Identifying Agglomeration and Congestion Spillovers: Evidence from Base Realignment and Closure

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Preliminary and incomplete. All errors and omissions are my own.

Abstract

I quantify agglomeration and congestion spillovers using variation from a natural experiment by instrumenting for changes in local employment with proposed changes to civilian employment at military installations through the Base Realignment and Closure (BRAC) process. I find an agglomeration spillover elasticity consistent with the existing literature. However, my estimate of the congestion spillover elasticity is smaller in magnitude than common parametrizations of quantitative economic geography models. All else equal, with a weaker congestion spillover elasticity, more of the distribution of economic activity across space is due to natural advantages and disadvantages, which implies that the gains from implementing an optimal spatial policy are smaller.

Keywords: Economic geography, Spillovers, Base Realignment and Closure (BRAC), Optimal spatial policy, Defense spending

JEL Classification: R12, H21, H23, R58, F10

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1 Introduction

The distribution of economic activity within the United States is far from uniform. To illustrate, in 2007 Fairfax County, Virginia, had an employment density of 1,486 workers per square mile. In contrast, Fall River County, South Dakota, had an employment density of only 0.86 workers per square mile. Further, wage premia exist for areas with a greater density of employment: Fall River County's per capita income was only $19,128 in 2007, compared to $57,120 for Fairfax County. Even between neighboring communities, differences in economic activity can be meaningful. Are these differences the result of location fundamentals, externalities from the concentration of employment, or a combination of both? And if both fundamentals and externalities matter for the distribution of economic activity, what are the relative contributions of each? To answer this question, it is necessary to know the relative strength of spillovers.

In this paper, I estimate the strength of agglomeration and congestion spillovers by exploiting variation in local employment of civilians at military installations due to the five rounds of BRAC between 1988 and 2005. Agglomeration and congestion spillovers are externalities on local productivity and amenities caused by the location choice of workers; therefore, they are central forces in determining the spatial equilibrium in quantitative economic geography models. In order to estimate the impact of local employment density on productivities and amenities, I first invert the structure of the model to recover these measures for each location (here, counties) from data on the observed equilibrium distribution of wages and employment (without the need to specify the strength of spillovers). However, the structure of the model implies that the agglomeration and congestion spillover elasticities cannot be identified from data on local employment density alone. To address this challenge, I use variation in local defense employment, instrumented by proposed changes to the level of local defense employment through BRAC, to estimate the strength of spillovers. The identifying assumption is that the proposed changes by the Department of Defense (DoD) to civilian employment at military installations were chosen based on their value to military objectives and not on local economic characteristics (conditional on state-by-year fixed effects).

The resulting estimate of the agglomeration spillover elasticity is 0.057, which implies that a doubling of the population density in a county results in a 5.7% increase in local productivity. This estimate is in line with the existing literature on agglomeration economies. However, the estimated congestion spillover elasticity is -0.078, which implies that a doubling of the population density in a county results in a 7.8% decrease in local amenities. This result is smaller in magnitude than common parameterizations of quantitative economic geography models. The direct implication of a weaker congestion elasticity is that the concentration of economic activity explains less about relative amenities between locations. Further, with weaker externalities relative to location fundamentals, the optimal amount of redistribution in the solution to the social planner's problem and the welfare gain from its implementation are both smaller. In addition, I find that the economic disutility from the distribution of defense employment relative to the competitive equilibrium is larger with weaker congestion spillovers.

2 Related literature

Some geographic concentration would be expected even if location decisions were made randomly. However, the extent of the geographic concentration of economic activity in the United States exceeds what would be expected under those conditions (Ellison and Glaeser 1997). In order to explain the observed degree of concentration Ellison and Glaeser (1997) suggest two possible mechanisms: natural advantages and spillovers. Natural advantages are the fundamental characteristics of locations that are unchanging with the concentration of economic activity, such as the climate or access to a river. Conversely, spillovers are the externalities of economic concentration, such as increased transfer of ideas between workers in larger areas or congestion of infrastructure. While Ellison and Glaeser (1999) provide evidence that natural advantages could explain a large portion of the observed concentration in industries, their findings suggest that neither fundamentals nor spillovers alone are sufficient explanations.

It follows that there exists a body of research empirically investigating the strength of spillovers. However, as noted in Ciccone and Hall (1996), with mobility, locations with natural advantages that make them more productive and attractive to live in will draw more workers. This complicates the effort to disentangle the strength of spillovers from the degree of variance in fundamentals. In the empirical literature on agglomeration economies, two primary approaches are used to instrument for local density and thus account for this simultaneity: lagged values of economic activity and geological features. Rosenthal and Strange (2004) summarize the empirical literature on the agglomeration spillover elasticity that uses local wages directly as a measure of productivity and find that it generally falls between 0.03 and 0.08. However, the specific magnitude of the estimate is sensitive to the details of the specification of agglomeration spillovers (Melo, Graham, and Noland 2009). This suggests that estimates of the agglomeration elasticity at different levels of geographic aggregation may not be interchangeable. Specifically, agglomeration economies attenuate with distance (Rosenthal and Strange 2008) so it is expected that the strength of spillovers will decrease as the geographic unit used in estimation becomes more aggregated. It is also suggestive that using wages as a proxy for productivity may not be comparable to direct estimation of agglomeration spillovers with structurally derived measures of productivity. Further, Melo, Graham, and Noland (2009) find that estimates vary systematically with the country the data used is sourced from. In addition to the literature surveyed in Rosenthal and Strange (2004) and Melo, Graham, and Noland (2009), multiple studies have attempted to recover the strength of agglomeration economies in the United States through the use of natural experiments. Two notable examples are Kline and Moretti (2014) and Greenstone, Hornbeck, and Moretti (2010). In the first paper, long-run agglomeration economies are estimated by comparing counties impacted by the Tennessee Valley Authority program with those that would have been impacted by similar programs that were proposed but never implemented. Kline and Moretti (2014) find an agglomeration spillover elasticity of 0.2. Further, they test if strength of spillovers varies with economic concentration, but do not find evidence of heterogeneity. In the second paper, short-run agglomeration economies are estimated by comparing plant-level total factor productivity measures in counties that win large factories compared with the counties that were runner ups in the firm's plant location choice. Here, Greenstone, Hornbeck, and Moretti (2010) find an agglomeration spillover elasticity of 0.12. Note that both of these values are larger than the wage based estimates surveyed in Rosenthal and Strange (2004).

In this paper, I estimate both the agglomeration spillover elasticity and the congestion spillover elasticity using quasi-experimental variation from the BRAC process. Specifically, I apply an extension of the model developed in Allen and Arkolakis (2014) that allows for government transfers and is therefore nested in the more generalized framework developed in Fajgelbaum and Gaubert (2020). With a quantitative model of economic geography, the strength of spillovers can be estimated directly as the impact of employment density on local productivities and amenities because the structure of the model provides a method of recovering these measures for each location. By combining variation from a natural experiment with direct measures of productivity, this method is most similar to Kline and Moretti (2014) and Greenstone, Hornbeck, and Moretti (2010). However, estimating both the agglomeration and congestion spillover elasticities is more novel. Two notable papers also estimate both parameters to quantify the strength of spillovers within cities. Ahlfeldt et al. (2015) use variation in neighborhood market access due to the division and reunification of Berlin to estimate spillover elasticities that capture the strength of within-block externalities. Specifically, Ahlfeldt et al. (2015) find an agglomeration spillover elasticity of 0.07. Brinkman (2016) similarly quantifies the strength of spillovers within American cities. With a focus on the internal arrangement of cities, these papers do not estimate a single net congestion spillover elasticity, but instead decompose congestion forces into multiple sources such as commuting, amenity, and residential externalities. It follows that these estimates have not been incorporated into parameterizations of quantitative economic geography models. Allen and Arkolakis (2014) base their value on the share of consumer expenditures spent on housing and Fajgelbaum and Gaubert (2020) use the structure of the model to invert labor demand elasticities estimated at the state-level from Diamond (2016). In this paper, I report estimates of the net agglomeration and congestion spillover elasticities at the county-level for the United States that differ from these previous parameterizations. Specifically, I find a net congestion elasticity that is smaller in magnitude and explore the impact this has on optimal spatial policy, which touches on a growing literature about the scope of optimal spatial policies (Fajgelbaum and Gaubert 2020; Fajgelbaum and Schaal 2020; Blouri and Ehrlich 2020).

Defense related spending and employment, the source of variation exploited in this paper, have been studied in other contexts and used as a source of variation to quantify various features of the macroeconomy including business cycles (Blanchard et al. 1992) and fiscal spending multipliers (Nakamura and Steinsson 2014). In particular, Nakamura and Steinsson (2014) employ a similar identification strategy as is used in this paper: using changes in aggregate defense objectives that create differential impacts on locations to address endogeneity. However, since their focus is to estimate fiscal multipliers, the defense activity in Nakamura and Steinsson (2014) is defense spending through procurement contracts instead of civilian employment by the DoD. Defense employment has not been studied as frequently as defense spending. However, like defense spending, defense employment is potentially influenced by political aims and requires an approach that separates military objectives (which are assumed in the literature to be orthogonal to local economic characteristics) from political considerations. The five rounds of BRAC between 1988 and 2005 have unique institutional characteristics that make them an ideal source of variation in defense employment. While the effects of BRAC have been studied directly (Krizan et al. 1998; Poppert and Herzog Jr 2003; Hultquist and Petras 2012) it has not been applied in many contexts. One example application is Zou (2018) who uses a shift-share design constructed from actual changes in defense employment over the first four BRAC rounds to study the impact of the base closures on local labor markets. However, in this literature, the identification strategy is more often based on the assumption that the observed changes due to BRAC are not correlated with local economic characteristics. In this paper, actual changes in civilian employment at military bases are instrumented with proposals by the DoD, which are not always implemented as requested at the end of the BRAC process. This novel approach aligns the implementation of defense employment more closely with that of defense spending in Nakamura and Steinsson (2014).

3 Model

This section develops a model of the spatial economy with a government that can redistribute resources between locations. Further, three examples of government policies are compared: a competitive equilibrium with no transfers, an allocative equilibrium that can represent the observed distribution of military personnel, and the solution to the social planner's problem.

3.1 Setup

The economy consists of a set of locations $s \in S$ and $\overline{L}$ freely mobile workers. Products are differentiated by location of origin. Trade between locations is costly and takes an iceberg form such that τ_{is} units need to be sent from i to s for a single unit to arrive in s. However, local trade costs, i.e., τ_{ii}, are normalized to equal one for all locations. Let the set of trade costs to each location s from location i for all $s \in S$ be defined as the geographic location of i. Workers in i, L_i, have constant elasticity of substitution (CES) preferences over the differentiated varieties they consume and additionally receive a benefit from the composite amenity value, u_i, in the location they choose. Welfare, W_i, in location i can be written as:

$$W_i = \left[\sum_{s=1}^{n} q_{si}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} u_i, \tag{1}$$

where q_{si} is the quantity of goods from s consumed in i and σ is the CES parameter. Workers in location i inelastically supply their labor and receive a wage w_i in return. With a production function that is linear in labor, the price at the source for the variety produced in i is $p_i = \frac{w_i}{a_i}$, where a_i represents the composite productivity of each worker in location i. Thus, the price of the variety from another location, s, in i is $p_{si} = \frac{\tau_{si} w_s}{a_s}$.

Define the local composite productivity, a_i, as a general function of local employment:

$$a_i = \overline{a_i} L_i^{\alpha}, \tag{2}$$

where α is the agglomeration elasticity, and $\overline{a_i}$ is the natural productivity value in i. Correspondingly, define local composite amenities as a general function of local employment:

$$u_i = \overline{u_i} L_i^{\beta}, \tag{3}$$

where β is the congestion elasticity, and $\overline{u_i}$ is the natural amenity level in i. As in Allen and Arkolakis (2014), combined for all locations, $\overline{a_s}$, $\overline{u_s}$, and the geographic location of s, represent the underlying geography of the world.

With consumption per capita in i defined as x_i, the standard gravity equation follows from the model:

$$X_{si} = \left(\frac{p_{si}}{\mathcal{P}_i}\right)^{1-\sigma} x_i L_i, \tag{4}$$

where X_{si} is the value of goods sent from s to i and $\mathcal{P}_i = \left(\sum_{s=1}^{n} p_{si}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$ is the price index in location i. Using equations (1) and (4), the per capita indirect utility of workers who locate in i can be expressed in terms of expenditures and prices:

$$W_i = u_i \frac{x_i}{\mathcal{P}_i}. \tag{5}$$

In the equilibrium, because labor is freely mobile, workers will locate so that welfare equalizes across space. This implication of workers location choices, when combined with the definition of the price index in i, $\mathcal{P}_i$, prices of the differentiated good in i, p_{si}, and equation 5, yields the first equilibrium condition,

$$w_i^{\sigma} L_i = a_i^{\sigma-1} \overline{W}^{1-\sigma} \sum_{s \in S} \tau_{is}^{1-\sigma} u_s^{\sigma-1} \, x_s^{\sigma} L_s. \tag{6}$$

Similarly, using equation (5) and the equilibrium condition that total labor income in i, $w_i L_i$ must be equal to the value of exports from i, $\sum_{s=1}^{n} X_{is}$, results in the second equilibrium condition,

$$x_i^{1-\sigma} u_i^{1-\sigma} = \overline{W}^{1-\sigma} \sum_{s=1}^{n} \tau_{si}^{1-\sigma} w_s^{1-\sigma} a_s^{\sigma-1}. \tag{7}$$

Together the two equilibrium conditions represent labor supply and demand. One additional component is required to complete the model: a description of the relationship between the value of local consumption, $x_s L_s$, to local production, $w_s L_s$. The following sections present three distinct formulations of this connection.

3.2 Competitive Equilibrium

The simplest connection between expenditures and the value of production in location i is to assume they are the same. This scenario, where there is no redistribution is equivalent to imposing balanced trade. With $x_i = w_i$, the equilibrium conditions reduce to

$$w_i^{\sigma} L_i = a_i^{\sigma-1} \overline{W}^{1-\sigma} \sum_{s \in S} \tau_{is}^{1-\sigma} u_s^{\sigma-1} w_s^{\sigma} L_s, \tag{8}$$

and

$$w_i^{1-\sigma} u_i^{1-\sigma} = \overline{W}^{1-\sigma} \sum_{s \in S} \tau_{si}^{1-\sigma} w_s^{1-\sigma} a_s^{\sigma-1}. \tag{9}$$

This model, which is a special case of the more generalized model with transfers is the same as the model developed in Allen and Arkolakis (2014). Given symmetric trade costs, equations (8) and (9) can be consolidated into a single set of equilibrium equations,

$$L_i^{\tilde{\sigma}\gamma_1} = \overline{u}_i^{(1-\tilde{\sigma})(\sigma-1)} \overline{a}_i^{\tilde{\sigma}(\sigma-1)} \overline{W}^{1-\sigma} \sum_{s \in S} \tau_{is}^{1-\sigma} \overline{u}_s^{\tilde{\sigma}(\sigma-1)} \overline{a}_s^{(1-\tilde{\sigma})(\sigma-1)} \left(L_s^{\tilde{\sigma}\gamma_1} \right)^{\frac{\gamma_2}{\gamma_1}}, \tag{10}$$

that express the equilibrium employment in each location as a function of the underlying geography as well as the distribution of employment.

3.3 Allocative Equilibrium

A more general specification of the model allows for a government that can make transfers between locations such that the value local consumption need not equal the value of local production. With this change, it is possible for overall welfare improvements via redistribution because agglomeration and congestion spillovers create externalities from workers location decisions. Specifically, assume expenditures and output per worker are connected by a local transfer, t_i, and well as a universal lump-sum transfer, $\bar{t}$, such that

$$x_i = w_i + t_i + \bar{t}. \tag{11}$$

The specific transfer represents any distributional policies and the universal lump-sum transfer is applied to balance the government budget, i.e.

$$\bar{t} = \frac{1}{\overline{L}} \sum_{i \in S} t_i L_i. \tag{12}$$

3.4 Social Planner Equilibrium

Equations (11) and (12) define a general set of transfers across locations. An application of the framework in Fajgelbaum and Gaubert (2020), implies that there exists a specific schedule of transfers that maximizes welfare and is thus the solution to the social planner's problem. Specifically, optimal transfers will take the form,

$$t_i = \left(\frac{\alpha + \beta}{1 - \beta}\right) (\omega_i - \overline{\omega}), \tag{13}$$

where $\overline{\omega}$ represents the average value of production per capita in the economy and the lump-sum transfer equals $\overline{t} = \left(-\frac{\alpha+\beta}{1-\beta}\right) \overline{\omega}$. The optimal spatial policy takes the form of an income tax and lump sum transfer that accounts for the agglomeration and congestion externalities that workers do not consider when choosing a location. In general, the solution to the social planner's problem is a function of the spillover elasticities that govern the agglomeration and congestion externalities, which highlights their centrality to the model. For example, in the case that local productivities and amenities are not functions of local employment (i.e., $\alpha = 0$ and $\beta = 0$) the optimal spatial policy is no policy at all and the competitive equilibrium is the solution to the social planner's problem. This follows from the fact that the agglomeration and congestion spillover elasticities are the determinant of how much of the observed distribution of economic activity (i.e., wages and employment) is due to natural amenities and productivities that do not respond to the level of employment (i.e., $\overline{u_i}$ and $\overline{a_i}$) and the composite amenities and productivities defined by equations (3) and (2). When $\alpha = 0$ and $\beta = 0$, only natural advantages determine the distribution of economic activity and thus there are no externalities to a worker's location choice. The specific non-zero estimates of α and β chosen to calibrate the model directly determine the strength of externalities and thus the scope of the channels that the social planner's solution offsets.

4 Recover geography

In order to estimate local spillover elasticities, it is necessary to utilize the structure of the model to recover composite productivities and amenities. Equation (10) represents a set of equilibrium conditions that define a solution for the distribution of labor in terms of geographic variables. However, in the data, it is the equilibrium distribution of economic activity, i.e., employment and wages, that is observed and not the underlying geography. It follows that the equilibrium conditions must be inverted to represent a solution for the geography in terms of the distribution of economic activity.

4.1 Model inversion

The first step towards inverting the model into a set of equilibrium equations that express the economic geography in terms of the observed equilibrium is to collapse the equilibrium conditions into a single set of equations. With symmetric trade costs, equating equations (6) and (7) yields,

$$w_i^{\sigma} L_i a_i^{1-\sigma} = \phi w_i^{1-\sigma} u_i^{1-\sigma}, \tag{14}$$

where ϕ is a constant. Plugging equation (14) back into the equilibrium condition (equation (6)) and dividing by a reference location $j \in S$ results in a set of equilibrium conditions that can be solved through an iterative procedure to recover local amenities up to scale given a distribution of wages, employment, and trade costs:

$$\frac{u_i}{u_j} = \left(\frac{x_i}{x_j}\right)^{-1} \frac{\left[\sum_{s \in S} \tau_{si}^{1-\sigma} x_s^{\sigma-1} u_s^{\sigma-1} w_s L_s\right]^{\frac{1}{1-\sigma}}}{\left[\sum_{s \in S} \tau_{sj}^{1-\sigma} x_s^{\sigma-1} u_s^{\sigma-1} w_s L_s\right]^{\frac{1}{1-\sigma}}}. \tag{15}$$

The recovered amenities from equation (15) can be used with a normalized version of equation (14) to recover local productivities (also up to scale):

$$\frac{a_i}{a_j} = \left(\frac{w_i}{w_j}\right)^{\frac{\sigma}{\sigma-1}} \left(\frac{L_i}{L_j}\right)^{\frac{1}{\sigma-1}} \left(\frac{x_i}{x_j}\right) \left(\frac{u_i}{u_j}\right). \tag{16}$$

4.2 Data

As outlined in equations (15) and (16), composite amenities and productivities that rationalize the observed equilibrium can be recovered with data on wages, employment, expenditures and trade costs.

The source of data on county-level wages and employment for the private sector is the Quarterly Census of Employment and Wages (QCEW)[1]. These data are combined to construct the measure of labor income used in the quantitative implementation. Further, total employment in each county is the combination of the private sector employment from the QCEW and data on installation-level employment of civilians from the annual reports on the Distribution of Personnel by State and Selected Locations from the DoD[2]. In order to combine installation-level personnel data with county-level economic data, each installation is mapped to a county using military data on the location of installations and mapping software. In addition, due to changes in county boundaries over the sample period, some counties in the quantitative analysis represent the aggregation of jurisdictions so that the definitions are consistent across the sample period[3]. Expenditures at the county level are constructed by combining data on labor income with government transfers due to civilian employment at military installations. The panel period is between 1983 and 2009[4] The resulting wages

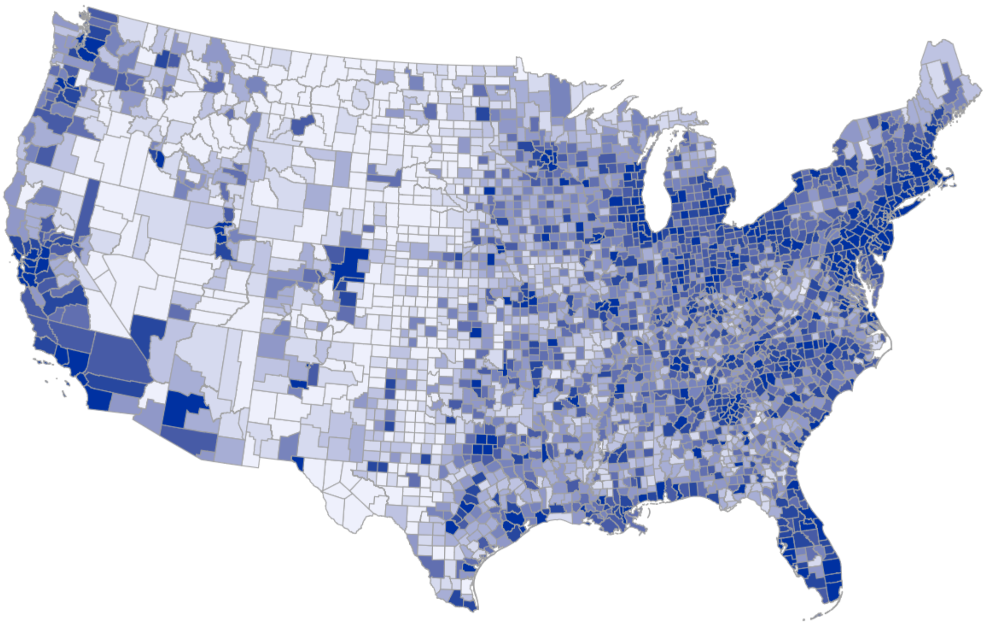
[1]Here, private sector is defined as all non-Federal, State, and Local Government employers

[2]Documentation suggests that installations with limited manpower, such as recruitment centers, are not included in these reports. Given this, to ensure consistent installations across the panel, only counties with military base employment that is non-zero for more than one year and has a maximum value over the sample period of at least two-hundred combined civilian and active duty personnel are included in the panel.

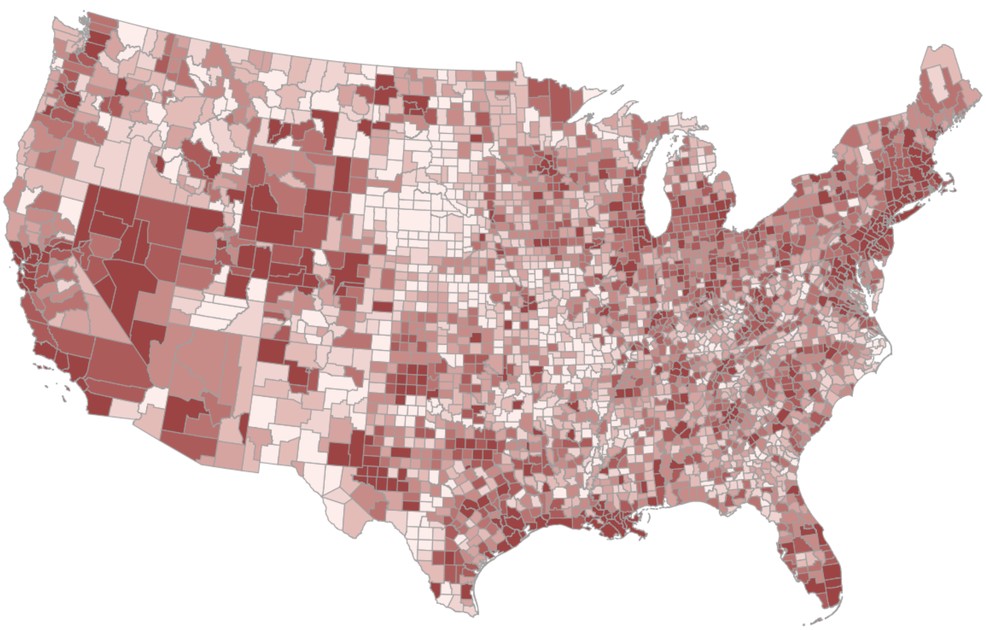
[3]The largest impact of this aggregation follows from the creation of Broomfield County in Colorado from a number of existing counties in the metropolitan Denver area.

[4]Since the first round of BRAC was implemented in 1988, it is necessary to have 5-years of pre-policy data to construct the instrumental variable which sets the initial year of 1983. In terms of the final year, 2009, this is the last year for which the same military census data is available. This results in the final year

and employment density by county are presented in Figure 1.



(a) Total Employment Density



(b) Annual Per Capita Wages

Figure 1: Each figure presents counties by decile of the respective variables in the year 2007 (with the darkest color representing the highest decile and the lightest color the lowest decile).

The final input required for model inversion is a set of bilateral symmetric trade costs.

of the 2005 BRAC round implementation window not being included in the panel.

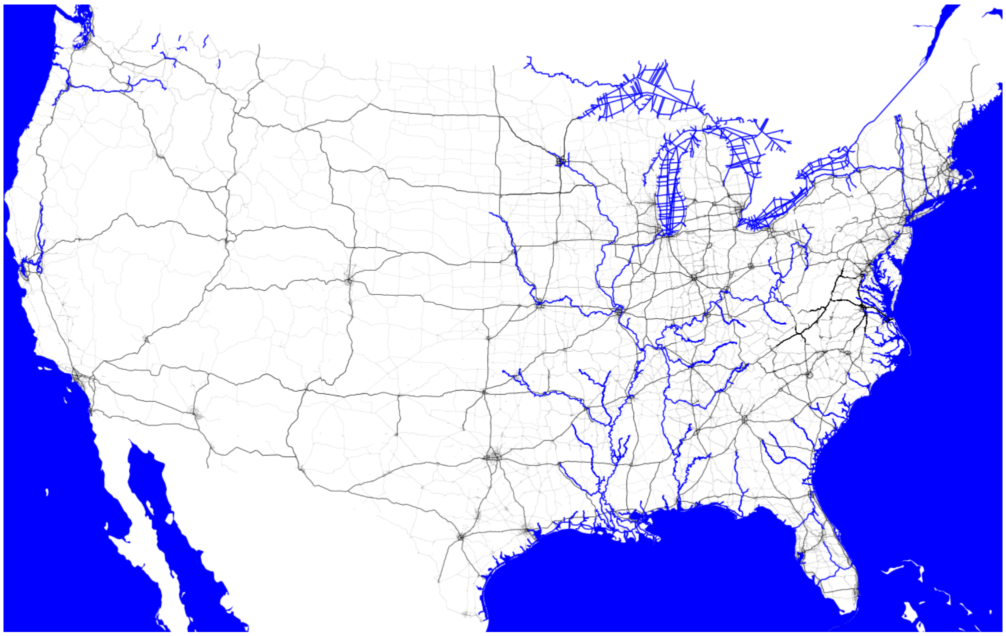
Trade costs are determined by combining data on the transportation network of the United States with data on intranational trade by mode following the methodology in Farrokhi and Jinkins (2019) which incorporates the use of the Fast Marching Method (FMM) from Allen and Arkolakis (2014). Data on intranational trade by mode is collected from the 2007 U.S. Commodity Flow Survey (CFS). This is the same data used in Farrokhi and Jinkins (2019) and includes data on trade between CFS areas by mode of transportation[5]. Trade costs are recovered by using maps of the U.S. transportation infrastructure (see Figure 2) to determine relative physical distances between locations for each mode of transportation. With relative weights within a mode (e.g. a "speed" for interstates versus other roads) from Allen and Arkolakis (2014) and maps of the mode-specific networks, the FMM can be applied to determine the least-cost distance between any two locations by mode. The railroad network was sourced from the Department of Homeland Security (DHS) and the road and commercially navigable waterway networks were sourced from the Department of Transportation (DOT).

To estimate mode-specific variable and fixed trade costs, the distances are combined with observed trade shares in a discrete choice framework. Mode-specific trade costs are combined to form total trade costs and estimation of the model-implied gravity equation produces a shape parameter that scales trade costs based on the observed value of trade flows. This results in single trade cost value for each bilateral link. Any small differences between estimated trade costs from i to j and j to i are accounted for by taking the average to ensure that the trade costs used in the estimation and counterfactuals are symmetric as in Farrokhi and Jinkins (2019). Finally, since CFS areas are more aggregated than counties, the estimates from the CFS area based estimation are applied to least-cost distances given by FMM for each county pair[6]. One parameter necessary to execute this methodology to

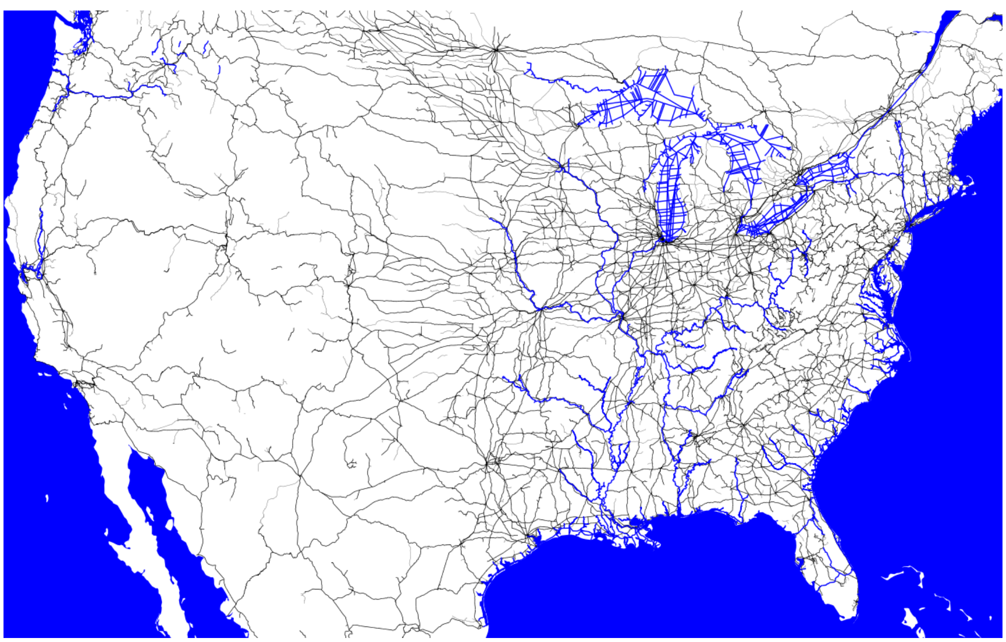
[5]In general CFS areas are equivalent to metropolitan statistical areas (MSAs), but are all contained within one state and additionally include an area for any portion of a state not included in an MSA. It follows that the estimation of trade cost parameters use CFS areas as the geographic unit.

[6]The resulting trade costs are similar to an alternative approach that assumes the same trade costs for all locations within a CFS area. The primary difference is an expected increase in within CFS area variation

recover trade costs is the value of the CES parameter, σ. In the quantitative implementation, $\sigma = 5$, which is consistent with both Head and Mayer (2014) and Fajgelbaum and Gaubert (2020). Alternative specifications ($\sigma = 9$ in Allen and Arkolakis (2014) and $\sigma = 4$ in Farrokhi and Jinkins (2019)) are tested in Appendix A.



(a) Roads and Navigable Waterways



(b) Railroads and Navigable Waterways

Figure 2: Each figure presents a set of transportation networks for the contiguous U.S.

4.3 Geography

The result of the application of equations (15) and (16) to the observed economic data as described in Section 4.2 results in the composite amenities and productivities presented in Figure 3.

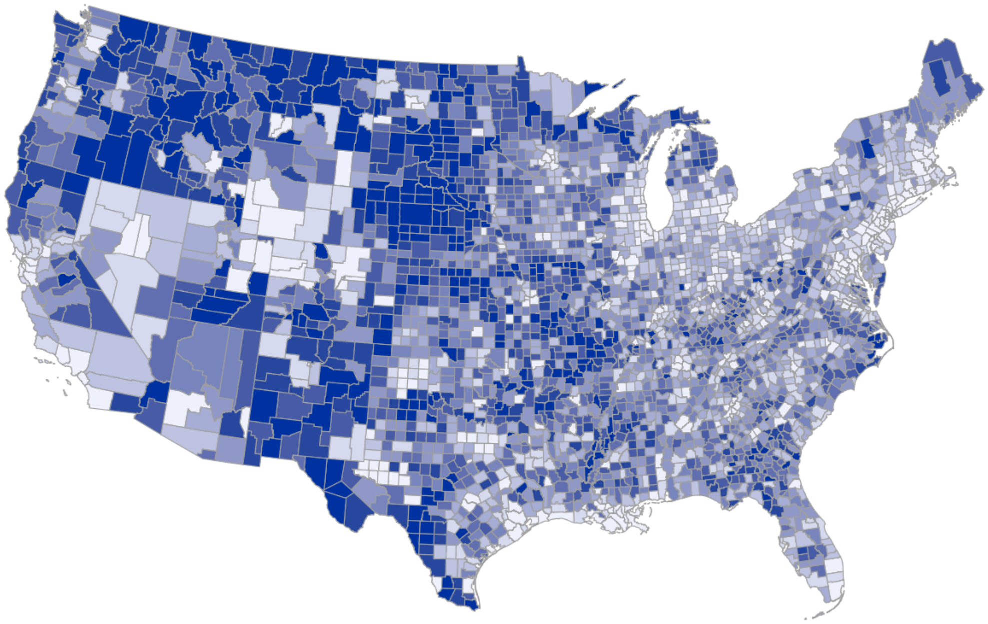
In the model, composite amenities represent compensating differentials for wage differences between otherwise similar locations. Specifically, in the competitive equilibrium, if two counties have the same location in space (set of trade costs to other locations), then they have the same cost of living and their relative amenities are equal to

$$\frac{u_i}{u_j} = \left(\frac{w_i}{w_j}\right)^{-1}, \tag{17}$$

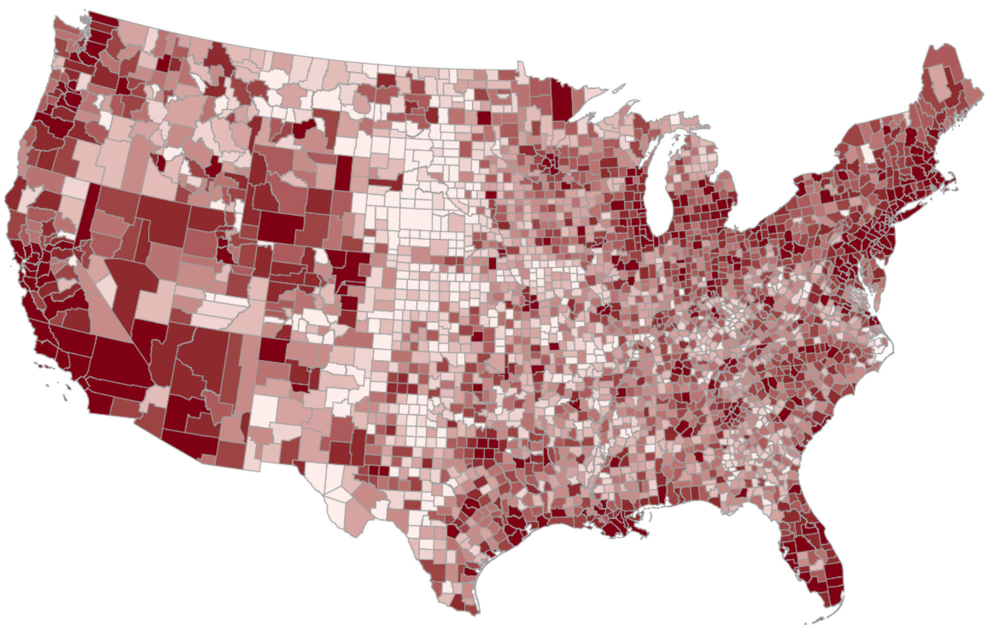
and their relative productivities are equal to,

$$\frac{a_i}{a_j} = \left(\frac{w_i}{w_j}\right)^{\frac{2\sigma-1}{\sigma-1}} \left(\frac{L_i}{L_j}\right)^{\frac{1}{\sigma-1}} \left(\frac{u_i}{u_j}\right). \tag{18}$$

For locations that are not similar, i.e. differ in their cost of living (here the price index captures remoteness conditional on the distribution of economic activity), amenities compensate for real wage differentials. In this sense, composite amenities that capture both natural amenities and congestion do not always align with the commonplace definition of amenities. While characteristics of a location such as the weather fall under natural amenities, the additional component of composite amenities that is dependent on the population level is a net effect. Thus composite amenities include both the positive and negative attributes that arise from living in a location with a larger population, such as the benefits of a diverse population and the negative effects of traffic congestion. This distinction is illustrated in Figure 3a by the composite amenity values in South Florida. Intuition suggests that natural amenities in South Florida are high and it even benefits from many of positive impacts of population density. Nonetheless, the composite amenities derived from the observed distribution of economic activity are in the second lowest decile in the Miami-Dade and Palm Beach counties.



(a) Composite Amenities



(b) Composite Productivities

Figure 3: Each figure presents counties by decile of the respective variables in the year 2007 (with the darkest color representing the highest decile and the lightest color the lowest decile).

On net, the balance between the positive and negative impacts of population density on amenities has an important implication for the uniqueness of the equilibrium distribution of economic activity. If the net effect of congestion is negative and sufficiently large to counteract the positive effects of agglomeration, then the model results in a unique equilibrium (Allen and Arkolakis (2014))[7]. If this is not the case, then there is exists the possibility of multiple equilibria. Thus, estimating the congestion and agglomeration elasticity not only will allow for a decomposition of amenities and productivities into their natural and spillover components, but also determines the ability of the quantitative model to sufficiently describe the observed economic equilibrium.

4.4 Estimating Equations

With local composite amenities and productivities for each location equations (2) and (3) constitute a set of estimating equations for the congestion and agglomeration elasticities, respectively. In log form,

$$log\left(a_i\right) = \mathcal{C}^a + \alpha \log\left(L_i\right) + \epsilon_i^a, \tag{19}$$

and

$$log\left(u_i\right) = \mathcal{C}^u + \beta \log\left(L_i\right) + \epsilon_i^u, \tag{20}$$

where $\mathcal{C}^u$ and $\mathcal{C}^a$ capture the normalization of composite amenities and productivities and ϵ_i^u and ϵ_i^a capture the relative natural amenities and productivities, respectively. However, ordinary least squares (OLS) estimates of α and β using these estimating equations will be biased because the labor supply (see equation (10)) is itself a function of the natural amenities and productivity of a location, i.e., ϵ_i^u and ϵ_i^a. In terms of the agglomeration elasticity, since a higher natural productivity encourages more workers to choose a location, the model suggests that the OLS estimate of α will be biased upwards (further from zero). Similarly, since workers choose locations with high natural amenities, but additional workers

[7]Specifically, the model has a unique equilibrium if and only if $\alpha + \beta \leq 0$.

lower amenities through congestion, the model suggests that the congestion elasticity will be biased downwards (closer to zero). However, since composite amenities and productivities are a function of the distribution of employment and wages there may be additional bias introduced through measurement error. Given the structural and statistical expectation of bias in the OLS estimates, additional sources of variation are necessary to identify the agglomeration and congestion spillover elasticities.

5 Identification Strategy

As discussed in Section 4.4, estimating α and β with equations (20) and (19) by OLS will result in biased estimates because the density of employment in a location, L_i, is an endogenous regressor. The ideal solution is an additional source of variation in local employment density that is independent to location fundamentals. Within the model, a source of this kind of variation is changes in relative government transfers. Specifically, the ideal form would be a government program that creates heterogenous shocks in local transfers which leads to movement across space that is uncorrelated with location fundamentals. Many real programs meet the first condition of an ideal source of variation: heterogenous shocks to local transfers. Examples include place-based policies such as Empowerment Zones (Busso, Gregory, and Kline 2013), regional transfers in the European Union (Blouri and Ehrlich 2020), and state-level subsidies for firm relocation (Ossa 2015). However, since the purpose of place-based policies is to address economically lagging locations by targeting them for investments and subsidies, the selection into such programs does not meet the second condition of an ideal source of variation, i.e., being uncorrelated with natural amenities and productivity. Given these constraints, one method that has been used is to source variation in local shocks from natural experiments (e.g. Black, McKinnish, and Sanders (2005), Greenstone, Hornbeck, and Moretti (2010), and Ahlfeldt et al. (2015)). In this paper, I pursue a similar strategy to recover unbiased estimates of the agglomeration and congestion elasticities. In remainder of this section, I present the institutional features of Base Realignment and Closure (BRAC), a government policy to rationalize the domestic organization of the military, and how to incorporate it as a source of variation to aid in estimation of the strength of spillovers.

5.1 BRAC

The current BRAC process was formalized at the end of the Cold War. In 1988, the Secretary of Defense was given authority by Congress to create recommendations to cut spending on excess capacity and decrease the size of the armed forces. This process was formalized in the Base Realignment and Closure Act of 1990 which was utilized to conduct four additional BRAC rounds in 1991, 1993, 1995 and 2005. Under the 1990 act, the BRAC process is initiated by Congress authorizing a new round. The DoD responds by conducting an analysis of their installation capacity, current, and projected military needs. These analyses are translated by the DoD into a list of recommendations according to a predetermined list of criteria where "military value is the primary consideration" that are forwarded to the BRAC commission, an independent body appointed by the President of the United States (BRAC Commission 2005). The BRAC commission then reviews the recommendations in light of the predetermined criteria (which are still primarily related to military value, but also require subordinate assessments of savings, environmental, and economic effects). Any recommendations that the commission decides are not aligned with the selection criteria are dropped from the final list of closures and realignments. In the most recent round the commission was also enabled to suggest additional bases for closure or to adjust realignment schedules through a process that involved an additional review by the DoD. The final list is presented to the President by the commission. The BRAC round only moves forward if the President decides to send the proposal to Congress. Finally, Congress has the opportunity to enact a resolution of disapproval which if passed stops the proposal. The President then has the normal veto powers with respect to the resolution of disapproval. If it is forward to

Congress by the President and Congress does not enact a resolution of disapproval within 45 days, then the proposal comes into effect and the DoD is tasked with executing the BRAC round within a five-year implementation window.

This process is designed to remove direct input from Congress on decisions about any specific installation when redistributing defense activity. This resolves the issue that individual congressmen are compelled by local interests to lobby against any base closures in their district even when they are contrary to the national interest. These features makes BRAC an ideal tool for economic analysis as the original recommendation list by the DoD is mandated by law to be based on defense needs and the BRAC commission is compelled to consider the military efficiency gain and cost savings of closing an installation before any local impacts such as economic or environmental concerns. In Table 1, summary statistics for local employment density, annual payroll per capita, amenities, and productivity are presented for all counties, non-military base counties, military base counties, and the subset of military base counties targeted by one or more round of BRAC. In general, military base counties have both higher wages and more employment density. It follows that they also have higher composite productivity and lower composite amenities. Some portion of the higher employment density (which influences each of the other variables) is mechanically driven by the presence of the military installation. However, it is possible that some of the features that make a location suitable for a military installation (such as a natural harbor for ships) are correlated with locations that having more concentrated economic activity. It follows that non-military base counties are likely not an effective comparison group for military base counties. On the other hand, military base counties targeted by BRAC proposals are similar to military base counties not targeted by BRAC proposals, especially in terms of the two most critical variables: local composite amenities and productivities.

In total, the five rounds of BRAC have significantly reduced defense employment, which has fallen from 1.2% of the civilian workforce in 1988 to a low of 0.47% of the civilian workforce in 2007 (see Figure 4). This national drawdown was not achieved by across the board

Table 1: Summary Statistics by Type of County (in 1987)

	All	Non-Mil.	Mil.	BRAC
Ann. Pay. Per Cap.				
Mean	15463	15113	18042	18438
Min	9427	9427	11113	11113
Max	26713	26713	26713	26713
Median	14912	14566	17642	18305
Emp. Density				
Mean	87.3	54.3	330.2	412.7
Min	0.0	0.0	0.4	0.5
Max	84516.6	84516.6	10259.0	10259.0
Median	7.8	6.3	68.4	94.2
Civ. Install. Emp.				
Mean	300	0	2511	3445
Min	0	0	0	0
Max	32691	0	32691	32691
Median	0	0	660	1445
Amenities				
Mean	1.35	1.37	1.16	1.13
Min	0.67	0.67	0.69	0.69
Max	2.51	2.51	2.05	2.05
Median	1.32	1.35	1.13	1.10
Productivity				
Mean	0.76	0.74	0.95	0.97
Min	0.19	0.35	0.19	0.19
Max	2.07	1.79	2.07	2.07
Median	0.72	0.70	0.92	0.96
Total				
N	3061	2695	366	260

Notes: This table reports summary statistics by county in 1987 (pre-BRAC) for annual payroll per capita, employment density, level of civilian employment by the DoD, composite amenities, and composite productivities. The first column presents the values for all counties in the panel. The second and third columns split counties into two groups: those with a military installation and those without. Finally, the fourth column presents the subset of counties that were subsequently targeted by at least one BRAC proposal.

reductions of similar magnitudes. Not only do the baseline shares of employment of civilians by the military vary greatly across space, but the changes due to base closures and realign-

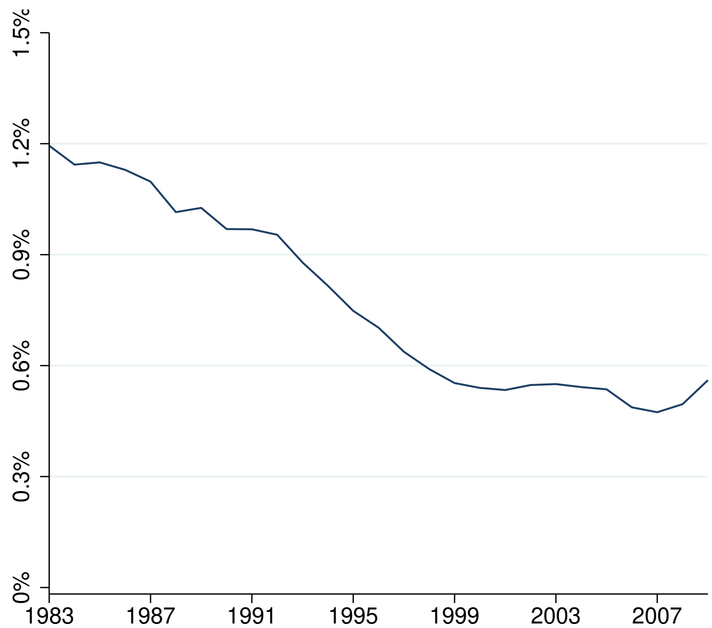
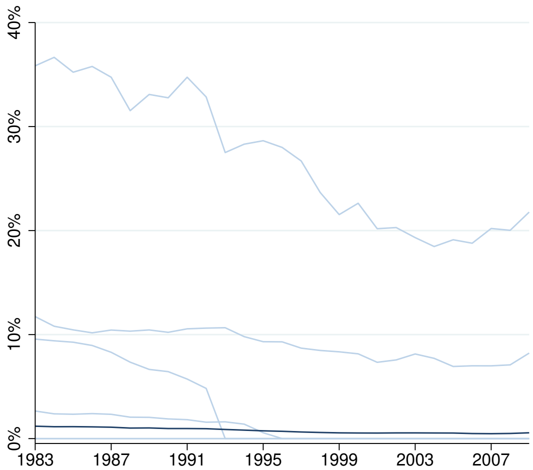
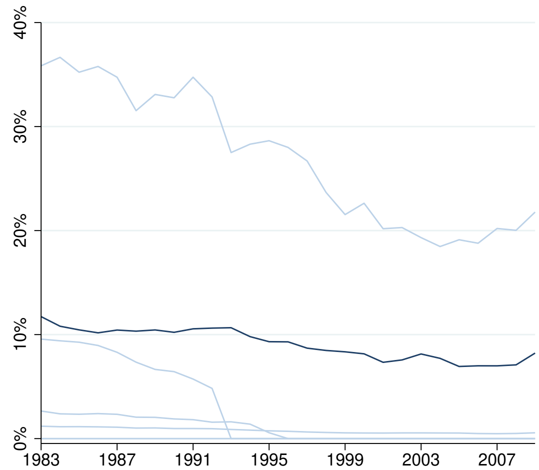


Figure 4: This figure presents the share of civilian employment by the DoD over the sample period (1983-2009).

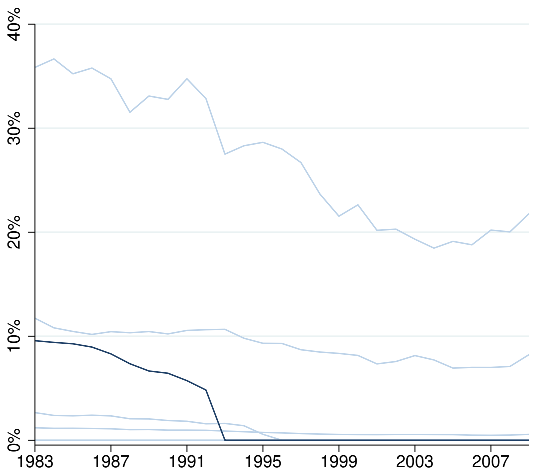
ments were heterogenous shocks. In Figure 5, the difference between the national trend and local trends is illustrated for a set of counties with very different military employment trajectories over the sample period. It is specifically this heterogeneity that makes local defense employment a suitable source of variation even when aggregate military activity in the U.S. is not a useful source of variation (Hall 2009). Nakamura and Steinsson (2014) make use of the differential impact of changes in the national trend of defense spending to instrument for state-level defense spending to estimate fiscal multipliers. Unlike military procurement contracts, the BRAC process allows for a more direct approach when using defense employment instead of spending.



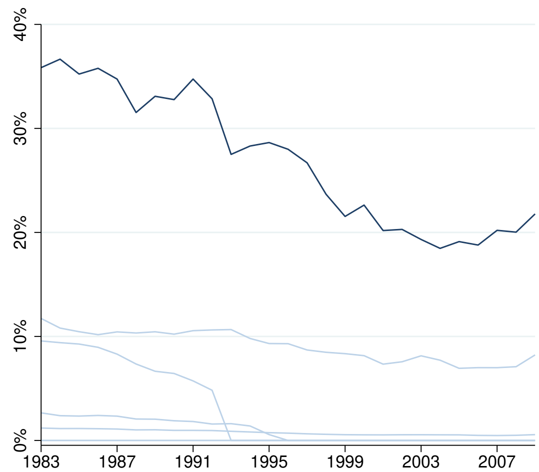
(a) Contiguous U.S.



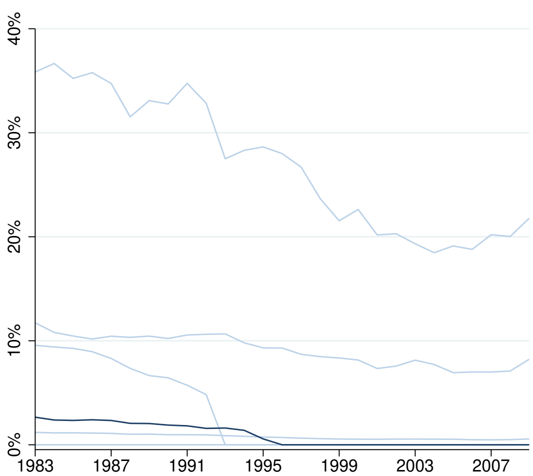
(b) Miami Co., IN (Grissom AFB)



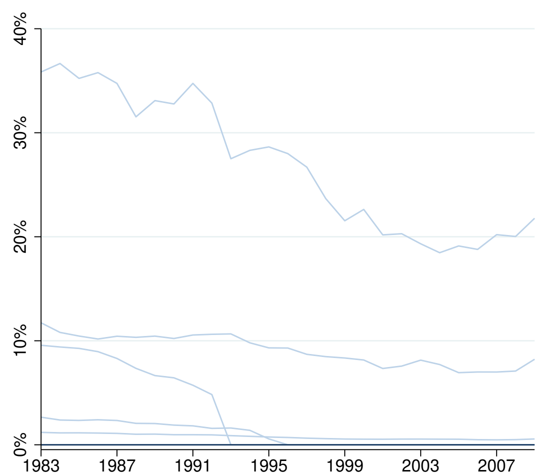
(c) Iosco Co. MI (Wurtsmtih AFB)



(d) Liberty Co., GA (Fort Stewart)



(e) Clinton Co., NY (Plattsburgh AFB)



(f) Wayne Co., MI (No Mil. Installation)

Figure 5: Each figure plots the share of civilian employment by the DoD over the sample period in the respective location (in bold) against the other locations.

5.2 Changes versus proposals

As discussed in Section 5.1, the BRAC process is designed to limit political interference to ensure that the distribution of military capacity is focused on defense objectives. However, the process features a non-military intermediary, the BRAC commission, that assesses the DoD's recommendations and has the ability to change them. Overall, the proposed changes and the implemented changes are correlated (as shown in Figure 6). However, there have been changes proposed that would greatly affect individual locations that were not implemented based on the BRAC commission's review.

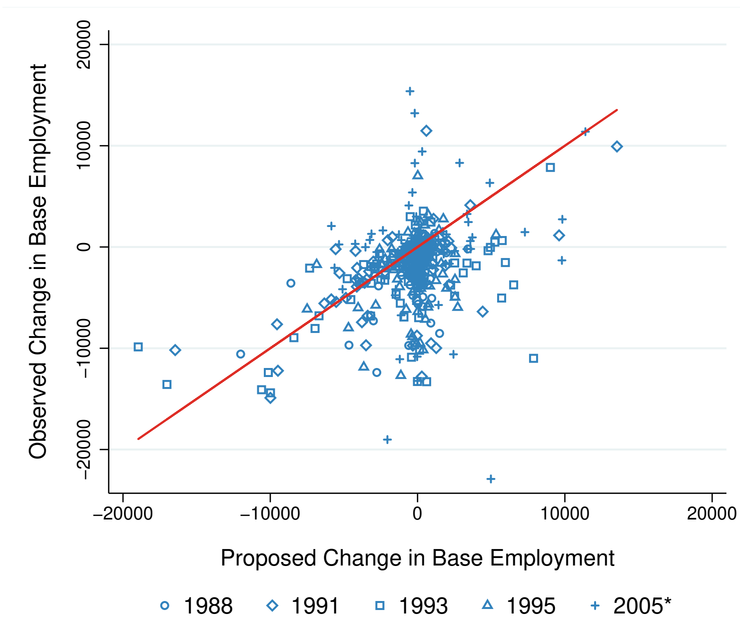


Figure 6: This figure presents the relationship between proposed changes in base employment compared with the actual changes that were observed in the military census of employment by the round of BRAC. Note that the sample period (1983-2009) only allows for observation of four of the five year implementation window for the 2005 round of BRAC.

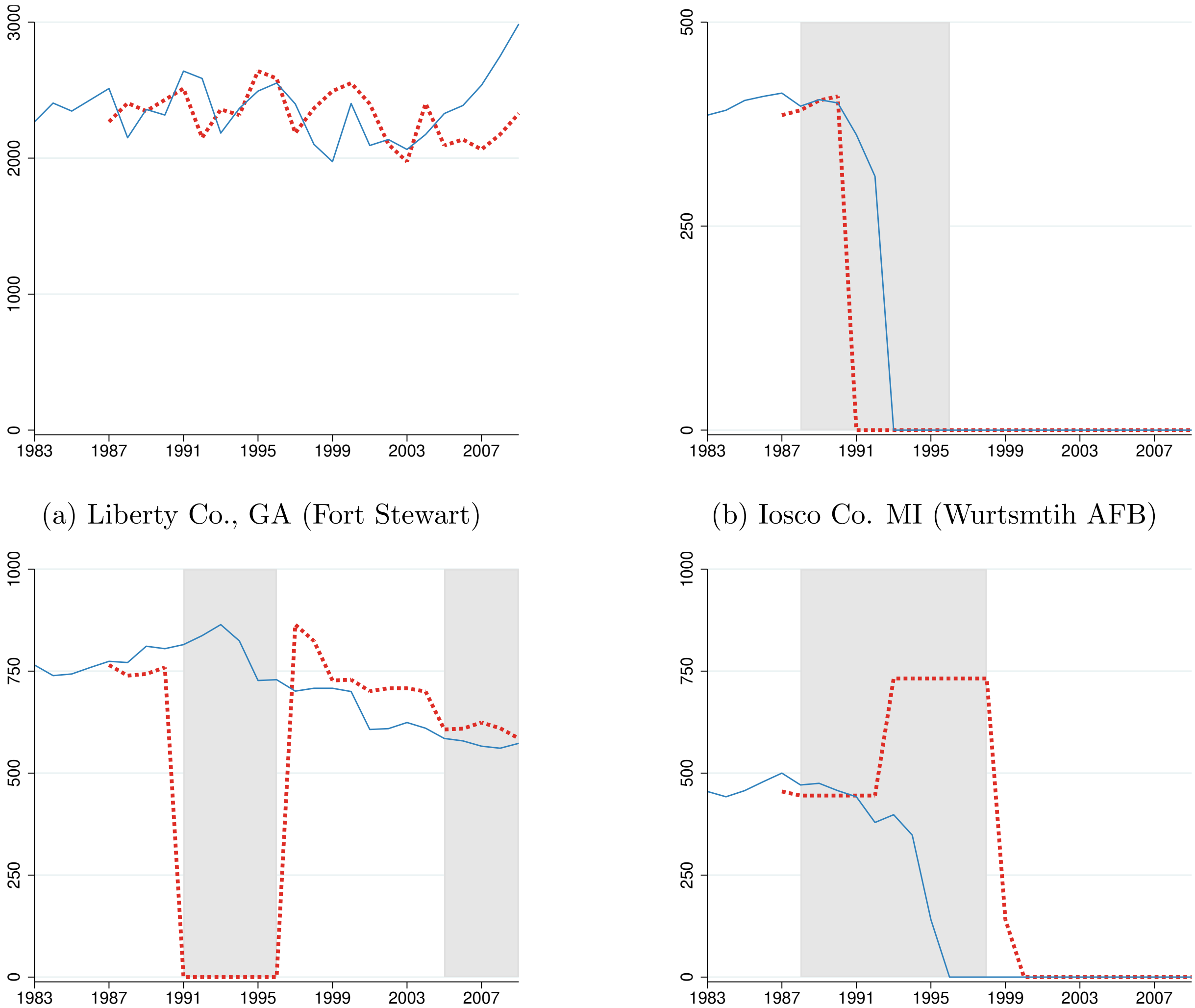
Differences between the DoD recommendations and the observed changes in base employment that reflect changes made by the BRAC Commission suggest that the initial proposals are more suitable for use as an instrumental variable than the actual changes that were implemented. However, most previous studies of the impact of local military employment do not account for potential correlation between implemented changes and local economic characteristics (Krizan et al. 1998; Poppert and Herzog Jr 2003; Hultquist and Petras 2012). In contrast, Zou (2018) uses a shift-share design that is constructed with initial shares of defense employment in 1988 and observed changes in total defense employment between 1988 and 2000 as well as synthetic controls. This primary identification strategy is a direct parallel of Nakamura and Steinsson (2014) in that it assumes that the national trend in defense employment is determined based on military objectives that are uncorrelated with local economic characteristics. The drawback of this approach is that it does not make full use of the amount of policy-induced variation available. In the following analysis, instead of using the national trend as a source of military-objective based variation, I use the proposed changes directly from the DoD to instrument for observed changes in local civilian employment at military installations.

5.3 Proposed base employment

To translate the proposed changes to employment at military installations into an instrumental variable that can be used to estimate the agglomeration and congestion elasticities with equations (20) and (19) requires relating the proposed employment shocks to the employment density. As noted in Section 5.1, the implementation window for a proposed change is five years. I construct the instrument, proposed base employment, by combining a lagged value of civilian base employment with proposed changes. Both features of the instrumental variable design are supported by the fact that the only mechanism for making significant changes to employment at a military installation is through the BRAC process. For bases with no proposed changes, the implication is the maintenance of the current employment levels into the future[8]. For installations with a proposed change, the new proposed level of employment is assumed to be the goal of the DoD for the subsequent five-years, unless an additional BRAC proposal is made during the implementation of the original change, in which case the second proposal is assumed to supersede the original. Four examples that

[8]This institutional feature aligns with the assumptions for the best-case use scenario of a lagged variable as a instrument outlined in Wang and Bellemare (2019).

each capture a distinct possibility for how implied base employment relates to actual base employment are presented in Figure 7.



(a) Liberty Co., GA (Fort Stewart)

(b) Iosco Co. MI (Wurtsmtih AFB)

(c) Miami Co., IN (Grissom AFB)

(d) Clinton Co., NY (Plattsburgh AFB)

Figure 7: Each plot presents the actual civilian employment (solid blue line) and the constructed BRAC-implied employment instrumental variable (dashed red line) over the panel period within a county. The four specific counties were chosen to illustrate the possible relationships between BRAC proposals and actual implementation: (a) no proposal and no implementation, (b) a BRAC proposal and straight-forward followthrough, (c) a proposal but no action taken, and (d) no proposal for closure but a closure action.

In each figure, actual civilian base employment and implied civilian base employment are plotted against one another and gray shading reflects implementation windows if a base was recommended for a change in employment by the DOD. In the first panel, an example of a military installation that was not impacted by BRAC is presented. In the five rounds of BRAC, the DOD never proposed changes in civilian employment at Fort Stewart in Liberty County, GA and it was similarly never slated for changes in the final decisions of the BRAC commission. The second panel presents an example of a straightforward BRAC implementation. In the first round of BRAC in 1988, the DOD recommended that Wurtsmith Air Force Base be closed. This proposal was unaltered by the BRAC commission and was implemented in the following years. The third panel contains an example of a DOD proposal that was never implemented. In 1991, the DOD recommend that Grissom Air Force Base be closed but this was reversed by the BRAC commission and civilian employment at the installation was maintained. Finally, the fourth panel illustrates an example of a DOD proposal that was not only reversed, but completely changed by the BRAC commission. In 1993, the DOD recommendations included a large increase in civilian employment at Plattsburgh Air Force Base in Clinton County, NY. However, the BRAC commission slated the installation for closure and this was ultimately implemented.

When combined, the economic geography model and the institutional features of the BRAC process support that proposed base employment meets the criteria for use as an instrument for local defense employment. In terms of the exclusion restriction, the structure of the model and the nature of the presence of a military installation in a location suggest that the only influence of proposed changes to base employment by the DoD on local productivity and amenities is through the changes to local employment at the installation that are actually implemented. Further, two features of the BRAC process support the independence of proposed base employment and local economic characteristics. First, the DoD is only capable of making significant changes to the distribution of defense employment through the BRAC process which implies that in the absence of a proposed change that lagged base employment is a measure for future employment that is not correlated with local economic characteristics. Second, because the process itself simultaneously insulates the DoD from local political lobbying and calls on the DoD to make its proposals based on military objectives, the actual proposed changes reflect decisions based on large-scale military objectives (like the fall of the Soviet Union necessitating less air defense in the northern reaches of the country) instead of local economic characteristics.

6 Results

This section is divided into two subsections. The first reports estimates of the agglomeration elasticity, α, and the congestion elasticity, β. Separate results are reported for estimation by OLS and using the proposed base employment instrument. The second subsection presents the resulting location fundamentals when the estimates of α and β from the preferred specification and the measures of local composite amenities, u_i, and productivities, a_i, are combined as in equations (2) and (3).

6.1 Spillover elasticities

In Table 2, the estimates of α and β and their standard errors using estimating equations (20) and (19) are reported. In each specification, state-by-year fixed effects are included. In particular, the year portion of the state-by-year fixed effects controls for any differences in the normalization of the productivities and amenities between years. In addition, reported standard errors are clustered for each county. The instrumental variable (IV) estimates are the preferred specification, with an estimate of α equal to 0.0570 and an estimate of β equal to -0.0781. These estimates imply that a doubling of the employment density in a county will increase local productivity by 5.7% and decrease local amenities by 7.8%. Comparing these estimates to those in the existing literature reveals differences. In particular, the IV estimate of β is smaller than the values generally used to parameterize economic geography models. Allen and Arkolakis (2014) use a β of -0.3 based on a mapping of average consumer expenditure on housing into the model and Fajgelbaum and Gaubert (2020) invert labor demand elasticity estimates from Diamond (2016) to recover a β of -0.19. The estimate of α

is in the middle of the range found by Rosenthal and Strange (2004) in their survey of the agglomeration economics literature. Further, it is very similar to the estimate from Ciccone and Hall (1996) that is used in Fajgelbaum and Gaubert (2020) ($\alpha = 0.06$). However, the value is lower than the parameterization in Allen and Arkolakis (2014).

Table 2: Estimating Spillovers

	OLS		IV	
	Log(Prod.)	Log(Amen.)	Log(Prod.)	Log(Amen.)
Log(Tot. Emp. Den.)	0.1438***	-0.0973***	0.0570**	-0.0781***
	(0.006)	(0.005)	(0.020)	(0.009)
(Year)x(State) F.E.	Yes	Yes	Yes	Yes
N	9882	9882	7333	7333
Kleibergen-Paap rk Wald F-stat			94.224	94.224

Notes: This table reports the estimated values of α and β from regressions of composite productivities and amenities on total employment density, respectively. The log-log form of the estimating equations is derived from equations (20) and (19). The first two columns present the results of OLS estimation and the last two columns present the results of IV estimation using implied base employment density as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level ($^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$).

In terms of the model, the IV estimates of α and β align with the conditions for a unique equilibrium to exist ($\alpha + \beta < 0$). One difference that is driven by the structure of the model is that the reported estimates in the range from Rosenthal and Strange (2004), 0.03-0.08, are primarily based on estimation that takes wages to be a proxy for productivity instead of using the structural measures. In Table 3, the same specification is applied, but with the dependent variable swapped for wages. In this specification, which maps the same data set used in the primary estimation to a specification comparable with the existing literature, the "agglomeration elasticity" is actually found to be on the higher end of the range of existing estimates. This difference suggests that the use of estimates of agglomeration spillovers specified in terms of wages may overstate agglomeration spillovers in economic geography models. One feature about the wage-based estimation is that the relative difference between the OLS and IV results is reduced compared to the structural estimates. This suggests that the finding in Melo, Graham, and Noland (2009) that instrumenting for local economic activity does not impact the magnitude the estimated strength of spillovers very much may not carry over to structural estimation of spillovers in quantitative economic geography models.

Table 3: Estimating Agglomeration (Wage-based)

	OLS	IV
	Log(Pay. Per Cap.)	Log(Pay. Per Cap.)
Log(Tot. Emp. Den.)	0.0895***	0.0708***
	(0.004)	(0.009)
(Year)x(State) F.E.	Yes	Yes
N	9882	7333
Kleibergen-Paap rk Wald F-stat		94.224

Notes: This table reports the estimated values of the reduced-form agglomeration spillover elasticity from regressions of payroll per capita on total employment density. The log-log form of the estimating equations yields an elasticity. The first column presents the results of OLS estimation and the second column presents the results of IV estimation using implied base employment density as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

With respect to the difference between the OLS and IV structural estimates, the magnitude of both α and β are reduced with the addition of the proposed base employment instrument. For α, this aligns with the bias that is implied by the model. Specifically, since workers will choose locations with high natural amenities, the effect of employment density on composite productivity is biased upwards. A Kleibergen-Paap rk Wald F-stat equal to 94 suggests that weak instrument bias is small. The benefits of these estimates is that the are estimated with the same structural assumptions as in Allen and Arkolakis (2014) which is nested in Fajgelbaum and Gaubert (2020). While these parameters do not capture all the mechanisms in the generalized version of the model in Fajgelbaum and Gaubert (2020), such as multiple worker skill types, they can be used in combination with data on each additional mechanism in order to decompose α and β into more specific components. An additional aspect of the estimation to note is that the set of included counties is limited to those with a military installation. As noted in Section 5.1, military base counties impacted by BRAC and those not impacted by BRAC have similar local composite amenities and productivities. Building on Allen and Arkolakis (2014), the model has a single agglomeration and congestion spillover elasticity. However, this can be relaxed, which raises the question of external validity. The finding from Kline and Moretti (2014) that the agglomeration elasticity does not vary with the amount economic activity in a location supports that these estimates of α and β hold across space.

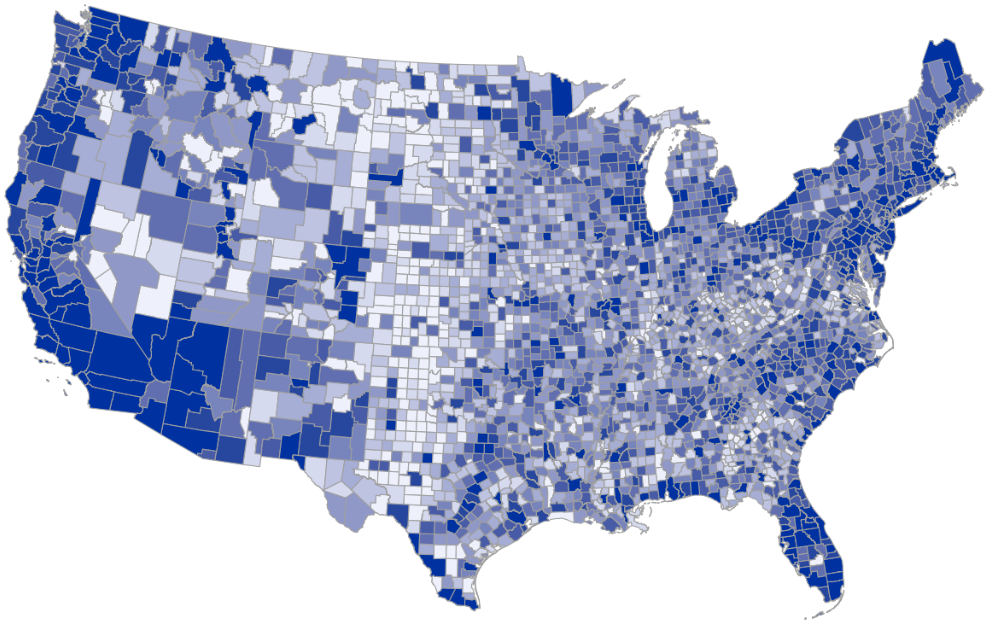
In Appendix A, two separate robustness exercises are presented. First, estimation of α and β with alternative specifications of the CES parameter are reported[9]. The estimated parameter values are broadly consistent with the primary findings presented in this section under different values of σ. Second, the estimation is conducted with a shift-share instrument more directly comparable with Nakamura and Steinsson (2014) and Zou (2018). While this instrument uses less of the available information, the results are similar to those found with the proposed base employment instrument.

6.2 Natural geography

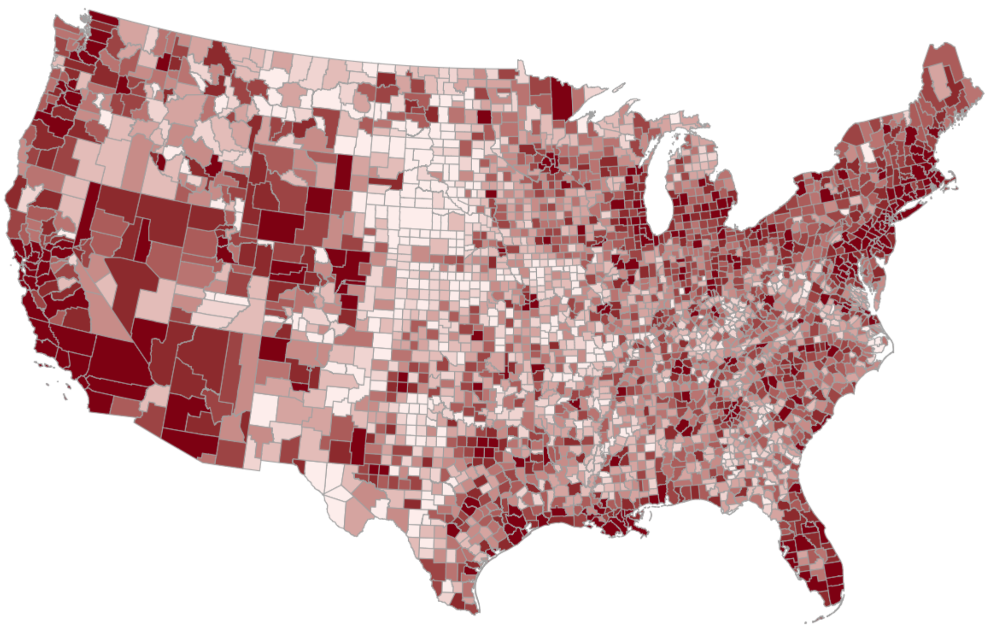
In Figure 8, the natural amenities and productivities for the United States in 2007 that are recovered through the inversion of equations (2) and (3) with the estimates of α and β from the previous section are presented.

Location fundamentals show that the regions that are most densely populated (the North-

[9]Specifically, with $\sigma = 4$ and $\sigma = 9$ as in Farrokhi and Jinkins (2019) and Allen and Arkolakis (2014), respectively.



(a) Exogenous Amenities



(b) Exogneous Productivities

Figure 8: Each figure presents counties by decile of the respective variables in the year 2007 (with the darkest color representing the highest decile and the lightest color the lowest decile).

east Corridor, Southern California, South Florida, etc.) are precisely the regions with the highest natural amenities and productivities. This aligns with determinants of the labor supply as expressed in equation (10). On the other hand, areas with limited populations, such as the western plains are characterized by having both low amenities and productivities. Exceptions include regions like the counties surrounding the Bakken Formation in western North Dakota which is home to high wages due to shale oil production. The opposite effect is apparent along the southern border of Texas, where the population is high and wages are low, which is characterized by modest natural productivity but some counties with very high natural amenities.

With the natural amenities and productivities, the competitive equilibrium can be recovered through an iterative procedure that parallels the model inversion procedure using Equation (10). In the quantitative implementation, the competitive equilibrium is equivalent to reducing government employment at military installations to zero and allowing the workers to adjust locations accordingly.

7 Optimal Spatial Policy

In this section, the estimates of α and β from the preferred specification are applied to find the competitive equilibrium and the distribution of economic activity under the optimal spatial policy to illustrate the impact of the lower estimate of β.

Equation (13) describes the unique optimal spatial policy that the social planner will implement to maximize welfare. In the case that $\alpha + \beta < 0$, which applies with $\alpha = 0.0570$ and $\beta = -0.0781$, the optimal spatial policy takes the form an income tax with a lump sum transfer. This redistribution of income from high-wage areas to low-wage areas accounts for the both the productivity and amenity externalities that arises from workers' location decisions. Specifically, the estimates of α and β from the previous section imply an optimal income tax rate of 1.95%. The optimal tax rate is primarily a function of two attributes of α and β, the absolute difference between them and the magnitude of β. The difference is important because the productivity externality offsets the congestion externality in part.

The greater the difference, the less this is the case. Further, the magnitude of β captures the overall presence of spillovers in the economy. Since the estimated α and β are close in value, most of the congestion externality is offset by the production externality. Further, because the magnitude of β is modest, the overall scale of spillovers in the economy is not large. Combined, a modest income tax is capable of offsetting the externalities and bringing the economy to its optimum. This also implies that the welfare gains between the social planner's equilibrium and the competitive equilibrium will be relatively modest.

In order to explore the quantitative implications of the estimates of α and β, I solve for both the distribution of economic activity under the competitive equilibrium and the social planner's solution. While the competitive equilibrium is recovered through an iterative procedure similar to that outlined in Section 4.1, the social planner's solution is found through constrained optimization and so the results are presented at the slightly aggregated geographic level of Commuting Zones (which are composed of approximately four counties each). In Figure 9, local net transfers (the combination of the income tax on earnings and the lump sum subsidy) are plotted for each commuting zone as a function of the per capita labor income which illustrates how the income tax of 1.95% and the lump-sum subsidy create redistribution from high-wage locations to low-wage locations.

In terms of employment, Figure 10 plots the change in employment for commuting zones from the observed distribution to the distribution under the optimal spatial policy. Given that the quantitative implementation takes the allocation of defense employment as given, the observed equilibrium does not represent the competitive equilibrium. Therefore, the changes represent two different forces. First, there is the transition from the observed allocation to the competitive equilibrium. The results of this step are apparent in some of the areas in the Northern Plains and Rocky Mountains where low-wage and rural locations lose population without the presence of large military installations like Minot Air Force Base in North Dakota and Mountain Home Air Force Base in Idaho. In addition, the implementation of the optimal spatial policy creates a general movement of workers away from the highest wage areas like

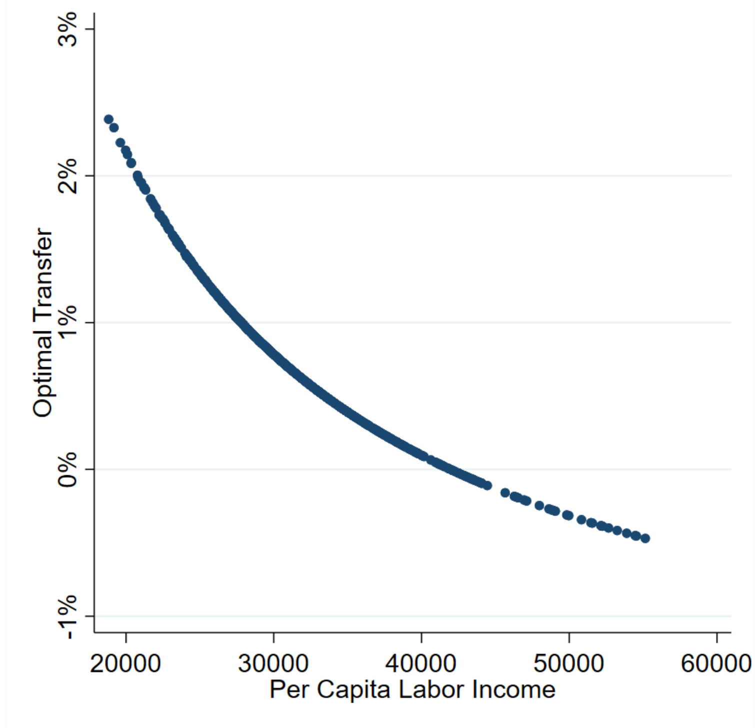


Figure 9: This figure plots the relationship between the optimal transfers (as a percent of labor income) and the optimal wages in the equilibrium where the optimal spatial policy is implemented.

the Northeast Corridor and Southern California to lower wage regions in the interior of the country. One area where both forces are applicable, which creates the most dramatic change, is in the Washington, D.C. metropolitan area.

Changes to welfare from implementing the optimal spatial policy can similarly be decomposed into two parts: returning to the competitive equilibrium and implementing the optimal policy from the competitive equilibrium. In total, under the estimates of α and β from Section 6, the welfare gain from implementing the optimal spatial policy instead of the observed allocation is 0.0514%. The majority of this gain is due to the gains from unwinding the defense equilibrium and not from the implementation of the optimal spatial policy[10]. However, as noted in Section 6, the estimated congestion spillover elasticity is

[10]The welfare effects of moving from the observed to competitive equilibrium assume that there is no value to the defense produced by the program and thus is solely evaluating the allocative impact of defense employment. However, it is relevant for evaluating the cost and benefits of defense spending to understand the economic impact of the policy as well as the defense value.

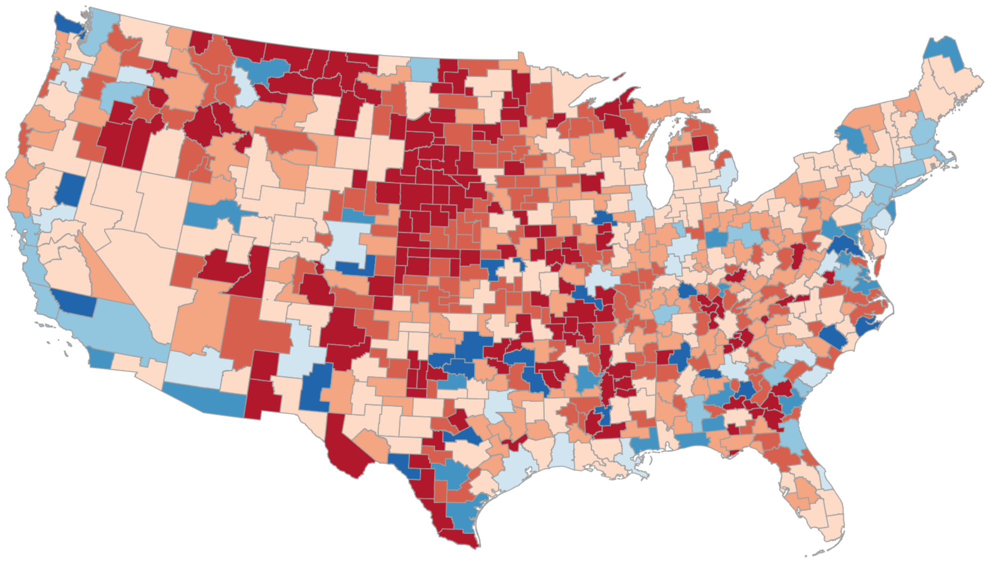


Figure 10: This figure presents the change in employment between the observed and optimal distribution of economic activity. Each color is split into quartiles for negative changes (blues) and positive changes (reds), where the darker color the higher the magnitude of the change.

smaller than common parameterizations. Keeping α constant and increasing β will increase the optimal income tax level, resulting in more transfers between high-wage and low-wage regions, and the gain from implementing the optimal policy should be larger. In Table 4, the gain in welfare for moving from the observed equilibrium to the competitive equilibrium, from the competitive equilibrium to the equilibrium under the optimal spatial policy, and the combined gain are presented for three different values of β: -0.078, -0.190, and -0.300.

Table 4: Welfare Changes by Parameterization

	Obs. to Comp. Eq.	Comp. Eq. to Opt.	Combined
$\beta = -0.078$	0.0472%	0.0042%	0.0514%
$\beta = -0.190$	0.0432%	0.0990%	0.1422%
$\beta = -0.300$	0.0203%	0.2268%	0.2472%

Notes: This table presents the welfare gains from moving to the competitive equilibrium from the observed equilibrium, to the optimal allocation from the competitive equilibrium, and the combined gain under different parameterizations of β.

Two distinct changes occur as the magnitude of β increases. First, the expected increase in the welfare gain to implementing the optimal spatial policy is observed. The total gain in welfare due to implementing the optimal spatial policy is nearly five times larger with $\beta = -0.300$ compared to the gain when $\beta = -0.078$. Second, the allocative cost of the second-best spatial policy implied by the distribution of civilian defense employment decreases as β increases. Since this represents the net effect of removing the transfers necessary to maintain employment at military installations, the value of the transfers to low-wage areas compared to the transfers in high-wage areas must be higher with a stronger congestion externality.

Overall, these results show that the specific value of the congestion elasticity is significant in determining the potential gains from implementing optimal spatial policy and the costs of implement non-optimal spatial policy. A lower congestion spillover elasticity suggests that the benefits of redistribution from high-wage locations to low-wage locations may not be as large as previous estimates would suggest. While the welfare effects are generally small in this specification of the model, the scale of welfare gains increases as additional frictions are included. For example, in Fajgelbaum and Gaubert (2020) the addition of frictions such as a housing market and two worker skill groups bring the scale of welfare gains within the range of 2% to 6%. However, the same basic relationship between the magnitude of β and the welfare gains of different spatial policies applies under those conditions as well suggesting that the range would lower under a parameterization based on a β of -0.0781.

8 Conclusion

In this paper, I use data on proposed changes to civilian employment at military installations to estimate the the strength of congestion and agglomeration spillovers. These parameters are central to determining the relative importance of natural advantages and location choice externalities for the distribution of economic activity.

I estimate that the agglomeration spillover elasticity, α, is equal to 0.057 and estimate that the congestion spillover elasticity, β, is equal to -0.078. These estimates imply that a doubling of the employment density in a county will increase local productivity by 5.7% and decrease local amenities by 7.8%. Compared to the existing literature, the magnitude of the agglomeration spillover elasticity falls within the range of previous estimates. However, the magnitude of the congestion spillover elasticity is smaller than values used in previous parameterizations of quantitative economic geography models. I solve for the equilibrium distribution of economic activity under the optimal spatial policy to illustrate the two primary implications of this smaller congestion spillover elasticity. First, the allocative cost of the observed equilibrium of civilian defense employment is higher with a β that is smaller in magnitude. Second, the gains from implementing the optimal spatial policy decrease as the magnitude of β decreases. Combined, these results suggest that the costs of implementing suboptimal spatial policy are higher and the gains from implementing optimal spatial policy are lower than would be implied under previous parameterizations in the literature.

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A Robustness

A.1 Constant elasticity of substitution

As noted in Section 4.2, the CES parameter, σ, is equal to 5 in the quantitive implementation. However, since the recovered amenities, productivities, and trade costs are a function of σ, it is important to test the robustness of the estimates of the spillover elasticities to different specifications. While $\sigma = 5$ is consistent with both Head and Mayer (2014) and Fajgelbaum and Gaubert (2020), it is not a universal parameterization. Allen and Arkolakis (2014) calibrate their model with $\sigma = 9$ and Farrokhi and Jinkins (2019) calibrate their model with $\sigma = 4$. In Table 5, the main regression specifications are replicated with the only difference being that the value of σ is set to 9 in the calibration of trade costs as well as the inversion of the model.

Table 5: Estimating Spillovers

	OLS		IV	
	Log(Prod.)	Log(Amen.)	Log(Prod.)	Log(Amen.)
Log(Tot. Emp. Den.)	0.1231***	-0.0938***	0.0452*	-0.0747***
	(0.006)	(0.004)	(0.018)	(0.009)
(Year)x(State) F.E.	Yes	Yes	Yes	Yes
N	9882	9882	7333	7333
Kleibergen-Paap rk Wald F-stat			94.224	94.224

Notes: This table reports the estimated values of α and β from regressions of composite productivities and amenities on total employment density, respectively. The log-log form of the estimating equations is derived from equations (20) and (19). The first two columns present the results of OLS estimation and the last two columns present the results of IV estimation using implied base employment density as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Similarly, in Table 6, the main regression specifications are replicated with σ set equal to 4 for the estimation of trade costs as well as the recovery of composite amenities and productivities.

Table 6: Estimating Spillovers

	OLS		IV	
	Log(Prod.)	Log(Amen.)	Log(Prod.)	Log(Amen.)
Log(Tot. Emp. Den.)	0.1576***	-0.0997***	0.0648**	-0.0804***
	(0.007)	(0.005)	(0.021)	(0.009)
(Year)x(State) F.E.	Yes	Yes	Yes	Yes
N	9882	9882	7333	7333
Kleibergen-Paap rk Wald F-stat			94.224	94.224

Notes: This table reports the estimated values of α and β from regressions of composite productivities and amenities on total employment density, respectively. The log-log form of the estimating equations is derived from equations (20) and (19). The first two columns present the results of OLS estimation and the last two columns present the results of IV estimation using implied base employment density as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Overall, the only feature that substantially differs with the changes to σ is the magnitude of the spillover elasticities. As σ increases, which implies consumers view the goods as more homogenous, the magnitude of the estimated spillovers increase. However, the relative magnitude of the estimates of α and β is relatively consistent.

A.2 Shift-share instrumental variable

In Table 7, estimates for α and β are reported from a specification that is the same as the one used in Section 6 except that the proposed base employment instrumental variable is replaced by a shift-share instrument. The shift-share instrument takes the total of the proposed changes in civilian employment at military bases for an entire state and applies the proposed percentage change in employment to each location with a military installation based on its initial base employment. This aligns closely with the specification in Nakamura and Steinsson (2014) and especially Zou (2018).

Table 7: Estimating Spillovers

	OLS		IV	
	Log(Prod.)	Log(Amen.)	Log(Prod.)	Log(Amen.)
Log(Tot. Emp. Den.)	0.1438***	-0.0973***	0.0751***	-0.0863***
	(0.006)	(0.005)	(0.016)	(0.008)
(Year)x(State) F.E.	Yes	Yes	Yes	Yes
N	9882	9882	7636	7636
Kleibergen-Paap rk Wald F-stat			103.245	103.245

Notes: This table reports the estimated values of α and β from regressions of composite productivities and amenities on total employment density, respectively. The log-log form of the estimating equations is derived from equations (20) and (19). The first two columns present the results of OLS estimation and the last two columns present the results of IV estimation using a shift-share of BRAC proposals within each state as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

Overall, the results are similar, with an estimate of $\alpha = 0.0751$ and $\beta = -0.0863$. The primary difference is that both estimates are of a larger magnitude. In Table 8, the results of the wage-based agglomeration elasticity is reported. This value is also similar to the estimate found with the proposed base employment instrument, although it is slightly larger at 0.0785 compared to 0.0708. The difference in the magnitude between the wage-based and productivity-based agglomeration elasticity is smaller than with the proposed base employment instrument. However, it is still larger in magnitude like was found with the preferred specification.

Table 8: Estimating Agglomeration (Wage-based)

	OLS	IV
	Log(Pay. Per Cap.)	Log(Pay. Per Cap.)
Log(Tot. Emp. Den.)	0.0895***	0.0785***
	(0.004)	(0.008)
(Year)x(State) F.E.	Yes	Yes
N	9882	7636
Kleibergen-Paap rk Wald F-stat		103.245

Notes: This table reports the estimated values of the reduced-form agglomeration spillover elasticity from regressions of payroll per capita on total employment density. The log-log form of the estimating equations yields an elasticity. The first column presents the results of OLS estimation and the second column presents the results of IV estimation using a shift-share of BRAC proposals within each state as an instrument for total employment density. Standard errors are in parentheses and clustered at the county-level (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).