MARKET POTENTIAL, INCREASING RETURNS, AND GEOGRAPHIC CONCENTRATION

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ABSTRACT

In this paper, I examine the relationship between increasing returns to scale and the geographic concentration of economic activity. Using data on U.S. counties, I estimate the structural parameters of the Krugman (1991) model of economic geography. The specification I use, which is derived from the equilibrium conditions of the model, resembles a spatial labor demand function, as it is proximity to consumer markets that determines nominal wages and employment in a given location. Parameter estimates show support for small but significant scale economies; the estimated price-marginal cost ratio is 1.1 in 1980 and 1.2 in 1990. The parameter estimates also suggest that geographic concentration is a stable feature of the spatial distribution of economic activity. As a prelude to the analysis, I estimate a reduced form of the Krugman model, which approximates Harris' (1954) market-potential function. The estimation results indicate how far demand linkages extend across space and how shocks to income in one location affect wages and employment in other locations. Demand linkages between regions are strong and growing over time, but limited in geographic scope. Simulations based on parameter estimates suggest that a 10% fall in personal income for a region the size of Illinois reduces employment by 6.0-6.4% in counties that are 100 kilometers in distance, with effects declining to zero for counties more than 800 kilometers in distance. The results are consistent with a high volume of trade within cities and between proximate cities.

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Most of the United States produces very little. In 1990, the 2,000 least economically-active U.S. counties, which had an average employment density of 4.0 workers per square kilometer, accounted for 75.8% of U.S. land area but only 11.7% of U.S. employment. In contrast, the 100 most economically-active U.S. counties, with an average employment density of 1,169 workers per square kilometer, accounted for 41.2% of U.S. employment but only 1.5% of U.S. land area. These figures illustrate the well-known fact that geographic concentration is a predominant feature of the economic landscape.

In this paper, I examine the spatial distribution of economic activity in the United States to see what it reveals about the strength of demand linkages between regions. The starting point for the exercise is the idea that the level of economic activity in a location is conditioned by that location's access to markets for its goods. While this view may seem narrow -- it ignores climate, natural-resource supplies, and other factors which surely influence city location -- I attempt to show that market access provides a useful way to characterize the forces that contribute to the geographic concentration of economic activity.

There is a large theoretical literature on the spatial organization of the economy. Fujita (1988) and Krugman (1991) explain city formation through the interaction of transport costs and firm-level increasing returns to scale, building on earlier work on the role of increasing returns in city formation by Henderson (1974) and Papageorgiou and Thisse (1985).[1] In the Fujita and Krugman models, firms are monopolistically competitive. Scale economies and transport costs give each firm an incentive to concentrate production in a single plant and to locate that plant

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[1] Rivera-Batiz (1988) also develops a model of city formation based on increasing returns. Krugman and Venables (1995) and Venables (1996) extend the monopolistic-competition model of spatial agglomeration to open economies (see Ottaviano and Puga (1997) for a survey). There is a much larger literature on increasing returns and spatial agglomeration than is cited here. Fujita and Thisse (1996) review the literature.

near a large consumer market. The resultant interdependence in firm location decisions contributes to the formation of cities. Cities exist, in effect, to provide a large local market for firms. Working against agglomeration are congestion costs, which arise from limited local supplies of housing or immobile supplies of some factor of production.

To assess the empirical importance of market access, I examine the spatial correlation of wages, employment, and consumer purchasing power. Using data on U.S. counties for the period 1970-1990, I estimate structural equations from the Krugman (1991) model. Despite the influence of the model in international and urban economics, it has been subjected to little empirical work. This is the first study, to my knowledge, that estimates the model's structural parameters.[2] The specification I use resembles a spatial labor demand function, as it is proximity to consumer markets that determines nominal wages and employment in a given location. Having estimated the model, I evaluate the magnitude of scale economies, the stability of the spatial distribution of economic activity, and how these features evolve over time.

As a prelude to the analysis, I estimate a reduced form of the Krugman model. Given the nonlinearity of the model, the reduced form is useful for establishing empirical regularities about how wages and employment vary with access to consumer markets. Of particular interest, the reduced form closely approximates Harris' (1954) market-potential function, which expresses the potential demand for goods produced in a location as the sum of the purchasing power in all other locations, weighted by transport costs. The market-potential function has a long history in urban economics (e.g., Clark et al. 1969, Dicken and Lloyd 1977, Keeble et al. 1982). Recent

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[2] In related work, Davis and Weinstein (1997a, 1997b) find some evidence that for OECD countries regional specialization in production is positively correlated with regional specialization in absorption, which is consistent with the Krugman (1980) model of international trade.

theory (Krugman 1992; Fujita and Krugman 1995) reinvigorates the concept by showing that a market-potential function can be derived from formal spatial models. Previous empirical research uses ad hoc functional-form assumptions to calculate the 'market potential' for a location, imposing no constraint that the estimated value be correlated with any measure of local economic activity. My approach is to econometrically estimate the market-potential function, using wages or spatial employment densities as the dependent variable.

Estimation results for the Krugman model and the market-potential function give an indication of how far demand linkages extend across space and how shocks to income in one location affect wages and employment in other locations. The spatial extent of demand linkages is an indirect measure of transport costs, broadly defined. For many products, physical shipping costs may be small, but the costs associated with gathering information about demand conditions in distant markets, dealing with remote merchants, or communicating with suppliers may be large. I evaluate the economic importance of distance and how it changes across time.

My work follows a resurgence in empirical research on the location of economic activity. One branch of literature examines the role of dynamic localization economies in regional industry location. Influential contributions include Glaeser et al. (1992), Jaffe, Trajtenberg, and Henderson (1993), and Henderson, Kuncoro, and Turner (1995). Another branch examines whether wages or labor productivity are correlated with the agglomeration of economic activity (Rauch 1993, Ciccone and Hall 1996, Hanson 1997).[3] These bodies of work have produced important insights about external economies of scale, providing indirect evidence on their contribution to city formation. The literature has so far paid relatively little attention to the implications of increasing

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[3] See also Eaton and Dekle (1994) and Justman (1994).

returns and transport costs for economic relationships between regions.

Other related literature include papers by Topel (1986) and Blanchard and Katz (1992) on how labor-market shocks are transmitted across regions, Dobkins and Ioannides (1996), Eaton and Eckstein (1997), and Black and Henderson (1997) on the size distribution of cities, and Quah (1996) on the correlation of per capita incomes across regions within Europe. These papers and my own examine the properties of the spatial distribution of economic activity and how it changes over time. What distinguishes my work is an attempt to quantify the importance of demand linkages in spatial economic relationships.

In the first section of the paper, I present summary statistics on the spatial distribution of economic activity in the United States in geographical form. In the second section, I discuss model specification and estimation strategy. In the third section, I present estimation results. In the fourth section, I discuss the results and offer concluding remarks.

I. Empirical Setting

To motivate the empirical analysis, I describe stylized facts about the spatial distribution of economic activity in the United States. While some of these facts may be well known, the geographical form in which I present the data offers an interesting perspective from which to examine how wages and employment vary across space and how these distributions evolve over time. There is a large empirical literature on regional wage differentials (e.g., Beeson and Eberts 1989, Gyourko and Tracy 1991, Topel 1994) and regional employment growth (e.g., Blanchard and Katz 1992), which generates important insights. Much of this work uses data either on large metropolitan areas, which selects information from spikes in the spatial distribution only, or U.S.

states, which ignores intra-state variation in the distribution of production. By using data on counties for the entire United States, I am able to characterize the spatial distribution of wages and employment in more detail.

A. Data Sources

I take counties in the continental United States as the geographic unit of analysis.[4] Data exist at finer geographic levels, such as zip codes or census tracts, but the size of geographic units in these classification schemes changes frequently over time and is influenced by the spatial distribution of economic activity. Counties are more suitable for my purposes given that their sizes are not determined by current levels of economic activity, and, except for a few western states, they cover relatively small geographic areas.

The data required for the analysis include wages, employment, income, and the housing stock. County-level data on annual earnings and average annual employment are available from the Regional Economic Information System (REIS), which the U.S. Bureau of Economic Analysis (BEA) compiles using data from state unemployment-insurance records and other sources.[5] I use employment and earnings data for wage and salary workers. Data at higher levels of aggregation include the self-employed, whose earnings are sensitive to regional variation in business cycles and industry composition; data for individual industries are unavailable for many counties due to disclosure restrictions or zero production. I measure income by total personal income, as

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[4] I limit the analysis to contiguous states to ensure that the concept of economic distance between locations, which plays an important role in the empirical estimation, is consistent across locations.

[5] The number of counties in the REIS data is 3,075. Data for independent cities in the state of Virginia are combined with data for the counties that surround them. I use county definitions from 1980 (between 1980 and 1990, Arizona and New Mexico both divided an existing county into two smaller counties).

computed by the U.S. BEA. Personal income is the best measure of purchasing power available at the county level. I measure the housing stock as total housing units, as reported in the U.S. Census of Population and Housing. The time period for my study are the three most recent census years, 1970, 1980, and 1990. Table 1 gives summary statistics on the variables.

B. The Spatial Distribution of Employment and Wages

In this section, I present data on wages and employment in U.S. counties. Wages are calculated as average annual earnings per worker. Employment is calculated as the average annual number of workers per square kilometer. All variables are expressed relative to weighted averages for the continental United States. Figure 1 shows the relative employment density of wage and salary workers for U.S. counties in 1970. In Figures 1-6, darker colors represent higher numerical values. The blackened counties represent spikes in the spatial distribution, which, unsurprisingly, adjoin major cities, such as Atlanta, Boston, Chicago, Houston, Los Angeles, Miami, New York, San Francisco, etc. Employment centers are concentrated around northeastern and midwestern cities and virtually absent in the region extending longitudinally from central Texas to eastern California. Employment densities in the most urbanized counties, which account for 5.2% of the total, range from 6.1 times the U.S. average in Niagara County to 3,542 times the U.S. average in New York County. Surrounding and connecting major cities are regions with moderately high employment densities, ranging from 1.5 to 6 times the U.S. average. A large mass of counties have very low employment densities, ranging from 0.02 to 0.6 times the U.S. average. These counties, which account 67.2% of the total, are located mostly in farm and mountain states. That major employment centers are located near large consumption masses is consistent with the idea that access to markets influences industry location.

Figure 2 shows relative employment densities for U.S. counties in 1990. The darkening of counties around cities in the southwest and southeast, such as Atlanta, Orlando, and San Diego, and the lightening of counties in New York, Pennsylvania, and Ohio, illustrates the long-run employment shift from the northeast and midwest to the west and southeast, as discussed in Blanchard and Katz (1992). Figure 3, which shows the log change in county employment relative to the log change in U.S. employment for 1970-1990, illustrates the transition clearly. Counties with high relative employment growth are concentrated in the southwest and southeast; counties with low relative employment growth are concentrated in plains states, the Great Lakes region, and the inland northeast. Interestingly, employment change in both high and low-growth regions is far from uniform. East and southwest Texas have high relative growth, but west and north Texas show relative declines. While most counties in plains states have low relative growth, the Twin Cities region has high relative growth. As employment relocates to the south and west, it appears to concentrate in certain pockets, leaving many areas untouched.

The spatial distribution of wages provides an alternative perspective on geographic concentration. Figure 4 shows county average wages relative to U.S. average wages for wage and salary workers in 1970. Wages are above the national average in only 7.8% of U.S. counties, which is an indirect indication of the fact that economic activity is highly spatially agglomerated. Similar to the spatial distribution of employment, wages are relatively high near areas of dense economic activity, such as the Boston-Washington, D.C. corridor and the major cities on the Great Lakes. This is consistent with the Fujita and Krugman models, which predict that nominal wages will be relatively high in regions near dense concentrations of economic activity.[6]

Forces other than market access also appear to create spatial wage differences. Wages are relatively high in unpopulated regions of western states, such as central Nevada and western Utah, and in moderately-populated counties on the Gulf Coast of Louisiana and Texas. Each of these regions specializes in a single activity -- mining in Utah, tourism (gambling) in Nevada, and petroleum refining along the Gulf Coast -- that requires an immobile resource. Concentrated pockets of specialized production suggest that idiosyncratic factors, including climate and natural-resource supplies, also influence the spatial distribution of wages.

Comparing Figures 1 and 4, it is apparent that while high relative-employment counties in the northeast, midwest, and west coast are also high relative-wage counties, the same is not true for the southeast. Major urban areas in the southeast show up as high-employment counties in Figure 1, but not as high-wage counties in Figure 4. This feature of the spatial distribution of wages changes somewhat between 1970 and 1990. Figure 5 shows relative wages for U.S. counties in 1990. The most striking difference between Figures 4 and 5 is the darkening of counties around major population areas in the southeast. This change is more apparent in Figure 6, which shows the log change in county wages relative to the log change in U.S. wages between 1970 and 1990. Counties with high relative-wage growth are overwhelmingly concentrated in the southeast. Most counties in the northern midwest and the northeast, with the exception of the Atlantic seaboard, have relative-wage declines. Comparing Figures 3 and 6, the geographic

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[6] By measuring wages as mean earnings for wage and salary workers in a county, I do not control for spatial variation in human capital per worker. Higher wages in agglomerated regions could be partly a result of geographic sorting of workers by skill, such as would result if high-skill workers concentrate in cities and low-skill workers concentrate in outlying areas (see Rauch (1993) and Glaeser and Mare (1994) on the geographic distribution of human capital). Though such sorting is not considered explicitly in Krugman (1991) or Fujita (1988), it is consistent with the models' overall thrust. Given there is a premium on space in cities, it would be more efficient for high-skill workers to concentrate in agglomerated regions.

expanse of relative-wage growth in the southeast appears to be larger than the geographic expanse of relative-employment growth in the region, suggesting that employment growth in high-activity counties may put upward pressure on wages in neighboring counties.

II. Theory

Recent theory on the economics of cities emphasizes the role of market access in the spatial distribution of economic activity. Access to markets matters because of increasing returns to scale in production and transport costs in delivering goods to market. It is useful to begin by reviewing Harris' (1954) concept of market potential, which is the idea that the potential demand for goods and services produced in a location is determined by that location's access to consumers for its goods. He summarizes this notion in the following expression:

$$MP_j = \sum_{k \in K} Y_k f(d_{jk}) \qquad (1)$$

where MP_j is the hypothetical market potential for location j, Y_k is income in location k, K is the set of locations, d_{jk} is distance between location j and location k, and $f()$ is a decreasing function that shows how distance affects transport costs. Without an independent formulation for how MP_j is determined, equation (1) lacks content. Recent theory provides such a formulation.

A. The Krugman Model

I present the basic structure of the Krugman model to motivate empirical specification. I refer to Thomas' (1997) extension of Krugman (1991), which, while very similar to the original model, is more tractable for empirical application.[7] All consumers have identical Cobb-Douglas preferences over two bundles of goods, manufacturing goods and housing services,

$$U = C_m^{\mu} C_h^{1-\mu} \qquad (2)$$

μ is the share of expenditure on manufactures, C_h is the quantity of housing services consumed, and C_m is a composite of symmetric manufacturing product varieties given by

$$C_m = [\sum_i^n c_i^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \qquad (3)$$

where σ is the elasticity of substitution between any pair of varieties and n is the number of varieties. As there are only two types of goods in the economy, it is important think of manufactures broadly as including all goods which are traded across space. There are increasing returns in the production of each individual variety such that

$$L_{im} = a + bx_i \qquad (4)$$

where a and b are constants, L_{im} is labor used to produce variety i, and x_i is the quantity of i produced. In equilibrium each variety is produced by a single monopolistically-competitive firm.

There are J regions in which production may occur. The supply of housing in region j, which is assumed fixed at H_j, is owned by absentee landlords, who supply their stock of housing inelastically in perfectly-competitive housing markets. There are L total laborers, who each supply one unit of labor and are perfectly mobile between regions. Finally, there are iceberg

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[7] In Krugman's (1991) original formulation, the housing sector is replaced by an agricultural sector, where agricultural goods are produced under constant returns to scale by an immobile agricultural labor force. The disadvantage of this formulation is the extreme nature of the spatial equilibria: it is the case that either all regions have symmetric manufacturing employment shares or that most regions have zero manufacturing employment and the remaining regions have symmetric shares. The Thomas model, by introducing a nontraded good whose price varies regionally, generates a more realistic distribution of manufacturing employment.

transport costs in shipping manufactured goods between regions, such that for each unit shipped from location j to location k the fraction that arrives, v_{jk}, is given by

$$v_{jk} = e^{-\tau d_{jk}} \qquad (5)$$

where τ is the transportation cost and d_{jk} is the distance between j and k.[8]

The equilibrium conditions for the model are described by five sets of equations (Krugman 1991 and 1992, Thomas 1997). Depending on parameter values, the equilibrium of the model has manufacturing activity concentrating in a small number of regions. Firms desire to be in a region with high levels of manufacturing activity, as they can serve a large local market at low transport cost without duplicating fixed production costs. The costs for being in a manufacturing center are more competition from local firms and higher labor costs, as labor must be compensated for high housing costs associated with local congestion. The model has multiple equilibria, as which regions contain manufacturing centers is indeterminant. However, the structure of the spatial equilibria -- in terms of how many manufacturing centers exist and what share of manufacturing activity each contains -- is in most cases determinant.

The first equilibrium condition is that real wages be equalized across regions,

$$\frac{w_j}{P_j^{1-\mu} T_j^{\mu}} = \frac{w_k}{P_k^{1-\mu} T_k^{\mu}}, \ \forall\ j \neq k \qquad (6)$$

where w_j is the wage in region j, P_j is the price of housing in region j, and T_j is the price index for manufactures in region j. In equilibrium region j's share of the manufacturing labor force, λ_j, equals the share of manufacturing firms located in region j, n_j/n. The next two equilibrium

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[8] Equation (5) embodies strong assumptions about the structure of transportation costs. These assumptions turn out to be rather benign. In section III, I estimate several different functional forms for transport costs and find that all specifications give very similar results.

conditions are that in each region total income equals labor income earned in the region,[9]

$$Y_j = \lambda_j L w_j, \ \forall j \qquad (7)$$

and that housing payments in each region equal the share of expenditure allocated to housing,

$$P_j H_j = (1 - \mu) Y_j, \ \forall j \qquad (8)$$

From Krugman (1992), the final two equilibrium conditions may be expressed as,

$$w_j = [\sum_k^J Y_k (T_k e^{-\tau d_{jk}})^{\sigma - 1}]^{\frac{1}{\sigma}}, \ \forall j \qquad (9)$$

and

$$T_j = [\sum_k^J \lambda_k (w_k e^{\tau d_{jk}})^{1-\sigma}]^{\frac{1}{1-\sigma}}, \ \forall j \qquad (10)$$

Equation (9) can be thought of as a labor-demand function -- the demand for labor is higher in regions that are close to areas with high consumer demand; equation (10) expresses the equilibrium supply of manufacturing goods -- the price index for these goods is higher in regions where a larger fraction of the goods must be imported from distant locations.[10] Equations (9) and (10) are very similar to the market potential function in (1) in the sense that overall economic activity is higher in regions that are proximate to large market centers.

The Krugman model is very simple. It ignores many features of production and

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[9] Thomas (1997) imposes the assumption of absentee landlords, which may be unrealistic. An alternative assumption is that each worker is endowed with equal ownership share of the total housing stock, in which case equation (7) becomes $Y_j = \lambda_j(w_j + \rho)L$, where $\rho = (1/L)\sum_j p_j H_j$. Other equilibrium conditions are unaffected.

[10] Equations (6)-(10) represent a system of 5*J*-1 equations in 5*J*-1 unknowns. The model in Krugman (1991,1992) contains four sets of equilibrium conditions. Equation (6) is instead $w_j/w_k=(T_j/T_k)^{\mu}$, equation (7) is instead $Y_j=(1-\mu)\phi_j+\mu\lambda_j w_j$, where ϕ_j is region *j*'s share of the (immobile) agricultural labor force, equation (8) is eliminated (since there is no housing sector), and equations (9) and (10) are the same.

consumption which may influence the spatial distribution of economic activity. Housing is the only nontraded good. There are no nontraded goods, such as services, which are produced from mobile resources. Labor is the only factor of production in manufactures. There are no intermediates inputs, immobile supplies of natural resources, or location-specific capital stocks used in production. The absence of these features reduces the realism of the model, but increases its analytical and empirical tractability. My strategy is to examine whether such simple models are informative about the spatial distribution of economic activity.

B. Model Specification

The first equation I estimate is a simplified version of equation (9), or what can be considered an application of the market-potential function in equation (1), given by,

$$\log(z_j) = \alpha_0 + \alpha_1 \log\left(\sum_k^J Y_k e^{-\alpha_2 d_{jk}}\right) + \epsilon_j \qquad (11)$$

where the dependent variable z_j is either the nominal wage or employment per unit of land in location j, α_0, α_1, and α_2, are parameters to be estimated, and ε_j is an error term whose structure I discuss below. I measure wages as average annual income and employment as average annual employment per square kilometer. Income is total personal income earned in a given location. The distance measure is discussed in the next section and in an appendix.

Equation (11) is not derived from an explicit model, but its relative simplicity makes it attractive as a first pass for assessing the strength of demand linkages between regions. One interpretation of (11) is as a local labor demand function in an economy where labor is perfectly mobile across space: employment and nominal wages in a location are a function of the implied demand for goods produced in that location, where consumer demand is determined by transport costs and the spatial distribution of income.[11]

The second specification I estimate is taken directly from the structural equations of the Krugman model. One problem with applying this model is that there are no data on price levels for manufactures (T_j) or housing (P_j) at any useful level of geographic detail. This means I cannot simultaneously estimate all of the model's structural equations. Instead, I substitute equations (6) and (8) into (9) to obtain,

$$\log(w_j) = \theta + \sigma^{-1}\log\left(\sum_{k}^{J} Y_k^{\frac{\sigma(\mu-1)+1}{\mu}} H_k^{\frac{(1-\mu)(\sigma-1)}{\mu}} w_k^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{jk}}\right) + \eta_j \qquad (12)$$

where θ is a function of fixed parameters and η_j is an error term whose structure I discuss below.[12] Equation (12) embodies three equilibrium conditions: the relation between the spatial distribution of consumer income and the spatial demand for labor (equation (9)), real-wage equalization across regions (equation (6)), and the equalization of supply and demand in local housing markets (equation (8)).[13] The parameters to be estimated are σ, the elasticity of substitution between manufactured goods, μ, the expenditure share on manufactures, and τ, the transportation cost of shipping one unit of manufactures a unit distance.

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[11] The missing condition that would make this interpretation complete is a specification for real-wage equalization across regions, as exists in the Krugman model.

[12] The analogous estimation equation to equation (12) derived from Krugman (1991,1992) would be

$$\log(w_j) = C + \sigma^{-1}\log\left(\sum_{k}^{J} Y_k w_k^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{jk}}\right) + \nu_j$$

where C is a function of the fixed parameters and υ_j is a disturbance term (see note 10).

[13] Data limitations prevent the joint estimation of equations (10) and (12). While estimation of (12) will produce estimates of the structural parameters, it is not a full-information approach. By failing to impose the complete set of constraints consistent with general equilibrium, I may lose some efficiency in estimation.

C. Estimation Issues

There are two main estimation issues to be addressed. The first is choosing the geographic unit of analysis. The more geographically disaggregated is the data, the lower is measurement error and the extent to which location-specific shocks, embodied in the error terms in equations (11) and (12), influence the independent variables that enter the regressor function. Too much geographic detail, however, creates computational problems. The summation expressions in (11) and (12) are over all locations and the distance variable, d_{jk}, is defined for each pair of locations. As the number of locations, and hence the number of terms in the summation expression, grows large, estimation of the model becomes intractable.

The approach I take balances the need for geographic detail with computational costs. For the dependent variable, I use counties in the continental United States as the unit of analysis. Specifying the independent variables in the summation terms in (11) and (12) at the county level, however, would create an expression with over 3,000 terms for each observation and a pair-wise matrix of distance measures with over 4.7 million distinct elements. I instead aggregate the independent variables that appear in the summation expressions to the level of U.S. states. In equation (11), for instance, the summation expression for each observation contains 49 terms (the continental states plus the District of Columbia), each consisting of total personal income in a state times the transportation-cost function. To avoid directly introducing simultaneity into the estimation, I subtract own-county values from the independent variables for the state that corresponds to the county on which an observation is being taken. In the case of the observation for Los Angeles County in equation (11), for instance, I subtract personal income in Los Angeles from the term for personal income in California that appears in the summation expression.

The distance variables that appear in the summation expression are distances from the county on which an observation is being taken to each state. I construct two measures of distance between locations: direct (geodesic) distance, which is the minimum-length arc that connects two locations, and hub-and-spoke distance, which assumes that goods being transported from county *i* to state *j* must pass through a transportation hub in the home state of county *i*. I give a detailed description of the distance calculations in an appendix. An additional concern is that counties vary greatly in land area. To control for the possibility that the variances of the disturbance terms in (11) and (12) differ across counties, I use the White (1980) estimator to obtain heteroskedasticity-consistent standard errors.

The second estimation issue is whether the error terms in equations (11) and (12) are correlated with the regressor function. Any such correlation would produce inconsistent coefficient estimates. The disturbance terms are unobserved idiosyncratic factors that influence wages or employment in U.S. counties, such as the fixed characteristics of regions that generate amenities in production or consumption (transportation infrastructure, water supply, climate) and temporary shocks that influence the local business cycle (extreme weather, military base closings). In equation (11), shocks to wages in one region affect income in that region, which by hypothesis influences wages in other regions. In equation (12), wages in other regions appear directly as independent variables in the regressor function for a given county.

One solution would be to use nonlinear-instrumental-variable techniques. The problem with this approach, as is often the case, is that it is difficult to find good instruments. Any current measures of local economic activity may be correlated with wage and employment shocks, and measures of fixed characteristics of regions, such as whether a county has a railroad station or an airport, are likely to be correlated with factors that are omitted from the analysis and present in the disturbance term. My approach is to minimize the potential effects of endogeneity through the choice of specification. I have already described three elements of this strategy: (i) measuring the dependent variable at the finest level of geographic detail possible, which minimizes the economic importance of location-specific shocks and the likelihood that they are correlated with the independent variables, (ii) aggregating the independent variables to the level of U.S. states, whose economies are less likely to be influenced by shocks to individual counties, and (iii) subtracting own-county values from the state-level independent variables that enter the regressor function, which avoids directly introducing simultaneity into the regression.

I adopt two other controls for correlation between the regressor function and the disturbance term. If the source of this correlation is unobserved factors that are constant across time, then these factors can be controlled for by using a time-differenced specification. As an example, Los Angeles County has a major port. Access to the port may influence wages in Los Angeles and wages and income in the rest of California, in which case the regressor functions and the error terms for Los Angeles County in equations (11) and (12) would be correlated. Using time differences of the regression equations, equation (11) becomes,

$$\Delta \log(z_{jt}) = \alpha_1 [\log(\sum_k^J Y_{kt} e^{-\alpha_2 d_{jk}}) - \log(\sum_k^J Y_{kt-1} e^{-\alpha_2 d_{jk}})] + \Delta\epsilon_{jt} \tag{13}$$

where t indexes the year and Δ is the difference operator, and equation (12) becomes,

$$\Delta \log(w_{jt}) = \sigma^{-1} [\log(\sum_k^J Y_{kt}^{\frac{\sigma(\mu-1)+1}{\mu}} H_{kt}^{\frac{(1-\mu)(\sigma-1)}{\mu}} w_{kt}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{jk}})$$
$$- \log(\sum_k^J Y_{kt-1}^{\frac{\sigma(\mu-1)+1}{\mu}} H_{kt-1}^{\frac{(1-\mu)(\sigma-1)}{\mu}} w_{kt-1}^{\frac{\sigma-1}{\mu}} e^{-\tau(\sigma-1)d_{jk}})] + \Delta\eta_{jt} \tag{14}$$

I assume that the random errors $\Delta\varepsilon_{jt}$ and $\Delta\eta_{jt}$ are uncorrelated with the regressors and uncorrelated across counties.[14]

Finally, as a check on whether the endogeneity of the independent variables poses a serious problem, I report estimation results for two samples of U.S. counties: all counties and counties with less than 0.05% of the U.S. population. Specific shocks to high-population counties, such as those that compose major metropolitan areas, may influence economic activity in other regions, while specific shocks to low-population counties are unlikely to have important effects on other regions. To the extent that coefficient estimates are similar for the two samples of counties, we have an indication that the endogeneity of the independent variables does not have dire consequences for the estimation results.

III. Estimation Results

To assess the empirical importance of market access for the spatial distribution of economic activity, I estimate equations (13) and (14) by nonlinear least squares. The sample is 3,075 counties in the continental United States. The dependent variables are, for equation (13), employment per square kilometer and wages, and, for equation (14), wages only. The independent variables are personal income and direct distance in equation (13), and personal income, the housing stock, wages, and direct distance in equation (14), all of which are measured at the state level (excluding own-county components). I estimate all specifications in time-difference form for 1970-1980 and 1980-1990. I also report results using restricted samples of counties, alternative distance measures, and additional control variables.

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[14] To check whether errors in adjoining counties are correlated, I examine geographic maps of the residuals. The maps reveal no geographic pattern in the errors.

A. The Market-Potential Function

The first two columns of Table 2a show coefficient estimates for the market-potential function in equation (13), using the log change in employment as the dependent variable.[15] The coefficient, α_1, is the effect of purchasing power in U.S. states on economic activity in a given county. Consistent with the market-access hypothesis, the coefficient is positive and very precisely estimated in both time periods. Higher consumer demand, adjusted for transport costs, appears to raise the demand for labor in a location. The coefficient, α_2, is the effect of distance from consumer markets on economic activity in given county. Also consistent with the market-access hypothesis, the coefficient is positive and precisely estimated in all specifications. Greater distance to consumer markets appears to reduce the demand for labor in a location. The second two columns of Table 2a show coefficient estimates for (13), using the log change in wages as the dependent variable. Similar to the employment results, coefficient estimates for α_1 and α_2 are positive and precisely estimated in all specifications. Overall, the results are consistent with the idea that spatial labor demand is conditioned by access to consumer markets.

While the signs of the coefficients are easy to interpret, their magnitudes are not. For instance, both coefficients become larger in absolute value over time. It is tempting to interpret the increase in α_2 as an increase in transport costs, which would contradict the popular view that improvements in communication and transportation technology have reduced the costs of transacting across space. To interpret the economic importance of the coefficient magnitudes and how they have changed over time, I perform the following experiment: I shock personal income in a particular location and then examine the predicted changes in wages and employment across

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[15] Since land area is constant, the log change in employment equals the log change in employment density.

space implied by the coefficient estimates. Given that I explore the direct effects of a shock only, this exercise is strictly partial equilibrium in nature. Changes in the spatial distribution of wages and employment would alter the spatial distribution of consumer purchasing power, which would lead to further changes in wages and employment and so on. The reduced-form nature of equation (13) prevents me from examining such feedback effects. The exercise is still useful as a means of interpreting the coefficient estimates. The shock I consider is a 10% reduction in personal income for the state of Illinois, which is an interesting case due to its large economic size and central location.[16] Shocks to other states produce qualitatively similar results.

Figure 7 shows the predicted effects of the income shock on employment across U.S. counties using coefficient estimates for 1970-1980 (column one, Table 2a) and values of the independent variables for 1990.[17] The effects of the income shock are largest in central Illinois and fall rapidly as one moves in any direction. Employment in Chicago (Cook County), at a distance of 74 kilometers from the economic center of Illinois (see appendix), falls by 4.5%; employment in St. Louis (St. Louis County), at a distance of 345 kilometers, falls by 1.2%; and employment in Wichita, Kansas (Sedgwick County), at a distance of 885 kilometers, falls by 0.002%. The income shock in Illinois has zero direct effect on economic activity west of Iowa, south of Kentucky, or east of Ohio. Figure 8 shows the same simulation, using estimated coefficient values for 1980-1990 (column two, Table 2a). The local magnitude of the shock is much larger in the later period. In Figure 8, employment in Chicago falls by 6.2%, employment

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[16] Since I subtract own-county values from independent variables for the corresponding state, for counties in Illinois the income shock is equivalent to an income shock to all *other* counties in the state.

[17] Given the nonlinearity of the specification, the values of the independent variables influence the simulation results. To provide a common basis of comparison, I use data from 1990 for all simulations.

in St. Louis falls by 1.1%, and employment in Wichita fall by 0.001%.

Figures 9 and 10 repeat the simulation exercise using coefficient estimates from the wage regressions in Table 2. Figure 9 shows the effects of a 10% income decline in the state of Illinois on the nominal wage of wage and salary workers in U.S. counties using coefficient estimates for 1970-1980 (column three, Table 2a) and values for the independent variables from 1990. Wages in Chicago fall by 1.2%; wages in St. Louis fall by 0.8%; and wages in Wichita fall by 0.07%. In Figure 10, which performs the same exercise using coefficient estimates for 1980-1990 (column four, Table 2a), wages in Chicago fall by 3.7%, wages in St. Louis fall by 1.4%, and wages in Wichita fall by 0.01%. Similar to the employment simulations, the local impact of the income shock on wages increases substantially over time, but, in contrast to the employment simulations, the spatial extent of the wage changes diminishes over time. For both wages and employment, the simulation results suggest that demand linkages between regions are strong and show a strong tendency to increase in strength over time but are limited in their geographic extent. I discuss interpretations of these findings in section IV.

To check the sensitivity of the results to the presence of high-population counties in the sample, I exclude all counties with greater than 0.05% of the U.S. population. In either time period, this omits 370 counties, which have 67.7% of the U.S. population in 1980 and 68.8% of the U.S. population in 1990. Table 2b shows estimation results for the sample of low-population counties. Coefficient estimates in Table 2b are very similar to those in Table 2a, which suggests that the exclusion of high-population counties, for which it seems most likely that county-level shocks are correlated with the regressors, do not influence the results. In unreported results, I experiment with more restrictive selection criteria, excluding counties with population shares greater than 0.025% or 0.01%. The results are also very similar to those in Table 2.

As a second check on the sensitivity of the results, I control for variation in trend growth rates across regions. Figures 3 and 6 show that changes in wages and employment vary across regions, which may reflect long-run changes in preferences or technology that I do not control for in the estimation. Part (a) of Table 3 shows estimation results for equation (13) in which I include dummy variables for eight geographic regions. Most coefficient estimates are very similar to those in Table 2. In regressions on the log change in wages for 1970-1980, however, coefficient estimates for α_2 are lower in regressions with region controls than in regressions without them. The sensitivity of the coefficient estimates to region controls may be due to the reduced-form nature of the specification in (13). Coefficient estimates for the Krugman model (equation (14)) are not sensitive to the inclusion of regional dummy variables.

As a third check on the sensitivity of the results, I reestimate equation (13) replacing direct distance with hub-and-spoke distance (see appendix). Direct, or geodesic, distance surely underestimates the actual distance travelled in transporting goods between locations. Hub-and-spoke distance, by assuming that all goods must pass through transportation hubs, approximates actual distance travelled along existing interstate highways and railways. Part (b) of Table 3 reports the results. Estimated coefficients are very similar to those in Table 2. One slight difference is that in regressions on the log change in employment, coefficient estimates for α_1 in Table 3b do not increase in value over time as they do in Table 2.

In unreported results, I perform additional checks on the robustness of the findings. First, I estimate equation (13) excluding all counties in Texas, Rocky Mountain states, or far west states from the sample, leaving 2,664 observations per period. Compared to eastern counties, western counties have larger land areas and lower population densities, which may influence demand links between regions. The estimation results are very similar to those in Tables 2. Second, I estimate equation (13) using a specification that allows for a more complex relationship between distance and transportation cost. I replace the function $e^{-\alpha d}$, which for positive α and d (distance) will be convex for all values of d, with the function $1/[1+(\beta d)^2]$, which for some values of β will have both convex and concave regions in d. The estimated values of β produce spatial decay functions that are nearly identical to those produced by the estimated values of α_2 in Table 2.

B. The Krugman Model

Table 4 reports estimation results for the Krugman model in equation (14). Coefficient estimates are for regressions using the log change in wages of wage and salary workers as the dependent variable. Column one shows results for 1970-1980 and column two shows results for 1980-1990. Columns three and four show results excluding counties with more than 0.05% of the U.S. population from the sample. As coefficient estimates for the two samples are very similar, I focus on results for the full sample.

The structural parameters, σ, the elasticity of substitution, μ, the expenditure share on manufactured goods, and τ, unit transportation costs, are all positive, as predicted by the theory, and very precisely estimated. Since the estimated values of σ and μ are not influenced by the units in which the dependent or independent variables are measured, their values are economically meaningful. The estimate of τ, however, is sensitive to units in which distance is measured and its value can only be interpreted in relative terms.

Consistent with the theory, the point estimates of σ are greater than 1. The lower is the value of σ, the lower in absolute value is the own-price elasticity of demand for any individual good and hence the more imperfectly competitive is the market for that good. The results suggest that markets have become more imperfectly competitive over time. Given profit-maximizing behavior by firms, Krugman (1991) shows that the ratio $\sigma/(\sigma-1)$ equals the ratio of price to marginal cost. The coefficient estimates indicate that between 1980 and 1990 the price-cost margin in manufacturing increases from 1.11 to 1.21, with both ratios precisely estimated. In equilibrium, price equals average cost, in which case a value of $\sigma/(\sigma-1)$ that is greater than one indicates that production is subject to increasing returns to scale.

Also consistent with the theory, the point estimates of μ are between 0 and 1. As mentioned in section II, μ should be interpreted as the expenditure share on all goods traded across space. With an average expenditure share on housing in the United States of approximately 0.2, the estimated value for μ of approximately 0.9 is somewhat high.

Estimated values for τ suggest, counterintuitively, that transportation costs have risen over time. Equation (14) indicates that the economic importance of distance depends both on τ and the magnitude of scale economies, which are captured by σ. Simulation results, reported below, suggest that demand linkages between regions have strengthened over time. Any decline in the economic importance of distance would thus be attributable to a rise in the magnitude of scale economies rather than a fall in transport costs.

The empirical results permit an interpretation of the stability of the spatial distribution of economic activity in the United States. While the Krugman model is subject to multiple equilibria, in the sense that which regions attract manufacturing activity and which do not is indeterminant, the range of equilibria that are attainable is determined by the values of the structural parameters. Krugman (1991,1992) shows that if it is the case that $\sigma(1-\mu)>1$, then scale economies are sufficiently weak or the manufacturing share is sufficiently low that the range of possible equilibria depends on transportation costs. At high transportation costs, regions are autarkic and economic activity is relatively evenly distributed across space; at low transportation costs, the geographic concentration of economic activity in a small number of regions is feasible. Alternatively, if $\sigma(1-\mu)<1$, then scale economies are sufficiently strong or the manufacturing share is sufficiently high that economic activity geographically concentrates for any value of τ. In 1980, the value of $\sigma(1-\mu)$ is 0.76, with a standard error of 0.13, and in 1990 the value is 0.5, with a standard error of 0.08. For the U.S. economy, it appears that production will geographically concentrate in a small number of locations and that this feature of the spatial distribution of economic activity will be insensitive to small changes in transportation costs.

The estimated values of the structural parameters are consistent with the predictions of the Krugman model. To see what the parameter values imply about the nature of demand linkages between regions, I perform simulation exercises similar to those in the last section. I reduce income in the state of Illinois by 10% and examine the predicted effects on wages in surrounding counties. The exercise is again strictly partial equilibrium in nature, as I do not take the indirect effects of the income shock into account. Without county-level data on housing and goods' prices, I am unable to perform general-equilibrium simulations.

Figure 11 shows the effects of the income shock in Illinois using coefficient estimates for 1970-1980 (column one, Table 4) and values for the independent variables from 1990. In contrast to Figure 9, the effects of the income shock are quite small. Wages in Chicago, at a distance of 74 kilometers from the economic center of Illinois, fall by 0.22%, wages in St. Louis, at a distance of 345 kilometers, fall by 0.15%, and wages in Wichita, at a distance of 885 kilometers, are essentially unaffected. Figure 12 performs the same exercise using coefficient estimates for 1980-1990 (column two, Table 4). Similar to the simulation results for the market-potential function, the magnitude of the income shock rises substantially between the two time periods. Wages in Chicago fall by 0.92%, wages in St. Louis fall by 0.17%, and wages in Wichita are unchanged. The geographic scope of the shock is similar in the two time periods. Confirming the results from the previous section, demand linkages between regions appear to be strong and rising over time but limited in geographic extent.

Comparing Figures 9-12, it is somewhat puzzling that coefficient estimates from the market-potential function produce larger changes in regional wages than do coefficient estimates from the Krugman model. One explanation is that the market-potential function is a reduced form of the Krugman model. The coefficient on income in equation (13) embodies the direct effect of the variable on wages in a given county plus its indirect effect through other regional variables. Simulation exercises using coefficient estimates from the Krugman model ignore such indirect effects, since I shock income but hold the other independent variables, wages and the housing stock, constant. While the nature of the simulation exercise in Figures 9 and 10 is different from that in Figure 11 and 12, the qualitative results are similar.

To check the sensitivity of the results, I use alternative specifications of the model and alternative measures of distance. Table 5 reports results for two samples of counties, all counties and low-population counties. In Part (a) of Table 5, I include dummy variables for eight geographic regions in the estimation. Parameter estimates for μ, σ, τ, and $\sigma/(\sigma-1)$ are very similar to those in Table 4. One change in the results is that the estimate for $\sigma(1-\mu)$ is greater than one in 1970-1980. This suggests that during the 1970's the characteristics of the spatial distribution of economic activity were sensitive to changes in transportation costs. Similar to the previous results, $\sigma(1-\mu)$ is less than one for 1980-1990. In Part (b) of Table 5, I replace direct distance with hub-and-spoke distance. While the results are qualitatively similar to those in Table 4, there are two differences worthy of note. First, estimated values of σ are larger than in Table 4, which produces estimated ratios of price to marginal cost which are slightly smaller. Second, estimated values of μ are very close to one, which may be implausibly large.

Finally, in unreported results, I estimate equation (14) imposing sample restrictions analogous to those that I impose in the previous section. In regressions excluding counties with high shares of the U.S. population (0.025%, 0.01%) or excluding counties in western states, the coefficient estimates are very similar to those Table 4.[18]

IV. Discussion

In this paper, I estimate simple nonlinear models of spatial economic relationships. The purpose of the exercise is to understand why the spatial distribution of economic activity is lumpy. Recent theoretical work explains the geographic concentration of economic activity through the interaction of increasing returns to scale and transportation costs. My empirical findings are broadly consistent with this hypothesis.

One contribution of the paper is the estimation of the structural parameters of the

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[18] In unreported results, I also estimate the structural parameters of the Krugman model using the formulation in Krugman (1991,1992) (see notes 10 and 12). For the period 1980-1990, the estimate (standard error) of σ is 8.27 (1.23), the estimate of μ is 1.15 (0.04), and the estimate of τ is 3.29 (0.37); for the period 1970-1980, the estimate of σ is 18.25 (3.55), the estimate of μ is 1.05 (0.04), and the estimate of τ is 1.62 (0.18). While the results of this exercise are qualitatively similar to those in Table 4, there is more variation in the estimates of σ and the estimates of μ are inconsistent with the theoretically specified range of 0 to 1.

Krugman (1991) model. The model has been enormously influential in theoretical research, but so far has received scant attention in the empirical literature. A second contribution of the paper is the estimation of reduced-form parameters for the market-potential function. Past applications of the market-potential concept, by imposing ad hoc assumptions about functional form, fail to test any hypothesis. In a regression context, I find that, analogous to the gravity model in international trade (e.g., Bergstrand 1984, Deardorff 1984), the market-potential function is a valuable empirical tool for describing the reduced-form relationship between the spatial distribution of consumer purchasing power and that for wages and employment.

Parameter estimates for the Krugman (1991) model suggest that production in U.S. industry is subject to increasing returns to scale. I find that the price-marginal cost ratio for industry rises from 1.1 in the 1970's to 1.2 in the 1980's, which is consistent with small but significant scale economies. There is a large literature on price-marginal cost markups in U.S. industries. Hall (1988) estimates price-marginal cost markups for two-digit U.S. manufacturing industries over the period 1958-1984 and finds a mean value of 1.46 to 1.68, depending on the estimation method. Roeger (1995) obtains similar results. Norrbin (1993) corrects the Hall estimation procedure for the presence of intermediate inputs and estimates price-marginal cost ratios of 1.05 to 1.08, which are roughly consistent with my estimates.[19]

One novel feature of the results in this paper is that I use the spatial covariation in income and wages, rather than the time-series covariation in outputs and inputs, to identify increasing returns. This approach reveals simultaneously the strength of scale economies at the plant or industry level and the extent to which such scale economies create pecuniary externalities that

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[19] In related literature, Bantu and Fernald (1997) estimate constant or decreasing returns to scale for U.S. industries, which would be inconsistent with positive markups of price over marginal cost.

contribute to the geographic concentration of economic activity. By using cross-sectional data, I am also able to examine how the magnitude of scale economies changes over time.

The results suggest that the combined effects of scale economies and the expenditure share on manufactured (or traded) goods make geographic concentration a stable feature of the spatial distribution of economic activity. This is not to imply that the *existing* spatial distribution is stable -- Figures 3 and 6 show that between 1970 and 1990 there were large increases in relative employment and wages in western and southeastern states -- but that as economic activity relocates it will reagglomerate in a small number of areas. While the empirical analysis does not address the source of shocks that contribute to regional employment shifts, it does help account for why geographic concentration is a persistent feature of the economic landscape.

One striking finding is that demand linkages between regions are strong and growing over time, but limited in geographic scope. Parameter estimates from the market-potential function suggest that a 10% fall in personal income in a region the size of Illinois produces a fall in employment for a county that is 100 kilometers distant of 4.5-4.8% in 1980 and 6.0-6.4% in 1990. Shocks to the Illinois economy strongly affect economic activity in counties in Indiana, Iowa, and Wisconsin. The direct effect of such shocks appears to have a relatively narrow geographic extent, showing zero effect on counties that are more than 800 kilometers in distance from the source of the shock. Shocks to the Illinois economy appear to have no direct effect on economic activity in counties in Colorado, Texas, or Georgia.

The narrow geographic scope of demand shocks that I find may seem surprising in an economy where communications, airfare, and freight costs are falling and an increasing amount of consumer purchases occur through mail order. These changes in relative costs have prompted many observers to claim that the economic importance of distance is decreasing. Cairncross (1997) goes so far as to predict that digital communications will replace the need for face-to-face interaction, rendering cities obsolete. If telecommunications and face-to-face interaction are in fact substitutes in production, then we would expect new technologies to reduce the economic importance of distance. Gaspar and Glaeser (1996) show, however, that under plausible assumptions telecommunications and face-to-face interaction are complements, in which case technological improvements in telecommunications may increase the spatial concentration of economic activity. My finding that scale economies have become stronger over time, and, consequently, that the local effect of demand shocks has risen over time, are consistent with the idea that new technologies have raised the benefits to spatial agglomeration.

An alternative explanation for my finding of an increase in the economic importance of distance is that production is shifting from low-transportation cost goods, such as manufactures, to high-transportation cost goods, such as services. During the time period I examine, 1970-1990, there is a strong compositional shift from manufacturers to services in the U.S. economy. The transportation-cost parameters I estimate could be interpreted as reduced-form parameters, which characterize the overall transport-intensiveness of production in the economy. Given that scale economies also appear to be rising over time, the apparent increase in aggregate transport costs would not diminish incentives for geographic concentration.

To put the results on the geographic scope of demand linkages in perspective, it is useful to observe that even with a large amount of trade between distant regions it is possible for demand shocks to have primarily local effects. Consider a firm in Austin, Texas, which sells half of its output locally and half of its output to consumers distributed across other regions of the country in proportion to each region's purchasing power. Suppose the firm experiences two different shocks to the demand for its output. First, consumer demand in San Antonio, Texas falls by 10%. Given that San Antonio accounts for 60% of the local consumer market, the direct effect of the shock is a fall in the firm's sales by 3%. Second, consumer demand in Los Angeles falls by 10%. Given that Los Angeles accounts for 3% of the national market, the direct effect of the shock is a fall in the firm's sales by 0.15%. The shock to San Antonio, even though it is a much smaller market than Los Angeles, causes a much larger reduction in firm sales.

In this example, though there is a large amount of long-distance trade in total, trade between any two distant regions is small in comparison to trade between any two neighboring regions. Changes in consumer demand have large effects on nearby locations but small effects on distant locations. My empirical results are thus consistent with a world in which each region engages in a small amount of bilateral trade with each of many outlying regions and a large amount of bilateral trade with a few proximate regions.

Finally, the analysis ignores a number of issues, which suggest fruitful areas for further research. In using time-differenced specifications, I ignore fixed region-specific characteristics. Climate, access to waterways, and other natural factors surely influence city location. There is also a limited treatment of heterogeneity in transport costs across goods and variation in industrial composition across regions. After suitably extending the Krugman model, these factors could in principle be incorporated into the empirical analysis. Additionally, the analysis fails to consider the impact of international trade on the spatial distribution of economic activity. Trade with the rest of the world would presumably raise the demand for goods and services produced in port cities and coastal areas relative to other regions.

Appendix: Distance Calculations

I construct two measures of distance. The first is a measure of direct (geodesic) distance, in which I assume that goods are transported along the minimum distance arc that connects two locations. The second is a measure of hub-and-spoke distance, in which I assume that goods are first transported from a county to a transportation hub in the county's home state and then from the transportation hub to the final destination.

Direct (Geodesic) Distance: Direct distance is the distance from the geographic center of a county (the latitude and longitude points for which are taken from the USA Counties 1996 CD-Rom) to the economic center of a state. To calculate the economic center of a state, I take the average of the latitude and longitude points for all counties within a state, weighting each county by its share of state personal income. To calculate direct, or more formally geodesic, distance, I convert the two sets of latitude and longitude points into Cartesian coordinates and then calculate the minimum-length arc that connects the points, where I impose the assumption that the Earth is a perfect sphere with radius equal to the mean of the polar and equatorial radii (the polar radius is 6,357 kilometers; the equatorial radius is 6,378 kilometers). For distances within the continental United States, the measurement error resulting from the perfect-sphere assumption is very small, generally less than 0.4% of the estimated distance.

Hub-and-Spoke Distance: As an alternative distance measure, I assume that goods must first be transported from a county to a transportation hub in the county's home state and then from the transportation hub to the economic center of the destination state. This corrects the direct-distance measure for the fact that road or rail distance between locations rarely follows the minimum-distance arc. I use geodesic distance, as described above, to measure distance from a county to a transportation hub and from a transportation hub to the geographic center of a state. I assume that the location of the transportation hub in each state is the economic center of the state. For most states, the location of the transportation hub corresponds to the location of the state's largest city. There are three exceptions, California, Pennsylvania, and Texas. To create realistic transportation hubs for these states, I divide each state roughly in half (California and Texas latitudinally and Pennsylvania longitudinally). The resulting transportation hubs are located very near the largest city in the respective region of each state.

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Table 1: Variable Means for U.S. Counties
(Standard Errors)

	Wage	Employment	Employment Density	Income	Housing Stock	Distance
1970	17.42	25,509	39.50	897,454	28,650	1,517.8
	(3.82)	(109,896)	(682.5)	(3,785,338)	(98,307)	(875.8)
1980	17.66	31,610	41.59	1,156,639	27,717	1,518.5
	(3.74)	(124,967)	(608.4)	(4,409,183)	(90,900)	(876.3)
1990	17.29	38,041	47.03	1,501,171	27,467	1,518.9
	(3.70)	(146,679)	(649.4)	(5,720,714)	(87,394)	(876.9)

Variable Definitions:

Wage	Average annual earnings (thousand of 1990 dollars) of wage and salary workers (Regional Economic Information System (REIS), U.S. BEA).
Employment	Average annual employment of wage and salary workers (REIS).
Employment Density	Employment per square kilometer.
Income	Total personal income (thousands of 1990 dollars) (REIS).
Housing Stock	Total housing units (U.S. Census of Population and Housing).
Distance	Distance in kilometers between county and economic center of a state (see appendix).

The Sample is 3,075 counties in the continental United States. County definitions are those for 1980. Each independent city in Virginia is combined with the surrounding county.

Table 2: Estimation of the Market-Potential Function

(a) All Counties

Dep. Variable	Log Change in Employment		Log Change in Wages	
Time Period	1970-1980	1980-1990	1970-1980	1980-1990
α_1	0.559 (0.036)	0.715 (0.041)	0.331 (0.024)	0.530 (0.023)
α_2	12.693 (1.266)	14.710 (1.063)	4.742 (0.745)	10.230 (0.627)
Adj. R^2	0.107	0.144	0.092	0.198
No. of Obs.	3,075	3,075	3,075	3,075

(b) Low-Population Counties

Dep. Variable	Log Change in Employment		Log Change in Wages	
Time Period	1970-1980	1980-1990	1970-1980	1980-1990
α_1	0.531 (0.041)	0.667 (0.045)	0.340 (0.027)	0.507 (0.027)
α_2	13.258 (1.188)	14.974 (1.207)	4.625 (0.763)	10.252 (0.708)
Adj. R^2	0.093	0.124	0.082	0.170
No. of Obs.	2,705	2,705	2,705	2,705

The full sample has 3,075 counties in the continental United States; the low-population sample has counties in the continental United States with less than 0.05% of the U.S. population in a given year. Parameters are estimated by nonlinear least squares. Heteroskedasticity-consistent standard errors are reported in parentheses. The specification of the market-potential function is that in equation (13). The dependent variable is expressed in log changes; the regressor function is expressed in time-differenced form. Coefficient estimates for the constant term are not shown. See Table 1 for variable definitions.

Table 3: Additional Estimation Results for the Market-Potential Function

Dep. Var.	Log Change in Employment				Log Change in Wages			
Time Pd	1970-1980	1980-1990	1970-1980	1980-1990	1970-1980	1980-1990	1970-1980	1980-1990
	(a) Region Controls							
α_1	0.451	0.661	0.414	0.611	0.402	0.378	0.356	0.366
	(0.067)	(0.051)	(0.070	(0.055)	(0.160)	(0.027)	(0.134)	(0.031)
α_2	14.653	15.636	15.731	16.044	1.477	12.696	1.912	12.305
	(1.266)	(1.318)	(2.623)	(1.520)	(0.712)	(1.065)	(0.963)	(1.177)
Adj. R^2	0.122	0.180	0.106	0.163	0.168	0.277	0.148	0.243
	(b) Hub-and-Spoke Distance Measure							
α_1	0.591	0.598	0.576	0.548	0.308	0.450	0.315	0.431
	(0.033)	(0.035)	(0.038)	(0.039)	(0.025)	(0.022)	(0.029)	(0.025)
α_2	13.107	14.772	13.485	14.679	4.035	8.737	3.897	8.571
	(1.119)	(1.418)	(1.214)	(1.624)	(0.657)	(0.757)	(0.675)	(0.856)
Adj. R^2	0.129	0.147	0.116	0.121	0.084	0.189	0.074	0.162
Counties in Sample	all	all	low pop.	low pop.	all	all	low pop.	low pop.

In Table (a), regressions include dummy variables for eight geographic regions (New England, Mideast, Great Lakes, Plains, Southeast, Southwest, Rocky Mountains, Far West). In Table (b), distance between locations is measured using a hub-and-spoke framework, as described in the appendix. Heteroskedasticity-consistent standard errors are reported in parentheses. See notes to Table 2 for details on estimation and the sample of counties.

Table 4: Estimation of the Krugman Model

Time Period	1970-1980	1980-1990	1970-1980	1980-1990
μ	0.927	0.913	0.926	0.906
	(0.017)	(0.018)	(0.018)	(0.018)
σ	10.414	5.770	10.754	5.878
	(2.007)	(0.821)	(2.214)	(0.936)
τ	1.580	4.133	1.472	3.932
	(0.234)	(0.502)	(0.231)	(0.545)
Adj. R^2	0.203	0.308	0.177	0.261
Counties in Sample	all	all	low pop.	low pop.
No. of Obs.	3,075	3,075	2,705	2,705
Implied Values				
$\sigma/(\sigma-1)$	1.106	1.210	1.103	1.205
	(0.023)	(0.036)	(0.023)	(0.039)
$\sigma(1-\mu)$	0.758	0.502	0.801	0.553
	(0.130)	(0.080)	(0.164)	(0.096)

The full sample has 3,075 counties in the continental United States; the low-population sample has counties in the continental United States with less than 0.05% of the U.S. population in a given year. Parameters are estimated by nonlinear least squares. Heteroskedasticity-consistent standard errors are reported in parentheses. The estimated specification is that in equation (14). The dependent variable is the log change in wages; the regressor function is expressed in time-differenced form. Coefficient estimates for the constant term are not shown. See Table 1 for variable definitions.

μ = the share of expenditure on manufactured goods (goods traded across space).
σ = the elasticity of substitution between any pair of commodities.
τ = transportation costs.

Table 5: Additional Estimation Results for the Krugman Model

Time Pd.	1970-1980	1980-1990	1970-1980	1980-1990	1970-1980	1980-1990	1970-1980	1980-1990
	(a) Region Controls				**(b) Hub-and-Spoke Distance Measure**			
μ	0.884	0.898	0.878	0.891	0.992	0.958	0.992	0.954
	(0.022)	(0.019)	(0.024)	(0.022)	(0.012)	(0.013)	(0.014)	(0.015)
σ	11.151	6.006	11.104	5.932	42.814	13.776	43.101	14.417
	(1.948)	(0.979)	(2.075)	(1.119)	(5.592)	(2.078)	(6.231)	(2.415)
τ	1.416	3.806	1.394	3.506	1.084	3.078	1.078	2.886
	(0.200)	(0.534)	(0.209)	(0.611)	(0.055)	(0.348)	(0.060)	(0.366)
$\sigma/(\sigma-1)$	1.099	1.200	1.099	1.203	1.024	1.078	1.024	1.074
	(0.019)	(0.039)	(0.020)	(0.046)	(0.004)	(0.013)	(0.004)	(0.013)
$\sigma(1-\mu)$	1.300	0.613	1.360	0.649	0.334	0.582	0.333	0.670
	(0.223)	(0.095)	(0.252)	(0.112)	(0.502)	(0.164)	(0.590)	(0.201)
Adj. R^2	0.219	0.320	0.195	0.277	0.208	0.308	0.180	0.259
Counties in Sample	all	all	low pop.	low pop.	all	all	low pop.	low pop.

In Part (a), regressions include dummy variables for eight geographic regions (New England, Mideast, Great Lakes, Plains, Southeast, Southwest, Rocky Mountains, Far West). In Part (b), distance between locations is measured using a hub-and-spoke framework, as described in the appendix. Heteroskedasticity-consistent standard errors are reported in parentheses. See notes to Table 4 for details on the estimation and the sample of counties.

Figure 1: Employment per sq. km Relative to U.S., 1970

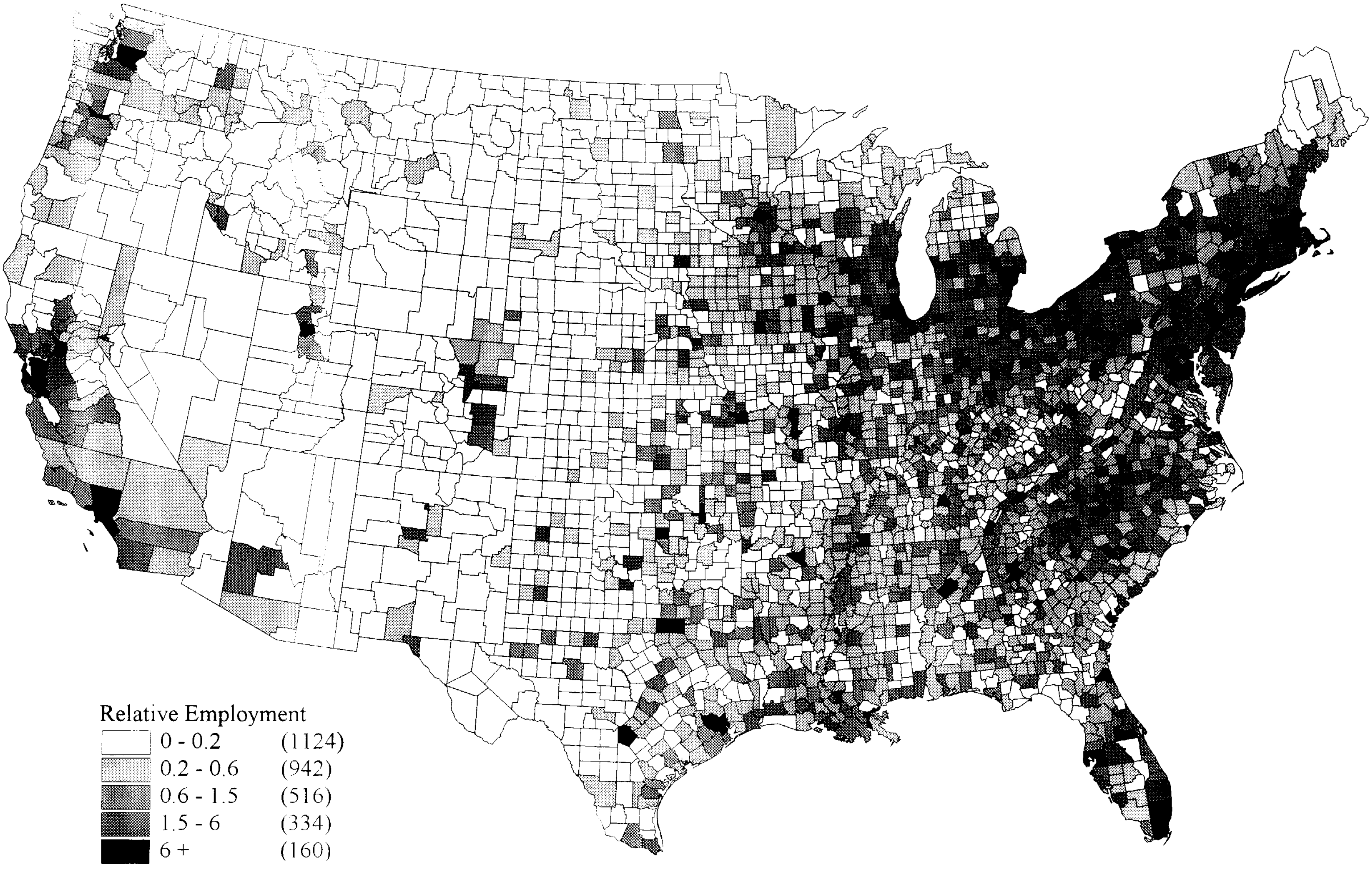

Figure 2: Employment per sq. km Relative to U.S., 1990

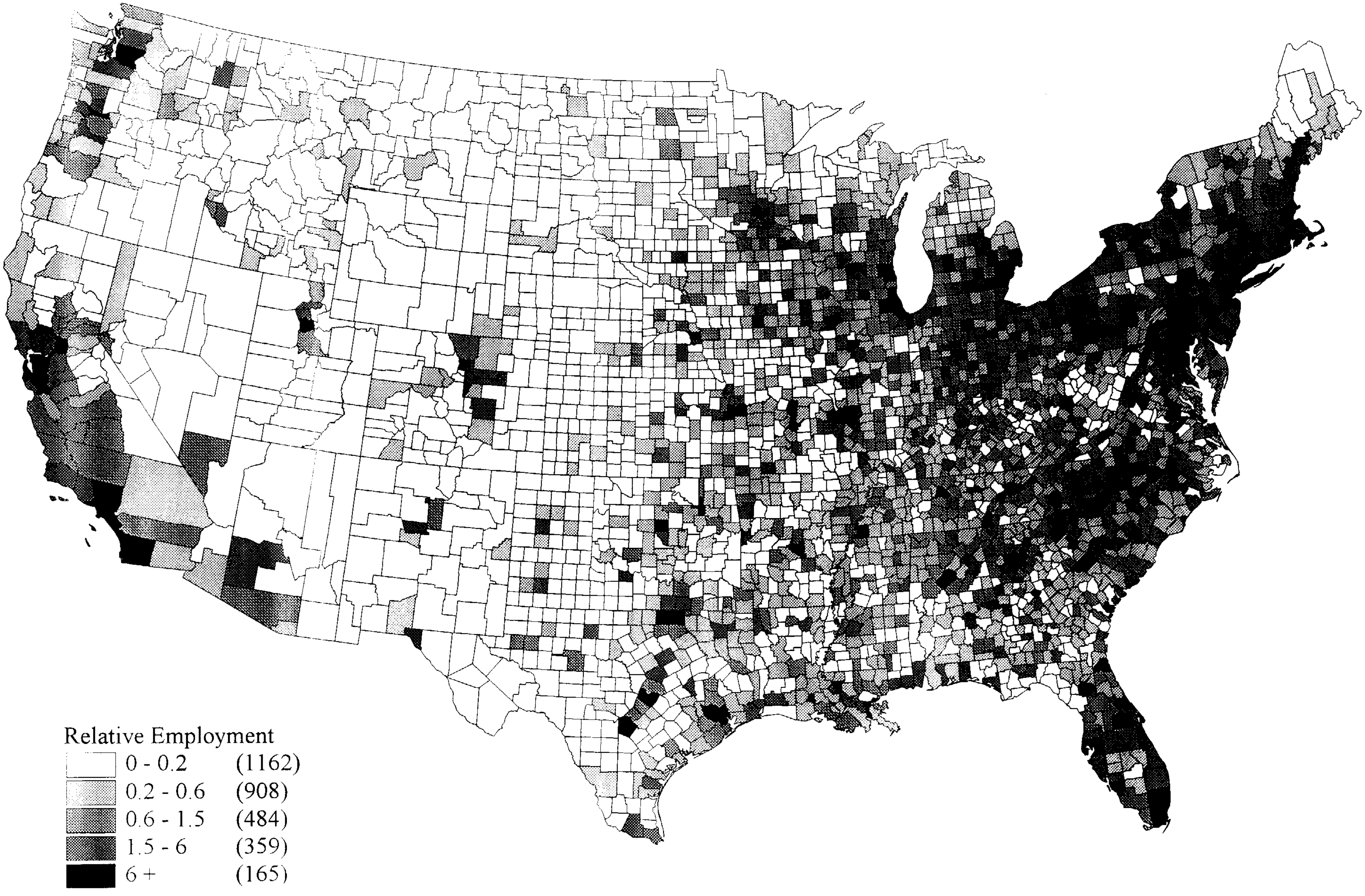

Figure 3: Log Change in Employment Relative to U.S., 1970-1990

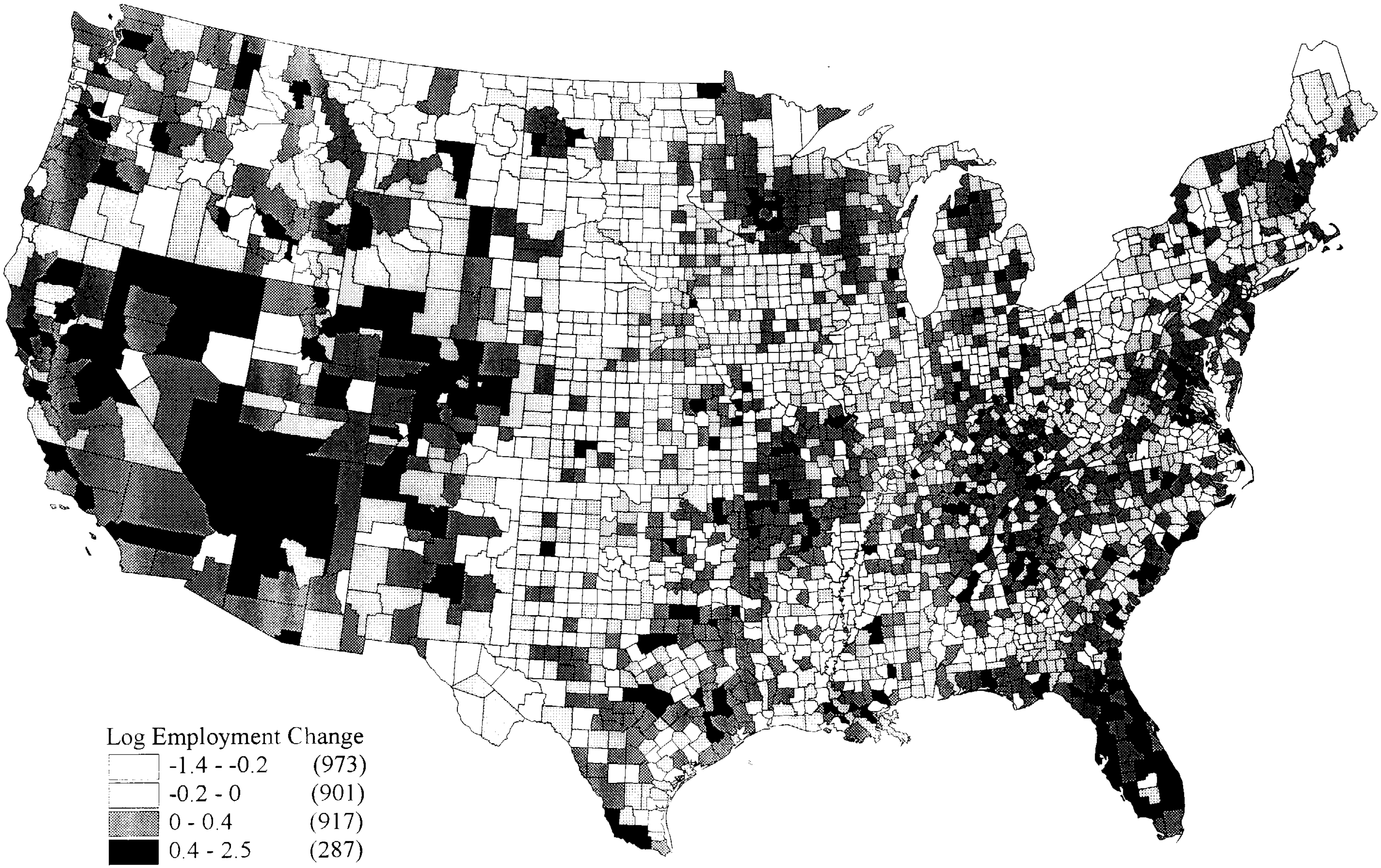

Figure 4: Average Wage Relative to U.S., 1970

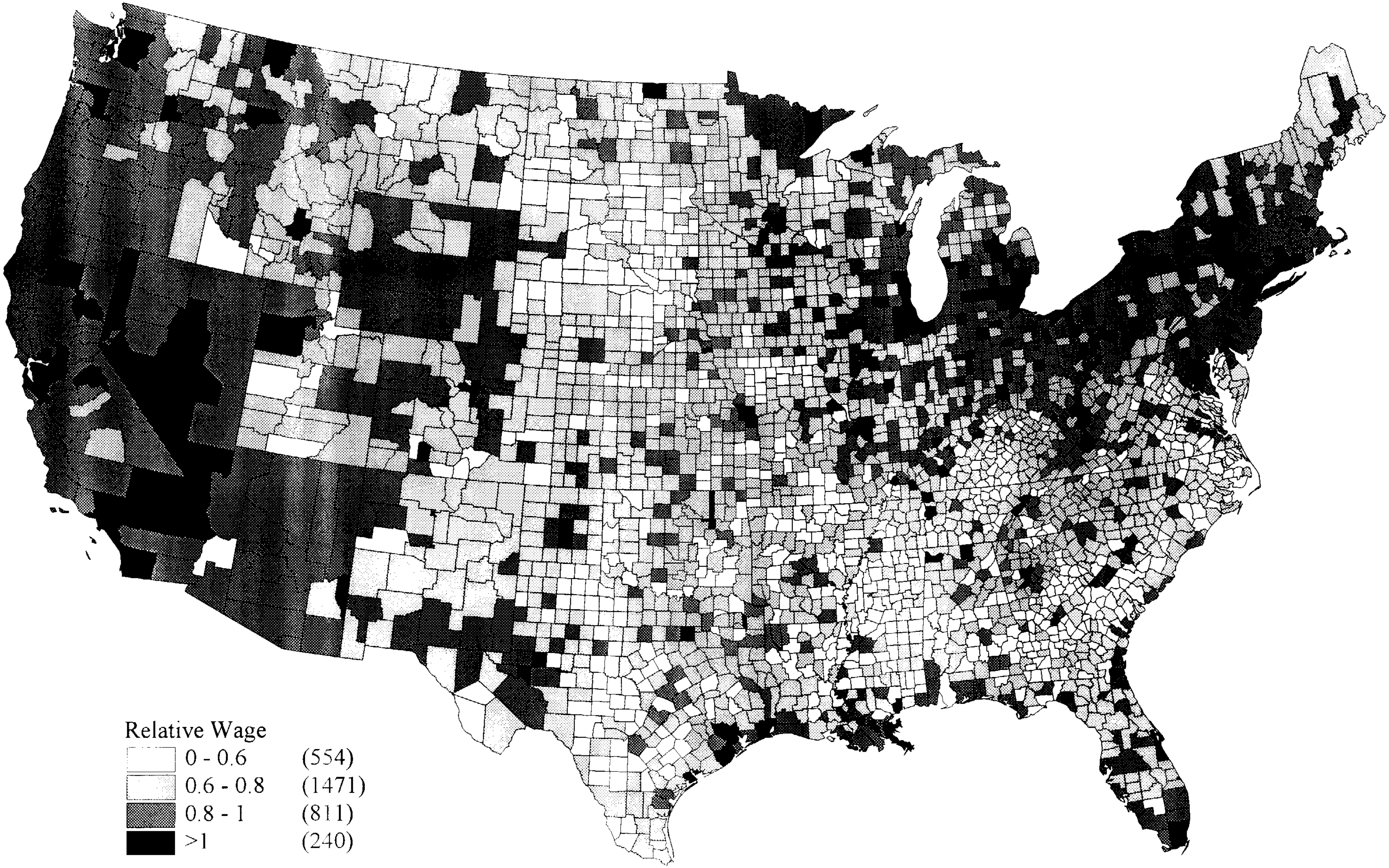

Figure 5: Average Wage Relative to U.S., 1990

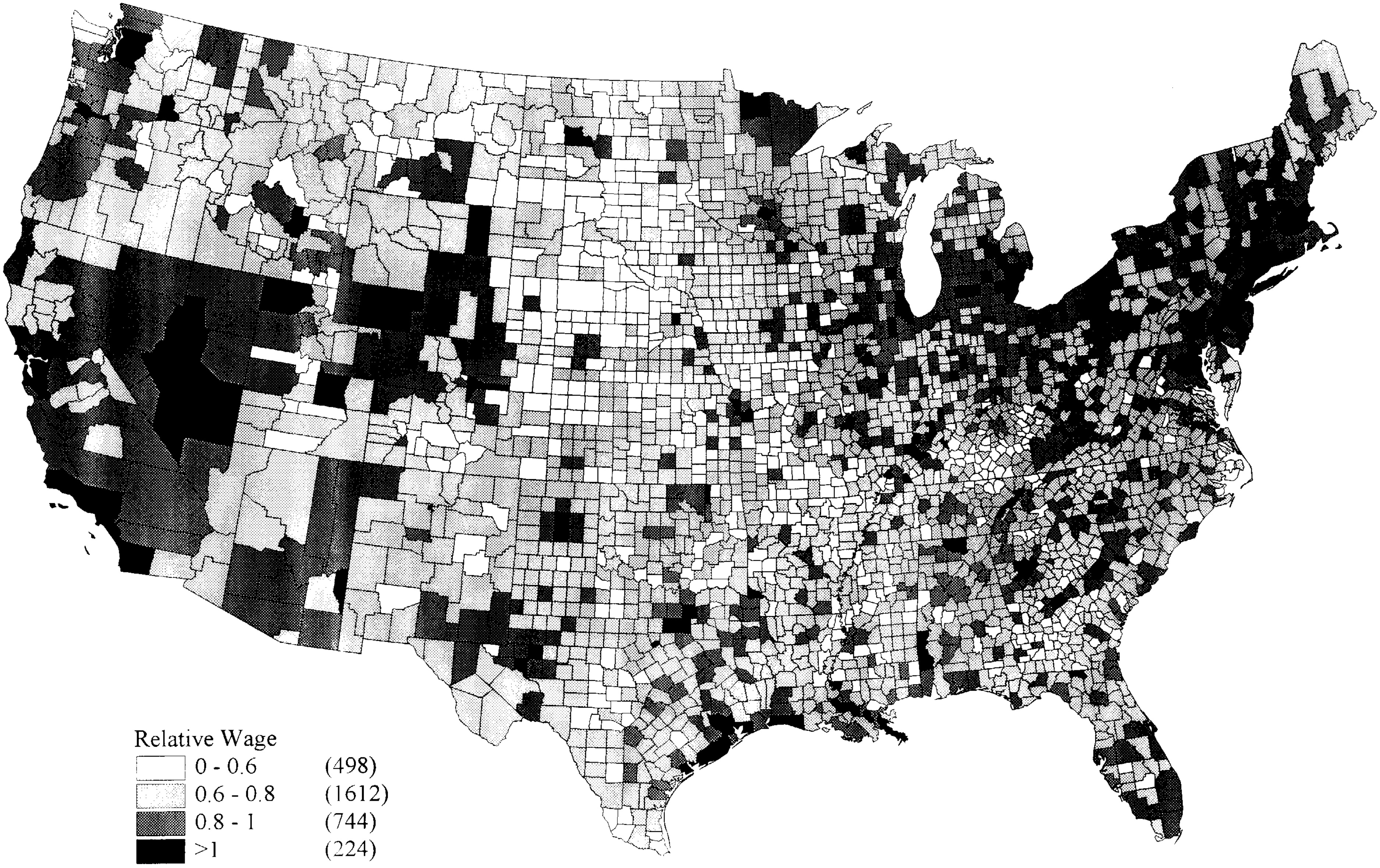

Figure 6: Log Change in Average Wage Relative to U.S., 1970-1990

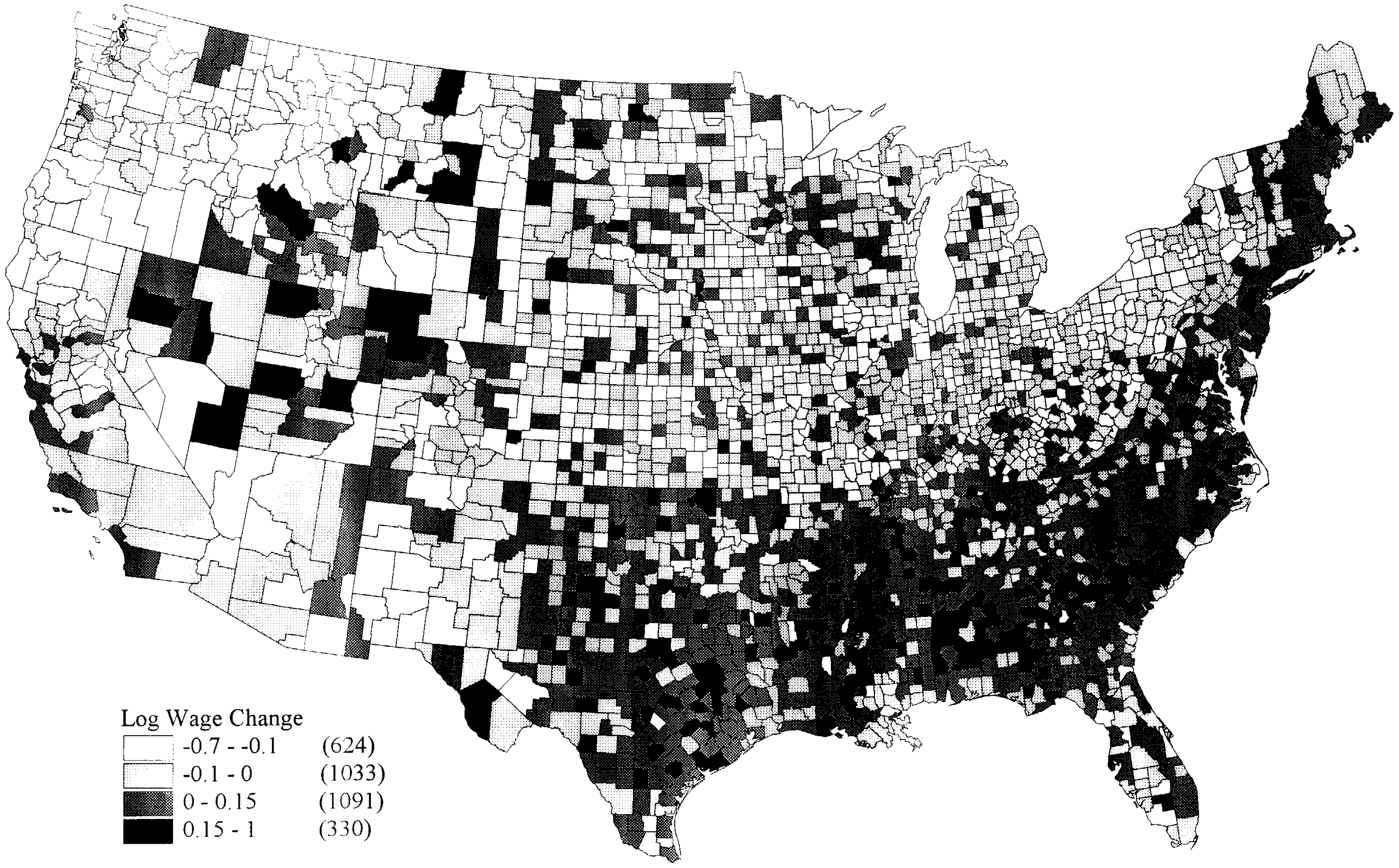

Figure 7: Simulated Employment Changes from Income Shock to Illinois, 1970-1980

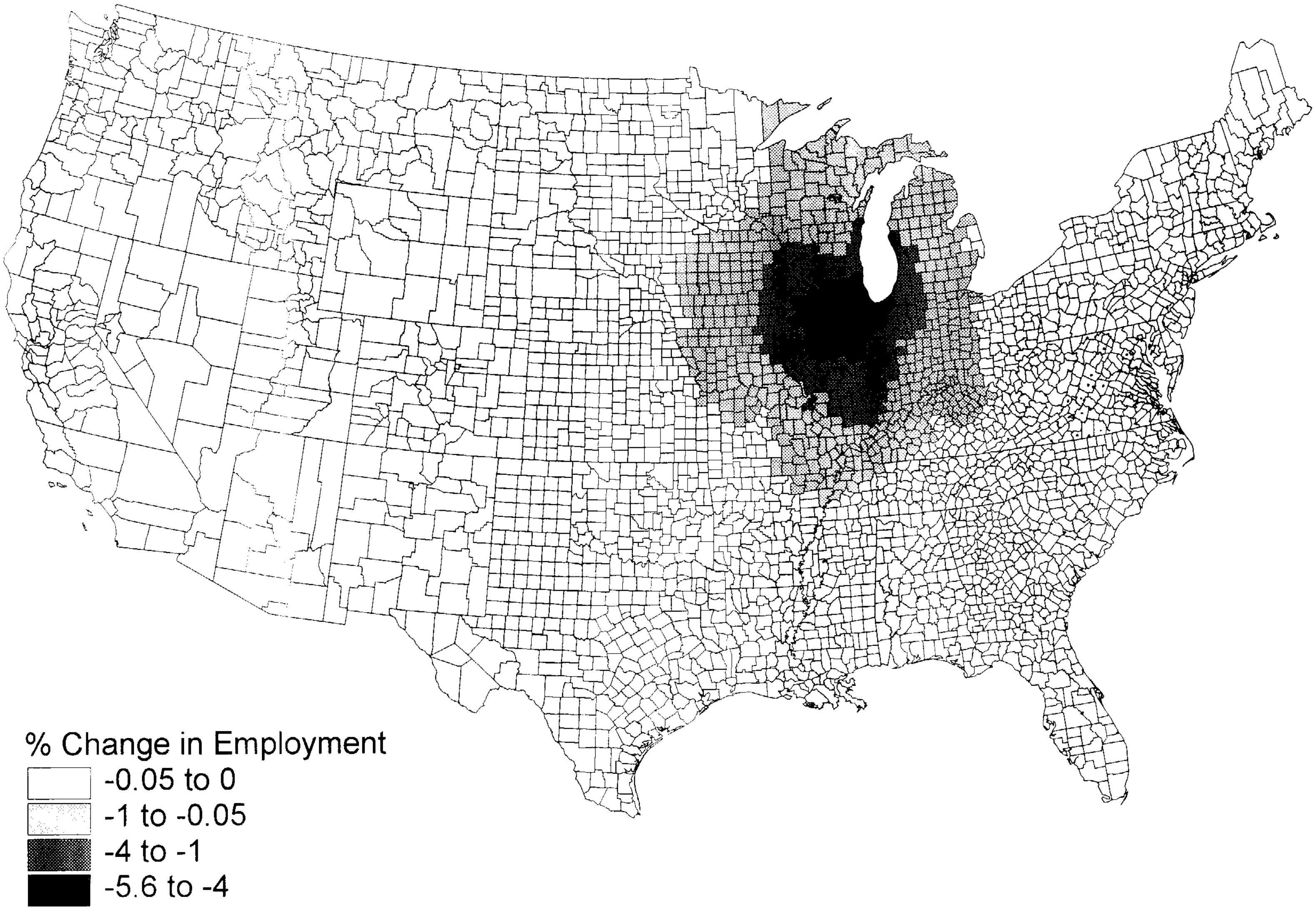

Figure 8: Simulated Employment Changes from Income Shock to Illinois, 1980-1990

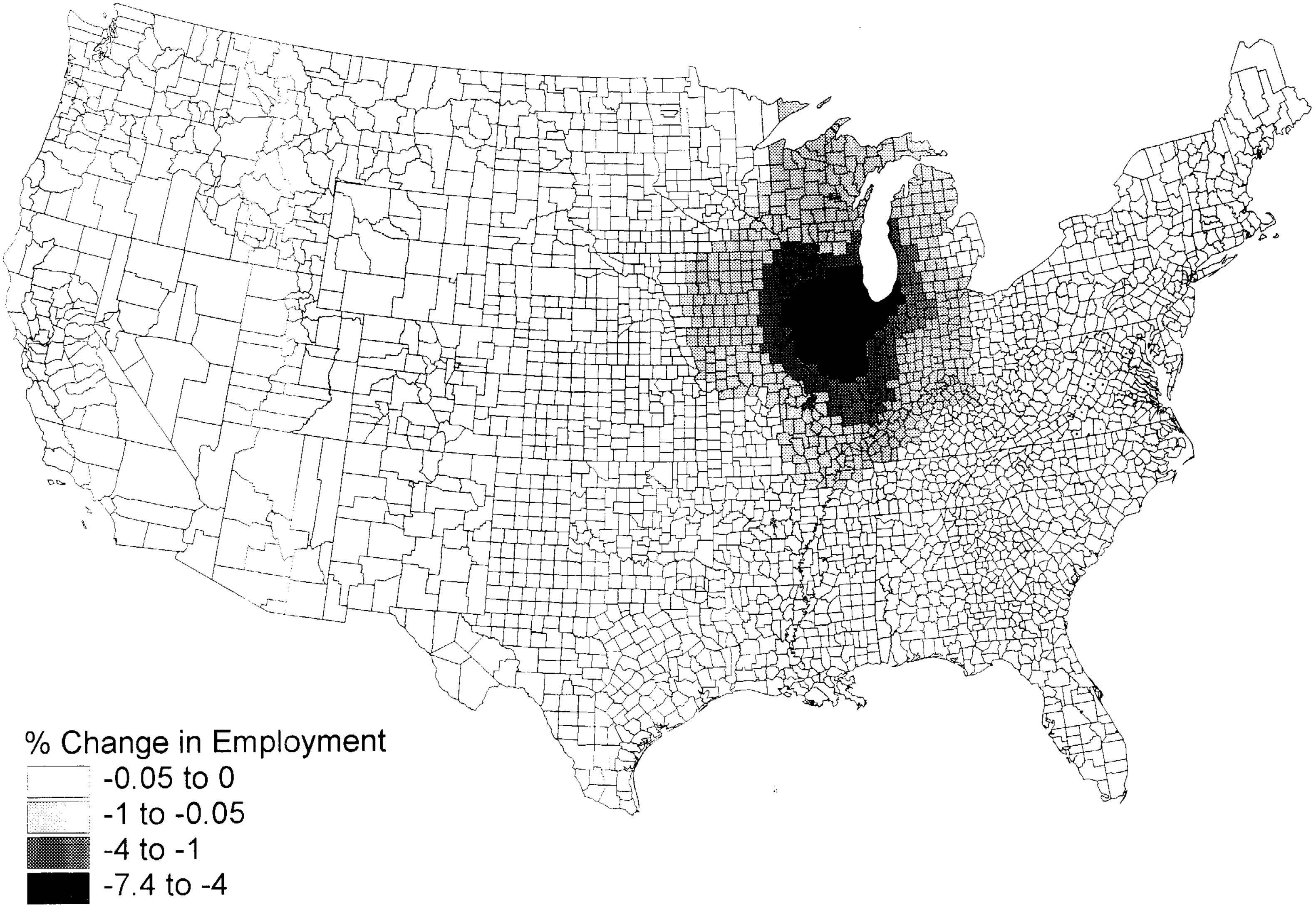

Figure 9: Simulated Wage Changes from Income Shock to Illinois, 1970-1980

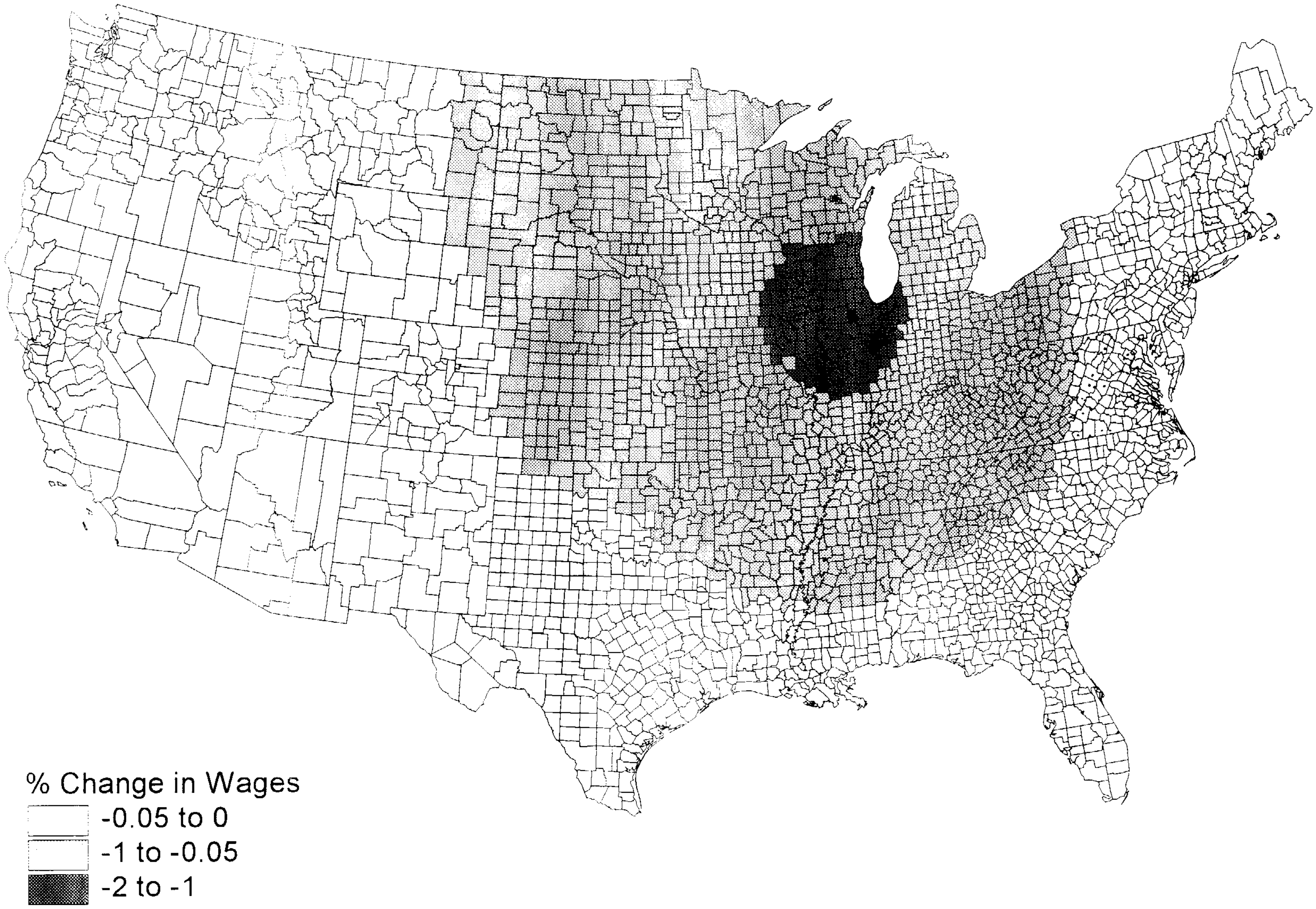

Figure 10: Simulated Wage Changes from Income Shock to Illinois, 1980-1990

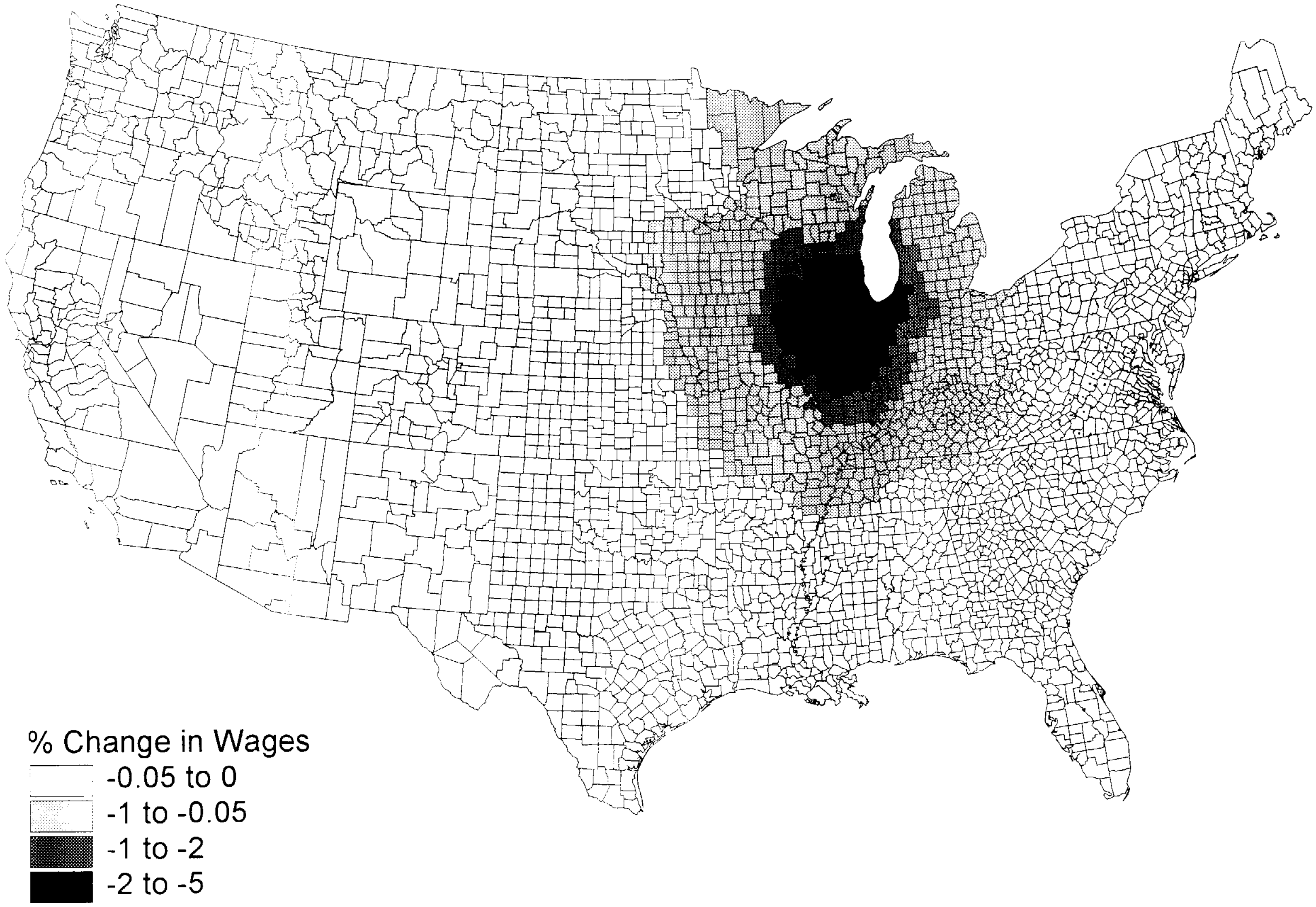

Figure 11: Simulated Wage Changes (Krugman Model), 1970-1980

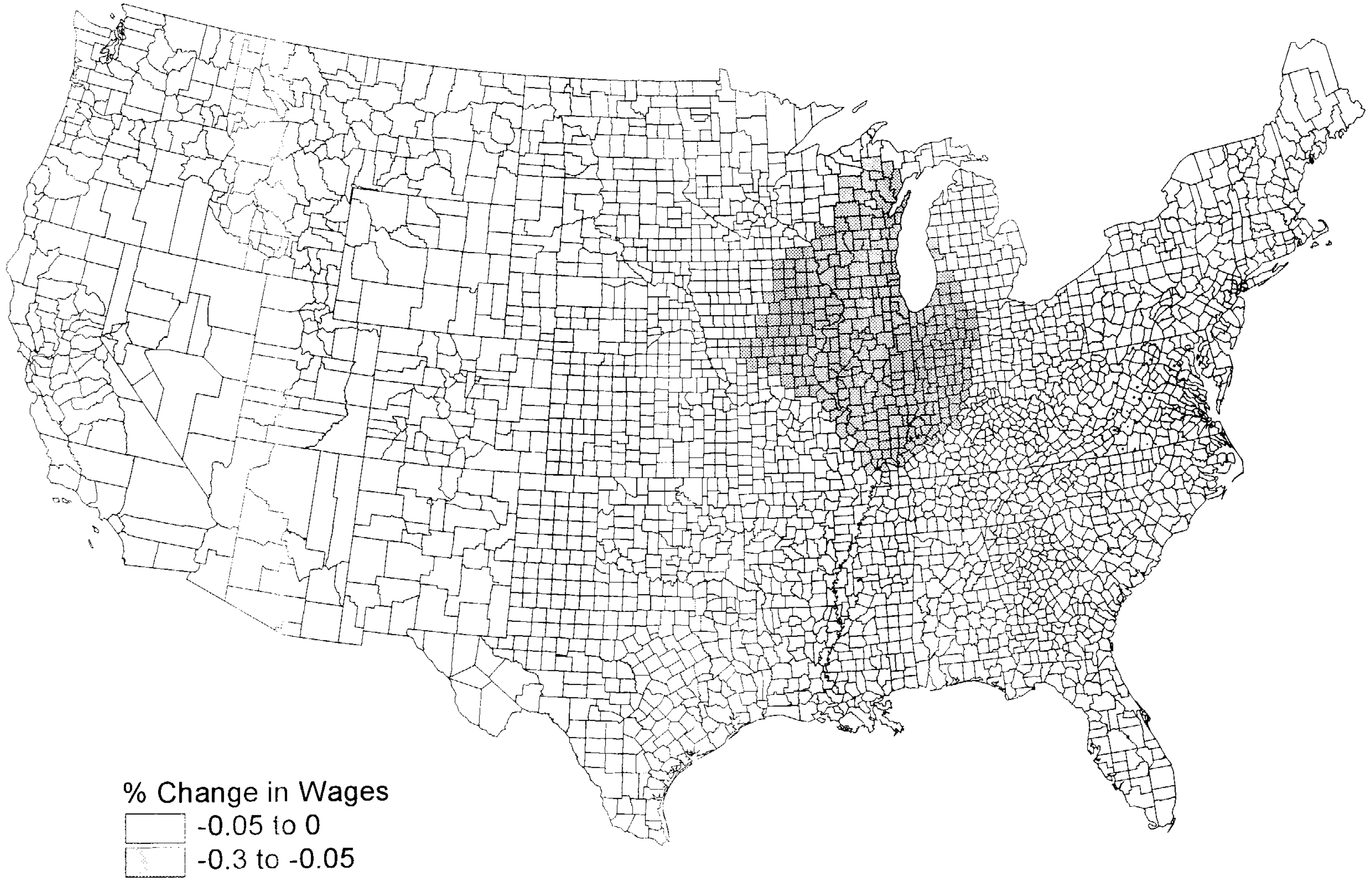

Figure 12: Simulated Wage Changes (Krugman Model), 1980-1990