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Federal Reserve Bank of Philadelphia

November 2006
(First Draft, April 2003)

RESEARCH DEPARTMENT, FEDERAL RESERVE BANK OF PHILADELPHIA
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Many thanks to Shannon Mail and Jim DiSalvo for timely research assistance and to Albert Saiz and Jordan Rappaport for several thoughtful comments. Comments from seminar participants at the Federal Reserve Banks of Richmond and Kansas City, Iowa State University, ITAM, Rice University, and University of Texas at Austin are also gratefully acknowledged. The views expressed in this paper are those of the author and do not necessarily represent those of the Federal Reserve Bank of Philadelphia or of the Federal Reserve System. This paper available free of charge at http://www.philadelphiafed.org/econ/wps.

ABSTRACT

This paper seeks to quantify the contribution of agglomeration economies to the spatial concentration of U.S. employment. A spatial macroeconomic model with heterogeneous localities and agglomeration economies is developed and calibrated to U.S. data on the spatial distribution of employment. The model is used to answer the question: By how much would the spatial concentration of employment decline if agglomeration economies were counterfactually suppressed? For the most plausible calibration, the answer is about 48 percent. More generally, the general equilibrium contribution of agglomeration economies appears to be substantial, with empirically defensible calibrations yielding estimates between 40 and 60 percent.

1 Introduction

The bulk of the economic activity of an industrially developed country takes place in densely settled areas that make up a small portion of a country's overall territory. This striking spatial concentration is thought to result from two distinct sources. The first source is locational fundamentals – i.e., the need to extract and/or use a natural resource. The second source are agglomeration economies – i.e., the cost advantages conferred by spatial concentration itself.

The goal of this paper is to quantify the relative importance of these two sources for the spatial concentration of U.S. employment. This goal is accomplished via an approach that is novel in this context but common in quantitative macroeconomics. A parametric general equilibrium model with heterogeneous localities and agglomeration economies is developed. The model describes the determination of employment in each of many locations that taken together exhaust the land area available for economic activity. The model's parameters are restricted to match evidence on the likely magnitude of net agglomeration benefits (spatial increasing returns net of congestion costs) and the observed spatial distribution of U.S. employment for a recent year, namely, 1999. The restricted model is then used to determine how employment for 1999 would be distributed if agglomeration economies were counterfactually suppressed. A comparison of the counterfactual employment distribution with the actual one provides the estimate of the importance of agglomeration economies for the spatial concentration of U.S. employment.

Agglomeration economies are a venerable topic in industrial organization – going back at least to Alfred Marshall's celebrated discussion of industry-level increasing returns. However, empirical studies that seek to confirm the perceived importance of agglomeration economies are of relatively recent vintage and are not very supportive of the importance of increasing returns. Kim (1999) used the predictions of the standard H-O-V trade model to argue that a small number of factor-endowment variables can account for a significant fraction of the variation in U.S. State manufacturing production in the late nineteenth and mid twentieth centuries. Ellison and Glaeser (1999) examined how measures of industry concentration decline when account is taken of the availability of a limited set of natural resources. Like Kim, they too conclude that natural advantages may well account for the bulk of the industrial concentration observed in the U.S. Rappaport and Sachs

(2002) sought to give prominence to the contribution of access to water (to a coast, navigable river or lake) for the spatial variation in employment. More recently, Rappaport (2006) has argued that differences in fundamentals seem necessary to account for the large spatial variation in population density in the U.S.

Excepting Rappaport (2006), a common feature of these studies is that each attempts to determine the relative importance of natural advantages by projecting spatial variation in the variable of interest (economic activity, employment, or measures of concentration) on proxies for specific natural resources. At least in the Kim and Ellison and Glaeser papers, the residual variation is viewed as an *upper* bound estimate of the impact of increasing returns. In contrast, the approach in this paper is to begin with estimates of agglomeration economies (surveyed in Moomaw (1981) and more recently in Rosenthal and Strange (2003)) and determine, with the aid of a general equilibrium model, the quantitative importance of these estimates for the spatial concentration of U.S. employment. To the extent that it is easier to establish a plausible range of variation of estimates of agglomeration economies than it is to measure the variation in natural resources, the approach developed in this paper is attractive.

The investigation is disciplined by requiring that the model on which the counterfactual is performed account for the *actual* spatial distribution of employment. In the model, both agglomeration economies and good location-specific fundamentals are *centripetal* forces (to use terms popularized by Fujita, Krugman, and Venables (1999)) that work to concentrate economic activity into a relatively small number of locations. These centripetal forces are opposed by a set of *centrifugal* forces that work to disperse employment, the most important of which is the cost imposed by congestion. For given magnitudes of agglomeration economies and congestion cost parameters, the requirement that the model account for the actual spatial distribution of employment results in an imputation for the value of each locality's location-specific fundamentals. Thus, the empirical strategy treats locational fundamentals as a residual. When agglomeration economies are suppressed, the imputed spatial pattern of locational fundamentals becomes the only counterweight to the centrifugal force of congestion costs. A comparison of the actual and counterfactual distributions reveals the general equilibrium effect of agglomeration economies.

The comparison suggests that agglomeration economies are an important determinant of spatial concentration. Measured by the Gini concentration index, the current spatial concentration of U.S. employment is 0.78 – a very high degree of concentration. In the baseline counterfactual, the Gini concentration index turns out to be only 0.38 – a decline of about 48.5 percent. For plausible variations in the magnitude of net agglomeration benefits around the baseline value, the implied decline in the Gini concentration index varies between 40 and 60 percent. Remarkably, these large effects result from modest values of agglomeration economies. In the baseline model the magnitude of agglomeration economies is such that a doubling of the local labor force raises firm-level productivity by a little over 2 percent.

The approach followed in this paper borrows from the growth and business-cycle accounting literatures. In analogy with growth accounting, the distribution of a primary factor – in this case labor – over space (as opposed to over time) is used to back out a location-specific "TFP" residual. However, unlike the Solow residual these location-specific "TFP" terms are a composite of both production function *and* utility function shifters. And in analogy with (real) business-cycle accounting, the counterfactual performed in this paper provides an estimate of the spatial fluctuation in economic activity that would result solely from spatial fluctuations in location-specific "TFP" terms.

An accounting exercise is most informative if it is done using a generally accepted model. Unlike the growth and business-cycle accounting literatures – where the neoclassical growth model is a widely accepted benchmark – there is no generally accepted benchmark model of economic geography. However, in a recent paper, Davis and Weinstein (2002) examined historical data with a view to discriminate between three competing models of economic geography. The models were (i) random growth model of city size, (ii) the market potential (costly transportation plus increasing returns) model of economic geography and (iii) a pure locational fundamentals model. In their view the evidence suggests that "the most promising direction for research is to consider a hybrid theory in which locational fundamentals play a key role in establishing the basic pattern of relative regional densities and in which increasing returns play a strong role in determining the degree of concentration."

The model used in this paper is of this hybrid type. Both locational fundamentals and increasing returns play important roles. Furthermore, the results of the counterfactual line up closely with roles of locational fundamentals and increasing returns expressed in the above quote. The imputed spatial pattern of locational fundamentals implies a much lower degree of spatial concentration but does not imply a ranking of relative densities that is very different from the one we see currently. Specifically, while the concentration index in the counterfactual is 48.5 percent smaller than the actual concentration, the rank correlation of actual employment density and counterfactual employment density is 0.85. Thus agglomeration economies seem to account for a large portion of spatial *concentration*, but locational fundamentals seem largely to determine the geographic *pattern* of economic activity.

The specific hybrid model used in this paper is consistent with the historical trend in employment concentration. As documented in Carlino and Chatterjee (2002), employment shares of high-density metro areas have declined in favor of employment shares of low-density metro areas during the post-WWII era. The form of the net agglomeration benefit in the model implies this de-concentration as a result of secular employment growth and – as shown in Chatterjee and Carlino (2001) – readily accounts for the magnitude of the actual de-concentration.[1]

The key challenge in doing the spatial accounting comes from the fact that when congestion is the *only* centrifugal force – which is the simplest case to analyze – low-density localities are predicted to be in an *unstable* equilibrium. This happens because at low levels of employment density, congestion costs are low and the net marginal benefit from agglomeration is positive. Consequently, theory predicts that low-density localities should either agglomerate up and become more dense or lose employment and vanish. Thus the simplest version of the model fails to account for the large numbers of low-density localities observed in reality.[2] To deal with this difficulty, two features are introduced into the model. The first feature is the presence of immobile individuals in some localities who do not make a location decision.[3] The second feature is a weakening of

[1]However, the model presented here is not identical to the one in Chatterjee and Carlino because the spatial scope of the current project is much wider – it attempts to account for the distribution of employment over all the 48 contiguous states and not simply metropolitan areas. This enlarged scope poses additional challenges that need to be addressed. This point is discussed in more detail below.

[2]This property of the model is not unusual – the instability of small localities is a well-known theme in urban economics.

[3]This feature was invoked by Ciccone and Hall (1996) to make sense of their finding that the net benefit from agglomeration is positive. With positive net benefits to agglomeration all economic activity should get concentrated in one giant location. Ciccone and Hall appeal to people's devotion to particular places as the force that prevents this extreme concentration from materializing.

the scope of increasing returns – specifically, local employment is required to attain a minimum level for agglomeration economies to manifest themselves. Roughly speaking, first feature helps to restore the stability of low-density *metro* areas and second feature helps to restore the stability of very low-density *rural* areas.

The paper is organized as follows. The next section describes the model. Section 3 has a detailed discussion of how immobility and the agglomeration threshold restore the stability of spatial equilibrium. Section 4 describes how the model is mapped to U.S. data. Section 5 presents the results of the baseline counterfactual and provides a sensitivity analysis of the results.[4] Section 6 concludes.

2 The Model Economy

The model is adapted from Chatterjee and Carlino (2001). There are M distinct geographical areas indexed by $i = 1, 2, 3, ..., M$. These areas will be referred to as localities. The collection of localities is assumed to exhaust the physical space available for economic activity in the economy. Localities can differ with respect to area, with respect to the availability of natural resources, and with respect to laws and regulations that affect production and consumption possibilities. There are a large number of individuals, $N > 1$, who live and work in these localities.

2.1 Firms

There is one costlessly transportable composite good. The plant-level production function for producing the transportable good in locality i is

$$y = \lambda\phi_i\beta(N_i)k^{1-\alpha}l^{\alpha},\ 0 < \alpha < 1, \tag{1}$$

where k and l are the capital and labor used by a plant, λ is an economy-wide technology index, and ϕ_i is an index that captures the combined impact of locality-specific factors on production capabilities. For instance, the production advantages conferred by being on the coast or on a navigable river and the impact of local labor and environmental regulations will all be captured in

[4]The sensitivity analysis plays the same role as "standard errors" in statistical inference. It gives the range uncertainty associated with the baseline estimate of the effects of agglomeration economies.

ϕ_i. $\beta(N_i)$ is a function of total employment in locality i, denoted N_i, that takes into account the external economies in production resulting from the scale of the locality's labor pool. This is one way in which *agglomeration economies* enter the model. The function is taken to be

$$\beta(N_i) = \max\left\{\overline{N}^{\nu}, N_i^{\nu}\right\}, \ \overline{N} \geq 1, \nu > 0. \tag{2}$$

The specification assumes that there is a threshold level $\overline{N}$, potentially 1, above which agglomeration economies operate. In the range where agglomeration economies do operate the elasticity of agglomeration benefits with respect to change in local employment is a positive constant ν.[5]

Each locality can also produce a good that cannot be shipped to a different locality. The plant-level production function for the non-transportable good produced in locality i is

$$g = \xi_i \Gamma(N_i, A_i) y, \tag{3}$$

where y is the transportable good used as input by the plant, ξ_i is an index that captures the combined impact of locality-specific factors on production of the non-transportable good (analogous to ϕ_i), and $\Gamma(N_i, A_i)$ is a function that takes into account the *diseconomies* imposed by local congestion on the production of the non-transportable good. This function is taken to be

$$\Gamma(N_i, A_i) = e^{-\gamma(N_i/A_i)}, \ \gamma > 0, \tag{4}$$

where A_i is land area of locality i. Thus, according to (3) and (4), higher employment density in a given locality makes the production of the non-transportable good less efficient. An important property of Γ is that the absolute value of its elasticity with respect to employment density is increasing in employment density:

$$\frac{d(\ln \Gamma)}{d \ln(N_i/A_i)} = -\gamma \cdot (N_i/A_i). \tag{5}$$

All plants behave competitively. Producers of locality i's non-transportable good take the

[5]An alternative specification of $\beta(N_i)$ is $\max\{1, (N_i - \overline{N})^{\nu}\}$. In this case, the elasticity of agglomeration benefit with respect to local employment, for $N_i > \overline{N}$, is $\nu \cdot [(N_i - \overline{N})/N_i]$. Since estimates of ν do not take the possibility of a threshold effect into account, the specification in the text was chosen over this one.

price of the transportable good and employment density in locality i as given. With the price of the transportable good as a numeraire, competitive production implies that price of the non-transportable good in location i, denoted p_i, cannot exceed its marginal cost:

$$p_i \leq \xi_i^{-1} e^{\gamma(N_i/A_i)}. \tag{6}$$

Producers of the transportable good in locality i take the level of local employment and the product wage in that locality, w_i, as given. They also takes r as given. Again, competitive production implies that the price of the transportable good cannot exceed its marginal cost of production in locality i:

$$1 \leq [\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}\lambda\phi_i\beta(N_i)]^{-1} w_i^{\alpha} r^{(1-\alpha)}. \tag{7}$$

2.2 People

There are two types of individuals: mobile individuals who can move between localities and immobile individuals who cannot. I assume that there is at least 1 immobile individual in each locality, i.e., $\underline{N}_i \geq 1$. Both types have one unit of labor which they supply inelastically to firms producing the transportable good in their locality.

The utility of an individual living and working in locality i is given by:

$$U = \psi_i c^{1-\theta} g^{\theta},\ 0 < \theta < 1, \tag{8}$$

where c and g are the individual's consumption of the transportable good and non-transportable good, respectively, ψ_i is an index that captures the combined impact of locality-specific amenity factors (such as climate) and laws and regulations on utility.

For tractability, I assume that mobile individuals do not have any capital income. Conditional on the choice of locality, utility maximization implies that a mobile individual in locality i chooses $g = \theta(w_i/p_i)$ and $c = (1-\theta)w_i$. Thus, the indirect utility of a mobile individual residing in locality

i is

$$V_i = [\psi_i(1-\theta)^{(1-\theta)}\theta^\theta]p_i^{-\theta}w_i. \tag{9}$$

Given costless mobility, a mobile individual will choose to live and work in location i only if

$$V_i = \max_j\{V_j\}. \tag{10}$$

The demand functions of immobile individuals who reside in locality i is similar to that of mobile individuals except that they derive income from capital as well. That is, an immobile individual with asset level x who resides in locality i will choose $g = \theta(w_i + rx)/p_i$ and $c = (1-\theta)(w_i + rx)$. For such an individual the indirect utility is

$$V_i(x) = [\psi_i(1-\theta)^{(1-\theta)}\theta^\theta]p_i^{-\theta}(w_i + rx).$$

Since they are immobile, their indirect utility is *not* required to satisfy a condition like (10).

2.3 Equilibrium

Since there are a large number of immobile individuals in every locality, there are individuals supplying labor inelastically to firms producing the transportable good in every locality. Therefore, in any equilibrium, there must be positive production of the transportable good in every locality. Then, it follows from (7) that

$$w_i = [\alpha^\alpha(1-\alpha)^{(1-\alpha)}\lambda\phi_i\beta(N_i)]^{\frac{1}{\alpha}}r^{\frac{-(1-\alpha)}{\alpha}}. \tag{11}$$

Additionally, since every locality has a large number of immobile individuals with strictly positive income (note that $w_i > 0$), it follows that there will be a positive demand for the non-transportable good in every locality for any $p_i \in [0,\infty)$. Therefore, in any equilibrium, there will be positive production of the non-transportable good in every locality. Then, it follows from (6) that

$$p_i = \xi_i^{-1}e^{\gamma(N_i/A_i)}. \tag{12}$$

Denote $\theta^\theta(1-\theta)^{(1-\theta)}\ \alpha^\alpha(1-\alpha)^{(1-\alpha)}\lambda^{1/\alpha}r^{\frac{-(1-\alpha)}{\alpha}}$ by $H(\alpha,\theta,\lambda,r)$, the product of locality-specific factors $\psi_i \cdot \xi_i^{-\theta} \cdot \phi_i^{1/\alpha}$ by S_i, the agglomeration economies term ν/α by μ, and the congestion externality term $\theta\gamma$ by δ. Then, substituting (11) and (12) into (9) and using (2), yields:

$$V_i = H(\alpha,\theta,\lambda,r) \cdot S_i \cdot \max\{\overline{N}^\mu, N_i^\mu\} \cdot e^{-\delta\, N_i/A_i}. \tag{13}$$

The r.h.s of equation (13) incorporates all the economic forces at work in this model. The first factor, $H(\alpha,\theta,\lambda,r)$ captures the effect on utility of economy-wide factors such as the level of technology λ and the level of interest rates r. The second factor, S_i, incorporates the effect of all local factors such as weather and amenities, availability of natural resources, and local regulations affecting the production of the transportable and non-transportable goods.[6] The third factor, $\max\{\overline{N}^\mu, N_i^\mu\}$, incorporates the positive effect of agglomeration economies. When $\overline{N}$ is 1, these effects operate as long as there is more than 1 person employed in the location, but when $\overline{N}$ is greater than 1 it operates only when local employment exceeds the threshold $\overline{N}$. The final factor, $e^{-\delta\, N_i/A_i}$, incorporates the negative effect of congestion. As a locality gets more dense, the price of the locally produced non-transportable good rises. For a given rise in density, the reduction in utility is greater if the share of non-transportable good in the worker's budget, θ, is higher, if the adverse effect on the production of the non-transportable good, δ, is higher, and if initial density, N_i/A_i, is higher.

An equilibrium for this economy is a number V^* and a vector $(N_i^*)_{i=1}^M$ that satisfy the following conditions:

$$N_i^* \geq \underline{N}_i \ \forall\ i = 1,2,3\ldots, M \tag{14}$$

$$\text{if } N_i^* > \underline{N}_i, V^* = H(\alpha,\theta,\lambda,r) \cdot S_i \cdot \max\{\overline{N}^\mu, N_i^{*\mu}\} \cdot e^{-\delta\, N_i^*/A_i} \tag{15}$$

$$\text{if } N_i^* = \underline{N}_i, V^* \geq H(\alpha,\theta,\lambda,r) \cdot S_i \cdot \max\{\overline{N}^\mu, N_i^{*\mu}\} \cdot e^{-\delta\, N_i^*/A_i} \tag{16}$$

$$\sum_{i=1}^{M} N_i^* = N. \tag{17}$$

[6] For instance, a mild climate or access to scenic spots would result in a higher S_i through a higher ψ_i, the availability of a valuable natural resource such as petroleum would result in a higher S_i through a higher ϕ_i, and tough labor and environmental regulations would result in a lower S_i through a lower ϕ_i and ξ_i but a possibly higher S_i through a higher ψ_i.

To see this, suppose that we have V^* and $(N_i^*)_{i=1}^M$ that satisfy (14) - (17). Choose $w_i^* = [\alpha^\alpha (1-\alpha)^{(1-\alpha)} \lambda \phi_i \max\{\overline{N}^\nu, N_i^{*\nu}\}]^{\frac{1}{\alpha}} r^{\frac{-(1-\alpha)}{\alpha}}$ and $p_i^* = \xi_i^{-1} e^{\gamma(N_i^*/A_i)}$. At these wages, production of the transportable good yields zero profits in every locality. So, production of the transportable good in any locality i can expand to the point where all N_i^* people are employed, i.e., at these wages the labor market in each locality can clear. Similarly, at the prices p_i^* the production of the non-transportable good yields zero profits in every locality. So, production of the non-transportable good in any locality i can expand to the point where total demand for the non-transportable good from mobile and immobile individuals is met, i.e., at these prices the non-transportable goods market in each locality can clear as well.[7] The only other markets in this model are those for the transportable good and capital and by assumption both are international markets with given prices. Finally, it is obvious that substituting w_i^* and p_i^* into (9) will yield $V_i = V^*$ for any i with $N_i^* > \underline{N}_i$ and $V_i \leq V^*$ for all other i. Therefore, mobile individuals do not have an incentive to move to a different location from their current one.

3 Agglomeration Economies and Instability of Low-Density Localities

While conditions (14) - (17) completely characterize an equilibrium, not all pairs $\left(V^*, (N_i^*)_{i=1}^M\right)$ that satisfy these conditions are economically meaningful. Because of increasing returns, an equilibrium may be unstable with respect to small perturbations. The aim of this section is to (i) explain why a model with congestion costs as the only centrifugal force predicts that low-density localities must be in an unstable equilibrium, (ii) explain how the assumptions of immobility and agglomeration threshold can restore the stability of low-density localities, and (iii) refine the definition of an equilibrium to exclude unstable equilibria.

It is convenient to work with logarithmic transforms. Let $\ln(N_i/A_i)$ be denoted by d_i, $\ln(\overline{N}/A_i)$ by $\overline{d}_i$, $\ln(H(\alpha, \theta, \lambda, r) \cdot S_i)$ by s_i, and $\ln(\overline{N})$ by $\overline{n}$. Then, equation (13) can be written as

$$\ln(V_i) = s_i + \mu\overline{n} + \mu \cdot \max\{d_i - \overline{d}_i, 0\} - \delta \cdot e^{d_i}.$$

[7] The total demand for the non-traded good in location i is $\theta(w_i^*/p_i^*)(N_i^* - N_i^I) + \theta(w_i^* + r\overline{x}_i)/p_i^*)N_i^I$, where $\overline{x}_i$ is the average asset holdings of immobile individuals residing in locality i.

Defining $\ln(V_i) - \mu\overline{n}$ as v_i, this becomes

$$v_i = s_i + \mu\overline{n} + \mu \cdot \max\{d_i - \overline{d}_i, 0\} - \delta \cdot e^{d_i}.$$

In what follows, I will treat N_i as a continuous variable. Then, the r.h.s. of the above equation can be viewed as a function of d, that is, define $v_i(d) : [\underline{d}_i, +\infty) \to R$, where $\underline{d}_i \equiv \ln(\underline{N}_i/A_i)$ is the smallest employment density possible in locality i and

$$v_i(d) = s_i + \mu \cdot \max\{d - \overline{d}_i, 0\} - \delta \cdot e^{d}. \tag{18}$$

First consider the case where $\overline{N} = \underline{N}_i = 1$. Then, $\underline{d}_i = \overline{d}_i = -a_i$. Observe that $v_i(d)$ is continuous over its entire domain and differentiable everywhere in its interior. The first two derivatives with respect to d are

$$\partial v_i/\partial d = \mu - \delta \cdot e^{d}, \text{ and} \tag{19}$$

$$\partial^2 v_i/\partial d^2 = -\delta \cdot e^{d} < 0. \tag{20}$$

Thus, $v_i(d)$ is strictly concave, but the sign of the first derivative depends on the value of d. In what follows, I will assume that $(\mu/\delta) > 1$ since (as we shall see) this is the empirically relevant case. Then, the first derivative is positive between $(\overline{d}_i\ , \ln[\mu/\delta]$, zero at $\ln[\mu/\delta]$, and negative between $(\ln[\mu/\delta], \infty)$.

Figure 1 illustrates the shape of the $v_i(d)$ function. It has an inverted-U shape, reflecting the differing elasticities of agglomeration benefits and congestion costs at different levels of density. Since the elasticity of congestion cost is proportional to density while that of agglomeration benefits is a constant, congestion costs rise more slowly than agglomeration benefits for low levels of density. This accounts for the rising segment of the $v_i(d)$ function. At $d = \ln[\mu)/\delta]$ the two elasticities balance each other and the function reaches its peak. Beyond $d = \ln[\mu/\delta]$, congestion costs rise proportionately faster than agglomeration benefits and the function declines with increasing density. Since this inverted-U shape has important implications for the model's ability to account for low-density localities, it's worth noting that models of urban areas often imply that the utility available to individuals is an inverted-U function of city size – see, for instance, Fujita (Ch.8, 1989). This feature of the model is therefore not unusual.

Let v^* be the equilibrium utility available to mobile individuals. Then, Figure 1 is consistent with three equilibrium levels of density for locality i, denoted d_L, d_M, and d_H, respectively.[8] Two of these equilibrium points have positive density and occur where the $v_i(d)$ function intersects the horizontal "utility-at-other-locations" line, namely, points d_M and d_H. The third equilibrium point, d_L, is an essentially zero-density equilibrium.[9] Focusing for the moment on the two positive density equilibria, note that the middle equilibrium, d^M, has the feature that *any* small exogenous increase or decrease in employment density around it raises the local utility level above or below what mobile individuals can get in other locations. If this property is coupled with the notion that a locality which offers a higher (lower) utility than v^* can expect to draw (lose) mobile individuals, then a transient perturbation in density around d_M will either result in the locality becoming more dense (i.e., moving to the d_H equilibrium) or result in it disappearing altogether (i.e., moving to the d_L equilibrium). In this sense, the equilibrium d_M is *unstable.* In contrast, the d_H equilibrium has the feature that for small enough changes in density, local utility moves in a direction opposite to the change in density. Hence, this equilibrium is stable. Although the $v_i(d)$ function is increasing at d_L, the d_L equilibrium is stable as well because if this equilibrium is perturbed to $d_L + \epsilon$ by the arrival of a sufficiently small number of mobile workers, $v_i(d_L + \epsilon)$ will continue to remain below v^*. Consequently, the inflow of mobile workers will eventually be reversed and the locality will go back to d_L.

The convention in static analysis is to ignore unstable equilibria as "razor's edge" configurations that are unlikely to be observed in reality. But for empirical work the instability of low density equilibria poses a problem because it implies that localities with density less than or equal to $\ln[\mu/\delta]$ should not be observed. As we shall see in the next section, this prediction is seriously at odds with the data. For empirically plausible values of μ, η, and δ, many localities in the U.S. have employment density well below μ/δ.

Suppose that we observe a locality with positive employment density d^* that is less than μ/δ.

[8] This assumes that the particular equilibrium attained in location i has a vanishingly small effect on v^*.

[9] This is an equilibrium with only one immobile resident. It is an equilibrium because the one immobile resident cannot move anywhere else and no mobile individual has an incentive to move to locality i as $v_i(d_L)$ is lower than v^*.

How can the model be modified to make d^* a stable equilibrium? The simplest modification is to allow for sufficient numbers of immobile individuals. Specifically, assume that $\underline{d}_i$ is equal to the observed density d^* and that s_i is such that $v_i(\underline{d}_i)$ is strictly less than v^*. With these assumptions we are back to Figure 1 with d_L now interpreted as d^*. As noted above, the d_L equilibrium is stable: a mobile individual will get less utility in location i than elsewhere and will have no incentive to either move to or stay in location i and the people who live in location i cannot move anywhere else because they are immobile.

An alternative modification is to assume that $\underline{d}_i$ is $-a_i$, i.e., there is only 1 immobile resident but set the agglomeration threshold $\overline{N}$ to a number large enough so that $\overline{d}_i$ exceeds d^* and choose s_i to be such that $v_i(d^*) = v^*$. Figure 2 illustrates this case. Observe that because agglomeration economies are absent below $\overline{d}_i$, the $v_i(d)$ function is downward sloping in the $[\underline{d}_i, \overline{d}_i)$ because of the effect of increasing congestion. Beyond $\overline{d}_i$, however, agglomeration economies are present and the $v_i(d)$ function is upward sloping until $d = \ln[\mu/\delta]$. By choosing s_i in such a way as to make the $v_i(d)$ function intersect the v^* line at d^* it is possible to make d^* coincide with the d_L equilibrium shown in the Figure. Then d^* is again a stable equilibrium because the $v_i(d)$ function is now downward sloping at d_L.

The important difference between these two modifications is that in the first one stability is assured by making every resident of locality i immobile, whereas in the second modification (almost) every resident can be mobile. Thus, in the quest for stability of low-density localities an agglomeration threshold can substitute for mobility restrictions. However, for a given $\overline{N}$ (the agglomeration threshold), the substitution may not work for every locality. Because localities differ in terms of land area, their $\overline{d}_i$ differs. Therefore, for some localities their actual density might fall between $[\overline{d}_i, \ln \mu/\delta]$. As shown in Figure 2, the $v_i(d)$ function is upward sloping in this range. In such cases, one would have to resort to mobility restrictions (as in Figure 1) to assure stability.

In the rest of this paper, I will focus only on stable equilibria. To be clear, a stable equilibria is defined as follows.

Definition : The collection $\{d_i^*, v^*, s_i, \underline{d}_i, \overline{d}_i, N\}$ is a stable equilibrium if it satisfies the following conditions:

$$d_i^* \geq \underline{d}_i \tag{21}$$

$$d_i^* > \underline{d}_i \Rightarrow v^* = v_i(d_i^*) \tag{22}$$

$$d_i^* = \underline{d}_i \Rightarrow v^* \geq v_i(d_i^*) \tag{23}$$

$$\sum_{i=1}^{M} A_i \cdot e^{d_i^*} = N \tag{24}$$

If $\bar{d}_i \leqq \ln[\mu/\delta]$, then

$$d_i^* > \underline{d}_i \Rightarrow d_i^* \notin [\bar{d}_i, \ln[\mu/\delta]] \text{ and} \tag{25}$$

$$d_i^* \in [\bar{d}_i, \ln[\mu/\delta]] \Rightarrow v^* > v_i(d_i^*). \tag{26}$$

Conditions (21)-(24) correspond to conditions (14)-(17). The stability requirements are incorporated in conditions (25) and (26). These conditions apply only when $\bar{d}_i < \ln[\mu/\delta]$, i.e., the corresponding $v_i(d)$ function has a flat or rising segment.[10] If a location has mobile workers in equilibrium, (25) prohibits d_i^* from lying in the closed interval $[\bar{d}_i, \ln[\mu/\delta]$; as shown in Figures 1 and 2, this interval corresponds to the domain of d for which the $v_i(d)$ function is upward sloping. If a location's equilibrium density lies in $[\bar{d}_i, \ln[\mu/\delta]$, (26) requires that the utility to mobile individuals be strictly less than v^* (if a location has employment density is in $[\bar{d}_i, \ln[\mu/\delta]$ then by (25) it cannot have any mobile workers and by (23) it cannot deliver utility greater than v^*; the stability condition (26) rules out utility *equal* to v^*).

4 Mapping the Model Economy to U.S. Data

The goal of this section is to restrict the parameters of the model so that the behavior of the model economy matches the behavior of the U.S. economy in as many dimensions as there are parameters. An important preliminary step in doing so is to decide what geographical areas in the U.S. correspond to localities in the model economy. There are two key assumptions about localities made in the model. First, the set of locations *exhausts* the physical space available for economic activity and, second, people live and work in the *same* locality. The second assumption

[10]In Figure 2 $\bar{d}_i$ is depicted to be less than $[\ln \mu/\delta]$ but this need not be the case. If $\overline{N}$ is chosen high enough, then $\bar{d}_i$ could exceed $[\ln \mu/\delta]$ and the $v_i(d)$ function would be downward sloping through out its entire domain.

suggests choosing the geographical areas so that there is little, or no, inter-area commuting. The first assumption suggests choosing a collection that is comprehensive enough to include most of U.S. territory. With these requirements in mind, the geographic areas were chosen to be the 17 consolidated metropolitan statistical areas (CMSAs), 258 metropolitan statistical areas (MSAs), and 2248 rural counties. Together, this gives a total of 2523 approximately self-contained labor market areas, covering all of the 48 contiguous states.[11]

The numerical specification of the model described by (21) - (25) involves setting values for the (i) five economy-wide parameters, namely, the technology parameter α, the preference parameter θ, the agglomeration parameters $\overline{N}$ and ν, and the congestion parameter γ, and (ii) the 3×2523 locality-specific parameters, namely, locality areas a_i, locality-specific factors s_i and locality-specific density of immobile individuals $\underline{d}_i$. The calibration of these parameters is discussed below.

The technology parameter α is the exponent to labor input in the production function for the traded good. Under perfect competition, the equality of wages and marginal product of labor implies that the share of value-added absorbed by compensation to workers is α. Average α, as measured by labor's share in U.S. GDP, is about 0.70 (see Gollin (2002)) and so the value of α was set to 0.70.

The preference parameter θ is the exponent to consumption of the local good in the utility function. Utility maximization by people implies that the expenditure share of the local good in household budgets should be θ. The expenditure shares of urban wage earners and clerical workers reported in Jacobs and Shipp (1990) suggest that people spend half their income on local goods and so θ was set to 0.50[12]

The value of ν is obtained from micro-studies that estimate the degree of agglomeration economies for U.S. cities. As discussed in Moomaw (1981), the most common way of obtaining such an estimate is to use the zero-profit condition for firms to deliver a relationship between a location's nominal wage and such characteristics as its population size, industry mix, etc. In this approach, an estimate of the coefficient on population size is an estimate of the strength of agglomeration

[11] All MSA and CMSA definitions pertain to 1990.

[12] The expenditure shares on food, shelter, utilities (including fuels and public services), public transportation, entertainment, and sundries summed amount to 56.8 percent of total household expenditures (Table 2, p. 22). Since some of these components are not entirely local a somewhat lower value of θ is appropriate.

economies. In the model, the zero-profit condition (11), in conjunction with agglomeration function (2), implies:

$$\ln w_i = \text{constant } + \alpha^{-1} \ln \phi_i + \nu \cdot \alpha^{-1} n_i \cdot \chi_i + \nu \cdot \alpha^{-1} \overline{n} \cdot (1 - \chi_i)$$

where n_i is the natural log of N_i, $\overline{n}$ is the natural log of $\overline{N}$, and χ_i is an indicator function that takes on the value 1 when n_i exceeds $\overline{n}$ and 0 otherwise. Empirical specifications surveyed in Moomaw do not take into account the possibility of an agglomeration threshold and so, in effect, assume that $\chi_i = 1$ for all locations. But these studies examine metropolitan areas only and so this omission will not create any problems provided $\underline{n}$ is relatively small. Sveikauskas (1975) estimated a relationship of this form for each of 14 two-digit manufacturing industries. He used SMSA population rather than employment as a regressor and obtained estimates of $\nu \cdot \alpha^{-1}$ that range from 0.0116 to 0.0855, with a median value of around 0.048 (Table IV, p. 404). Using the estimated relationship between log employment and log population for our CMSAs/MSAs, and a labor share of 0.7, Sveikauskas' estimates imply a median estimate of ν of about 0.03. However, Sveikauskas' estimates of $\nu \cdot \alpha^{-1}$ probably suffer from an upward bias because he used only a limited number of variables to control for location-specific factors ϕ_i. Because in equilibrium there is a positive dependence between ϕ_i and n_i, omission of relevant location-specific factors will bias the estimates of $\nu \cdot \alpha^{-1}$ upward. The baseline calibration will take ν to be 0.02 but will examine the sensitivity of the results to lower and higher values.[13]

There are no direct estimates of the agglomeration threshold parameter $\underline{N}$. However, as noted above, empirical researchers interested in measuring the strength of agglomeration economies have looked only at metropolitan areas. Therefore, the implicit assumption in the empirical literature seems to be that agglomeration economies are not relevant for rural areas. Given this, baseline calibration of the model will take $\overline{N}$ to be $35,000$. This value is only slightly smaller than the smallest employment level among metropolitan localities in 1999. Thus, with this value, rural counties do not experience any benefits of agglomeration but all urban localities do. The sensitivity of the results to higher and lower values of $\overline{N}$ will be discussed.

[13]Moomaw (1981) adjusted Sveikauskas' estimates of $\nu \cdot \alpha^{-1}$ for the observed labor share in each industry and reported estimates of ν that range from 0.006 to 0.0485, with a median value of 0.0266.

The congestion cost parameter γ controls the response of the price of the non-transportable good to variations in local employment density. The non-transportable good is a stand-in for goods and services that are locally produced and consumed of which housing services is clearly the most important. Figure 3 plots the logarithm of 1990 median house values in metropolitan areas against metropolitan employment density. The plot shows a positive relationship and yields a regression coefficient of 9.3×10^{-4}. The baseline calibration will take 10.0×10^{-4} as the starting point for the value of γ, but sensitivity of results to values of γ between 6.0×10^{-4} and 14.0×10^{-4} will be considered.[14]

The land area of each locality is obtained from direct observation.[15] The parameter choices and ranges discussed so far are summarized in Table 1.

Table 1

Calibration Guidelines of Some Model Parameters	
ν	$\{0.01, \mathbf{0.02}, 0.03, 0.04, 0.05\}$
$\underline{N}$	$\{17, \mathbf{35}, 70\} \times 10^3$
α	0.70
θ	0.50
γ	$\{6, 8, \mathbf{10}, 12, 14\} \times 10^{-4}$
a_i	ln(1990 area of CMSA/MSA/Rural County i)

The remaining locality-specific parameters, namely, s_i and $\underline{d}_i$, are restricted by requiring that, for any given values of the parameters in Table 1, the model reproduce the actual 1999 employment densities for each locality as a *stable* equilibrium outcome. Denote the observed employment density in each locality in 1999 by d_i^{obs} and suppose, without any loss of generality, that the utility received by *mobile* individuals, v^*, is ln(100). Observe that for any choice of parameter values listed in Table

[14] Roback (1982) estimated a relationship between the logarithm of the site price of residential land and population density, controlling for several city-specific factors. The coefficient on the density variable in her regression is 2.0×10^{-4} (Table 3, p. 1272). Since the median employment to population ratio for metropolitan areas in my data set is 0.57, Roback's estimate of the density coefficient implies a γ value of 3.6×10^{-4}. This is estimate is of the same order of magnitude as the one used in the calibration.

[15] For CMSAs and MSAs the land area refers to the area of a commuting unit. Since commuting presupposes the existence of transportation infrastructure, taking the land area as given is tantamount to taking the transportation infrastructure as given. The counterfactuals performed in this paper thus assume no change in the transportation infrastructure.

1 the implied values of μ/δ and $\bar{d}_i$ divide the set of localities into two mutually exclusive groups. In the first group, denoted Group I, are localities for which $\bar{d}_i \leq \ln[\mu/\delta]$ *and* $d_i^{\text{obs}} \in [\bar{d}_i, \ln[\mu/\delta]]$ and in the second group, denoted Group II, are localities for which either $\bar{d}_i > \ln[\mu/\delta]$ or $d_i^{\text{obs}} \notin [\bar{d}_i, \ln[\mu/\delta]]$. For localities in Group I, it follows from (25) that

$$\underline{d}_i = d_i^{\text{obs}}. \tag{27}$$

That is, all localities in this group are in a corner equilibrium without any mobile workers. Furthermore, (26) implies an upper bound on the strength of locality-specific factors, namely

$$s_i < \ln(100) - \mu \cdot d_i^{\text{obs}} + \delta \cdot e^{d_i^{\text{obs}}}. \tag{28}$$

For localities in Group II, (21) implies

$$\underline{d}_i \leq d_i^{\text{obs}}, \tag{29}$$

and (23), implies

$$s_i \leq \ln(100) - \mu \cdot \max\{d_i^{\text{obs}} - \overline{d}_i, 0\} + \delta \cdot e^{d_i^{\text{obs}}}. \tag{30}$$

In addition, (22) implies that

$$\left(\underline{d}_i - d_i^{\text{obs}}\right) \cdot \left(s_i - \ln(100) + \mu \cdot \max\{d_i^{\text{obs}} - \overline{d}_i, 0\} - \delta \cdot e^{d_i^{\text{obs}}}\right) = 0. \tag{31}$$

This last restriction asserts that if there is at least one mobile individual in locality i, s_i must attain its upper bound and, conversely, if s_i does not attain its upper bound, there must not be any mobile individuals in locality i. In what follows it is assumed that every locality in Group II has $\underline{d}_i$ equal to $-a_i$, i.e., in each of these localities there is a single immobile resident. Since every location in our data set has more than 1 resident, this assumption means that s_i of a Group II locality is given by

$$s_i = \ln(100) - \mu \cdot \max\{d_i^{\text{obs}} - \overline{d}_i, 0\} - \delta \cdot e^{d_i^{\text{obs}}}. \tag{32}$$

The final set of parameters to be pinned down are the s for Group I localities. As noted earlier, the model and the data do not restrict the level of s for these localities other than to say that each must be strictly less than the upper bounds implied by the stability of low-density equilibria. To make the s "observable," it is assumed that the distribution of s for localities in Group I is no different from the distribution of s for localities in Group II. Under this assumption, the observed distribution of s for localities in the Group II is used to assign to each i in Group I the *average* value of s conditional on s_i not exceeding its upper bound given by (28).[16]

5 Computational Experiments

To quantitatively assess the role of agglomeration economies in spatial concentration, we need a way to describe and summarize the degree of spatial concentration in employment. An attractive way to do this is by using Lorenz curves. In the present context, a Lorenz curve is constructed by first ordering the localities by their employment density, with the most dense locality being ranked first. Then, the cumulative percentage of land areas (running from 0 to 100) of localities so ordered is plotted against the cumulative percentage of employment. If employment were uniformly distributed over the U.S. continental landmass, this plot would coincide with the 45-degree line. But if employment is not uniformly distributed, the curve will be bowed above the 45-degree line. As Figure 4 shows, the curve is indeed heavily bowed. The top 1 percent of the densest U.S. territory accounts for about 15 percent of total employment, the top 2 percent accounts for about 25 percent, and the top 15 percent accounts for 50 percent. The Gini coefficient associated with this Lorenz curve is 0.78. This summary measure of spatial concentration is used in this study.[17]

In the baseline calibration, parameters for which a range is specified in Table 1 ($\nu, \overline{N}$ and δ) are set to the values noted in boldface. All other parameters are set as noted in Table 1. Thus, the baseline calibration implies μ/δ is 57 workers per square mile (rounded). Since $\overline{N} = 35,000$, any locality with employment greater than $35,000$ and employment density less than or equal to 57 is in Group I, i.e., in the group of localities that are in a corner equilibrium with $\underline{d}_i = d_i^{\text{obs}}$.

[16] This is clearly a simplification. The value of s in any given location is unlikely to be independent of values of s in nearby locations. A more sophisticated approach would recognize the spatial correlation in the values of s and give more weight to the values of s in nearby Group II localities when calculating the conditional average of s for any Group I locality.

[17] Carlino and Chatterjee (2002) provide a more extensive discussion of Lorenz curves based on employment density.

In the baseline calibration Group I contains 104 localities and 5.17 percent of employment. The remaining $2,419$ localities fall into Group II. For these Group II localities the value of s_i is given by equation (32). As described at the end of the previous section, the distribution of s for Group II localities is used to estimate the s_i's for Group I localities.

For the counterfactual, a new equilibrium is calculated with the agglomeration parameter ν set to zero (all other parameters unchanged) and allowing for free mobility of all workers. In the absence of agglomeration economies, the $v_i(d)$ function is downward sloping for every locality and, consequently, there is no possibility of multiple equilibria. Figure 5 plots the actual Lorenz curve for 1999 along with the Lorenz curve corresponding to the new equilibrium. The new (counterfactual) Lorenz curve lies inside the actual one, indicating that in the model agglomeration economies contribute unambiguously to the concentration of employment. The Gini index for the new Lorenz curve is 0.40, which is 48.5 percent less than the actual Gini index of 0.78. Thus agglomeration economies appear account for almost one-half of the observed degree of spatial concentration.

In the new unique equilibrium, differences in employment density across localities stem entirely from differences in the s_i. So, whatever inequality remains after elimination of agglomeration economies is the result of inequality in fundamentals. Figure 6 plots the frequency distribution of the imputed location-specific factors. The mean of the distribution is about 4 and most of the mass is concentrated around the mean. However, there are a few localities with very high and very low location-specific factors.

It is useful then to understand where these differences in fundamentals come from. Consider first rural localities, that is, all localities with d_i^{obs} less than $\overline{d}_i$. For such localities

$$s_i = \ln(100) + \delta \cdot e^{d_i^{\text{obs}}}.$$

Hence there is a direct linear relationship between s_i and employment density: higher density implies better imputed fundamentals. Next, consider metro localities, that is, localities with d_i^{obs} greater than $\overline{d}_i$. Ignoring for the moment metro localities in a corner equilibrium, the imputed fundamentals of such localities is given by

$$s_i = \ln(100) - \mu \cdot \max\{d_i^{\text{obs}} - \overline{d}_i, 0\} + \delta \cdot e^{d_i^{\text{obs}}}.$$

Now the imputation of fundamentals depends on the contribution of agglomeration economies and the tight connection between observed density and imputed fundamental is lost. To see this most clearly, consider two localities with the *same* employment density but commuting areas of different size. The locality with a larger commuting area will have a higher level of employment and, therefore, a higher contribution of agglomeration economies. In the above equation, this effect is captured by the fact that the locality with a larger commuting has a smaller $\overline{d}_i$. It follows that the locality with the larger-sized commuting area will be imputed a lower s_i than the locality with a smaller-sized commuting area. Hence, two metro areas with the same observed employment density can be imputed rather different fundamentals. By continuity, a metro area with a higher employment density but smaller commuting area may be imputed a lower value of s_i than a metro area with a lower employment density but a larger commuting area. Nevertheless, the rank correlation between employment density and imputed fundamentals is positive for metro areas – being 0.70 for the baseline calibration.

The fact that observed imputed fundamentals are positively related to observed employment density suggests an important distinction between the effects of agglomeration economies on *employment concentration* and its effects on *economic geography*. That high-density localities tend to have high TFP/amenity index means the ranking of localities in the *new* equilibrium need not be very different from the current ranking of localities with respect to employment density. Indeed, the rank correlation between actual density and the density in the counterfactual is 0.85. Thus the counterfactual does not imply vastly different economic geography – localities that are currently dense are also the localities that tend to be relatively dense in the counterfactual.

Another important and distinct effect of agglomeration economies concerns its effect on welfare. In principle, eliminating agglomeration economies need not affect welfare. The easiest way to see this is to consider mobile workers in rural areas. These workers are not directly affected by the suppression of agglomeration economies. But they are indirectly affected because suppression of agglomeration economies releases urban workers who seek employment in rural areas. If these displaced urban workers could be accommodated without increasing the price of the locally produced good, then there would be *no* change in economic welfare (but there will still be large changes in employment concentration). However, land available for production in rural areas is fixed and increasing employment density in these areas raises congestion costs. Consequently, utility obtained by mobile workers decline. We can calculate the welfare loss of a mobile worker by calculating the wage tax a mobile worker would be willing to pay to not live in world where agglomeration economies are absent.[18] For the baseline calibration, this equivalent wage tax is 6.81 percent.

It is remarkable that the rather small increasing returns parameter of 0.02 (which implies that the productivity of a locality increases by 2 percent as the locality doubles in size) implies such a large welfare loss from its elimination. The reason the change is so large is because the elimination of agglomeration economies means that 93.5 percent of workers cannot be profitably employed in their existing location: firms cannot pay their workers enough to compensate them for congestion costs associated with living in dense localities. These urban workers would prefer to move to less dense rural localities – the localities that are initially unaffected by the suppression of agglomeration economies. Consequently, congestion costs rise rapidly in the rural areas and causes the new equilibrium utility to be significantly lower.

So far it has been assumed that individuals are free to relocate when agglomeration economies are suppressed. However, in the calibration of the model it was necessary to assume that some localities had only immobile workers. If we interpret this immobility as an overarching desire to live and work in a particular location, then the immobility reflects an aspect of preferences that we might wish to respect in the counterfactual. This can be done by requiring that for any location in a corner equilibrium must have at least as many workers in the new, counterfactual, equilibrium. For the baseline calibration, the results are not very different when this requirement is imposed. The counterfactual Gini coefficient is somewhat lower than the Gini coefficient reported earlier, being 0.36. The percentage decline in the Gini index is 51 percent. The rank correlation between the actual and counterfactual employment densities is 0.87. The welfare loss (in terms of the equivalent wage tax) remains the same. That difference in the result is small is not surprising because only slightly more than 5 percent of workers are immobile.

[18] The indirect utility function of a mobile worker is linear in the amenity-adjusted real wage. Hence, the equivalent wage tax can be calculated from the ratio of equilibrium utilities in the actual and counterfactual equilibria.

Table 2

Impact of Agglomeration Economies

$\overline{N} = 35,000$, $\gamma = 10^{-3}$

ν	% Decline in Gini	Rank Correlation	Welfare Loss
0.01	28.9	0.97	3.43
0.02	**48.5**	**0.85**	**6.85**
0.03	55.7	0.68	10.23
0.04	58.1	0.58	13.56
0.05	58.7	0.50	16.86

How sensitive are these results to the choice of parameter values? Table 2 presents results for different choices of ν and Table 3 for γ. Evidently, higher values of the agglomeration parameter and lower values of the congestion parameter are associated with a greater contribution of agglomeration economies to spatial concentration, a more different economic geography, and a larger contribution to economic welfare. Except for the case where $\nu = 0.01$, the decline in spatial concentration upon elimination of agglomeration economies remains substantial.

Table 3

Impact of Congestion Costs

$\overline{N} = 35,000$, $\nu = 0.02$

γ	% Decline in Gini	Rank Correlation	Welfare Loss
8×10^{-4}	53.3	0.77	6.84
9×10^{-4}	50.9	0.82	6.84
$\mathbf{10} \times 10^{-4}$	**48.5**	**0.85**	**6.85**
12×10^{-4}	46.0	0.88	6.86
14×10^{-4}	43.9	0.91	6.86

Finally, Table 4 shows the sensitivity of the results to a change in the value of the agglomeration threshold. In this case the results are rather sensitive to the choice of threshold parameter. If the threshold parameter is set at half its baseline value, there is a small change in the contribution of agglomeration economies to spatial concentration, but there is a large effect on economic geography – the rank correlation between actual and counterfactual density drops to 0.56. In contrast, if the agglomeration threshold is set to twice its baseline value, the contribution of agglomeration economies to spatial concentration drops to 41.6 percent while the rank correlation rises to 0.97. There is not much change in the welfare loss figures.

Table 4

Impact of Agglomeration Threshold

$\nu = 0.02, \gamma = 10^{-3}$

$\overline{N}$	% Decline in Gini	Rank Correlation	Welfare Loss
17×10^3	49.8	0.56	6.54
$\mathbf{35} \times 10^3$	**48.5**	**0.85**	**6.85**
70×10^3	41.5	0.97	7.18
140×10^3	32.1	0.99	7.54

6 Summary and Conclusions

This paper explored a novel approach to quantifying the role of agglomeration economies in the spatial concentration of U.S. employment. It posed and answered the following question: If agglomeration economies are counterfactually suppressed, how much would the spatial concentration of employment decline?

The approach is to start with estimates of the magnitude of agglomeration economies and use a general equilibrium model to account for the observed spatial distribution of employment (across all rural and urban localities in the 48 contiguous states) in terms of these estimates, locality-specific endowments of natural advantage and mobility restrictions. The approach is analogous to business-cycle or growth accounting. The findings suggested that for the most plausible calibration of the model the agglomeration economies accounted for a little under 50 percent of the observed spatial concentration of employment. More generally, the importance of agglomeration economies ranges between 40 and 60 percent of observed spatial concentration.

References

[1] Carlino, G. and S. Chatterjee. "Employment Deconcentration: A New Perspective on America's Postwar Urban Evolution," *Journal of Regional Science*, 42, pp. 455-476, 2002.

[2] Chatterjee, S. and G. Carlino. "Aggregate Metropolitan Employment Growth and the Deconcentration of Metropolitan Employment," *Journal of Monetary Economics*, 48, pp. 549-583, 2001.

[3] Ciccone, A. and R. E. Hall. "Productivity and the Density of Economic Activity," *American Economic Review*, 86, pp. 54-70, 1996.

[4] Davis, D. R. and D. E. Weinstein. "Bombs, Bones, and Breakpoints: The Geography of Economic Activity," *American Economic Review*, 92, pp. 1269-89, 2002

[5] Ellison, G. and E. L. Glaeser. "The Geographic Concentration of Industry: Does Natural Advantage Explain Agglomeration?" *American Economic Review*, 89, pp. 311-316, 1999.

[6] Fujita, M. *Urban Economic Theory* Cambridge: Cambridge University Press, 1989.

[7] Fujita, M., P. R. Krugman, and A. J. Venables. *The Spatial Economy: Cities, Regions, and International Trade*. Cambridge: The MIT Press, 1999.

[8] Gollin, D. "Getting Income Shares Right," *Journal of Political Economy*, 110, pp. 458-474, 2002.

[9] Jacobs, E. E. and S. Shipp. "How Family Spending Has Changed in the US," *Monthly Labor Review*, March, pp. 20-27, 1990.

[10] Kim, S. "Regions, Resources, and Economic Geography: Sources of U.S. Regional Comparative Advantage, 1880-1987," *Regional Science and Urban Economics*, 29, pp. 1-32, 1999.

[11] Krugman, P. R. "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99, pp. 483-499, 1991.

[12] Moomaw, R.L. "Productivity and City Size: A Critique of the Evidence," *The Quarterly Journal of Economics*, 116, pp. 675-89, 1981.

[13] Rappaport, J. "A Productivity Model of City Crowdedness," Federal Reserve Bank of Kansas City, RWP 06-06, June 2006.

[14] —— and J. D. Sachs. “US as a Coastal Nation,” Federal Reserve Bank of Kansas City, RWP 01-11, October 2002.

[15] Roback, J. “Wages, Rents and the Quality of Life,” *Journal of Political Economy*, 90, pp. 1257-78, 1982.

[16] Rosenthal, S. and W. C. Strange. “Evidence on the Nature of and Sources of Agglomeration Economies,” in *Handbook of Urban and Regional Economics*, Volume IV, (Eds.) V. Henderson and J.F. Thisse, 2004.

[17] Sveikauskas, L. “The Productivity of Cities,” *The Quarterly Journal of Economics*, 89, pp. 393-413, 1975.

Figure 1: Equilibrium Density

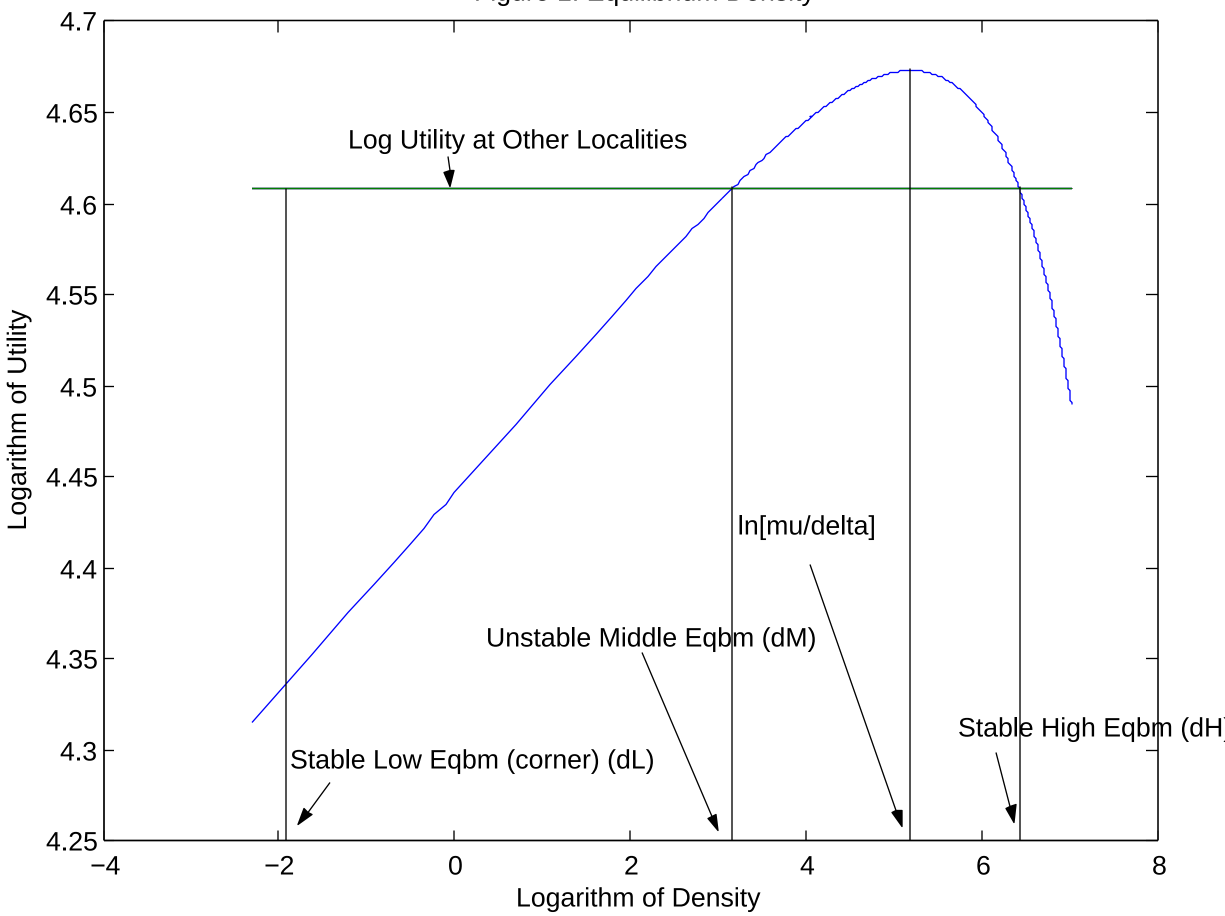


Figure 2: Equilibria With an Agglomeration Threshold

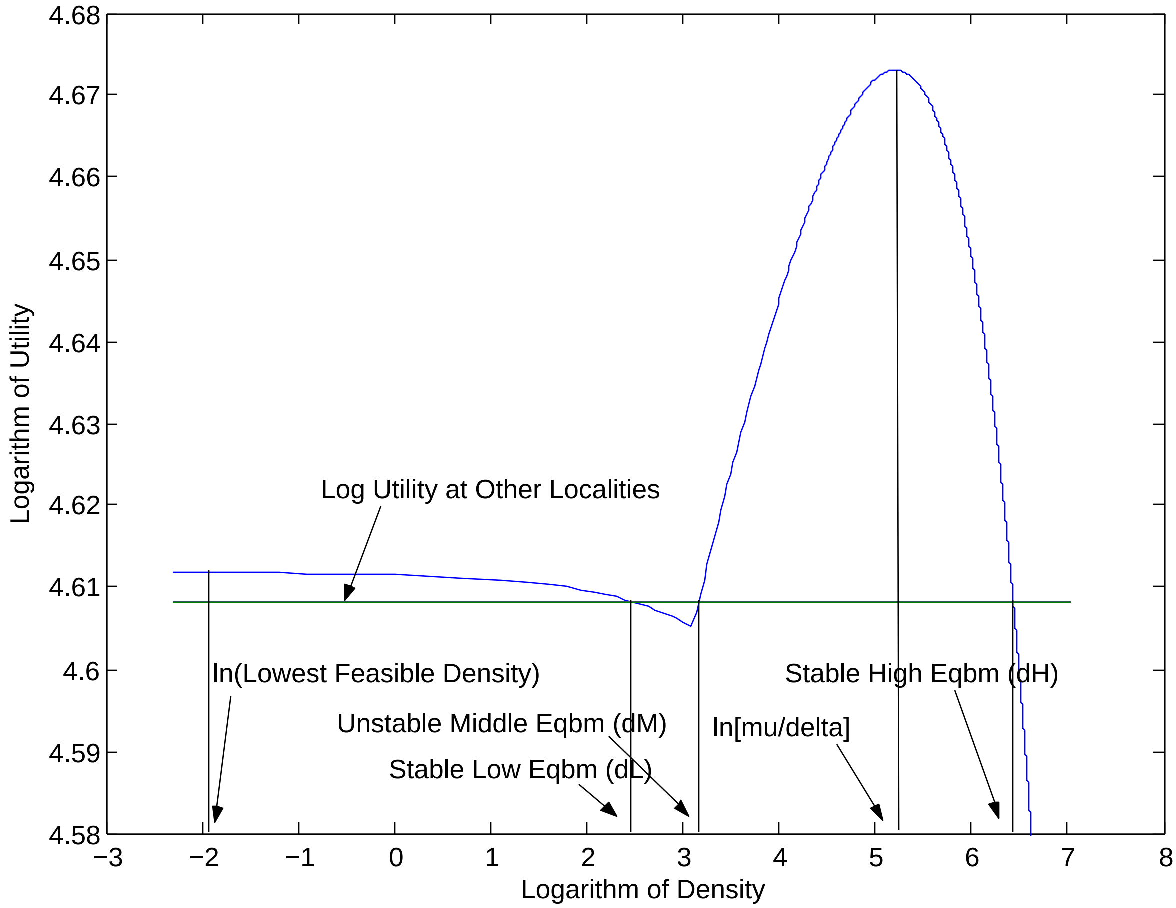
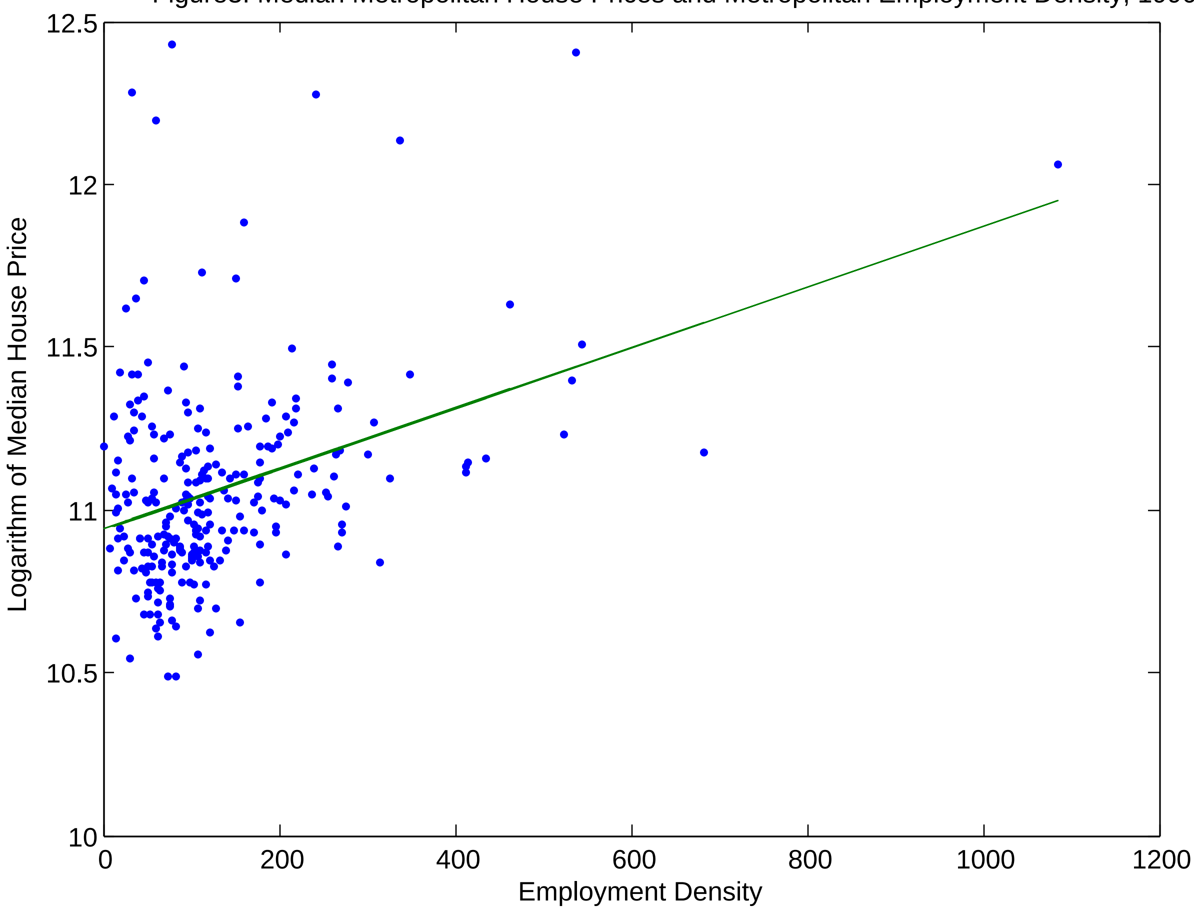


Figure3: Median Metropolitan House Prices and Metropolitan Employment Density, 1990



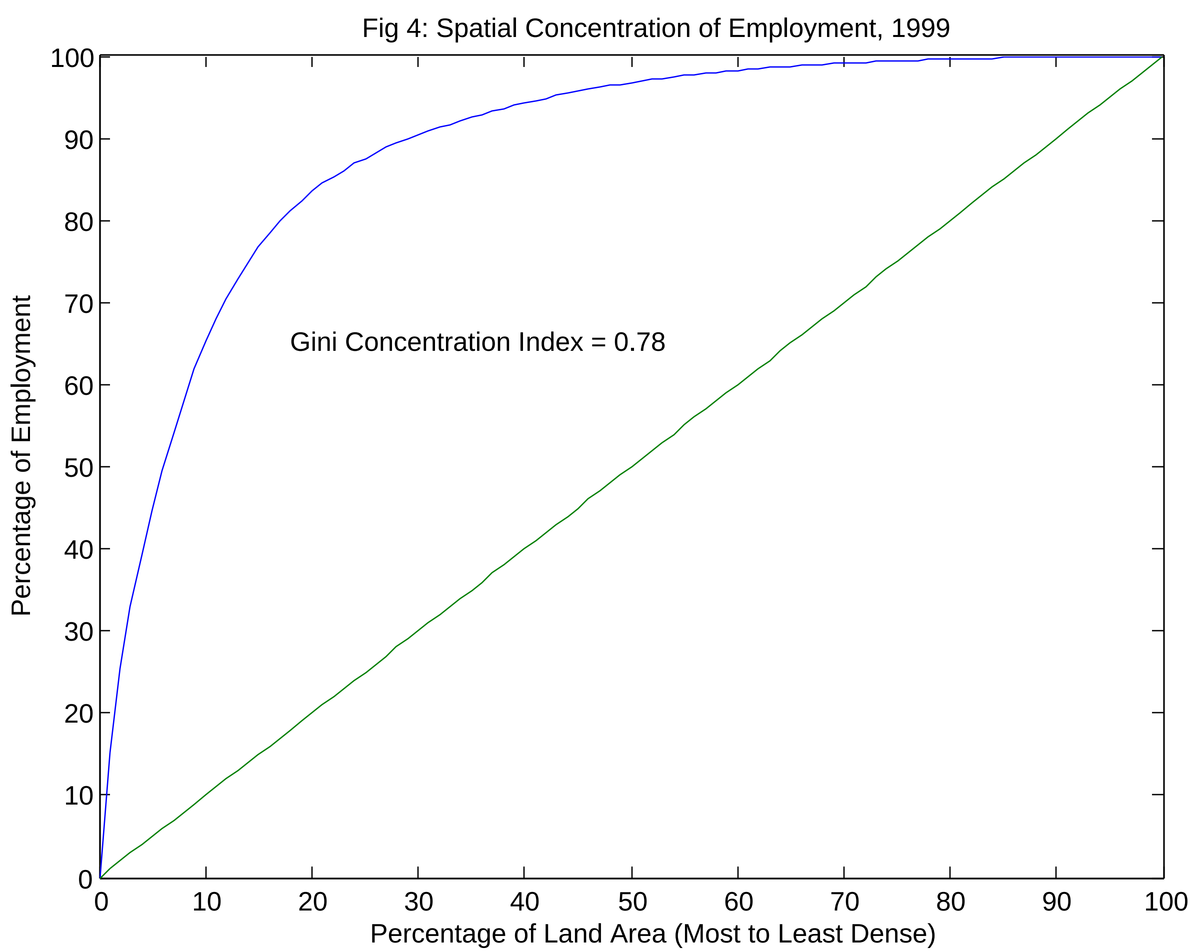


Fig 4: Spatial Concentration of Employment, 1999
Percentage of Employment
Percentage of Land Area (Most to Least Dense)
Gini Concentration Index = 0.78
0
10
20
30
40
50
60
70
80
90
100

Figure 5: Lorenz Curve Without Agglomeration Economies

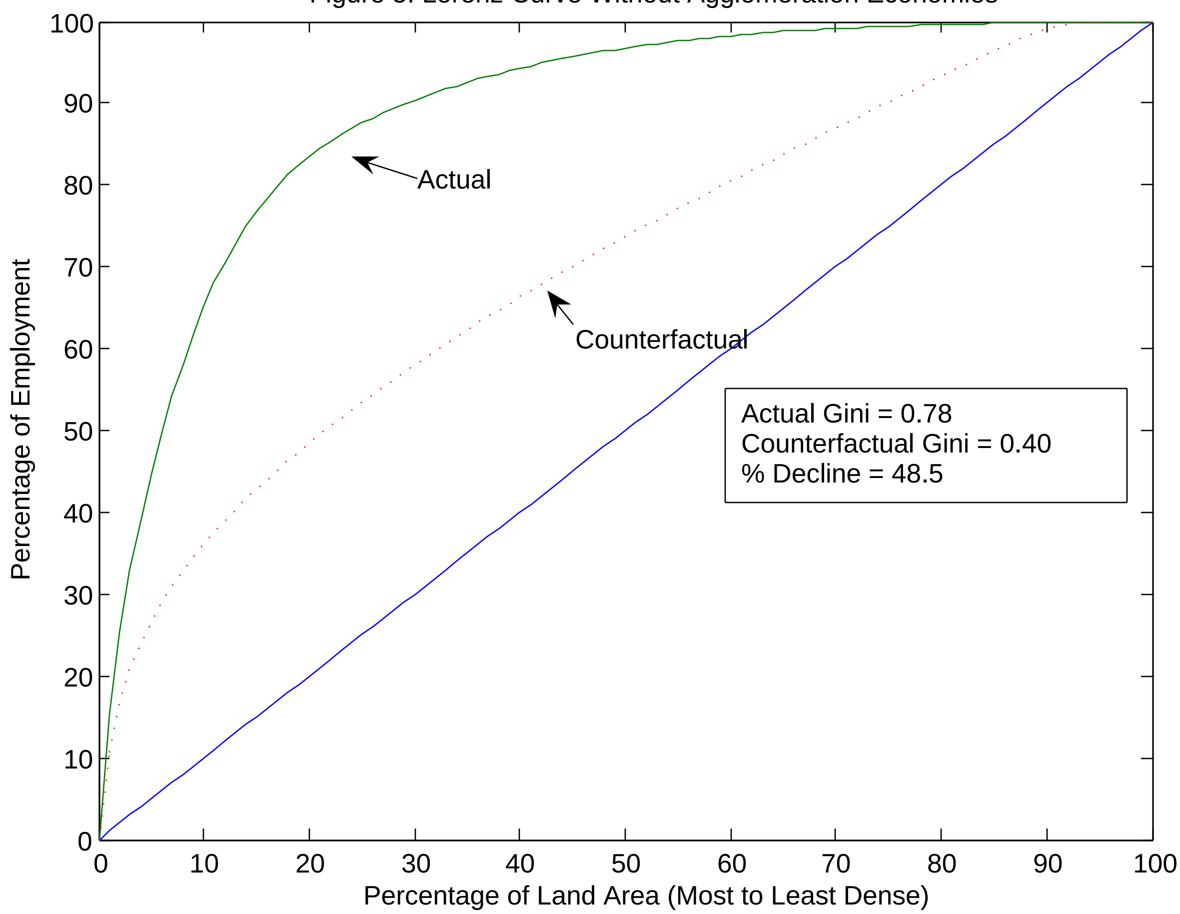


Figure 6: Frequency Distribution of the Imputed Location−Specific Factors