alpha_s^{d,t}$ is provided in Appendix A.2. In the model, the relative effect of home-state government spending on consumption of home-produced goods is negative. This force is what generates the analytic result, in this model, that the region-wide, cumulative output multiplier is a lower bound on the aggregate multiplier at the ZLB. The coefficients $\{\alpha_s^{d,t}\}$ themselves are determined by the eigenvalues of the system. These are defined formally in

Appendix A.2.

Empirically, however, there is scant evidence that the relative effect on consumption is negative. Chodorow-Reich (2019) reviews the local multiplier literature and finds that most papers tend to find local (relative) multipliers greater than one, suggesting that local government spending shocks tend to have a positive, relative effect on consumption. In the context of the Recovery Act, Dupor et al. (2018) estimate a positive elasticity of local consumption to a local spending shock.

Theoretically, there are a number of ways to generate a positive relative effect on consumption in a currency union model akin to the one developed here, including complementarities between consumption and labor, introducing hand-to-mouth households, or through modifying the extensive margin decisions of firm hiring and entry.[25] In general, such channels tend to amplify the aggregate multiplier at the ZLB. Thus, the logic underlying the lower bound result in the baseline model tends to carry over to these more complicated extensions of the model.

Experiment 2: Region Spending Only In the second experiment, I suppose that there is no state-level government spending ($g_t = 0$ for all $t \geq 0$) but that there is government spending in the rest of the region in which the home-state is located.

To determine the spillover effects of g_t^M on consumption of home-produced goods, one must account not only for its effect through the production of intermediate goods needed to furnish the government with the goods it has demanded but also the effect upon home-state consumption mediated by the change in region-wide consumption. Formally, there are two forcing variables in the state-level system that depend upon the path of region-wide government spending: g_t^M and $\tilde{c}_t^M$.

Again, with the initial condition $\tilde{c}_0 = 0$ and because the model is linear, we can write:

---

[25]See, e.g., Nakamura and Steinsson (2014), Farhi and Werning (2016), and Auerbach et al. (2019).

$$\tilde{c}_t = \underbrace{\int_{-t}^{\infty} \alpha_s^{s,t} g_{t+s}^M ds}_{\text{Spillover from } g_t^M} + \underbrace{\int_{-t}^{\infty} \alpha_k^{c,t}}_{\text{Loading on } \tilde{c}_{t+k}^M} \underbrace{\int_{-(t+k)}^{\infty} \alpha_s^{M,t+k} g_{t+k+s}^M ds}_{\equiv \tilde{c}_{t+k}^M} dk \tag{8}$$

Also by Proposition 3 in Farhi and Werning (2016), the coefficients $\{\alpha_s^{s,t}, \alpha_s^{M,t}\}$ are all weakly negative. $\alpha_s^{s,t}$ represents the first channel of spillovers through the trade in intermediates: the production of intermediates by the home state to meet the government demand for goods produced by the rest of the region. The coefficients $\{\alpha_k^{c,t}\}$ determine the loading of consumption of home-produced goods on the path of consumption of home-region produced goods.

In the previous expression, I've replaced $\tilde{c}_{t+k}^M$ with the effect of region-level spending on region-level production of privately consumed goods, which is pinned down by the coefficients $\{\alpha_s^{M,t}\}$. Specifically, $\tilde{c}_t^M = \int_{-t}^{\infty} \alpha_s^{M,t} g_{t+s}^M ds$. The coefficients are defined in terms of primitives in Appendix A.2.

Experiment 3: Equal State and Region Spending The final experiment I consider is one in which government spending in the home state is the same for the typical state in the rest of the region. In particular, suppose that $g_t = g_t^M$ for all $t \geq 0$. Coupled again with the initial condition that $\tilde{c}_0 = 0$, the path of private consumption of home-produced goods is simply given by summing together the previous two expressions:

$$\tilde{c}_t = \int_{-t}^{\infty} (\alpha_s^{d,t} + \alpha_s^{s,t}) g_{t+s}^M ds + \int_{-t}^{\infty} \alpha_k^{c,t} \int_{-(t+k)}^{\infty} \alpha_s^{M,t+k} g_{t+k+s}^M ds dk = \int_{-t}^{\infty} \alpha_s^{M,t} g_{t+s}^M ds. \tag{9}$$

The latter equality follows from the fact that, by symmetry, $g_t = g_t^M \implies \tilde{c}_t = \tilde{c}_t^M$ for all $t \geq 0$.

Cumulative State Multipliers Define the home-state cumulative consumption multipliers for direct spending in the home state (local consumption multiplier) and spending in the

rest of the home region (spillover consumption multiplier) as

$$\underbrace{\mathcal{M}_{c,g} \equiv \frac{\int_0^\infty \tilde{c}_s ds}{\int_0^\infty g_s ds}}_{\text{Local Consumption Multiplier}} \quad \text{and} \quad \underbrace{\mathcal{M}_{c,g^M} \equiv \frac{\int_0^\infty \tilde{c}_s ds}{\int_0^\infty g_s^M ds}}_{\text{Spillover Consumption Multiplier}} \tag{10}$$

The local consumption multiplier represents the (undiscounted) cumulative, relative multiplier of a particular path of government spending on private consumption of home-state produced goods. For a fixed total value of the denominator, the effect on consumption will vary as a function of the particular path of spending. This is clearly the case since the instantaneous multiplier coefficients $\{\alpha_s^{d,t}\}$ are functions both of both t and s.

Similarly, the spillover consumption multiplier represents the (undiscounted) cumulative, relative multiplier of a particular path of government spending in the region on private consumption of home-state produced goods. This cumulative multiplier will in general also be a function of the particular path of region-level spending.

The relation between the local and spillover consumption multipliers and cumulative consumption multipliers at the region level and for the currency union as a whole is discussed below. I also defer until then a discussion of the relationship between consumption multipliers, output multipliers, and value-added multipliers.[26]

I.4.5 The Region-Wide Open Economy Relative Multiplier

Region-Wide Relative Multiplier   Consider an arbitrary sequence of government spending $\{g_t^M\}$ for $t \geq 0$ allocated equally to all states within the home region. Given the equivalence between the region-level dynamic system with trade in intermediates and equations (5) and (6) in Farhi and Werning (2016), the initial condition $\tilde{c}_0^M = 0$ implies that the path of consumption of region produced goods is given by:

---

[26]Given the trade in intermediates between states, consumption (both public and private) of home-produced goods is not necessarily the same as home state value added.

$$\tilde{c}_t^M = \int_{-t}^{\infty} \alpha_s^{M,t} g_{t+s}^M ds, \tag{11}$$

where $\alpha_s^{M,t} \leq 0$. This expression is the same one that appears above in Equation (8).

The cumulative consumption multiplier is defined similarly to multipliers at the state level:

$$\mathcal{M}_{c^M,g^M} \equiv \frac{\int_0^{\infty} \tilde{c}_s^M ds}{\int_0^{\infty} g_s^M ds} \tag{12}$$

This multiplier represents the (undiscounted) cumulative, relative multiplier of a particular path of government spending for the region as a whole on private consumption of region-produced goods.

Because all factors of production required for region-produced goods are contained within the region, the natural region-wide output multiplier is simply $1 + \mathcal{M}_{c^M,g^M}$. This multiplier represents the cumulative output multiplier of one dollar of government spending relative to other regions contained within the currency union.

When the path of government spending in the home state is proportional to government spending in the rest of the region for all $t \geq 0$, the local and spillover consumption multipliers sum to the region-wide cumulative consumption multiplier. This result is stated formally in the following proposition (proof in Appendix A.2.3):

Proposition 1. *If $g_t = \kappa_g g_t^M$ for all $t \geq 0$ and $|\kappa_g| > 0$, then*

$$\mathcal{M}_{c,g} + \mathcal{M}_{c,g^M} = \mathcal{M}_{c^M,g^M}$$

One implication of Proposition 2 is that whenever home-state and region-wide spending are $AR(1)$ with a common decay factor, the sum of the state-level local and spillover cumulative consumption multipliers will be equal to the region-wide cumulative consumption multiplier. Empirically, this condition appears to hold approximately for the Recovery Act

spending series, as portrayed in Figure 4.

In the data, I estimate output multipliers rather than multipliers on private consumption of home-produced goods. As a result of Proposition 2, it is nevertheless straightforward to show that the local and spillover *output* multipliers (based on local value-added) together sum to the region-wide output multiplier.[27]

In the following sections, I use geographic variation in government spending under the Recovery Act to recover both the local and spillover multipliers. Because the literature already focuses considerable attention on estimating the local multiplier, I focus my discussion primarily on estimating the spillover multiplier.

II   Data

II.1   Commodity Flow Survey

To empirically investigate the spillover effects of fiscal policy that operate through trade linkages between states, I first construct a regional import/export matrix using data from the 2007 Commodity Flow Survey (CFS). This survey is taken every five years by the Census Bureau and the Bureau of Transportation Statistics to determine the characteristics of commodities shipped between regions within the United States.

For the purposes of this study, the CFS provides the dollar value of goods shipped between all pairs of states j and i in 2007 for the mining, manufacturing, wholesale, and selected retail and services trade industries. The CFS defines a shipment as the "single movement of goods, commodities, or products from an establishment to a single customer or to another establishment owned or operated by the same company as the originating establishment (e.g., a warehouse, distribution center, or retail or wholesale outlet)."[28] Thus, the reported values in the CFS correspond to the total value of final and intermediate goods shipped between

---

[27]I show this equivalence in terms of local value-added multipliers in Appendix A.3.

[28]See https://www.census.gov/programs-surveys/cfs.html for more details about the CFS methodology and the specific implementation details.

states in 2007 for the subset of industries specified above. However, shipments between states are primarily between manufacturers and wholesalers, suggesting that these flows capture primarily the shipment of intermediate goods (see Hillberry and Hummels (2003)). Note that the CFS also includes shipments between establishments within each state.

With these data I construct import shares for every pair of states i and j. Specifically, I calculate

$$w_{i,j} = \frac{imports_{j \leftarrow i}}{Inbound\text{-}Shipments_j}$$

where $w_{i,j}$ measures the share of commodities imported by state j from state i as a share of all commodities shipped to state j.[29] These import shares will be combined with data on government spending to construct a *spillover treatment* variable for each state. As a reminder, relative to the model, the states from which each state imports intermediate goods are viewed collectively as regions.

In the benchmark specification, I set $w_{i,i}$ to be equal to zero. I denote the full matrix of these weights by $\mathbf{W}$.

The column sums of $\mathbf{W}$ are equal to the proportion of inbound shipments of goods imported from outside the state. Letting $\bar{\omega}_j$ indicate the sum of the elements in the jth column:

$$\bar{\omega}_j \equiv \frac{\sum_{k \neq j} imports_{j \leftarrow k}}{Inbound\text{-}Shipments_j}$$

The average value of $\bar{\omega}_j$ is 0.63, which means that on average states imported approximately 63% of the goods reported in the CFS 2007 from the rest of the country. California has the smallest value of 0.33, which implies that, as a share of all goods reported as being shipped to California in the CFS, only a third came from states other than California. On the opposite end of the spectrum, unsurprisingly, the largest is Washington D.C. with an import share of 0.86. Of the value of goods reported as being shipped to D.C., 86% come from the rest of

---

[29]The commodity flow survey also reports commodities shipped between locations within the same state. I include these shipments in the denominator of $w_{i,j}$. Thus, $Inbound\text{-}Shipments_j \equiv \sum_k imports_{j \leftarrow k}$.

Figure 2: Share of Imported Goods from Outside the State
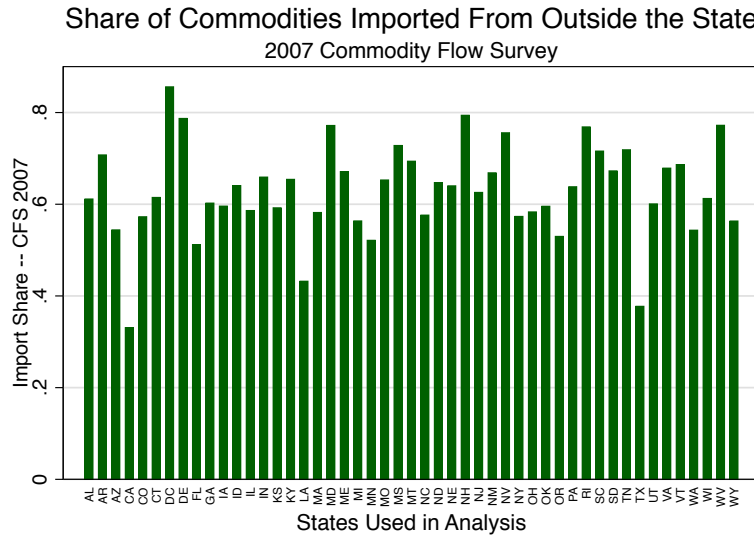
- This figure reports the share of shipments reported in the 2007 Commodity Flow Survey imported from the rest of the country.
- Each bar plot is the column sum of **W**, which has typical element $w_{i,j} = \frac{imports_{j \leftarrow i}}{\sum_k imports_{j \leftarrow k}}$ and $w_{i,i} = 0$.

the country.

II.2   Recovery Act Data

Data on the state-level spending component of the Recovery Act come from Wilson (2012). Every agency administering funds made available through the ARRA was required to provide a weekly detailed report, entitled the Financial and Activity Report, in which the value of obligations and payments to each state were specified. Under the ARRA, funds were made available to various Federal agencies. These agencies then determined—through discretion and formula—how much of such funds would be designated to each state. The bulk of such funds designated for each state were then announced as available to applicants.

When funds were obligated to a particular contractor or recipient—whether previously announced or unannounced—they were classified in the weekly Financial and Activity Reports as "obligations." For example, Wilson (2012) writes:

The Department of Transportation (DOT) might award a contract to a construc-

tion firm or municipal agency at which point the DOT is said to have obligated

those funds to that recipient. Finally, when recipients satisfy the terms of their

contracts, the agency actually pays out the funds.

Payments, also reported in the weekly reports, correspond to when funds were actually
transferred between the government and the recipient.

Figure 3: ARRA Spending Measures over Time From Wilson (2012)
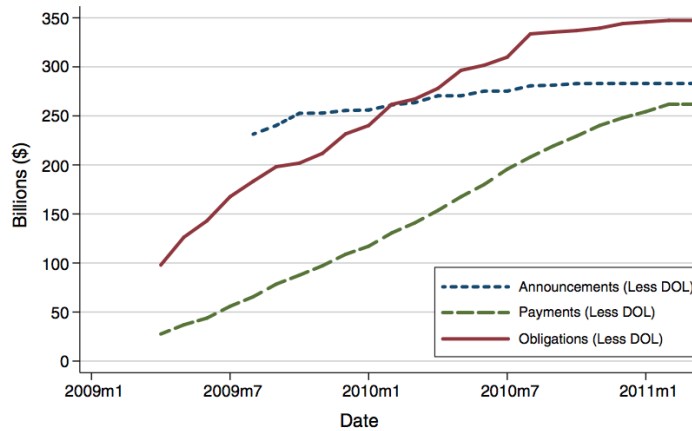
I use the state-level obligations series constructed by Wilson (2012). Reported in Figure

3 are three measures of ARRA spending over time, from April 2009 through March 2011.[30]

As compiled by Wilson (2012), the spending component (i.e. obligations) of the Recovery

Act totaled $418 billion in all fifty U.S. states and Washington D.C. Four agencies represent

the majority of Recovery Act spending: Health and Human Services (27%), Department of

Education (22%), Department of Labor (15%), and Department of Transportation (10%).[31]

I use $ARRA_{i,t}^{D}$ to indicate the cumulative dollar value of Recovery Act obligations directly

---

[30]This is Figure 2 in Wilson (2012).

[31]Wilson (2012) excludes Department of Labor obligations since there is "virtually no source of exogenous variation to use as an instrument for [DOL funding]". The results presented below are robust to the exclusion or inclusion of this series in the construction of the cumulative value of obligations to which a state was exposed. Thus, for completeness, I include DOL obligations when I calculate how much each state was exposed to spending elsewhere in the country. Appendix Table C.3 reports results from using the cumulative obligation series net of DOL agency obligations.

made to recipients in state i through quarter t. This variable is, by construction, set equal to zero prior to 2009Q2. Let $ARRA_t^D$ be the vector of obligations recorded for all states in quarter t.

II.3   Recovery Act Exposure Variable

I construct the extent to which state j was exposed to spending in all other states using the matrix of weights $\mathbf{W}$ and the vector of obligations $ARRA_t^D$:

$$ARRA_t^S = \mathbf{W} \times ARRA_t^D \tag{13}$$

where $ARRA_t^S$ records the cumulative dollar value of Recovery Act obligations each state was exposed to through quarter t. Specifically, each state's exposure is a weighted sum of spending elsewhere in the country:

$$ARRA_{i,t}^S = \mathbf{w}_i \cdot ARRA_t = \sum_{j \neq i} w_{i,j} ARRA_{j,t}$$

where $\mathbf{w}_i = (w_{i,1}, \ldots, w_{i,i-1}, 0, w_{i,i+1}, \ldots, w_{i,49})'$. I will often refer to this variable as a trade-weighted or import-weighted spillover ARRA.

There are 49 weights because I do not include Alaska or Hawaii in the benchmark analysis but I do include Washington DC. In what follows, references made to the collection of states used in the analysis refer to the 48 continental states plus DC. This vector would be equal to zeros if no state imported commodities from state i.

As explained below in Section III, the variable of interest is

$$\frac{\Delta ARRA_{i,t}^S}{GSP_{i,t-1}} = \frac{ARRA_{i,t}^S - ARRA_{i,t-1}^S}{GSP_{i,t-1}},$$

which is the value of *additional* import-weighted obligations to which state i was exposed in quarter t relative to real Gross State Product (GSP) in the prior quarter.

27

Figure 4 plots the time series of this variable for the two states most exposed to trade-weighted obligations in 2009Q2 relative to output (Tennessee and Indiana) and the two states least exposed (Florida and Washington D.C.). In all cases, this trade-weighted spillover variable attains its maximum in 2009Q2, when the bulk of Recovery Act obligations were designated. Subsequently, the series all decline monotonically towards zero. Although all series exhibit similar patterns of dynamic exposure, it is clear that these states were differentially exposed to government spending that occurred in the rest of the country. It is this variation in exposure to spending elsewhere, geographic and temporal, that is used to estimate the spillover effects of fiscal policy.

Figure 4: Differences in the Path of $\frac{ARRA^S_{i,t} - ARRA^S_{i,t-1}}{GSP_{i,t-1}}$ for States with Highest and Lowest Values in 2009Q2
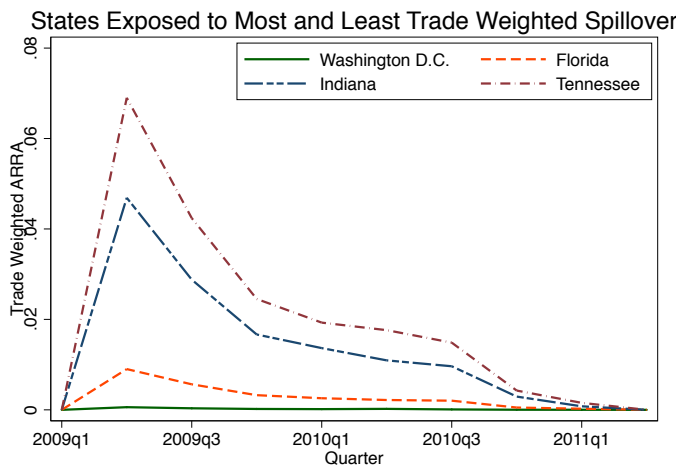
In the following section, I describe my empirical specification and present visual evidence that is consistent with my identifying assumption that the distribution of ARRA spending, coupled with the structure of trade flows between states, induced variation in exposure to spending elsewhere that was uncorrelated with contemporary or anticipated relative economic conditions in U.S. states. I then present my results, showing that there were large spillover effects of the Recovery Act mediated by trade linkages between states.

II.4   Other Data Sources

I consider three outcome variables: state-level output, employment, and unemployment. The quarterly real Gross State Product (GSP) series is from the Bureau of Economic Activity Regional Economic Accounts database.[32] Seasonally adjusted employment and unemployment data for each state were acquired from the Bureau of Labor Statistics.

III   Estimation and Results

III.1   Empirical Specification

The principal object I seek to estimate is the spillover multiplier of fiscal policy between U.S. states. Relative to the model presented in Section I, each state's trading partners are analogous to regions in the model. Thus, I estimate how an additional dollar of government spending elsewhere in the country affects relative economic outcomes in each state.

To determine the spillover effect of fiscal policy upon an outcome variable Y, I estimate a series of Jordà (2005) local projections for horizons $h = 0, \ldots, 11$. The benchmark set of equations that I estimate on the panel data are of the following form:

$$\frac{Y_{i,t+h} - Y_{i,t-1}}{GSP_{i,t-1}} = \theta_{i,h} + \eta_{t,h} + \beta_h^Y \frac{\Delta ARRA_{i,t}^S}{GSP_{i,t-1}} + \alpha_h^Y \frac{\Delta ARRA_{i,t}^D}{GSP_{i,t-1}} + X_{i,t}\Gamma_h + \varepsilon_{i,h,t}, \qquad (14)$$

where $GSP_{i,t}$ is the gross state product in state i in quarter t, $ARRA_{i,t}^D$ is the cumulative value of Recovery Act obligations to state i through quarter t, and $ARRA_{i,t}^S$ is the spillover treatment to which state i was exposed to in quarter t (see construction above), with Δ indicating the time difference of each variable. These equations include horizon-specific time fixed effects ($\eta_{h,t}$) and state fixed effects ($\theta_{i,h}$). $X_{i,t}$ is a vector of control variables. In the main analysis, the control variables comprising $X_{i,t}$ are four lags of $\frac{\Delta Y_{i,t}}{GSP_{i,t-1}}$, four lags of

---

[32]The GSP series are in chained 2009 dollars and are seasonally adjusted by the BEA.

$\frac{\Delta ARRA^S_{i,t}}{GSP_{i,t-1}}$, and four lags of $\frac{\Delta ARRA^D_{i,t}}{GSP_{i,t-1}}$.[33]

The coefficients of interest are $\{\beta^Y_h\}^{11}_{h=0}$, each of which provides an estimate of the change in the outcome variable over h quarters in response to one-million dollars of import-weighted ARRA obligations elsewhere to which a state was exposed. I also report a cumulative exposure multiplier, which is scaled to incorporate the cumulative government spending shock. Specifically, the K-quarter cumulative exposure multiplier is given by:

$$\phi^{S,Y}_K \equiv \frac{\sum^{K-1}_{h=0} \beta^Y_h}{\sum^{K-1}_{h=0} \beta^{ARRA^S}_h}$$

where $\beta^{ARRA^S}_h$ is the cumulative impulse response of the spillover measure of K quarters, which I also estimate according to equation (14) with the cumulative spillover exposure as the dependent variable.

The interpretation of $\phi^{S,Y}_K$ is as follows: It is the cumulative effect on the outcome variable Y over K quarters for each dollar of Recovery Act aid a state was exposed to over the same K-quarter period. As discussed in Ramey and Zubairy (2018), one can succinctly estimate this statistic by estimating the model in a single step, replacing the left hand side of equation (14) with the accumulated change in the outcome variable of the relevant horizon and similarly replacing $\frac{\Delta ARRA^S_{i,t}}{GSP_{i,t-1}}$ with the cumulative increase in obligations over the same period.

Similarly, I will report the cumulative direct output multiplier over K quarters:

$$\phi^{D,Y}_K \equiv \frac{\sum^{K-1}_{h=0} \alpha^Y_h}{\sum^{K-1}_{h=0} \alpha^{ARRA^D}_h}$$

When presenting my results below, I directly estimate $\phi^{S,Y}_K$ and $\phi^{D,Y}_K$ by running the following specification:

---

[33]This specification mirrors quite closely that of Auerbach and Gorodnichenko (2013). I have also estimated the model with regional fixed effects and varying the number of lag-lengths. Such changes have immaterial effects upon the estimated parameters.

$$\sum_{h=0}^{K-1} \frac{Y_{i,t+h} - Y_{i,t-1}}{GSP_{i,t-1}} = \phi_K^{S,Y} \sum_{h=0}^{K-1} \left(\frac{\Delta ARRA_{i,t+h}^S}{GSP_{i,t-1}} \right) \mathbf{1}(t \geq 2009Q2) \tag{15}$$

$$+ \phi_K^{D,Y} \sum_{h=0}^{K-1} \left(\frac{\Delta ARRA_{i,t+h}^D}{GSP_{i,t-1}} \right) \mathbf{1}(t \geq 2009Q2)$$

$$+ X_{i,t}\Gamma_K + \epsilon_{i,K,t}$$

where $\mathbf{1}(t \geq 2009Q2)$ is an indicator for whether the quarter is at or beyond $2009Q2$ and $X_{i,t}$ is a vector of controls described in the previous equation. The purpose of specifying the model in this way is so that the cumulative exposure multiplier is identified solely from variation in output growth following the passage of the Act. Estimating the impulse response at all horizons jointly for both output and spillover ARRA exposure and combining estimates yields quantitatively similar results as estimating Equation (15) in a single step.

I estimate the model using data from 2006Q2 to 2015Q1. The benchmark tables report Driscoll and Kraay (1998) standard errors, which allow for general forms of spatial and temporal dependence of the error terms $\varepsilon_{i,t,h}$.[34]

Summary statistics as of 2009Q1 of the variables used to estimate equations (14) and (15) are reported in Appendix Table D.6. Specifically, this table records the change and accumulated change in output, employment, unemployment, $ARRA^D$, and $ARRA^S$ over one and two years, scaled by lagged GSP.

---

[34]In my case, Driscoll and Kraay (1998) standard errors tend to be smaller relative to those constructed with heteroskedasticity consistent standard errors clustered by state. Table C.1 and Table C.2 report the counterparts to Tables 1 and 2 with the heteroskedasticity consistent standard errors clustered by state. Running a Pesaran (2004) cross-sectional dependence test on the residuals from Equation (14) strongly rejects the null hypothesis that the residuals are cross-sectionally uncorrelated. See Hoechle (2007) for more details on implementing this test.

III.2 Assessing the Identifying Assumption

III.2.1 Pre-Recession Growth of High and Low Spillover States

In estimating the direct effects of fiscal policy, one must overcome the omitted variable bias that arises because policymakers (typically) do not randomly assign treatment. More to the point, during a recession, the goal of countercyclical fiscal intervention is to stimulate economic activity and provide assistance to those local labor markets most severely affected by the downturn. Indeed, this was the stated purpose of the Recovery Act. To the extent that this endogenous allocation of Recovery Act aid occurred, then the estimates of $\{\alpha_h^Y\}_{h=0}^{11}$ from Equation (14)—the estimates of the direct effect of Fiscal Aid—will be biased downwards.

However, this study is concerned principally with the spillover effects of fiscal policy. As discussed Appendix D.1, there was only weak correlation between the initial severity of the downturn, prior to the passage of the Recovery Act, and the value of spillover aid to which a state was exposed. Similarly, there was limited correlation between the pre-Recovery Act severity of the recession and the centrality of a state in the network constructed from imports and exports between states.

Even if policymakers allocated funds according to the weakness of the local economy, it is unlikely that funds were allocated in order to affect the economic conditions of those states from which the recipient state imported goods.[35] For example, Colorado imports the bulk of its out-of-state commodities from California. Of all the commodities imported by Colorado, 7.5% originated in California. If the ultimate goal was to improve economic conditions in California, obligating funds to Colorado would presumably be an inefficient way to do so.[36]

Nevertheless, there may still be unobserved factors that introduce bias into the estimates

---

[35]Boone et al. (2014) provide evidence that the allocation of ARRA expenditure was generally uncorrelated with the severity of the economic downturn, strengthening this line of reasoning. Dube et al. (2018) also find that the amount of stimulus a county received was only weakly correlated with the downturn, as measured by the unemployment rate.

[36]The correlation between cumulative spillover exposure $\sum_{h=0}^{7} \Delta ARRA_{i,2009Q2+h}^S / GSP_{i,2009Q1}$ and direct aid $\sum_{h=0}^{7} \Delta ARRA_{i,2009Q2+h}^D / GSP_{i,2009Q1}$ over the two years following the passage of the Recovery Act is essentially 0. Even if direct aid were systematically correlated with local economic conditions, it appears unlikely the spillover exposure was.

of $\{\beta_h^Y\}_{h=0}^{11}$. As a further check on my identifying assumption, I look at the pre-treatment and post-treatment path of state GSP for states receiving high versus low spillover exposure. I view the results of this exercise as illustrative of both my identifying assumption and of the striking evidence of large spillover effects of the Recovery Act.

To construct relevant treatment and control groups, I first calculate the cumulative value of import-weighted obligations to which each state was exposed relative to the state's pre-recession level of output, observed in 2005: $Z_i = \frac{ARRA_{i,2011Q2}^S}{GSP_{2005}}$.[37] The "control" group is designated as the set of states for which the accumulated import-weighted obligation series relative to state GSP was below the median:

$$\text{Control Group} = \{i \in States : Z_i \leq median(\{Z_i\}_{i=1}^{49})\}$$

The "treatment" group is the remaining set of states whose exposure to import-weighted obligations relative to GSP was above the median for the entire sample.

I then re-index the value of each state's level of output to be relative to the level of output in 2005Q1. For each of these groups I take the average value of this GSP index. The time-series of the average values of these indices are reported in Figure 5.

The reason for choosing 2005Q1 as the base quarter is to highlight two facts: First, in the two years prior to the passage of the Recovery Act the growth path of output in these two groups was comparable prior to and during the early stages of the recession; Second, both groups reached the nadir of output in 2009Q2—the quarter in which the effects of the Recovery Act likely began—but the subsequent growth in the treatment group was considerably faster than that in the control group. The common pre-trends in state-level output in the two years prior to the act is further evidence that the identifying assumption

---

[37]Recall that cumulative obligations are observed only through 2011Q2.

Figure 5: Differences in Gross State Product Growth since 2005Q1: High versus Low Values of Spillover ARRA Aid

Differences in Growth in Gross State Product
High and Low Spillover ARRA per GSP (Index: 2005 = 1)
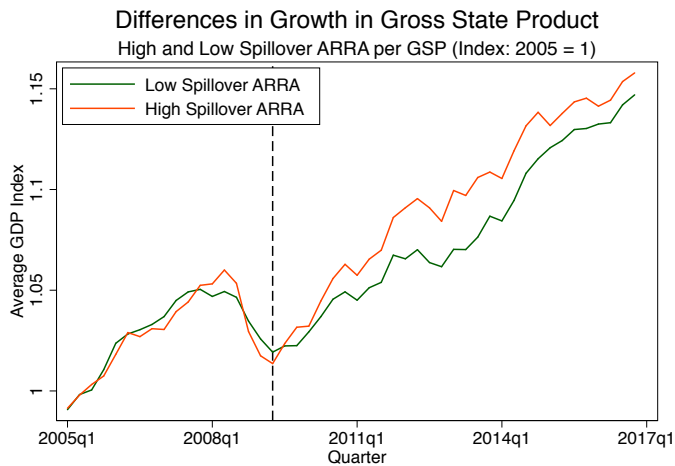
- Low spillover states are those for which $Z_i \leq median(\{Z_i\}_{i=1}^{49})$, where $Z_i \equiv \frac{ARRA^S_{i,2011Q2}}{GSP_{2005}}$. High spillover states are the remaining states.
- Each line corresponds to the average within-group average of real GSP, after re-indexing each state's GSP to its level as of 2005Q1.

holds.[38]

The top panel of Figure 6 follows this line of reasoning a bit further by plotting the accumulated change in output between 2009Q2 and 2011Q2 against the accumulated value of ARRA spending in the rest of the country to which a state was exposed, relative to its lagged level of gross state product. Despite not conditioning on any set of controls, there is a clear upward sloping relationship between the value of import-weighted obligations to which a state was exposed and its output growth in the first two years of the recovery from the recession. In the second panel of Figure 6, I change the horizon over which output growth changes are accumulated: between 2007Q2 and 2009Q2. If anything, the states ultimately disproportionately exposed to spending elsewhere in the country experienced relatively lower

---

[38]Consistent with evidence of local hysteresis in labor markets presented in Yagan (2019), this plot suggests that the spillover effects were extremely long-lived. Over longer horizons, one may suspect that factor reallocation of capital and labor may produce persistent relative differences in output (see Blanchard and Katz (1992)). Investigating whether the long-run relative differences in outcomes arising from spillovers are due to local employment hysteresis or factor reallocation is beyond the scope of this paper.

Figure 6: Scatter Plots of Cumulative Output Change and Cumulative ARRA Exposure Over 2 Years Following Passage of Recovery Act
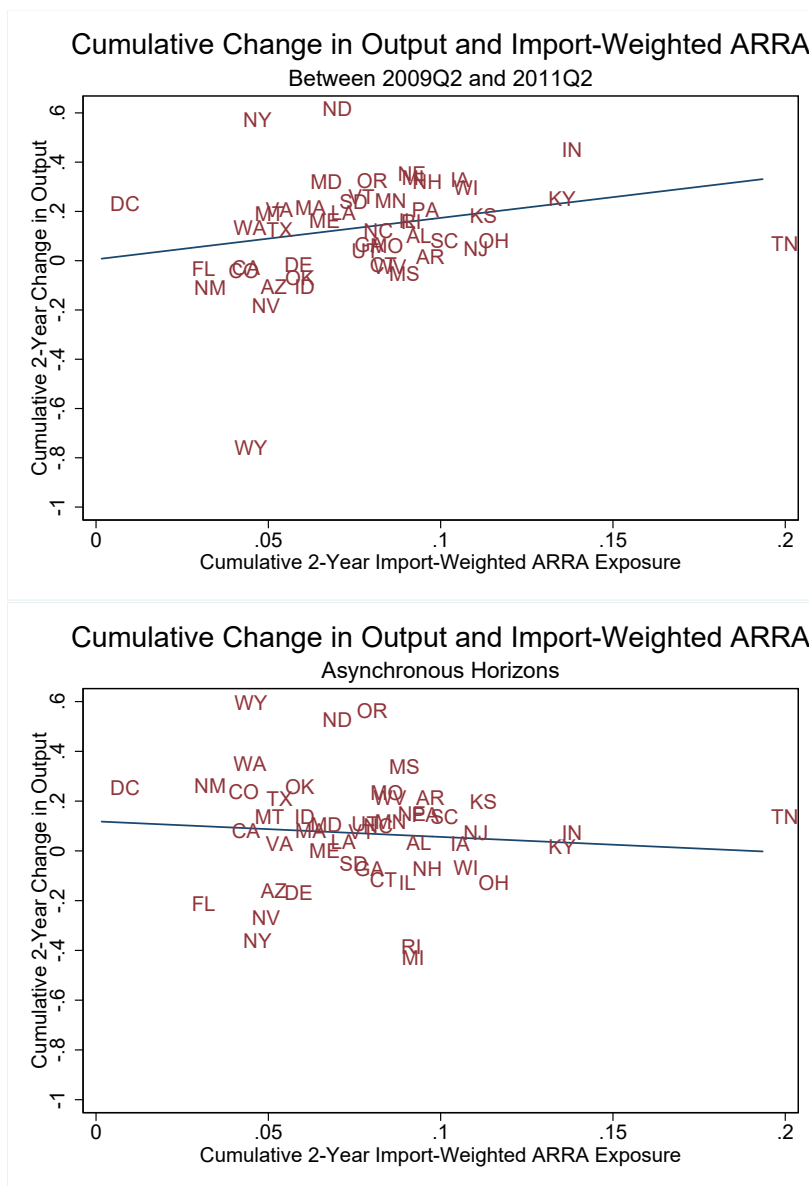
output growth in the two years prior to the passage of the Recovery Act.

III.3   Effects on Output and Import Weighted Obligations

In this subsection I discuss the estimated impulse responses of output and the exposure series itself to a \$1 innovation to $ARRA_{i,t}^{S}$, the central empirical findings of my paper. The

estimating equations are given by Equation (14), reprinted here for convenience:

$$\frac{Y_{i,t+h} - Y_{i,t-1}}{GSP_{i,t-1}} = \theta_{i,h} + \eta_{t,h} + \beta_h^Y \frac{\Delta ARRA_{i,t}^S}{GSP_{i,t-1}} + \alpha_h^Y \frac{\Delta ARRA_{i,t}^D}{GSP_{i,t-1}} + X_{i,t,h}\Gamma_h + \varepsilon_{i,h,t}$$

Figure 7a plots the estimated effect on output (GSP) of a \$1 innovation to import-weighted obligations over 12 quarters, including the impact quarter: $\{\hat{\beta}_h^{GSP}\}_{h=0}^{11}$. As seen in the figure, output increases on impact, rising by approximately 0.16 (SE: 0.05). Recall, that this has the interpretation that real output rose \$0.16 for every \$1 of import-weighted ARRA obligations to which a state was exposed. By quarter four, the estimates stabilize at close to 1, where they remain for the subsequent 8 quarters. Taking the integral of this impulse response over eight quarters ($h = 0, \ldots, 7$) yields the 2-year cumulative effect on output of a \$1 innovation to $ARRA_{i,t}^S$. This value is 5.68, which has the interpretation that the cumulative increase in output over two years was \$5.68 following a \$1 innovation to $ARRA_{i,t}^S$.

However, to properly scale this effect on output, we need to know the persistence of innovations to import-weighted obligations. Figure 4 suggests that import-weighted obligations, $ARRA_{i,t}^S$, have a strong auto-regressive component, even after controlling for other factors. Indeed, Figure 7b reports the impulse response of import-weighted obligations, $ARRA_{i,t}^S$ to a one dollar innovation to $ARRA_{i,t}^S$. Specifically, it plots the estimated coefficients $\{\hat{\beta}_h^{ARRA^S}\}_{h=0}^{11}$ from Equation (14). By construction, this IRF is equal to 1 on impact. The IRF then exhibits a near geometric decay, declining to 0.56 (SE: 0.04) in the quarter following impact and to 0.30 (SE: 0.05) the quarter after. Eventually, the IRF of the import-weighted obligation series becomes statistically indistinguishable from zero after 5 quarters. The integral of this IRF through the fifth quarter following the innovation is 2.4.

Taken together, this implies that the 2-year cumulative effect on output of being exposed to one dollar of import-weighted ARRA obligations over the same 2-year window, ϕ_8^S, is approximately \$2.37 ($= 5.68/2.4$).

In Table 1 I report the estimates of $\hat{\phi}_8^S$ when estimating the model in a single step according to Equation (15). The benchmark specification corresponds to the column entitled "All Controls". This specification includes the following control variables: state and time fixed effects, four lags of $\frac{\Delta ARRA_{i,t}^S}{GSP_{i,t-1}}$, four lags of $\frac{ARRA_{i,t}^D}{GSP_{i,t-1}}$, and four lags of $\frac{\Delta GSP_{i,t}}{GSP_{i,t-1}}$. The point estimate is \$2.12 (SE: 0.25). Recall that this has the interpretation that output increased by \$2.12 over two years for each one dollar of ARRA obligations to which a state was exposed, over the same two year horizon.

In the first four columns of Table 1, I consider various restrictions to the benchmark specification. In the left-most column I report the most restrictive model, the bivariate regression estimate in which I exclude state fixed effects, time fixed effects and all other controls from the benchmark model. The point estimate is \$1.88 (SE: 0.75). In the second through the fourth columns, I sequentially introduce additional controls: state fixed effects, time fixed effects, the two-year ahead cumulative value of directly received aid, and lags. In all cases, the point estimates are quantitatively similar to the benchmark estimate of \$2.12.

Table 1: Two Year Cumulative Exposure Multipliers of Recovery Act Spending on Gross State Product: Varying Controls

	Bivariate b/se	+ State FEs b/se	+ Quarter FEs b/se	+ Direct ARRA b/se	All Controls b/se
8-Qtr Ahead Spill. ARRA	1.88** (0.75)	2.03** (0.82)	2.80*** (0.38)	2.82*** (0.40)	2.12*** (0.25)
8-Qtr Ahead ARRA				2.30*** (0.52)	1.46*** (0.43)
No. Obs.	1764	1764	1764	1764	1764
R-Squared	0.018	0.236	0.456	0.461	0.474
State FEs	No	Yes	Yes	Yes	Yes
Quarter FEs	No	No	Yes	Yes	Yes
Lagged Variable	No	No	No	No	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 8 quarters) is set to zero in quarters prior to 2009Q2.
- The controls in column (5) represent the benchmark specification.
- On average, each \$1 of directly received ARRA aid is associated with \$0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the top line by 0.63.

Figure 7: Impulse Response of Output, Employment, Unemployment, and Import-Weighted ARRA Obligations to Innovation to Import-Weighted ARRA Obligation

(a)

Change in Gross State Product

(b)

Change in Spillover ARRA Shock

(c)

Change in Employed
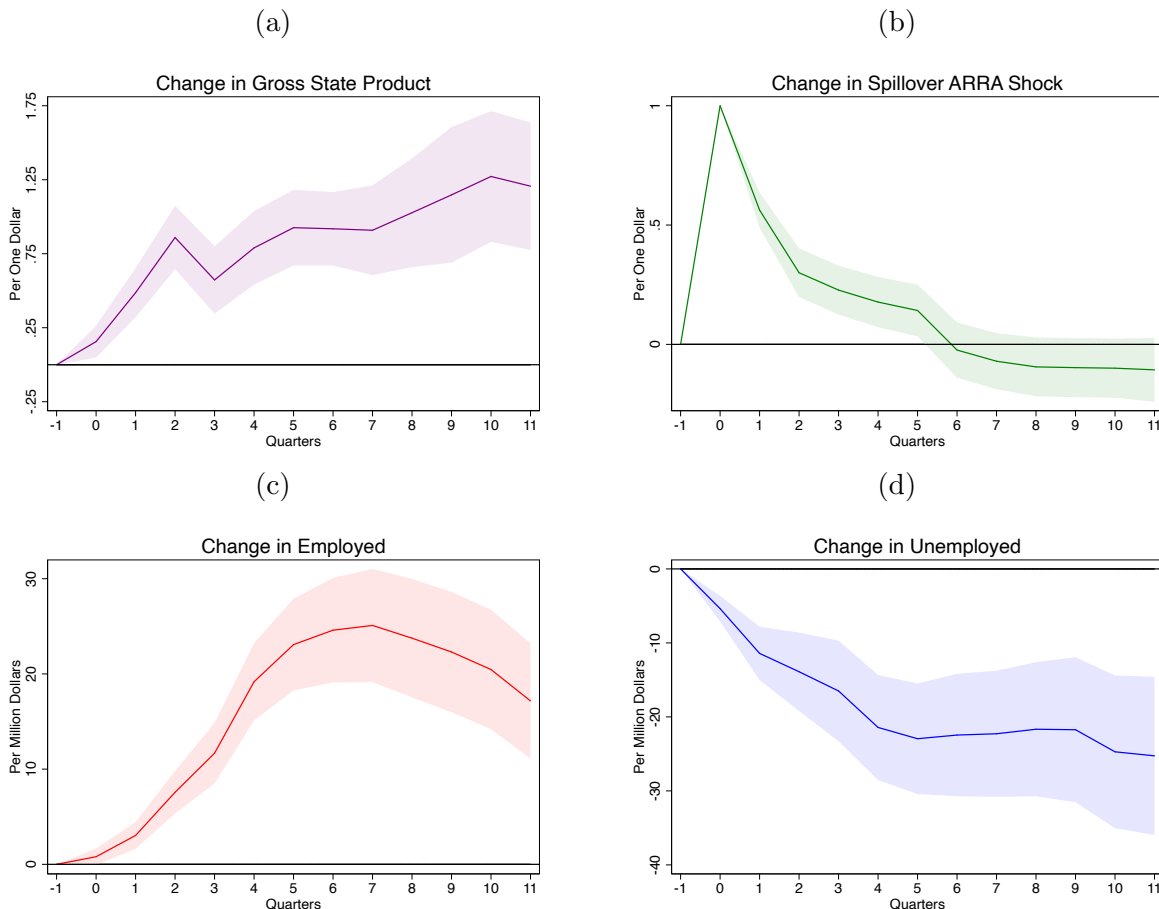

(d)

Change in Unemployed

- Figures report 95% confidence intervals constructed from Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- Effects on GSP and $ARRA^S$ scaled to be the effect per \$1 of $ARRA^S$. Employment and unemployment figures scaled to be effect per \$1 million of $ARRA^S$.

I convert this number to the appropriate spillover effect per \$1 of funding in the following way. First, I calculate the average import share across all states: $\bar{\omega} \equiv \mathbb{E}_i [\bar{\omega}_i]$, which is 0.63. This means that, in the context of my empirical specification in Equation (14), on average each \$1 of ARRA obligations is associated with \$0.63 of spillover obligations, distributed among other states in the country. For example, each additional \$1 of $ARRA_{i,t}^D$ corresponds to, on average, \$0.63 of $\sum_{j \neq i} ARRA_{j,t}^S$.[39]

Thus, we can calculate the 2-year cumulative effect on other states from one dollar of

---

[39]Intuitively, the rescaling is necessary because the theoretical analog of the spillover exposure I construct is $\int_0^\infty \bar{\omega} g_s^M ds$, where spending in the rest of the region is scaled down by $\bar{\omega}$.

direct aid by multiplying the coefficient $\hat{\phi}_8^S$ by 0.63, yielding \$1.33 (SE: 0.16). All else equal, for each \$1 of Recovery Act aid allocated to a given state over two years, output increased elsewhere in the country by an additional \$1.33.

Table 1 also reports the 2-year cumulative effect on output of directly allocated ARRA funding. Relative to the literature studying the Recovery Act, I do not instrument for this measure of local fiscal aid because I am primarily interested in estimating the spillover effects of the Recovery Act. Nevertheless, my estimate of the 2-year cumulative output multiplier of directly received ARRA obligations, \$1.46 (SE: 0.43), is consistent with the existing literature: Chodorow-Reich (2019) using only cross-sectional variation in government spending under the Recovery Act and a battery of instruments, estimates a 2-year multiplier of 1.53 (SE: 1.19). The trade-mediate spillover effects of fiscal policy that I estimate is quantitatively significant, representing approximately 90% of the estimated local effect.

Combining both the local multiplier and the spillover multiplier estimates, the implied region-wide relative multiplier from Recovery Act spending was approximately 2.80 (SE: 0.48). Absent other forces, this would suggest an implied, rough lower bound on the aggregate multiplier of the Recovery Act of approximately 2.80, since monetary policy was constrained by the ZLB.

III.4 Effects on the Labor Market

To what extent were the spillover effects of fiscal policy, identified in the previous section, also manifested in the labor market? To answer this question, I investigate the spillover effects of the Recovery Act aid on employment and unemployment. The estimated effects on employment yield a measure of the extensive margin spillover effect of fiscal policy, as compared to the intensive margin effect upon hours worked by already-employed workers.[40]

Complementing the results for employment, I also estimate the spillover effect on the

---

[40]Dupor and Mehkari (2016) present evidence that this intensive margin adjustment is quantitatively important.

number of people unemployed. These unemployment effects should be of comparable magnitude and opposite sign if the increase in employment is primarily due to people moving from unemployment to employment, as opposed to moving from non-participation in the labor force directly to employment.[41]

Consider first the effects of import-weighted ARRA obligations in all other states on a particular state's employment. Figure 7c plots the estimated parameters, $\{\hat{\beta}_h^{EMP}\}_0^{11}$, in an identical fashion to the output estimates. In these regressions, $ARRA_{i,t}^S$ is normalized to be per million dollars of obligations. In response to a million dollars of import-weighted government spending, the number of people employed in a particular state increases slowly at first, increases sharply by the end of the first year following the intervention, eventually attains a maximum value of 28 jobs in quarter 7, and then declines slightly.

As with the output estimates, we can calculate the integral of this figure to calculate the cumulative employment effect for every \$1 million innovation to import-weighted ARRA obligations. Over two years, the cumulative effect is 28.75 job-years created or saved. Dividing through by 2.4, the cumulative value of trade weighted exposure over the same two years and multiplying by 0.63 yields the 2-year spillover employment multipler of approximately 7.5 job-years created or saved in all other states other than the state receiving the million dollars of fiscal stimulus. The implied cost per spillover job-year created is thus approximately \$133K.

The unemployment estimates, $\{\hat{\beta}_h^{UR}\}_{h=0}^{11}$, are reported in Figure 7d. Each coefficient represents the reduction in the number of unemployed persons at horzion h for every million dollars of ARRA aid to which the state was exposed. The dynamic spillover effect of fiscal aid exhibits a similar, though opposite, pattern to that upon employment. The decline in unemployment stabilizes after approximately five quarters. Integrating over two years and appropriately annualizing yields a 2-year cumulative reduction in unemployment by 34 job-

---

[41]An alternative interpretation is that the higher employment is due to fewer job losses. In the counterfactual world of no spillover exposure and increased job losses, the previously employed workers would be moving primarily into unemployment.

years for every million dollars of aid to which a state was exposed. Multiplying this by 0.63 and dividing by 2.4 yields a reduction in unemployment in all other states by 8.9 job-years for every $1 million of ARRA aid.

III.5   Taking Stock: Cumulative One & Two Year Trade Exposure Multipliers

In this section I summarize the findings of the previous two subsections by tabulating the cumulative one and two year trade exposure multipliers of Recovery Act aid. I do so by estimating equation (15) for $K = 4$ and $K = 8$ for output, employment, and unemployment. The coefficients for the employment and unemployment regressions have been scaled so as to represent the cumulative annualized effect of $1 million of import-weighted ARRA exposure.[42] As before, I include four lags of the quarterly change of the outcome variable scaled by lagged GSP, four lags of the quarterly change in the ARRA exposure variable, state fixed effects, and time fixed effects.

Table 2 reports the results. Over one year, for each $1 million of ARRA obligations to which a state was exposed: output increased by $0.97 million (SE: 0.14), employment increased by 2.79 (SE: 0.53) job-years, and unemployment fell by 5.40 (SE: 0.98) job-years. Over two years, the effects are even more pronounced. Output increased by $2.12 million (SE: 0.25) for every million of ARRA obligation exposure, with employment rising by 10.54 job-years (SE: 1.44) and unemployment falling by 12.61 (SE: 2.25) job-years.

These results suggest the aggregate effect (direct plus spillover) of the Recovery Act was large. Each $1 of Recovery Act aid increased output by $1.46 (SE: 0.43) in the recipient state and increased output elsewhere in the country by $1.33 (SE: 0.16). Absent any other offsetting forces, the implied aggregate multiplier of the Recovery Act was 2.80 (SE: 0.48).

Each $1 million of Recovery Act aid increased employment by 10.56 (SE: 1.87) job-years

---

[42] As above, annualizing the employment effects means dividing through by 4 since the model is estimated with quarterly data.

Table 2: Benchmark One and Two Year Cumulative Exposure Multipliers of Recovery Act Spending on Gross State Product, Employment, and Unemployment

| | 4-Quarter Effect | | | 8-Quarter Effect | | |
| | Output | Job-Years | Unemployed -Years | Output | Job-Years | Unemployed -Years |
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead	0.97***	2.79***	-5.40***			
Spill. ARRA	(0.14)	(0.53)	(0.98)			
4-Qtr Ahead	0.27	3.53***	-2.35			
ARRA	(0.27)	(0.70)	(1.67)			
8-Qtr Ahead				2.12***	10.54***	-12.61***
Spill. ARRA				(0.25)	(1.44)	(2.25)
8-Qtr Ahead				1.46***	10.56***	-6.14**
ARRA				(0.43)	(1.87)	(2.53)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.417	0.722	0.799	0.474	0.698	0.823
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.
- On average, each $1 of directly received ARRA aid is associated with $0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the first and third lines by 0.63.

in the recipient state and increased employment by 6.63 (SE: 0.91) job-years elsewhere in the country. The combined employment effect was thus 17.20 (SE: 2.62) job-years per $1 million of ARRA aid. The implied cost of creating a job lasting one year in the local state economy was $95K and $150K elsewhere in the country. The combined cost of creating a job anywhere in the country was $58K.

III.6 Decomposing Output Effects By Sector

In this subsection I decompose the cumulative direct and spillover output effects over one and two years by sector. Specifically, I estimate Equation (15) with K equal to 4 and 8 and change the left hand side variable to represent various broad sectors, indexed with s, of the

economy:

$$\sum_{h=0}^{K-1} \frac{Y_{i,s,t+h} - Y_{i,s,t-1}}{GSP_{i,t-1}} = \phi_{s,K}^{S,Y} \sum_{h=0}^{K-1} \left(\frac{\Delta ARRA_{i,t+h}^{S}}{GSP_{i,t-1}} \right) \mathbf{1}(t \geq 2009Q2)$$

$$+ \phi_{s,K}^{D,Y} \sum_{h=0}^{K-1} \left(\Delta \frac{ARRA_{i,t+h}^{D}}{GSP_{i,t-1}} \right) \mathbf{1}(t \geq 2009Q2)$$

$$+ X_{i,s,t}\Gamma + \epsilon_{i,s,t}$$

As before, $\phi_{s,K}^{S,Y}$ has the interpretation of the cumulative K-quarter effect on the outcome variable $Y_{i,s,t}$ for each \$1 of ARRA aid to which the state was exposed over the same K quarters. $X_{i,t}$ includes four lags of the outcome variable and the exposure variable, as well as the cumulative value of ARRA aid received by the state over the same K quarters.[43] The analogue coefficient for directly received ARRA obligations, which I will refer to as $\phi_{s,K}^{D}$, has the interpretation of the cumulative effect over K quarters for each \$1 of ARRA aid a state directly received over the same K quarters.

Table 3 reports the estimated coefficients $\hat{\phi}_{s,K}^{S,Y}$ and $\hat{\phi}_{s,K}^{D,Y}$ for eight broad sectors of the economy: construction, non-durable manufacturing, durable manufacturing, retail trade, wholesale trade, transportation and warehousing, all other private sectors, and the government sector. Each panel of table records the effects by sector. The first row of the column reports the cumulative one year effect of being exposed to one additional dollar of Recovery Act spending in the rest of the country (column 1) and the one year effect of directly receiving one additional dollar of aid (column 2).

At neither the one nor the two year horizon is there a statistically significant effect on construction of spending elsewhere in the country; however, at the two year horizon, each \$1 of ARRA obligations led to an additional \$0.16 (SE: 0.06) of construction output in the local economy. Approximately 10% of the ARRA obligations in my sample were apportioned to states through the Department of Transportation, the bulk of which was designated for

---

[43]Recall that $\hat{\phi}_{s,K}^{S}$ should be rescaled by 0.63, since on average only \$0.63 of every dollar of aid is used to construct $ARRA_{t}^{S}$.

Table 3: One and Two Year Cumulative Exposure Multipliers of Recovery Act Spending on Sectoral Output

	Cumulative Spillover ARRA b/se	Cumulative Direct ARRA b/se
Construction Effects		
Over One Year	0.03	0.02
	(0.02)	(0.02)
Over Two Years	0.03	0.16**
	(0.05)	(0.06)
Manufacturing Effects		
Over One Year	0.52***	-0.01
	(0.08)	(0.10)
Over Two Years	1.47***	0.11
	(0.16)	(0.19)
Retail Trade Effects		
Over One Year	0.02**	0.05**
	(0.01)	(0.01)
Over Two Years	0.06***	0.12***
	(0.01)	(0.02)
Wholesale Trade Effects		
Over One Year	-0.01	0.05*
	(0.02)	(0.02)
Over Two Years	-0.00	0.19**
	(0.03)	(0.07)
Transportation and Warehousing Effects		
Over One Year	0.05***	0.01
	(0.01)	(0.01)
Over Two Years	0.14***	0.04
	(0.02)	(0.05)
Private All Other Effects		
Over One Year	0.51***	0.22
	(0.05)	(0.17)
Over Two Years	0.82***	0.92***
	(0.09)	(0.25)
Government Effects		
Over One Year	-0.06*	-0.03
	(0.03)	(0.03)
Over Two Years	-0.16*	0.01
	(0.06)	(0.06)

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 8 quarters) is set to zero in quarters prior to 2009Q2.
- On average, each \$1 of directly received ARRA aid is associated with \$0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the first column by 0.63.

highway construction. It may thus be unsurprising that there is a direct effect on construction output but no indirect effect through trade linkages between states.

The differential effects by direct and indirect exposure to the Recovery Act, as detailed in Table 3, are consistent with the spillover effects being mediated by the trade in goods, particularly intermediate goods. For example, wholesale trade activity between wholesalers and retailers occurs primarily within state borders. As such, one would expect any effect on wholesale trade to be concentrated in the state receiving aid, with little or no spillover effect on wholesale trade elsewhere. This is exactly what I find. Over two years, roughly one tenth of the direct effect of government spending is through an increase in wholesale trade activity: each $1 of directly received aid over two years led to increased wholesale trade production of $0.19 (SE: 0.07). There is no discernible spillover effect on wholesale trade activity.

Perhaps more convincingly, the spillover exposure effect is principally concentrated in two sectors most associated with the production and shipment of intermediate goods: manufacturing and transportation/warehousing activity. Over two years, each additional $1 of aid to which a state was inderectly exposed led to an increase in manufacturing output of $1.47 (0.16). In contrast, there was no statistically discernible effect on local manufacturing of directly received aid. The same holds for the effect on transportation and warehousing, which only manifests itself in the spillover effect of government spending.

III.7 Robustness Exercises

In Section C of the Appendix I show that my baseline estimates are robust to various concerns. First, I do an outlier analysis and show that no single state or pair of states are driving my results. Next, I address the concern that I have imposed the normalization that $w_{ii} = 0$. To do this, I include own-spending multiplied by self-import shares in the construction of my spillover exposure regressor. The point estimate on direct spending falls and the spillover exposure estimate rises. No longer needing to rescale the spillover exposure estimate, I find that the sum of the two coefficients is approximately 3, consistent with my baseline results.

In the third exercise, I address the concern that maybe states disproportionately exposed

to spending elsewhere in the country recovered more rapidly simply because such states load more heavily on the aggregate business cycle and, in turn, the general recovery that began around the passage of the Recovery Act. My results are robust to explicitly controlling for state-level excess cyclicality.

The fourth exercise is a type of placebo test. I construct a new measure of spillover exposure by taking the transpose of $\mathbf{W}$ and assess whether there are additional spillovers propagating downstream from recipient states to states to which they tend to export. I find no evidence of downstream propagation of Recovery Act spending.

Fifth, I address the concern raised by Ramey (2019) that with heterogeneous treatment effects the unweighted regressions will tend not to yield estimates of the policy relevant closed economy multiplier. When weighting my results by state population, I find that that the direct effect on output rises to $2.50 and the indirect estimate falls to $1.29. Larger states source more intermediate goods internally within the state, so this result is unsurprising. Again, the implied aggregate multiplier from combining both the direct and indirect effect is in line with my baseline findings.

As a sixth robustness exercise, I assess whether my results differ when explicitly incorporating higher order linkages between states when determining how much a particular state was exposed to spending elsewhere in the country. Specifically, I use trade flows from the CFS to construct a Leontief Inverse weighting matrix that calculates for each state the total implied demand for local factors of production, such as labor, mediated by the trade in intermediate goods. The results of this exercise confirm the benchmark findings, suggesting that the first order linkages between states capture the bulk of indirect exposure.

Finally, to allay remaining concerns, I estimate an event study style specification to determine whether states disproportionately exposed to total spending elsewhere fared better or worse economically leading up to and following the passage of the Recovery Act, relative to states receiving less aid. This exercise formalizes the results already presented in Figures 5 and 6 (bottom panel). I find no evidence of a pre-trend in output growth among states

more indirectly exposed to spending elsewhere in the country. Following the passage of the Recovery Act, there is a sharp effect on output growth, again consistent with the benchmark results.

IV Conclusion

This paper proposes and identifies a novel and economically important mechanism—trade in intermediate goods among labor markets—by which local government spending shocks propagate through the economy and ultimately determine the local, spillover, and aggregate effects of fiscal policy. To illustrate this mechanism formally, I generalize a benchmark currency union model to incorporate roundabout production among local labor markets within the currency union. In this setting, there is a local relative multiplier and a spillover relative multiplier of government spending, the sum of which yields an approximate lower bound on the aggregate, ZLB multiplier.

In the context of the Great Recession, I empirically estimate quantitatively large spillover effects of the Recovery Act mediated through the trade in intermediate goods between U.S. states. Using the spending component of the Recovery Act of 2009, I construct a measure of how much each state was exposed to spending in other parts of the country. The regional and time-series variation in this exposure allows me to identify the spillover relative multiplier. My estimate of the local relative multiplier is in line with the extant literature and the spillover relative multiplier is of a comparable magnitude.

In my preferred specification, for every dollar of Recovery Act aid to a recipient state over two years there is a corresponding increase in output of $1.33 elsewhere in the country. Coupled with the estimated direct effect of $1.46, this implies an approximate lower bound on the aggregate fiscal multiplier when monetary policy is constrained by the ZLB—as it was during the Great Recession—of around 2.8. Taken together, this evidence implies that the Recovery Act had large effects on aggregate output and, more generally, that fiscal

policy is an effective policy tool for stabilizing economies in distress when monetary policy interventions have been exhausted.

References

ACEMOGLU, D., U. AKCIGIT, AND W. KERR (2016): "Networks and the Macroeconomy: An Empirical Exploration," *NBER Macroeconomics Annual*, 30, 273–335.

ACEMOGLU, D., V. M. CARVALHO, A. OZDAGLAR, AND A. TAHBAZ-SALEHI (2012): "The Network Origins of Aggregate Fluctuations," *Econometrica*, 80, 1977–2016.

AUERBACH, A. J. AND Y. GORODNICHENKO (2013): "Output Spillovers from Fiscal Policy," *American Economic Review*, 103, 141–146.

AUERBACH, A. J., Y. GORODNICHENKO, AND D. MURPHY (2019): "Macroeconomic Frameworks," National Bureau of Economic Research.

BAQAEE, D. R. (2018): "Cascading Failures in Production Networks," *Econometrica*, 86, 1819–1838.

BAQAEE, D. R. AND E. FARHI (2019): "The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten's Theorem," *Econometrica*, 87, 1155–1203.

BASU, S. (1995): "Intermediate Goods and Business Cycles: Implications for Productivity and Welfare," *The American Economic Review*, 85, 512–531.

BAXTER, M. AND R. G. KING (1993): "Fiscal Policy in General Equilibrium," *The American Economic Review*, 83, 315–334.

BLANCHARD, O. AND R. PEROTTI (2002): "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *The Quarterly Journal of Economics*, 117, 1329–1368.

BLANCHARD, O. J. AND L. F. KATZ (1992): "Regional evolutions," *Brookings Papers on Economic Activity*, 1992, 1–75.

BOONE, C., A. DUBE, AND E. KAPLAN (2014): "The Political Economy of Discretionary Spending: Evidence from the American Recovery and Reinvestment Act," *Brookings Papers on Economic Activity*, 375–441.

CHODOROW-REICH, G. (2019): "Geographic Cross-Sectional Fiscal Multipliers: What Have We Learned ?" *American Economic Journal: Economic Policy*, 11, 1–34.

CHODOROW-REICH, G., L. FEIVESON, Z. LISCOW, AND W. G. WOOLSTON (2012): "Does State Fiscal Relief During Recessions Increase Employment? Evidence from the American Recovery and Reinvestment Act," *American Economic Journal: Economic Policy*, 4, 118–145.

COLE, H. L. AND M. OBSTFELD (1991): "Commodity trade and international risk sharing. How much do financial markets matter?" *Journal of Monetary Economics*, 28, 3–24.

DRISCOLL, J. C. AND A. C. KRAAY (1998): "Consistent Covariance Matrix Estimation with Spatially Dependent Panel Data," *The Review of Economics and Statistics*, 80, 549–560.

DUBE, A., T. HEGLAND, E. KAPLAN, AND B. ZIPPERER (2018): "Excess Capacity and Heterogeneity in the Fiscal Multiplier: Evidence from the Recovery Act," Working Paper.

DUPOR, B., M. KARABARBOUNIS, M. KUDLYAK, AND S. M. MEHKARI (2018): "Regional Consumption Responses and the Aggregate Fiscal Multiplier," Federal Reserve Bank of San Francisco.

DUPOR, B. AND P. B. MCCRORY (2018): "A Cup Runneth Over: Fiscal Policy Spillovers from the 2009 Recovery Act," *Economic Journal*, 128, 1476–1508.

DUPOR, B. AND M. S. MEHKARI (2016): "The 2009 Recovery Act: Stimulus at the extensive and intensive labor margins," *European Economic Review*, 85, 208–228.

FARHI, E. AND I. WERNING (2016): "Liquidity Traps and Currency Unions," Elsevier, vol. 2 of *Handbook of Macroeconomics*, 2417–2492.

FEYRER, J. AND B. SACERDOTE (2012): "Did the Stimulus Stimulate? Effects of the American Recovery and Reinvestment Act," Working Paper.

GALI, J. AND T. MONACELLI (2008): "Optimal monetary and fiscal policy in a currency union," *Journal of International Economics*, 76, 116–132.

HALL, R. E. (2009): "By How Much Does GDP Rise If the Government Buys More Output?" *Brookings Papers on Economic Activity*, 2009, 183–231.

HILLBERRY, R. AND D. HUMMELS (2003): "Intranational Home Bias: Some Explanations," *The Review of Economics and Statistics*, 85, 1089–1092.

HOECHLE, D. (2007): "Robust Standard Errors for Panel Regressions with Cross-Sectional Dependence," *The Stata Journal*, 7, 281–312.

HULTEN, C. R. (1978): "Growth Accounting with Intermediate Inputs," *The Review of Economic Studies*, 45, 511–518.

ILZETZKI, E., E. G. MENDOZA, AND C. A. VÉGH (2013): "How big (small?) are fiscal multipliers?" *Journal of Monetary Economics*, 60, 239–254.

JACKSON, M. (2010): *Social and Economic Networks*, Princeton University Press.

JORDÀ, Ò. (2005): "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, 95, 161–182.

LONG, J. B. AND C. I. PLOSSER (1983): "Real Business Cycles," *Journal of Political Economy*, 91, 39–69.

MOUNTFORD, A. AND H. UHLIG (2009): "What are the effects of fiscal policy shocks?" *Journal of Applied Econometrics*, 24, 960–992.

NAKAMURA, E. AND J. STEINSSON (2014): "Fiscal Stimulus in a Monetary Union: Evidence from US Regions," *American Economic Review*, 104, 753–792.

PESARAN, M. H. (2004): "General Diagnostic Tests for Cross Section Dependence in Panels," Cambridge Working Papers in Economics.

RAMEY, V. A. (2011): "Identifying Government Spending Shocks: It's all in the Timing*," *The Quarterly Journal of Economics*, 126, 1–50.

——— (2019): "Ten Years After the Financial Crisis: What Have We Learned from the Renaissance in Fiscal Research?" *Journal of Economic Perspectives*, 33, 89–114.

RAMEY, V. A. AND S. ZUBAIRY (2018): "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data," *Journal of Political Economy*, 126, 850–901.

SHEREMIROV, V. AND S. SPIROVSKA (2019): "Fiscal multipliers in advanced and developing countries: evidence from military spending," .

STUMPNER, S. (2019): "Trade and the geographic spread of the great recession," *Journal of International Economics*, 119, 169–180.

WILSON, D. J. (2012): "Fiscal Spending Jobs Multipliers: Evidence from the 2009 American Recovery and Reinvestment Act," *American Economic Journal: Economic Policy*, 4, 251–282.

YAGAN, D. (2019): "Employment hysteresis from the great recession," *Journal of Political Economy*, 127, 2505–2558.

Appendix to

"Tradable Spillovers of Fiscal Policy: Evidence from the 2009 Recovery Act"

By Peter B. McCrory

A   Appendix to Currency Union Model With Roundabout Production

A.1   Solving for Log-Linearized Differential Equations

For a typical variable Z_t, I use the notation $\check{z}_t$ to refer to the log-deviation in Z_t around its steady state value. As defined in the main text, this implies that $\check{c}_t(1 - \mathcal{G}) = c_t$ and $\check{g}_t \mathcal{G} = g_t$. Deviations in consumption of home-state produced goods scaled by steady state consumption is denoted by $\tilde{c}_t$. Deviations in terms of gross production are defined as $\check{\tilde{y}}_t$. Variables for states in the rest of the currency union are defined similarly.

A.1.1   Defining Various Price Indices, Terms of Trade, and Real Exchange Rates

Because states in the home-region are treated symmetrically and because all other states are treated symmetrically, the currency-wide price index

$$P_t^* = \left(\mu P_t^{M1-\gamma} + (1 - \mu) P_t^{-M1-\gamma} \right)^{\frac{1}{1-\gamma}},$$

where P_t^M is the PPI for the typical home-region state (not the home state):

$$P_t^M = \left(\int_0^1 P_t^M(j)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}.$$

The price index associated with the typical state in the foreign region is similarly defined. The home state consumer price index (CPI) is

$$P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_t^{*1-\eta}\right]^{\frac{1}{1-\eta}},$$

with the home state PPI given by

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\epsilon}dj\right)^{\frac{1}{1-\epsilon}}.$$

The CPI for the home region M is similarly given by:

$$P_{M,t} = \left[(1-\alpha)P_t^{M1-\eta} + \alpha P_t^{*1-\eta}\right]^{\frac{1}{1-\eta}}.$$

The CPI for the foreign regions $-M$ are defined in the same way.

The introduction of roundabout production within regions of the currency union implies that we need to keep track of multiple terms of trade and real exchange rates. Define the home-state terms of trade (for a foreign import) as

$$S_t = \frac{P_t^*}{P_{H,t}},$$

the home-state terms of trade (for a region-wide import) as

$$S_t^M = \frac{P_t^M}{P_{H,t}},$$

the union-wide real exchange rate as

$$\mathcal{Q}_t = \frac{P_t^*}{P_t},$$

and the real exchange rate with the region in which the home-state is located:

$$Q_t^M = \frac{P_{M,t}}{P_t}$$

Useful Steady State Ratios   In the symmetric, no inflation steady state, we have for the typical firm in state j :

$$\tilde{\theta} = \frac{P^* M(j)}{P^* \tilde{Y}(j)}$$

Integrating over all home-state firms, we get:

$$\tilde{\theta}(Y + X^M) = \tilde{X}$$

where $\tilde{X}$ is the home-state demand for intermediates and X^M is home-production of intermediates. In the symmetric steady state, the home price is the same as the price in the rest of the region. Thus, we have that the ratio of final value added produced to gross production in the home (and typical) state is as in the closed economy case:

$$\frac{Y}{\tilde{Y}} = (1 - \tilde{\theta})$$

And similarly

$$\frac{\tilde{X}}{\tilde{Y}} = \tilde{\theta}$$

Exchange Rates   Note:

$$P_t = ((1 - \alpha)P_{H,t}^{1-\eta} + \alpha P_t^{*1-\eta})^{\frac{1}{1-\eta}}$$

Around steady state:

$$\check{p}_t = (1 - \alpha)\check{p}_{H,t} + \alpha \check{p}_t^* \implies \check{p}_t^* - \check{p}_t = (1 - \alpha)(\check{p}_t^* - \check{p}_{H,t})$$

So that

$$\check{q}_t = (1 - \alpha)\check{s}_t$$

We can also decompose the currency wide price index

$$\check{p}_t^* = \mu\check{p}_t^M + (1 - \mu)\check{p}_t^{-M}$$

Market Clearing Condition   As a matter of accounting, total consumption of home-state produced goods is given by:

$$\tilde{C}_t = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}C_t + \alpha\left[\mu\left(\frac{P_t^*}{P_{M,t}}\right)^{-\eta}\left(\frac{P_{H,t}}{P_t^*}\right)^{-\gamma}C_t^M + (1-\mu)\left(\frac{P_t^*}{P_{-M,t}}\right)^{-\eta}\left(\frac{P_{H,t}}{P_t^*}\right)^{-\gamma}C_t^{-M}\right].$$

Log-linearizing this market-clearing condition for total consumption of home produced goods, we get

$$\tilde{c}_t = (1 - \alpha)(c_t + \alpha\eta(1 - \mathcal{G})\check{s}_t) + \alpha\gamma(1 - \mathcal{G})\check{s}_t$$
$$+ \alpha\eta(1 - \mathcal{G})(\mu(\check{p}_{M,t} - \check{p}_t^*) + (1 - \mu)(\check{p}_{-M,t} - \check{p}_t^*)) + \alpha(\mu c_t^M + (1 - \mu)c_t^{-M})$$

which implies, since $\mu\check{c}_t^M + (1 - \mu)\check{c}_t^{-M} = \check{c}_t^*$ and $\check{p}_t^* = \mu\check{p}_t^M + (1 - \mu)\check{p}_t^{-M}$,

$$\tilde{c}_t = (1 - \alpha)c_t + \alpha((1 - \alpha)\eta + \gamma)(1 - \mathcal{G})\check{s}_t + \alpha c_t^*$$

Time differentiating:

$$\dot{\tilde{c}}_t = (1 - \alpha)\dot{c}_t + \alpha((1 - \alpha)\eta + \gamma)(1 - \mathcal{G})(\pi_t^* - \pi_{H,t}) + \alpha\dot{c}_t^*$$

Next, log-linearize the Backus-Smith condition:

$$\tilde{c}_t = \mu c_t^M + (1 - \mu)c_t^{-M} + \frac{1}{\sigma}(1 - \mathcal{G})(\check{p}_t^* - \check{p}_t) = c_t^* + \frac{1}{\sigma}(1 - \mathcal{G})(1 - \alpha)\check{s}_t$$

4

Time differentiating the Backus-Smith condition:

$$\dot{c}_t = \dot{c}_t^* + \frac{1}{\sigma}(1-\alpha)(1-\mathcal{G})(\pi_t^* - \pi_{H,t})$$

Solving for $(1-\mathcal{G})(\pi_t^* - \pi_{H,t})$ yields

$$(1-\mathcal{G})(\pi_t^* - \pi_{H,t}) = \frac{\sigma}{1-\alpha}\dot{c}_t - \frac{\sigma}{1-\alpha}\dot{c}_t^*$$

Plugging into the previous expression:

$$\ddot{c}_t = (1-\alpha)\dot{c}_t + \frac{\alpha((1-\alpha)\eta + \gamma)\sigma}{1-\alpha}\dot{c}_t - \frac{\alpha((1-\alpha)\eta + \gamma)\sigma}{1-\alpha}\dot{c}_t^* + \alpha\dot{c}_t^*$$

yielding

$$\ddot{c}_t = \dot{c}_t + \alpha\left[\frac{((1-\alpha)\eta + \gamma)\sigma}{1-\alpha} - 1\right](\dot{c}_t - \dot{c}_t^*)$$

Rearranging, we get the following:

$$\ddot{c}_t = \dot{c}_t + \alpha\left[\frac{(1-\alpha)\eta\sigma + \gamma\sigma - 1 + \alpha}{1-\alpha}\right](\dot{c}_t - \dot{c}_t^*)$$

which simplifies with $\omega \equiv \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$ to

$$\ddot{c}_t = \frac{1-\alpha + \alpha\omega}{1-\alpha}\dot{c}_t - \frac{\alpha\omega}{1-\alpha}\dot{c}_t^*$$

Plugging in the Euler equation then yields

$$\ddot{c}_t = \frac{1-\alpha + \alpha\omega}{1-\alpha}\frac{1-\mathcal{G}}{\sigma}(i_t^* - \pi_t - \rho) - \frac{\alpha\omega}{1-\alpha}\dot{c}_t^*$$

Observing that $\pi_t = (1-\alpha)\pi_{H,t} + \alpha\pi_t^*$:

$$\ddot{c}_t = \hat{\sigma}^{-1}\frac{1}{1-\alpha}((1-\alpha)i_t^* - (1-\alpha)\pi_{H,t} - (1-\alpha)\rho) + \hat{\sigma}^{-1}\frac{\alpha}{1-\alpha}(i_t^* - \pi_t^* - \rho) - \frac{\alpha\omega}{1-\alpha}\dot{c}_t^*$$

with $\hat{\sigma} \equiv \frac{\sigma}{(1-\alpha+\alpha\omega)(1-\mathcal{G})}$.

Simplifying, using the Euler equation for the currency union, we have

$$\dot{\tilde{c}}_t = \hat{\sigma}^{-1}(i_t^* - \pi_{H,t} - \rho) + \frac{\alpha(1-\alpha+\alpha\omega)}{1-\alpha}\dot{c}_t^* - \frac{\alpha\omega}{1-\alpha}\dot{c}_t^*$$

which further simplifies to

$$\dot{\tilde{c}}_t = \hat{\sigma}^{-1}(i_t^* - \pi_{H,t} - \rho) + \alpha\left[\frac{1-\alpha+\alpha\omega-\omega}{1-\alpha}\right]\dot{c}_t^*$$

and finally

$$\dot{\tilde{c}}_t = \hat{\sigma}^{-1}(i_t^* - \pi_{H,t} - \rho) - \alpha(\omega-1)\dot{c}_t^*$$

which is equation (6) in Farhi and Werning (2016).

Relating Consumption of Home Produced Goods, Union Consumption, and Terms of Trade Recalling the market clearing condition for consumption of home-produced goods:

$$\tilde{c}_t = (1-\alpha)c_t + \alpha((1-\alpha)\eta + \gamma)(1-\mathcal{G})\check{s}_t + \alpha c_t^*$$

Plug in for home consumption deviations with the Backus-Smith condition $c_t = c_t^* + \frac{1-\mathcal{G}}{\sigma}(1-\alpha)\check{s}_t$:

$$\tilde{c}_t = (1-\alpha)c_t^* + \frac{(1-\alpha)^2(1-\mathcal{G})}{\sigma}\check{s}_t + \alpha((1-\alpha)\eta + \gamma)(1-\mathcal{G})\check{s}_t + \alpha c_t^*$$

Simplifying:

$$\tilde{c}_t = c_t^* + (1-\mathcal{G})\frac{(1-\alpha)^2 + \alpha((1-\alpha)\eta + \gamma)\sigma}{\sigma}\check{s}_t$$

Observe that

$$(1-\alpha)^2 + \alpha((1-\alpha)\eta + \gamma)\sigma = (1-\alpha)^2 + \alpha(1-\alpha)\eta\sigma + \alpha\gamma\sigma = (1-\alpha)(1-\alpha+\alpha\eta\sigma) + \alpha\gamma\sigma)$$

The RHS becomes $1 - \alpha + \alpha\omega$ with, as a reminder, $\omega \equiv \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$. Thus, using again the definition that $\hat{\sigma} \equiv \frac{\sigma}{(1-\mathcal{G})(1-\alpha+\alpha\omega)}$, we have $\tilde{c}_t = c_t^* + \hat{\sigma}^{-1}\check{s}_t$, implying

$$\check{s}_t = \hat{\sigma}\tilde{c}_t - \hat{\sigma}c_t^*$$

This additionally implies that

$$\check{s}_{M,t} = \hat{\sigma}\tilde{c}_t^M - \hat{\sigma}c_t^*$$

where $\check{s}_{M,t} \equiv \check{p}_t^* - \check{p}_t^M$.

Together, these two expressions further imply

$$\check{p}_t^M - \check{p}_t = \hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + \alpha\hat{\sigma}(c_t^* - \tilde{c}_t) \quad \text{and} \quad \check{p}_t^M - \check{p}_{H,t} = \hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M),$$

two expressions that ease the derivation of the NKPC.

Real Marginal Costs Real marginal costs for the firm deflated by home PPI, in log deviations,

$$MC_t \propto \frac{W_t^{1-\theta}P_t^{M\theta}P_t^{1-\theta}}{P_{H,t}P_t^{1-\theta}} \implies \check{mc}_t = (1-\theta)(\check{w}_t - \check{p}_t) + \theta(\check{p}_t^M - \check{p}_t) + \check{p}_t - \check{p}_{H,t}$$

simplifying slightly yields:

$$\check{mc}_t = (1-\theta)(\check{w}_t - \check{p}_t) + \theta(\check{p}_t^M - \check{p}_t) + \alpha\check{s}_t$$

Plugging in for $(\check{p}_t^M - \check{p}_t)$ and $\check{s}_t$ yields

$$\check{mc}_t = (1-\theta)(\check{w}_t - \check{p}_t) + \theta(\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + \alpha\hat{\sigma}(c_t^* - \tilde{c}_t)) + \alpha\hat{\sigma}(\tilde{c}_t - c_t^*)$$

Combining like terms yields:

$$\check{m}c_t = (1 - \theta)(\check{w}_t - \check{p}_t) + \theta\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + (1 - \theta)\alpha\hat{\sigma}(\tilde{c}_t - c_t^*)$$

Real Wage The household's intratemporal condition in the home state is unchanged:

$$\sigma\check{c}_t + \phi\check{n}_t = (\check{w}_t - \check{p}_t)$$

Log linearizing total labor demand:

$$\check{n}_t = \check{\tilde{y}}_t - \theta(\check{w}_t - \check{p}_t) + \theta(\check{p}_t^M - \check{p}_t)$$

which we get from adding and subtracting home CPI price-deviations. Plugging this into labor supply equation and solving for the real wage

$$\check{w}_t - \check{p}_t = \frac{\phi}{1 + \theta\phi}\check{\tilde{y}}_t + \frac{\sigma}{1 + \theta\phi}\check{c}_t + \frac{\theta\phi}{1 + \theta\phi}\left[\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + \alpha\hat{\sigma}(c_t^* - \tilde{c}_t)\right]$$

Substituting home consumption with union consumption from the Backus-Smith condition and substituting for $\check{s}_t$ yields

$$\check{w}_t - \check{p}_t = \frac{\phi}{1 + \theta\phi}\check{\tilde{y}}_t + \frac{\sigma}{1 + \theta\phi}\left(\frac{1}{1 - \mathcal{G}}c_t^* + \frac{1}{\sigma}(1 - \alpha)\hat{\sigma}(\tilde{c}_t - c_t^*)\right) + \frac{\theta\phi}{1 + \theta\phi}\left[\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + \alpha\hat{\sigma}(c_t^* - \tilde{c}_t)\right]$$

Combining like terms:

$$\check{w}_t - \check{p}_t = \frac{\phi}{1 + \theta\phi}\check{\tilde{y}}_t + \frac{\frac{\sigma}{(1 - \mathcal{G})}}{1 + \theta\phi}c_t^*$$
$$+ \left(\frac{(1 - \alpha)\hat{\sigma}}{1 + \theta\phi} - \frac{\theta\phi\alpha\hat{\sigma}}{1 + \theta\phi}\right)(\tilde{c}_t - c_t^*)$$
$$+ \frac{\theta\phi\hat{\sigma}}{1 + \theta\phi}(\tilde{c}_t - \tilde{c}_t^M)$$

which can be simplified further to

$$\check{w}_t - \check{p}_t = \frac{\phi}{1 + \theta\phi}\check{\check{y}}_t + \frac{\frac{\sigma}{(1-\mathcal{G})}}{1 + \theta\phi}c_t^*$$
$$+ \left(\frac{\hat{\sigma}}{1 + \theta\phi} - \alpha\hat{\sigma}\right)(\tilde{c}_t - c_t^*)$$
$$+ \frac{\theta\phi\hat{\sigma}}{1 + \theta\phi}(\tilde{c}_t - \tilde{c}_t^M)$$

Region-Wide Intermediates in Terms of Region Consumption and Union Government Spending Next, log-linearize the market clearing condition for gross output $(\tilde{Y}_t^M = C_t^M + G_t^M + X_t^M)$:

$$\check{\check{y}}_t^M = (1 - \tilde{\theta})\check{y}_t^M + \tilde{\theta}\check{x}_t^M$$

Note that $\frac{P_t^M X_t^M}{P_t^M \tilde{Y}_t^M} = \theta MC_t^M \Delta_t^M$, where Δ_t^M is a measure of region-wide price dispersion which is approximately zero in log-deviations. This implies that $\check{x}_t^M = \check{\check{y}}_t^M + \check{mc}_t^M$, further implying that $\check{\check{y}}_t^M = \check{y}_t^M + \frac{\tilde{\theta}}{1-\tilde{\theta}}\check{mc}_t^M$. Implying that deviations in region-wide intermediates depends upon final consumption of region-wide goods adjusted by changes in region-wide marginal costs:

$$\check{x}_t^M = \tilde{c}_t^M + g_t^M + \frac{1}{1 - \tilde{\theta}}\check{mc}_t^M$$

Simplifying Marginal Costs Gross production of home-produced goods is (see Steady State Section)

$$\check{\check{y}}_t = (1 - \tilde{\theta})\check{y}_t + \tilde{\theta}\check{x}_t$$

which, after plugging in for deviations in intermediates production, becomes

$$\check{\check{y}}_t = (1 - \tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left[\tilde{c}_t^M + g_t^M + \frac{1}{1 - \tilde{\theta}}\check{mc}_t^M + \gamma(\check{p}_t^M - \check{p}_{H,t})\right]$$

Plugging in for $(\check{p}_t^M - \check{p}_{H,t}) = \hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)$, we have:

$$\check{\check{y}}_t = (1 - \tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left[\tilde{c}_t^M + g_t^M + \frac{1}{1 - \tilde{\theta}}\check{mc}_t^M + \gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)\right]$$

9

Plugging this into the real wage equation:

$$
\begin{aligned}
\check{w}_t - \check{p}_t &= \frac{\phi}{1+\theta\phi}\left[(1-\tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left[\tilde{c}_t^M + g_t^M + \frac{1}{1-\tilde{\theta}}\check{m}c_t^M + \gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)\right]\right] \\
&+ \frac{\frac{\sigma}{(1-\mathcal{G})}}{1+\theta\phi}c_t^* \\
&+ \left(\frac{\hat{\sigma}}{1+\theta\phi} - \alpha\hat{\sigma}\right)(\tilde{c}_t - c_t^*) \\
&+ \frac{\theta\phi\hat{\sigma}}{1+\theta\phi}(\tilde{c}_t - \tilde{c}_t^M)
\end{aligned}
$$

Real Marginal Costs and Real Wage in Terms of Consumption of Home Produced, Home-Region Produced, and Union Wide Consumption   Recall the definition for real marginal costs:

$$
\check{m}c_t = (1-\theta)(\check{w}_t - \check{p}_t) + \theta\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) + (1-\theta)\alpha\hat{\sigma}(\tilde{c}_t - c_t^*)
$$

Together with the real wage expression, this implies

$$
\begin{aligned}
\frac{\check{m}c_t}{1-\theta} &= \frac{\phi}{1+\theta\phi}\left[(1-\tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left[\tilde{c}_t^M + g_t^M + \frac{1}{1-\tilde{\theta}}\check{m}c_t^M + \gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)\right]\right] \\
&+ \frac{\frac{\sigma}{(1-\mathcal{G})}}{1+\theta\phi}c_t^* \\
&+ \left(\frac{\hat{\sigma}}{1+\theta\phi} - \alpha\hat{\sigma}\right)(\tilde{c}_t - c_t^*) \\
&+ \frac{\theta\phi\hat{\sigma}}{1+\theta\phi}(\tilde{c}_t - \tilde{c}_t^M) \\
&+ \frac{\theta}{1-\theta}\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) \\
&+ \alpha\hat{\sigma}(\tilde{c}_t - c_t^*)
\end{aligned}
$$

10

Simplifying a bit:

$$\frac{\check{m}c_t}{1-\theta} = \frac{\phi}{1+\theta\phi}\left[(1-\tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left[\tilde{c}_t^M + g_t^M + \gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)\right]\right]$$
$$+ \frac{\frac{\sigma}{(1-\mathcal{G})}}{1+\theta\phi}c_t^*$$
$$+ \left(\frac{\hat{\sigma}}{1+\theta\phi}\right)(\tilde{c}_t - c_t^*)$$
$$\left[\frac{\theta\phi\hat{\sigma}}{1+\theta\phi} + \frac{\theta}{1-\theta}\hat{\sigma}\right](\tilde{c}_t - \tilde{c}_t^M)$$
$$+ \frac{\tilde{\theta}\phi}{(1+\theta\phi)(1-\tilde{\theta})}\check{m}c_t^M$$

Combining like terms:

$$\frac{\check{m}c_t}{1-\theta} = \left[\frac{\phi(1-\tilde{\theta}) + \phi\tilde{\theta}\gamma\hat{\sigma}}{1+\theta\phi} + \hat{\sigma} + \frac{\theta}{1-\theta}\hat{\sigma}\right]\tilde{c}_t$$
$$+ \frac{(1-\tilde{\theta})\phi}{1+\theta\phi}g_t$$
$$+ \frac{\tilde{\theta}\phi}{1+\theta\phi}g_t^M$$
$$+ \left[\frac{\frac{\sigma}{(1-\mathcal{G})} - \hat{\sigma}}{1+\theta\phi}\right]c_t^*$$
$$+ \left[\frac{\tilde{\theta}\phi - \tilde{\theta}\phi\gamma\hat{\sigma} - \theta\phi\hat{\sigma}}{1+\theta\phi} - \frac{\theta}{1-\theta}\hat{\sigma}\right]\tilde{c}_t^M$$
$$+ \frac{\tilde{\theta}\phi}{(1+\theta\phi)(1-\tilde{\theta})}\check{m}c_t^M$$

We now need to solve for region-wide marginal costs, $\check{m}c_t^M$. At the region-level we replace state-level variables with their region-level counterparts (i.e. $\tilde{c}_t = \tilde{c}_t^M$). Some terms cancel

11

out so that we are left with

$$\frac{\check{m}c_t^M}{1-\theta} = \frac{\phi + \hat\sigma}{1+\theta\phi}\tilde{c}_t^M$$
$$+ \frac{\phi}{1+\theta\phi}g_t^M$$
$$+ \left[\frac{\frac{\sigma}{(1-\mathcal{G})} - \hat\sigma}{1+\theta\phi}\right]c_t^*$$
$$+ \frac{\tilde\theta\phi}{(1+\theta\phi)(1-\tilde\theta)}\check{m}c_t^M$$

Next, we solve for marginal costs as a function of consumption of region-produced goods, union-wide consumption and the forcing variable of region-wide government spending:

$$\check{m}c_t^M = \left[1 - \frac{(1-\theta)\tilde\theta\phi}{(1+\theta\phi)(1-\tilde\theta)}\right]^{-1} \frac{1-\theta}{1+\theta\phi}\left[(\phi+\hat\sigma)\tilde{c}_t^M + \phi g_t^M + \left(\frac{\sigma}{1-\mathcal{G}} - \hat\sigma\right)c_t^*\right]$$

Which implies that

$$\check{m}c_t^M = \underbrace{\frac{(1-\tilde\theta)(1-\theta)}{(1+\theta\phi)(1-\tilde\theta) - (1-\theta)\tilde\theta\phi}}_{\chi(\theta)}\left[(\phi+\hat\sigma)\tilde{c}_t^M + \phi g_t^M + \left(\frac{\sigma}{1-\mathcal{G}} - \hat\sigma\right)c_t^*\right],$$

where $\chi(\theta)$ is a function of θ, holding fixed other primitives in the model. It is straightforward to show that $\chi(\theta) < 1$.[44]

---

[44]Consider the denominator. Because $\theta > \tilde\theta$, we have $(1+\theta\phi)(1-\tilde\theta)-(1-\theta)\tilde\theta\phi > (1+\theta\phi)(1-\tilde\theta)-(1-\tilde\theta)\tilde\theta\phi = (1-\tilde\theta)(1+\theta\phi-\tilde\theta\phi) = (1-\tilde\theta)(1+\phi(\theta-\tilde\theta)) > (1-\tilde\theta)$. Thus, the ratio is less than 1.

Plugging this back into the expression for state-level marginal costs, yields:

$$
\begin{aligned}
\frac{\widecheck{mc}_t}{1-\theta} =& \left[\frac{\phi(1-\tilde{\theta}) + \phi\tilde{\theta}\gamma\hat{\sigma}}{1+\theta\phi} + \hat{\sigma} + \frac{\theta}{1-\theta}\hat{\sigma} \right] \tilde{c}_t \\
&+ \frac{(1-\tilde{\theta})\phi}{1+\theta\phi} g_t \\
&+ \left[\frac{\tilde{\theta}\phi}{1+\theta\phi} + + \frac{\tilde{\theta}\phi\chi(\theta)}{(1+\theta\phi)(1-\tilde{\theta})}\phi \right] g_t^M \\
&+ \left[\frac{\frac{\sigma}{(1-\mathcal{G})} - \hat{\sigma}}{1+\theta\phi} + \frac{\tilde{\theta}\phi\chi(\theta)}{(1+\theta\phi)(1-\tilde{\theta})} \left(\frac{\sigma}{1-\mathcal{G}} - \hat{\sigma} \right) \right] c_t^* \\
&+ \left[\frac{\tilde{\theta}\phi - \tilde{\theta}\phi\gamma\hat{\sigma} - \theta\phi\hat{\sigma}}{1+\theta\phi} - \frac{\theta}{1-\theta} + \frac{\tilde{\theta}\phi\chi(\theta)}{(1+\theta\phi)(1-\tilde{\theta})}(\phi+\hat{\sigma}) \right] \tilde{c}_t^M
\end{aligned}
$$

Define the coefficients pre-multiplying consumption of home produced goods, government spending in the home state, government spending in the home region, union-wide consumption, and consumption in the home region as $\{\beta_{\tilde{c}}, \beta_g, \beta_{g^M}, \beta_{c^*}, \beta_{c^M}\}$. Combining with the log-linearized firm's problem yields the state NKPC.

A.2 Definitions of Instantaneous Multiplier Coefficients

In this subsection I define the instantaneous multiplier coefficients that appear in Section I for both the state-level and region-level dynamic systems. To ease exposition, I restate the dynamic systems for both.

Because the instantaneous multiplier coefficients at the state-level depend upon the consumption response at the region-level, I first define the region-level instantaneous multiplier coefficients before turning to the state-level system.

A.2.1 Region Multiplier Coefficients

The system of differential equations characterizing the path of consumption of home region produced goods and PPI in the home region is

$$\dot{\tilde{c}}_t^M = \hat{\sigma}^{-1}(i_t^* - \pi_{H,t} - \rho) - \alpha(\omega - 1)\dot{c}_t^* \tag{16}$$

$$\dot{\pi}_t^M = \rho\pi_t^M - \rho_\delta(\rho_\delta + \rho)\chi(\theta)\left[(\hat{\sigma} + \phi)\tilde{c}_t^M + \phi g_t^M + \hat{\sigma}\alpha(\omega - 1)c_t^*\right]. \tag{17}$$

As in the main body of the text, I let $\mu \to 0$. Thus, coupled with the initial condition that $\tilde{c}_0^M = c_0^* = 0$, the path of region-wide consumption in response to region-wide government spending is, again, given by

$$\tilde{c}_t^M = \int_{-t}^{\infty} \alpha_s^{M,t} g_{t+s}^M ds. \tag{18}$$

To define $\{\alpha_s^{M,t}\}$, it is helpful to first calculate the eigenvalues of the region-wide system:

$$\nu^M = \frac{\rho - \sqrt{\rho^2 + 4\kappa_M \hat{\sigma}^{-1}}}{2}$$

$$\bar{\nu}^M = \frac{\rho + \sqrt{\rho^2 + 4\kappa_M \hat{\sigma}^{-1}}}{2},$$

where $\kappa_M \equiv \rho_\delta(\rho_\delta + \rho)\chi(\theta)(\hat{\sigma} + \phi)$

Then, because the region-wide system is isomorphic to the model presented in Farhi and Werning (2016), we have:

$$\alpha_s^{M,t} = \begin{cases} -\hat{\sigma}^{-1}\kappa_M \frac{\phi}{\hat{\sigma}+\phi} e^{-\nu^M s} \frac{1-e^{(\nu^M - \bar{\nu}^M)(t+s)}}{\bar{\nu}^M - \nu^M} & s < 0, \\ -\hat{\sigma}^{-1}\kappa_M \frac{\phi}{\hat{\sigma}+\phi} e^{-\nu^M s} \frac{1-e^{-(\bar{\nu}^M - \nu^M)t}}{\bar{\nu}^M - \nu^M} & s \geq 0. \end{cases} \tag{19}$$

A.2.2 State Multiplier Coefficients

The system of differential equations characterizing the path of consumption of home produced goods and home PPI in the home state is

$$\dot{\tilde{c}}_t = \hat{\sigma}^{-1}(i_t^* - \pi_{H,t} - \rho) - \alpha(\omega - 1)\dot{c}_t^* \tag{20}$$

14

$$\dot{\pi}_{H,t} = \rho \pi_{H,t} - \rho_\delta (\rho_\delta + \rho)(1 - \theta) \left[\beta_{\tilde{c}} \tilde{c}_t + \beta_g g_t + \beta_{g^M} g_t^M + \beta_{c^*} c_t^* + \beta_{c^M} \tilde{c}_t^M \right]. \tag{21}$$

Coupled with the initial condition that $\tilde{c}_0 = c_0^* = 0$, the path of consumption in response to a particular path of state-level government spending, $\{g_t\}$, and region-wide government spending, $\{g_t^M\}$, is, again, given by

$$\tilde{c}_t = \int_{-t}^{\infty} \alpha_s^{d,t} g_{t+s} ds + \int_{-t}^{\infty} \alpha_s^{s,t} g_{t+s}^M ds + \int_{-t}^{\infty} \alpha_k^{c,t} \int_{-t}^{\infty} \alpha_s^{M,t} g_{t+s}^M ds dk, \tag{22}$$

with $\{\alpha_s^{M,t}\}$ defined above.

The coefficients $\{\alpha_s^{d,t}, \alpha_s^{s,t}, \alpha_k^{c,t}\}$ rely upon the eigenvalues of the system:

$$\nu = \frac{\rho - \sqrt{\rho^2 + 4\kappa \hat{\sigma}^{-1}}}{2}$$

$$\bar{\nu} = \frac{\rho + \sqrt{\rho^2 + 4\kappa \hat{\sigma}^{-1}}}{2},$$

where $\kappa \equiv \rho_\delta (\rho_\delta + \rho)(1 - \theta)\beta_{\tilde{c}}$.[45]

To determine the coefficients $\{\alpha_s^{d,t}, \alpha_s^{s,t}, \alpha_k^{c,t}\}$ it is helpful to define the function

$$f(\beta) = \begin{cases} -\hat{\sigma}^{-1} \kappa \frac{\beta}{\beta_{\tilde{c}}} e^{-\nu^M s} \frac{1 - e^{(\nu - \bar{\nu})(t+s)}}{\bar{\nu} - \nu} & s < 0, \\ -\hat{\sigma}^{-1} \kappa \frac{\beta}{\beta_{\tilde{c}}} e^{-\nu s} \frac{1 - e^{-(\bar{\nu} - \nu)t}}{\bar{\nu} - \nu} & s \geq 0. \end{cases} \tag{23}$$

Then, we have

$$\alpha_s^{d,t} = f(\beta_g)$$

$$\alpha_s^{s,t} = f(\beta_{g^M})$$

$$\alpha_s^{c,t} = f(\beta_{c^M}).$$

---

[45] Observe that when $\theta = 0$ that $\kappa_M = \kappa$.

15

A.2.3 Proof of Proposition 1

Proposition 2. *If $g_t = \kappa_g g_t^M$ for all $t \geq 0$ and $|\kappa_g| > 0$, then*

$$\mathcal{M}_{c,g} + \mathcal{M}_{c,g^M} = \mathcal{M}_{c^M,g^M}$$

Proof.

$$
\begin{aligned}
\mathcal{M}_{c,g} + \mathcal{M}_{c,g^M} &= \frac{\int_0^\infty \tilde{c}_s ds}{\int_0^\infty g_s ds} + \frac{\int_0^\infty \tilde{c}_s ds}{\int_0^\infty g_s^M ds} \\
&= \frac{\kappa_g \int_0^\infty \int_{-s}^\infty \alpha_u^{d,s} g_{s+u}^M du\, ds}{\kappa_g \int_0^\infty g_s^M ds} + \frac{\int_0^\infty \tilde{c}_s ds}{\int_0^\infty g_s^M ds} \\
&= \frac{\int_0^\infty \left[\int_{-s}^\infty (\alpha_u^{d,s} + \alpha_u^{s,s}) g_{s+u}^M du + \int_{-s}^\infty \alpha_k^{c,s} \int_{-(s+k)}^\infty \alpha_u^{M,s+k} g_{s+k+u}^M du\, dk \right] ds}{\int_0^\infty g_s^M ds} \\
&= \frac{\int_0^\infty \tilde{c}_s^M ds}{\int_0^\infty g_s^M ds} = \mathcal{M}_{c^M,g^M}
\end{aligned}
$$

The first equality follows by definition. The second by assumption of proportionality and by definition of $\{\tilde{c}_t\}$. The third follows again by definition. The final equality follows by symmetry whenever the home state and the rest of the region have the same level of spending for all $t \geq 0$. □

A.3 Consumption Versus Value-Added Multipliers

To align the model with the notation used in Farhi and Werning (2016) I have opted to describe the dynamic system in terms of consumption of home state produced goods. However, given how state output measures are constructed, empirically I estimate local and spillover value-added relative multipliers.

This is without loss when adding together the local and spillover multipliers. To see this,

write out the PPI-deflated value-added (wage income and profits):

$$VA_t \equiv \tilde{Y}_t - \frac{P_t^M X_t}{P_{H,t}} = \tilde{Y}_t - \theta MC_t \tilde{Y}_t \Delta_t,$$

where Δ_t is a term reflecting dispersion in prices in the home-state.[46] In log-deviations, this is

$$\check{v}a_t = (1 - \tilde{\theta})(\tilde{c}_t + g_t) + \tilde{\theta}\left(c_t^M + g_t^M + \frac{1}{1 - \tilde{\theta}}\check{m}c_t^M + \gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M)\right) - \frac{\tilde{\theta}}{1 - \tilde{\theta}}\check{m}c_t, \quad (24)$$

where I've used the fact that $\check{x}_t^M = c_t^M + g_t^M + \frac{1}{1-\tilde{\theta}}mc_t^M$. Rearranging:

$$\check{v}a_t = (1 - \tilde{\theta})\tilde{c}_t + \tilde{\theta}c_t^M \qquad (25)$$

$$+ (1 - \tilde{\theta})g_t + \tilde{\theta}g_t^M \qquad (26)$$

$$+ \tilde{\theta}\gamma\hat{\sigma}(\tilde{c}_t - \tilde{c}_t^M) \qquad (27)$$

$$+ \frac{\tilde{\theta}}{1 - \tilde{\theta}}(\check{m}c_t^M - \check{m}c_t) \qquad (28)$$

Define

$$\mathcal{M}_{va,g} \equiv \frac{\int_0^\infty \check{v}a_s ds}{\int_0^\infty g_s ds} \quad \text{and} \quad \mathcal{M}_{va,g^M} \equiv \frac{\int_0^\infty \check{v}a_s ds}{\int_0^\infty g_s^M ds}$$

Thus, when the path of government spending is proportional in the home state and in the region in which the home state is located for all t, by symmetry we have $\mathcal{M}_{va,g} + M_{va,g^M} = 1 + \mathcal{M}_{c^M,g^M}$.

---

[46]This is a slight abuse of notation in that this term will be proportional to the term defined in the main-body of the paper, implying in log-deviations they are the same and equal to zero.

17

B   Variants of Main Tables

Table C.1: Benchmark One and Two Year Cumulative Exposure Multipliers of Recovery Act Spending on Gross State Product, Employment, and Unemployment (State-Clustered Standard Errors)

	Bivariate b/se	+ State FEs b/se	+ Quarter FEs b/se	+ Direct ARRA b/se	All Controls b/se
8-Qtr Ahead	2.01***	2.03***	2.80**	2.82**	2.12*
Spill. ARRA	(0.38)	(0.39)	(1.33)	(1.31)	(1.21)
8-Qtr Ahead				2.30**	1.46
ARRA				(1.09)	(1.04)
No. Obs.	1764	1764	1764	1764	1764
R-Squared	0.018	0.236	0.456	0.461	0.474
State FEs	No	Yes	Yes	Yes	Yes
Quarter FEs	No	No	Yes	Yes	Yes
Output Lags	No	No	No	No	Yes

- Tables report heteroskedasticity consistent standard errors, clustered by state.
- The spillover and direct measure of ARRA spending (over the subsequent 8 quarters) is set to zero in quarters prior to 2009Q2.
- The controls in column (5) represent the benchmark specification.
- On average, each \$1 of directly received ARRA aid is associated with \$0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the top line by 0.63.
- The estimate in the first column differs slightly from that reported in the first column of Table 1 because, without state fixed effects, the random effects GLS estimator is invoked.

Table C.2: Benchmark One and Two Year Cumulative Exposure Multipliers of Recovery Act Spending on Gross State Product, Employment, and Unemployment (State-Clustered Standard Errors)

	4-Quarter Effect			8-Quarter Effect		
	Output	Job-Years	Unemployed -Years	Output	Job-Years	Unemployed -Years
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead	0.97	2.79**	-5.40***			
Spill. ARRA	(0.59)	(1.29)	(0.95)			
4-Qtr Ahead	0.27	3.53**	-2.35*			
ARRA	(0.53)	(1.61)	(1.34)			
8-Qtr Ahead				2.12*	10.54***	-12.61***
Spill. ARRA				(1.21)	(3.62)	(2.24)
8-Qtr Ahead				1.46	10.56**	-6.14*
ARRA				(1.04)	(5.08)	(3.43)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.417	0.722	0.799	0.474	0.698	0.823
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report heteroskedasticity consistent standard errors, clustered by state.
- The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.
- On average, each \$1 of directly received ARRA aid is associated with \$0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the first and third lines by 0.63.

Table C.3: Benchmark One and Two Year Cumulative Exposure Multipliers of Recovery Act Spending (Less DOL) on Gross State Product, Employment, and Unemployment

	4-Quarter Effect			8-Quarter Effect		
	Output	Job-Years	Unemployed -Years	Output	Job-Years	Unemployed -Years
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead	1.16***	4.13***	-6.78***			
Spill. ARRA (Less DOL)	(0.16)	(0.96)	(1.19)			
4-Qtr Ahead	0.35*	3.95***	-2.07			
ARRA (Less DOL)	(0.17)	(0.91)	(1.46)			
8-Qtr Ahead				2.52***	13.80***	-15.27***
Spill. ARRA (Less DOL)				(0.31)	(2.10)	(2.64)
8-Qtr Ahead				1.52***	9.02**	-7.90***
ARRA (Less DOL)				(0.49)	(4.29)	(2.77)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.414	0.724	0.799	0.473	0.698	0.824
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (less DOL; over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.
- On average, each \$1 of directly received ARRA aid is associated with \$0.63 of import-weighted exposure. To convert to a spillover multiplier, multiply the coefficients in the first and third lines by 0.63.

C   Robustness Exercises

C.1   Outlier Assessment

In this subsection I assess whether my estimates are driven by any one state, which is a concern when analyzing outcomes at the state level. To do so, I sequentially select each state from the sample and re-estimate Equation (15) using the benchmark set of controls with gross state product as the outcome variable. Only one state is dropped at a time.

As an example, the benchmark two-year cumulative output spillover estimate is $2.12. When excluding Washington D.C. from the sample, the point estimate rises slightly to $2.36 (SE: 0.24).

Figure D.1: Outlier Analysis: Estimated 2-Year Cumulative Spillover Output Multiplier from Dropping Each State

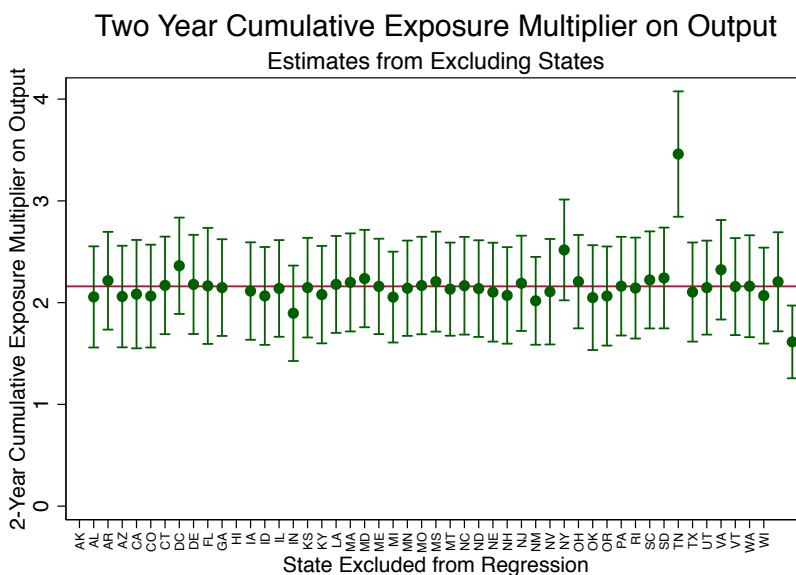

Figure D.1 reports the results from this exercise. The height of each bullet indicates the point estimate when excluding the given state from the sample. 90% confidence intervals are drawn around each bullet point.[47] The solid, red horizontal line indicates the benchmark

---

[47]Since Alaska and Hawaii are dropped from the analysis to begin with, there is no bullet point for these states.

point estimate of 2.12.

There are two takeaways from this exercise. First, in the vast majority of cases, dropping a state from the analysis does not matter: the point estimates cluster around the 2.12. Second, in only two cases does the point estimate change by more than one standard deviation relative to the benchmark: dropping Tennessee and Wyoming. When dropping Tennessee, the point estimate rises to 3.46 (SE: 0.31) but dropping Wyoming produces a point lower point estimate relative to the benchmark: 1.61 (SE: 0.18).

Multiplying by the scaling factor of 0.63 discussed above in Section III yields a range of estimates of the increase in output in all other states for every \$1 of Recovery Act aid dispersed to a particular state: between 1.01 and 2.17. Although there is a considerable range in the implied output effect, the finding that fiscal policy has quantitatively large spillover effects is not driven by the experience of any particular state.

To allay any further concerns of this nature, I repeat the state exclusion exercise as described above, except that instead of dropping only a single state I drop two states at once from the analysis. Figure D.2 provides the kernel density plot of the estimated coefficients. As expected, the vast majority of the estimates are close to the benchmark estimate of 2.12.

C.2   Including Own-Share in Weight Matrix

Motivated by the findings in Hillberry and Hummels (2003) that many shipments within state are between wholesalers and retailers, I do not include own-shipments in the calculation of the spillover exposure variable. The reason for this was to focus on a consistently defined measure of exposure to interventions in other states that are mediated by the trade in intermediate goods. However, by setting w_{ii} equal to zero I am implicitly forcing my estimates of the direct effect to include indirect own-state effects mediated through the trade channel studied above.

If the within-state effect is comparable to the cross-state effect, then including the own-share spillover in the construction of $ARRA_{i,t}^S$ should not alter my baseline findings. In

Figure D.2: Outlier Analysis: Estimated 2-Year Cumulative Spillover Output Multiplier from Dropping Combinations of Two States

Density Plot of Estimates from Dropping Two States
Two Year Cumulative Exposure Multiplier

kernel = epanechnikov, bandwidth = 0.0217
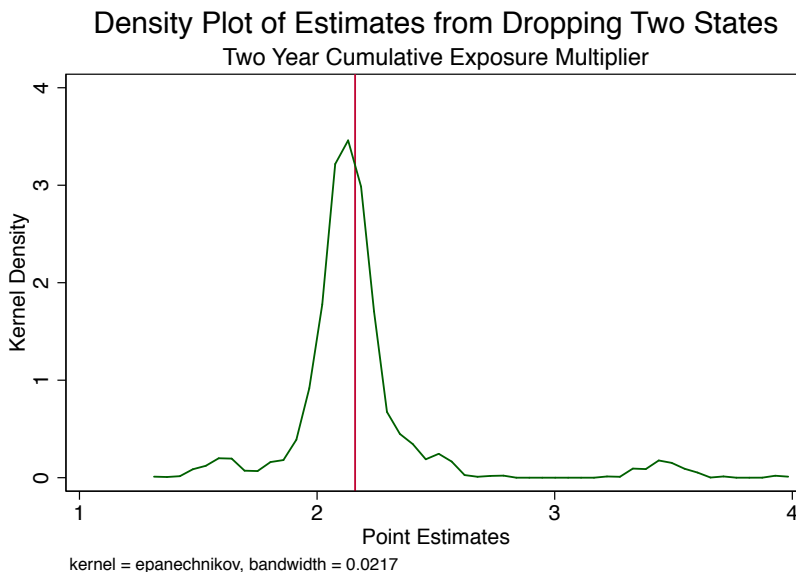
particular, in what follows I set w_{ii} equal to the share of reported within-state shipments among all reported inbound shipments from the CFS. I then include $w_{ii} \times ARRA_{i,t}^D$ in the construction of $ARRA_{i,t}^S$, as implied by (13).

The following table reports the cumulative 2-year exposure multiplier when the own-share spillover effect is included. Since every \$1 of direct ARRA is, in this analysis, associated with \$1 of spillover aid, there is no need to rescale the coefficients as I did above. Looking at column six of Table D.1, we see that, all else equal, every \$1 of direct aid led to \$1.94 (SE: 0.33) of increased output over two years. This is quantitatively similar to our benchmark (rescaled) finding of \$1.33. Under this specification, one cannot reject the null that \$1.33 is the true effect.

Perhaps unsurprisingly, the coefficient on directly allocated ARRA obligations falls from \$1.46 to \$1.07 (SE: 0.41), suggesting that the direct effect estimated in Table 2 in part captures the indirect, local effect mediated by trade within the state.

23

Table D.1: One and Two Year Cumulative Exposure Multiplier of Recovery Act Spending—
Self-Share Weight Included

	4-Quarter Effect			8-Quarter Effect		
	Output b/se	Job-Years b/se	Unemployed -Years b/se	Output b/se	Job-Years b/se	Unemployed -Years b/se
4-Qtr Ahead	0.86***	2.34***	-4.93***			
Spill. ARRA (Self-Share)	(0.16)	(0.41)	(1.10)			
4-Qtr Ahead	0.09	3.09***	-1.37			
ARRA	(0.29)	(0.65)	(1.60)			
8-Qtr Ahead				1.94***	8.76***	-12.74***
Spill. ARRA (Self-Share)				(0.33)	(1.36)	(2.40)
8-Qtr Ahead				1.07**	8.71***	-3.72
ARRA				(0.41)	(1.67)	(2.41)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.417	0.721	0.801	0.475	0.696	0.826
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

 - Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
 - The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.

C.3   Excess Cyclicality

In this subsection I assess the concern that states disproportionately exposed to spending elsewhere in the country through the trade in goods exhibit greater co-movement with the aggregate business cycle. States with business cycles that tend to co-move more strongly with the aggregate business cycle may have exhibited both a deeper decline in the early stages of the downturn relative to other states and a relatively stronger recovery in the years following the passage of the Recovery Act in exactly the pattern documented for the high and low spillover states described above in Section III. If this is indeed the case, then my benchmark estimates would be upwardly biased, tending to overstate the spillover effects of the Recovery Act.

In what follows, I present evidence that this concern has some legitimacy: those states that were disproportionately exposed to spending elsehwere in the country tend to have busi-

ness cycles that co-move more with the aggregate business cycle. However, when controlling for this co-movement directly in Equation (15), I find that my benchmark estimates are quantitatively unchanged, even though the co-movement regressor is significantly—statistically and quantitatively—correlated with accumulated changes in output, employment, and unemployment.

Using data from the BEA, I calculate annual real output growth rates for every state and the nation between 1977 and 2008. For each state, I then separately estimate the following regression:

$$\Delta ln(GSP_{i,t}) = \alpha_i + \psi_i \Delta ln(GDP_t) + \epsilon_{i,t} \tag{29}$$

States with larger estimates of $\hat{\psi}_i$ tend to load more heavily on the aggregate business cycle.

Figure D.3 below reports the scatter plot of $\{\hat{\psi}_i\}$ against $\frac{ARRA^S_{i,2011Q2}}{GSP_{2009Q1}}$, which is the cumulative value of import-weighted ARRA obligations to which a state was exposed between 2009Q2 and 2011Q2, relative to GSP in 2009Q1. As can be seen from this figure, there is an upward sloping relationship between state-level output cyclicality and a state's import-weighted ARRA exposure in 2009Q2.

This exercise suggests that the relatively faster recovery among states differentially exposed to spending elsewhere in the country might simply be attributable to the national economic recovery that began in the latter half of 2009. If the national economy would have recovered during this time for reasons unrelated to the Recovery Act, then my estimates of the spillover effects are biased upwards, if not spurious altogether.

To directly address the concern that my results are driven solely by differential loadings on the business cycle, I interact the K-quarter ahead cumulative change in aggregate real GDP with the estimated coefficient $\hat{\psi}_i$:

Figure D.3: Scatter Plot of Output Growth Volatility and Cumulative ARRA Exposure Over 2 Years Following Passage of Recovery Act
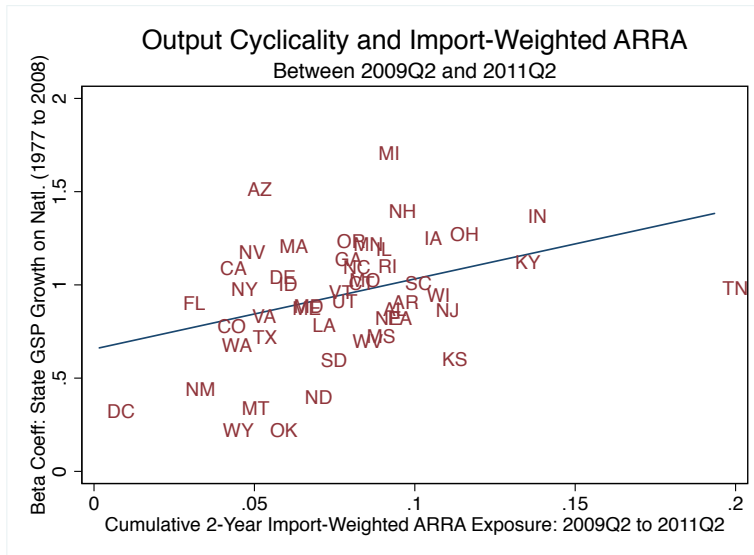
$$C_{i,t}^K \equiv \left(\frac{\sum_{h=0}^{K} GDP_{t+h} - GDP_{t-1}}{GDP_{t-1}} \right) \hat{\psi}_i$$

I then estimate Equation 15, including $C_{i,t}^K$ as an additional regressor for the output, employment, and unemployment specifications. For the output specifications, the estimated coefficient on $C_{i,t}^K$ should be close to one. If the accumulated change in output over K quarters is entirely attributable to movements in aggregate output, the coefficient of interest $\phi_K^{S,Y}$, the spillover exposure effect, should be close to and statistically indistinguishable from zero.

The results of this exercise are reported in Table D.2. As before, in the first three columns I report estimated cumulative effects on output, employment, and unemployment over one year; in the final three columns I report the estimated cumulative effects over two years.

There are two takeaways from this exercise. First, at both the one year and two year horizon, the estimates of the spillover exposure effect on output, employment, and unemployment are quantitatively similar to my benchmark results. For example, after controlling for excess cyclicality, the cumulative two-year output effect of being exposed to one additional

Table D.2: One and Two Year Cumulative Exposure Multiplier of Recovery Act Spending—Excess Cyclicality Interaction

	4-Quarter Effect			8-Quarter Effect		
	Output	Job-Years	Unemployed -Years	Output	Job-Years	Unemployed -Years
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead	0.88***	2.62***	-4.71***			
Spill. ARRA	(0.13)	(0.45)	(0.58)			
4-Qtr Ahead	0.24	3.43***	-2.05			
ARRA	(0.25)	(0.73)	(1.37)			
8-Qtr Ahead				1.71***	8.93***	-10.06***
Spill. ARRA				(0.32)	(1.20)	(1.38)
8-Qtr Ahead				1.44***	10.35***	-5.73***
ARRA				(0.43)	(2.20)	(2.05)
K-Qtr GDP	1.06***	2.79***	-4.34***	1.16***	5.31***	-5.18***
Interaction	(0.21)	(0.69)	(0.34)	(0.20)	(1.04)	(0.50)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.451	0.728	0.821	0.518	0.716	0.851
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.

dollar elsewhere in the country is \$1.71 (SE: 0.32) additional dollars of output. This is similar to and statistically indistinguishable from the benchmark estimate of \$2.12. Second, in both output specifications, the coefficient on $C_{i,t}^K$ is close to and statistically indistinguishable from the null value of one.

In sum, this subsection shows my estimates of the spillover effects of the Recovery Act are robust to controlling for each state's excess sensitivity to the aggregate business cycle. It is not the case that states highly exposed to spending elsewhere exhibited relatively faster recoveries simply because they tend to co-move more strongly with the aggregate economy, which began recovering in the latter half of 2009.

C.4 Export Weight Matrix

In this section I investigate whether there is evidence that the tradable spillovers of fiscal policy estimated above also propagate through an export channel in addition to an import channel. In particular, I construct a different measure of exposure to spending elsewhere in the country by using the transpose of $\mathbf{W}$ as the weight matrix. Specifically, I calculate

$$ARRA_t^{\tilde{S}} = \mathbf{W}' \times ARRA_t^D$$

Again, each state's exposure is a weighted sum of spending in all other states, now given by:

$$ARRA_{i,t}^{\tilde{S}} = \sum_{j \neq i} w_{j,i} ARRA_{j,t}^D$$

Recall that $w_{j,i}$ has the equivalent interpretation as the share of goods exported by state j to state i as as share of all goods imported by state i. Values close to one would indicate that exports from state j represent a large share of goods imported by state i.

Figure D.4 reports the impulse response of output estimated according to Equation (14), where the only change is replacing $ARRA_{i,t}^S$ variables with $ARRA_{i,t}^{\tilde{S}}$. At all horizons, an innovation to export-weighted exposure has no impact on relative output growth. As discussed in the introduction, this is consistent with the predictions of the stylized production network model presented in Acemoglu et al. (2016).

C.5 Weighting by Population

In this section, I estimate the benchmark cumulative specifications in equation (15), except that I weight by state population at the beginning of my sample to address concerns that my results are not nationally representative. Ignoring for a moment the common effects of the Recovery Act that effect all states symmetrically, if small states tend to have large local

---

[48]This concern is raised in Ramey (2019) when discussing the relation between local multiplier estimates and the aggregate multiplier that macroeconomists are interested in estimating.

Figure D.4: Placebo Test: Estimated IRF for Change in Gross State Product for every 1$ of Export-Weighted ARRA Spending
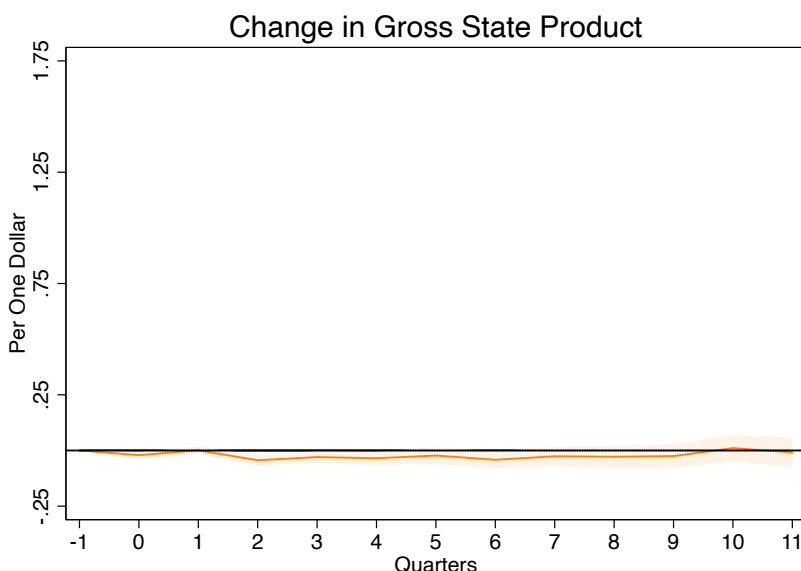
multiplier effects (either direct or spillover), the unweighted regression will tend to overstate the aggregate multiplier[48]

Table D.3 reports the results of this exercise. Focusing first on the fourth column, the two year cumulative output effect from an additional $1 of spillover exposure is $1.29 (SE: 0.28). This estimate is lower than the unweighted result in which the spillover exposure effect was an additional $2.12 over two years for each $1 of exposure. Larger states are thus less effected by spending elsewhere in the country through the trade in intermediate goods.

Supposing that the spillover exposure effect is monotonically declining in the size of the state, as measured by population, a lower bound on how much each $1 of local spending increased output elsewhere can be calculated using the scaling factor of 0.63. This lower bound is $0.81 (SE: 0.17).

While the spillover exposure effect is smaller for larger states, the estimated direct effect increases. Over two years, each $1 of local ARRA spending increased cumulative output by $2.50 (SE: 0.38). This result likely stems from the fact that larger states tend to source a larger share of their intermediate goods from within their own state. For example, the share

of goods reported as sourced by California in the CFS from other states is approximately 0.3 (see 2).

Moving to the final two columns, both the employment and the unemployment spillover exposure effects are smaller relative to the benchmark estimates in Table 2, in line with the results for output. As with output, the direct effect on output rises considerably such that the fall in unemployment over two years for each $1 million of Recovery Act aid was 18 unemployed years.

The employment estimate falls relative to the benchmark, which parallels the findings in Ramey (2019), where the local employment multiplier falls when weighting by population; however, the standard errors on the direct employment effect rise considerably, such that one is unable to reject a direct employment effect of 10 job-years created or saved for each $1 million of locally received ARRA aid.

Table D.3: One and Two Year Cumulative Exposure Multiplier of Recovery Act Spending—Weighted by Population at Beginning of Sample

| | 4-Quarter Effect | | | 8-Quarter Effect | | |
| | Output | Job-Years | Unemployed -Years | Output | Job-Years | Unemployed -Years |
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead	0.40***	2.82***	-4.70***			
Spill. ARRA	(0.14)	(0.70)	(0.97)			
4-Qtr Ahead	0.96***	2.10	-6.27***			
ARRA	(0.16)	(1.61)	(2.18)			
8-Qtr Ahead				1.29***	9.91***	-11.26***
Spill. ARRA				(0.28)	(1.76)	(2.10)
8-Qtr Ahead				2.50***	5.40	-18.13***
ARRA				(0.38)	(5.35)	(4.16)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.545	0.773	0.845	0.604	0.760	0.872
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.

C.6 Leontief Inverse Specification

In my benchmark specification I only incorporate the first order connection between states as implied by trade flows reported in the CFS between U.S. states. A natural question to ask is whether my results differ when explicitly incorporating higher order linkages between states that arise as the fiscal shock propagates upstream from states directly receiving fiscal stimulus to their upstream trading partners, to their upstream trading partners, and so on.

Let θ be the cost-share of intermediates in firm production with elements in $\mathbf{W}$ representing the share of intermediate goods sourced by state j from state i. Moroever, suppose that labor is the only other factor of production, with cost-share $(1 - \theta)$. Under Cobb-Douglas production, with prices held fixed, and the wage as the numeraire, each additional nominal unit of output produced requires employing $(1 - \theta)$ labor locally and purchasing θ nominal units of intermediate goods, split across regions according to the elements in $\mathbf{W}$.

If the effect on final, state-level output is proportional to local labor employed, both to satisfy direct government demand and to meet indirect government demand through the trade in intermediate goods, then this change in output, in partial equilibrium, may be written as

$$
\begin{aligned}
dy_t &= \tilde{\beta}_d(1-\theta)dg_t + \tilde{\beta}_N \left[(1-\theta)\theta W + (1-\theta)\theta^2 W^2 + \dots \right] dg_t \\
&= \tilde{\beta}_d(1-\theta)dg_t + \tilde{\beta}_N(1-\theta)\theta W[I - \theta W]^{-1}dg_t \\
&= \beta_d dg_t + \beta_N \theta W[I - \theta W]^{-1}dg_t
\end{aligned} \tag{30}
$$

where $\tilde{\beta}_d$ represents the direct effect of higher labor demand that is required to furnish the government with the goods and services it has purchased and $\tilde{\beta}_N$ represents the indirect effect of increased labor demand originating through the regional production network. In the final equation I absorb the $(1 - \theta)$ terms into the coefficients β_d and β_N to simplify the interpretation. They represent, respectively, the direct change in output arising from

increasing government demand for locally produced goods and the indirect change in output arising from increasing government demand for goods elsewhere in the country.[49]

I estimate the empirical analog to Equation (30) by first calculating the matrix $\mathbf{W}_L \equiv \theta \mathbf{W}[I - \theta \mathbf{W}]^{-1}$. I set $\theta = 0.44$ to be consistent with the share of intermediate inputs relative to gross production in the years prior to the Great Recession. Then, I construct a new spillover exposure measure

$$ARRA_{i,t}^{S,L} \equiv \mathbf{W}_L \times ARRA_t$$

and re-estimate Equation (15), replacing $ARRA_{i,t+h}^S$ with $ARRA_{i,t+h}^{S,L}$. The results of this exercise are reported in Table D.4.

At both the one and two year horizon, for both the direct and indirect effects of Recovery Act aid, the cumulative effect on output, employment, and unemployment is quantitatively similar to the benchmark results reported in Table 2. Focusing on the two year cumulative effect on output, each \$1 of directly received aid over a two year period is estimated to increase output by \$1.32 (SE: 0.42). For comparison, the comparable estimate in Table 2 is 1.46 (SE: 0.43).

Turning to the spillover effects, I find that each additional \$1 of exposure to spending elsewhere in the country, as implied by $\mathbf{W}_L$, increased output by \$2.15 (SE: 0.34). For comparison, the benchmark spillover estimate is \$2.12 (SE: 0.25). This suggests that the higher order linkages, and in turn spillover exposure, between states are well-approximated by using only the first order linkages as implied by $\mathbf{W}$.

Since this exercise uses a different weighting matrix than in the baseline specification, one needs to again rescale the point estimate on the spillover exposure variable. The column sums of $\mathbf{W}_L$ are all essentially equal to 0.785. Thus, by construction each one dollar of directly received Recovery Act aid is associated with 0.785 dollars of spillover exposure.

---

[49] A Long and Plosser (1983) style production network would be one way to rationalize Equation 30. See, for example, Proposition 1 in Acemoglu et al. (2016) (and equation (A10)), where there is an additional "resource constraint" effect of government spending which leaves fewer resources for households to consume (today or in the future) through taxation needed to finance spending.

Multiplying the spillover output effect by 0.785, one would conclude that each \$1 of ARRA aid received over two years increased output elsewhere in the country over two years by \$1.68 (SE: 0.26), a point estimate somewhat elevated relative to my baseline findings but otherwise quantitatively similar. Performing a similar exercise with the labor market variables, using $\mathbf{W}_L$ to construct the spillover exposure variable I find that over two years each one million dollars of direct Recovery Act aid increased employment elsewhere by 7.63 (SE: 1.03) job-years and lowered unemployment by 10.69 (SE: 1.95) unemployed years.

Combining both the direct and the indirect effects, each \$1 of Recovery Act aid over two years increased cumulative output by \$3 (SE: 0.56) over two years. Absent other offsetting forces, the aggregate fiscal multiplier is again estimated as having a rough lower bound of approximately 3.

Table D.4: One and Two Year Cumulative Exposure Multiplier of Recovery Act Spending— Weighted by Population at Beginning of Sample

| | 4-Quarter Effect | | | 8-Quarter Effect | | |
| | Output | Job-Years | Unemployed -Years | Output | Job-Years | Unemployed -Years |
	b/se	b/se	b/se	b/se	b/se	b/se
4-Qtr Ahead Spill. ARRA	0.92***	2.50***	-5.25***			
	(0.17)	(0.40)	(1.13)			
4-Qtr Ahead ARRA	0.21	3.40***	-1.99			
	(0.28)	(0.67)	(1.65)			
8-Qtr Ahead Spill. ARRA				2.15***	9.73***	-13.62***
				(0.34)	(1.31)	(2.48)
8-Qtr Ahead ARRA				1.32***	9.82***	-5.32**
				(0.42)	(1.79)	(2.47)
No. Obs.	1764	1764	1764	1764	1764	1764
R-Squared	0.418	0.722	0.800	0.475	0.696	0.826
State FEs	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FEs	Yes	Yes	Yes	Yes	Yes	Yes
Lagged Variables	Yes	Yes	Yes	Yes	Yes	Yes

- Tables report Driscoll and Kraay (1998) standard errors, which are robust to general forms of spatial and temporal dependence.
- The spillover and direct measure of ARRA spending (over the subsequent 4 and 8 quarters) is set to zero in quarters prior to 2009Q2.

C.7 Event Study Specification

In this subsection I investigate the identifying assumption that the spatial distribution of spillover ARRA funding was orthogonal to potential growth in the quarters following the passage of the act. To do so, I restrict my use of the data in the following way. First, I assume that at the passage of the act (2009Q1) the eventual distribution of ARRA funding to the states was known by all agents in the economy—households, firms, etc. In this sense, the spillover exposure each state experienced, as a result of their trade with the rest of the country, occurred in a single period, the quarter of the passage of the act.

This restriction implies that the effects I estimate exploit *only* the cross-sectional variation in exposure. Indeed, it would be inappropriate to use the temporal variation in the spillover treatment if households and firms knew at the passage of the act how the future ARRA spending in the rest of the country would affect them and adjusted their behavior in response.[50] By collapsing the spillover exposure to a single date, I am able to investigate how economic conditions varied in the quarters prior to and following the passage of the act.

First, I estimate an analog to an event-study specification:

$$\frac{GSP_{i,t} - GSP_{i,t-1}}{GSP_{i,t-1}} = \sum_{s=-12}^{12} \chi_s \mathbf{1}(t = 2009Q2 + s) \frac{ARRA_i^S}{GSP_{i,t-1}} + \theta_i + \eta_t + \epsilon_{i,t}$$

This specification includes time fixed effects, η_t, as well as state fixed effects, θ_i. $ARRA_i^S$ does not have a time t subscript because it represents the cumulative value of ARRA spending to which a state was exposed according to the weight matrix $\mathbf{W}$ constructed from the CFS.

It is useful to point out two key differences between this specification and standard event-study designs: First, an event-study analysis is typically used in scenarios in which different observational units have different unit-specific event times. In this specification, I assume

---

[50]Ramey (2011) presents evidence that incorrectly measuring the news shock of future government spending shocks matters for correctly estimating the consumption effects of fiscal policy and, in turn, the overall multiplier.

34

the event-time is the same for every state: 2009Q2. In this sense, the interaction coefficients, $\{\chi_s\}$, provide estimates of the correlation between output growth and spillover exposure in the quarters prior to and following 2009Q2.

The second obvious difference between the standard event-study specification and what I consider here is that the "treatment" variable, $\frac{ARRA_i^S}{GSP_{i,t-1}}$, is a continuous measure of treatment. Unlike standard event-studies, this specification imposes parametric restrictions on the interaction terms—namely, linearity.

The results of this exercise are provided in Figure D.5. Here I have accumulated the coefficients, χ_s, around 2009Q1 to convert the results to level differences. For example, the coefficient at 2010Q1 is equal to 0.25, which indicates that each additional \$1 of spillover ARRA exposure was associated with \$0.25 additional output in the first quarter of 2010, relative to the level of its output in the first quarter in 2009. The shaded areas indicate 90% confidence intervals using Driscoll and Kraay (1998) standard errors. For comparison, I have also included 90% confidence intervals using cluster-robust standard errors.
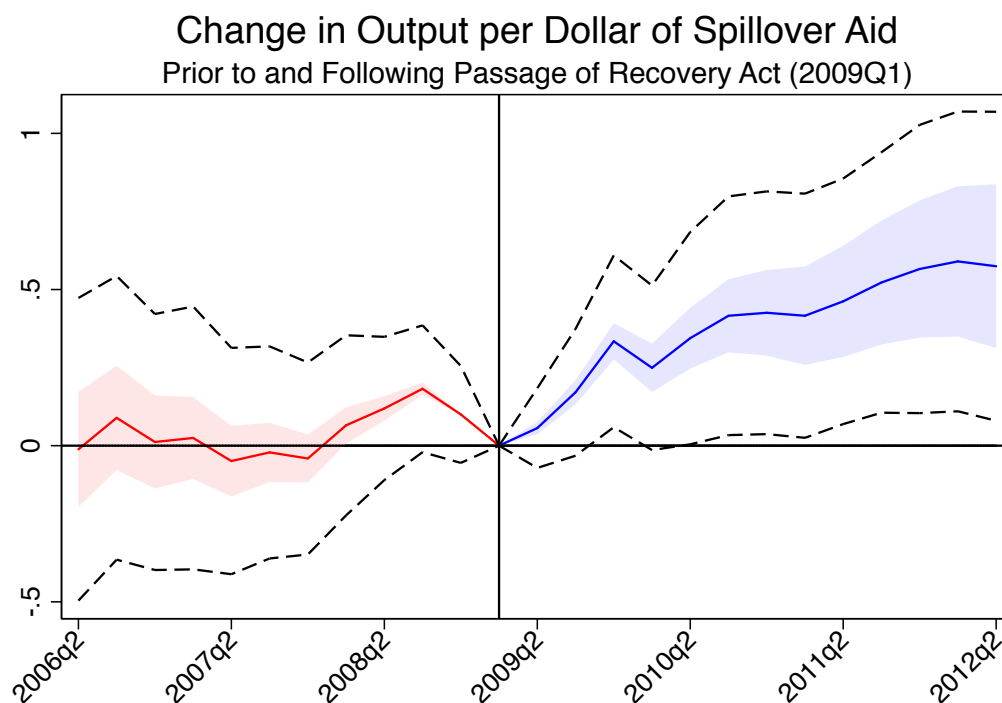
There are three observations to make about this plot: first, prior to 2007Q4, more and less exposed states appear to have been on similar growth trajectories, indicated by the near-zero and statistically insignificant values from 2006Q2 to 2007Q4.

Second, more highly exposed states appear to have been less affected *initially* by the onset of the Great Recession. The estimated growth rates between 2007Q4 and 2008Q3 are positive; however, these states also experienced a similarly sized relative economic decline in the two quarters prior to 2009Q1, as evinced by the negative growth rates implied by the figure.[51] Thus, at the time of the passage of the Recovery Act, more highly exposed states to ARRA spending elsewhere were contracting economic production at a faster rate.

Third, following the passage of the Recovery Act, states exposed to higher levels of ARRA spending elsewhere had a faster and sustained expansion of production from 2009Q2 onwards. One can calculate a two-year cumulative exposure multiplier from this figure by

---

[51]This pattern of relatively faster growth in the early quarters of the recession alongside a more severe contraction just prior to the passage of the Recovery Act is also quite apparent in Figure 5.

Figure D.5: Pre-Post Specification: Change in Gross State Product 12 quarters before and after 2009Q1

Change in Output per Dollar of Spillover Aid
Prior to and Following Passage of Recovery Act (2009Q1)

- The solid line is constructed from the coefficients $\hat{\chi}_s$, accumulated so as to represent the level of output relative to the level as of 2009Q1.
- The shaded areas represent 90% confidence intervals, which are based on the Driscoll and Kraay (1998) methodology, which allows for general forms of spatial and temporal correlation of the error terms.
- The dashed lines represent 90% confidence intervals based on heteroskedasticity consistent standard errors, clustered by state.

accumulating the coefficients from 2009Q2 to 2011Q2. The cumulative multiplier from this analysis is equal to $2.65, indicating that, over two years, output in a state exposed to an additional $1 increased by $2.65. Multiplying by 0.63 again yields the implied 2-year cumulative multiplier on output in other states for each $1 of Recovery Act allocated to a given state. This implied multiplier is 1.67, consistent with the baseline findings above.

In Figure D.6, I repeat the exercise for the labor market variables. Figure D.6a presents the results for unemployment. In the twelve quarters prior to the passage of the act, relative unemployment among states highly exposed to spending elsewhere through the Recovery Act was close to and, for the majority of quarters, statistically indistinguishable from zero. Following the passage of the Recovery Act, highly exposed states see a rapid and sustained

decline in unemployment relative to less exposed states.

This pattern of a sharp relative response is replicated for employment, with the results presented in Figure D.6b. However, in this figure there is clear evidence of a downward pre-trend in employment among relatively highly exposed states. Nevertheless, there is a stark trend-break in employment growth at the passage of the Recovery Act. By the close of 2010, relative trend employment growth appears to have return to its pre-recession rate.

Figure D.6: Pre-Post Specification: Change in Unemployment and Employment 12 quarters before and after 2009Q1
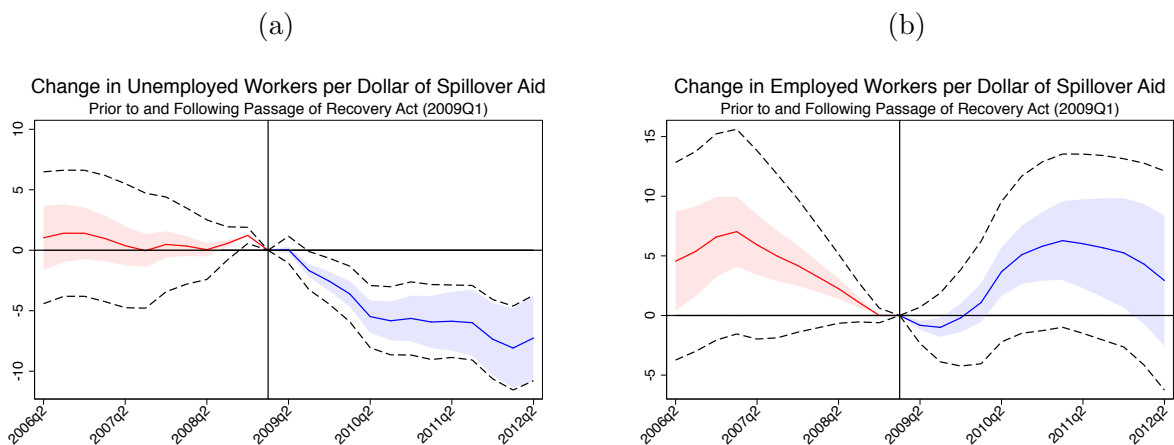
<div align="center">(a)   (b)</div>

- The solid line is constructed from the coefficients $\hat{\chi}_s$, accumulated so as to represent the level of unemployment/employment relative to the level as of 2009Q1.
- The shaded areas represent 90% confidence intervals, which are based on the Driscoll and Kraay (1998) methodology, which allows for general forms of spatial and temporal correlation of the error terms.
- The dashed lines represent 90% confidence intervals based on heteroskedasticity consistent standard errors, clustered by state.

D   Additional Tables

D.1   Correlating Spillover Exposure with Initial Downturn

In principle, the sum of the elements of the $\mathbf{w}_i$ vector, defined in Section II, can range anywhere from zero to 48 if every state imported all commodities from a single state. In practice, the smallest sum is equal to 0.005 (Washington DC) and the largest sum is equal to 2.449 (California).

Table D.5 collects these values in the first column. One way of interpreting these values is to consider the following hypothetical. Suppose that every state in the country imported one dollar's worth of commodities from other states in exact proportion to the import weights constructed using the CFS data. For a given state, say Massachusetts, this statistic specifies the value of commodities imported from Massachusetts as a result of increasing imports in all other states by one dollar. The sum of elements in $\mathbf{w}_{Massachusetts}$ is approximately 1.

Thus, in this one-dollar counterfactual, imports from Massachusetts would increase by approximately \$1. Intuitively, this statistic is a measure of the centrality of each state to the regional import/export network. Higher values imply that those states play a more central role in the regional production network.[52]

Now, one might be concerned that states that tend to ship more goods to other states (e.g. California, Texas, Illinois) were disproportionately exposed the economic downturn. The second column of Table D.5 reports the change in the unemployment rate for every state between the onset of the recession (2007Q4) and the quarter in which the Recovery Act was passed (2009Q1). This statistic measures, to some degree, the pre-Recovery Act severity of the economic downturn in each state. A strongly positive correlation between the one-dollar counterfactual statistic and the change in the unemployment rate would be troubling, suggesting that the distribution of spending intentionally or unintentionally targeted worse-off states.

The raw correlation between state-level unemployment changes and this one-dollar statistic is 0.18, suggesting that the severity of the downturn was only weakly associated with the centrality of the state in the state import/export network.[53]

Of course, the geographic allocation of Recovery Act aid was not uniform, as in the one-dollar counterfactual scenario. Since the bulk of obligations were designated by the end of

---

[52]This statistic is also known as the weighted out-degree of the directed, weighted graph of U.S. states as nodes and import shares as the weighted edges.

[53]Alternatively, one can instead calculate the eigenvector measure of centrality of the weighted, directed graph, $\mathbf{W}$. The correlation between the one-dollar hypothetical value and the eigenvector centrality is high; unsurprisingly, the correlation between the change in unemployment and the eignvector centrality is 0.18. See Jackson (2010) for additional information related to the eigenvector measure of centrality.

2009Q2 (see Figure 3), we can compare the geographic distribution of obligations in this quarter to the change in the unemployment rate in the quarters preceding the passage of the ARRA. In the third column of Table D.5, I report $\frac{ARRA_{j,2009Q2}^{S}}{GSP_{j,2009Q1}}$, the value of import-weighted obligations to which each state was exposed relative to its own output in the prior quarter.

Although California tops the list as the most central state in terms of the CFS import/export network, it ranked 44 in terms of its import-weighted obligations exposure in 2009Q2, relative to output. With the possibility for such large rank-reversals, one might be concerned that the geographic allocation of Recovery Act aid, coupled with the weight matrix $\mathbf{W}$, induced exposure that was inadvertently correlated with the severity of the local downturn, either positively or negatively. I find that the correlation between the change in the unemployment rate and the value of import-weighted obligations relative to output in 2009Q1 was similar as before: 0.20.[54]

---

[54]If, instead, one looks at the entire value of import-weighted obligations to which a state was eventually exposed, this correlation drops further to approximately 0.06.

Table D.5: Dollar Counterfactual Exercise

	One-Dollar Conterfactual	Change UR: 2007Q4 - 2009Q1	Spillover ARRA: 2009Q2	Eigenvector Centrality
California	2.533	4.6	0.013	0.304
Texas	2.040	2.2	0.017	0.229
Illinois	1.783	4.1	0.031	0.218
Pennsylvania	1.630	3.1	0.031	0.227
New York	1.571	3.1	0.014	0.208
Ohio	1.510	4.3	0.038	0.197
Tennessee	1.420	5.0	0.069	0.201
New Jersey	1.245	3.9	0.036	0.198
Massachusetts	1.030	3.2	0.020	0.163
Indiana	0.962	5.4	0.047	0.154
North Carolina	0.920	5.4	0.027	0.136
Michigan	0.857	5.8	0.031	0.135
Minnesota	0.850	3.0	0.028	0.118
Georgia	0.845	4.5	0.026	0.128
Wisconsin	0.738	3.4	0.036	0.131
Maryland	0.714	3.4	0.023	0.189
Virginia	0.675	2.9	0.017	0.145
Missouri	0.650	3.5	0.028	0.124
Kentucky	0.618	4.7	0.046	0.134
Connecticut	0.571	2.6	0.027	0.129
Florida	0.544	5.1	0.009	0.103
Iowa	0.534	2.7	0.036	0.102
Washington	0.532	3.1	0.013	0.109
Kansas	0.482	2.2	0.039	0.100
Alabama	0.452	6.0	0.032	0.103
Utah	0.447	4.2	0.025	0.118
Colorado	0.432	2.9	0.013	0.110
Louisiana	0.420	2.5	0.024	0.089
Oregon	0.405	6.3	0.025	0.097
South Carolina	0.397	5.4	0.033	0.112
Arizona	0.372	5.0	0.016	0.121
Nebraska	0.329	1.5	0.031	0.096
Oklahoma	0.297	2.3	0.019	0.103
Arkansas	0.283	2.5	0.033	0.113
Mississippi	0.237	3.3	0.030	0.105
New Hampshire	0.200	2.6	0.031	0.127
Nevada	0.169	5.4	0.015	0.152
Maine	0.141	3.2	0.021	0.105
South Dakota	0.133	2.2	0.025	0.084
Idaho	0.130	4.5	0.019	0.091
Montana	0.129	2.7	0.016	0.106
West Virginia	0.124	2.4	0.027	0.121
Rhode Island	0.109	4.8	0.030	0.125
North Dakota	0.099	1.1	0.023	0.091
Wyoming	0.086	2.8	0.014	0.073
Vermont	0.063	2.6	0.025	0.111
Delaware	0.063	4.2	0.017	0.141
New Mexico	0.055	3.3	0.009	0.108
District of Columbia	0.005	2.9	0.001	0.147
N	49			

- The one-dollar counterfactual indicates the value of goods shipped from each state if each state were to import one dollar's worth of goods according to the import weights constructed in the baseline model. The second column provides the change in the unemployment rate for each state between 2007Q4 and 2009Q1. The correlation between these two statistics is 0.18. The correlation between trade-weighted spillover ARRA funds received in 2009Q2 and the change in the unemployment rate is 0.20.

D.2 Summary Statistics of Key Variables in Empirical Analysis

Table D.6: Summary Statistics of Variables as of 2009Q1 for States Included in the Benchmark Analysise

	Min	Mean	Median	Max	SD
GSP Change (4-Qtr Ahead)	-0.0955	0.0096	0.0125	0.0730	0.0274
Cumulative GSP Change (4-Qtr Ahead)	-0.3920	0.0138	0.0291	0.2406	0.0893
GSP Change (8-Qtr Ahead)	-0.1011	0.0293	0.0284	0.1698	0.0427
Cumulative GSP Change (8-Qtr Ahead)	-0.7599	0.1265	0.1326	0.6159	0.2153
Employment Change (4-Qtr Ahead)	-1.5429	-0.5418	-0.4660	0.8979	0.5132
Cumulative Employment Change (4-Qtr Ahead)	-1.3160	-0.5208	-0.4941	0.2599	0.3303
Employment Change (8-Qtr Ahead)	-1.6791	-0.0930	-0.2658	2.3119	0.8230
Cumulative Employment Change (8-Qtr Ahead)	-2.5473	-0.7433	-0.8286	2.0642	0.9340
Unemployment Change (4-Qtr Ahead)	-0.3397	0.3318	0.3239	1.2871	0.3283
Cumulative Unemployment Change (4-Qtr Ahead)	-0.2100	0.3234	0.3026	1.0098	0.2564
Unemployment Change (8-Qtr Ahead)	-1.6661	0.0000	-0.0263	1.2979	0.4934
Cumulative Unemployment Change (8-Qtr Ahead)	-0.8425	0.4417	0.4270	2.2306	0.6291
Cumulative Spill. ARRA (4-Qtr Ahead)	0.0013	0.0576	0.0570	0.1548	0.0259
Cumulative Spill. ARRA (8-Qtr Ahead)	0.0016	0.0719	0.0725	0.1934	0.0323
Cumulative ARRA (4-Qtr Ahead)	0.0597	0.1011	0.0995	0.1565	0.0218
Cumulative ARRA (8-Qtr Ahead)	0.0741	0.1269	0.1246	0.2140	0.0283
N	49				

- All variables are per million, relative to lagged Gross State Product
- Accumulated employment and unemployment statistics annualized by dividing through by 4.