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Mark D. Partridge
Ohio State University

Dan Rickman
Oklahoma State University

Kamar Ali
University of Saskatchewan

M. Rose Olfert
University of Saskatchewan

Department of Economics
Oklahoma State
University
Stillwater, Oklahoma

339 BUS, Stillwater, OK 74078, Ph 405-744-5110, Fax 405-744-5180

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Mark Partridge[1]
Dan Rickman[2]
Kamar Ali[3]
M. Rose Olfert[3]

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Abstract

The New Economic Geography (NEG) was motivated by the desire to formally explain the emergence of the American urban system. Although the NEG has proven useful in this regard, few empirical studies investigate its success in explaining current population dynamics in a more developed *mature* urban system, particularly across the urban hierarchy and in the rural hinterlands. This study explores whether proximity to same-sized and higher-tiered urban centers affected the patterns of 1990-2006 U.S. county population growth. Rather than casting agglomeration shadows on nearby growth, the results suggest that larger urban centers by and large promote growth for more proximate places of less than 250 thousand people. However, there is some evidence the largest urban areas cast growth shadows on proximate medium-sized metropolitan areas (population between 250 thousand and 1.5 million) and of spatial competition among small metropolitan areas. The weak evidence of growth shadows suggests a need for a broader framework in understanding population movements.

Keywords: New Economic Geography; Agglomeration shadows; Population; Urban hierarchy

1. AED Economics, Ohio State University, Columbus, OH, USA. Phone: 614-688-4907; Fax: 614-688-3622; Email: partridge.27@osu.edu, webpage: http://aede.osu.edu/programs/Swank/.
2. Department of Economics, Oklahoma State University, Stillwater, OK, Phone: 405-744-1434, Fax: 405-744-5180. Email: dan.rickman@okstate.edu.
3. Department of Agricultural Economics, University of Saskatchewan. E-mails: kamar.ali@usask.ca and rose.olfert@usask.ca

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The New Economic Geography (NEG) was motivated by the desire to formally explain the emergence of the American urban system. Although the NEG has proven useful in this regard, few empirical studies investigate its success in explaining current population dynamics in a more developed *mature* urban system, particularly across the urban hierarchy and in the rural hinterlands. This study explores whether proximity to same-sized and higher-tiered urban centers affected the patterns of 1990-2006 U.S. county population growth. Rather than casting agglomeration shadows on nearby growth, the results suggest that larger urban centers by and large promote growth for more proximate places of less than 250 thousand people. However, there is some evidence the largest urban areas cast growth shadows on proximate medium-sized metropolitan areas (population between 250 thousand and 1.5 million) and of spatial competition among small metropolitan areas. The weak evidence of growth shadows suggests a need for a broader framework in understanding population movements.

1. Introduction

The interrelationships among urban centers and between them and their rural fringes are among the most visible features of the expanding American urban landscape. Responding to technological, economic, and quality-of-life stimuli, households relocate to areas that offer greater net utility. The resulting population flows drive the evolution of the hierarchical urban system.

Interest in the spatial dimension of population dynamics burgeoned with the advent of the New Economic Geography (NEG) (Krugman 1991), which built on the urban-hierarchy lattice from traditional Central Place Theory (CPT) (Christaller 1933). In CPT, lower-tiered places depend on higher-tiered places for access to progressively higher-ordered goods and services offered at each tier. In extending CPT, the NEG formalizes the role of agglomeration in the dynamic formation of an urban system. Both theories prominently feature an urban hierarchy based on regional market potential, creating symbiotic interrelationships among tiers, including the rural fringe (Fujita et al. 1999). A core prediction of standard NEG formulations is the existence of agglomeration shadows preventing urban areas from forming too closely to other equal or larger-size urban areas due to fierce spatial price competition.

Explaining the emergence of the American urban system through the early 20th Century was one of the primary goals of NEG proponents. Despite many successes in this area, there is a need for better empirical understanding of how agglomeration economies influence *current* population mobility (Eeckhout 2004; Tabuchi and Thisse 2006). For example, as a result of the declining costs of transporting goods, relative to moving people, NEG models may less accurately predict 21st century U.S. population movements (Glaeser and Kohlhase 2004).

Most related research is limited to larger urban centers and metropolitan areas (MAs) (Brülhart and Koenig 2006; Eaton and Eckstein 1997; Glaeser and Maré 2001; Head and Mayer 2004, 2006; Knaap 2006; Lucas and Rossi-Hansberg 2002) with surprisingly little work examining related spatial interactions beyond major urban areas. Partridge et al. (2007b) examined population growth for nonmetropolitan and small metropolitan areas for 1950-2000 within the context of the urban hierarchy. However, they did not consider interactions among mid-sized and larger metropolitan areas, particularly potential agglomeration shadows on growth, and did not focus on the most recent growth experience. Recent changes in transportation costs (Glaeser and Kohlhase 2004), technology, and the nature of transactions costs and firm interactions (McCann and Shefer 2004; McCann 2007), may have caused shifts in spatial growth dynamics. Continued policy interests, such as with land use patterns underscore the need to understand the current general applicability of NEG models for area growth within the urban hierarchy.

One prediction of NEG (CPT) models is that spatial price competition causes population growth to be positively related to distance from (other) urban centers; i.e., there are 'growth shadows.' Yet, agglomeration economies may have a greater *positive* geographic reach than is usually assumed, with cities being an economic driver far beyond their borders (Partridge et al. 2007a). The relationship between lower- and higher-tiered places is increasingly comprised of commuting to (urban) jobs, accessing higher-ordered urban services and amenities, and urban sprawl and related centrifugal forces that push residences further into rural exurbia. Improved transportation and communication technologies may have extended spatial urban input-output linkages beyond what is typically presumed. To reveal the spatial richness and heterogeneity that underlies the urban system, distances and interactions among the full set of proximate higher-tiered urban centers must be directly considered.

This study fills this void by using both 1990-2000 and 1990-2006 U.S. county level population growth, which allows us to consider interactions among places from the lowest to highest-tiered urban centers. Unlike NEG and CPT models, we model population change in a broad interregional context. Our departing point follows a model of city development, in which we add commuting and input-output externalities outside of the 'city' border, along with the desire for proximity to urban amenities and services only available in the largest urban centers. With these extended commuting or input-output linkages, nearby population growth may be *inversely* related to distance from the city rather than positively related (i.e., growth shadows) as predicted by standard NEG/CPT models.

We focus on how an individual county's geographic location in relation to the urban hierarchy affects its growth, based on distances to small urban centers all the way up to the largest centers. We examine whether nearby same-size or larger urban neighbors on net provide beneficial access to agglomeration effects, or produce a growth shadow as predicted in many NEG (CPT) formulations. We conclude that some elements of NEG models are valuable in explaining the evolution and interactions within a *mature* urban system, but that other perspectives and models also are needed.

2. Theoretical Considerations

The distribution of economic activity across the American urban landscape reflects a multitude of location decisions by firms and households. A synthesis of theories regarding how these decisions cause population to agglomerate into core areas informs our empirical model and distinguishes the key competitors from the NEG (CPT) framework (Brülhart 1998).

Neoclassical economic theory explains an uneven spatial distribution of economic activity as resulting from regional differences in geography, endowments, and technology. Product and factor market competition limit the degree of economic concentration in regions with natural advantages. Continued concentration in many developed areas, and development of core areas without natural advantages, require other explanations.

New Economic Geography models incorporate imperfect competition, increasing returns to scale, and mobile factors, making the concentration of economic activity endogenous. Labor resides in the region of employment and migrants respond mostly to labor demand. Continued agglomeration is facilitated by the preference for product variety among laborers. Yet, because NEG models do not fully consider the diversity of factors underlying household location such as commuting or access to urban amenities, they may be limited in explaining 21st century urban hierarchy and core-periphery dynamics (Glaeser and Kohlhase, 2004). Thus, we also consider competing theories for agglomeration of economic activity and the related spatial interactions.

New Economic Geography Population Dynamics

In NEG models, with their focus on pecuniary effects, close proximity to suppliers of intermediate inputs and customers lowers firm transportation costs (Venables 1996). Combined with scale economies in the production of non-traded intermediate inputs (Fujita 1988) this creates agglomeration. Yet, increased competition associated with proximity of economic activity acts as a dispersal force (Combes 2000), limiting agglomeration. Firms in the areas closest to agglomeration centers find themselves in a 'growth shadow' (Dobkins and Ioannides 2001), in which they are competitive in producing only the most basic goods and services. Small cities serve their local markets, while larger cities serve wider markets that include small cities, leading to an urban hierarchy (Fujita and Thisse 1996).

NEG models predict that population in the distant hinterlands expand to provide the urban center with farm products, until densities are sufficient for a new urban center to emerge (Fujita et al. 1999). In a *mature* urban system, the hinterlands would be approximately uniformly settled (as in CPT), with growth shadow effects as the key NEG mechanism for a positive distance-population *growth* relationship.

Modern agglomeration patterns reflect improved transportation and communication technology, shifts in trade patterns, and industry structural change. Industrial restructuring away from goods and towards services could produce vastly different patterns of spatial interactions compared with those based on 19th and early 20th century parameters (Glaeser and Kohlhase, 2004). For example, falling transportation costs can have an ambiguous effect on agglomeration. To the extent that agricultural goods become cheaper to ship into core areas, the tendency towards agglomeration increases (Fujita and Thisse 1996). Yet falling transportation costs can also disperse manufacturing activity to less congested areas (Desmet and Fafchamps 2005). Shifting international trade patterns can cause economic activity to move away from historic urban centers to border areas to reduce associated transportation costs (Hanson 1997). Yet empirical evidence suggests a strong lock-in effect at the top of the urban system, with more churning at lower levels (Black and Henderson 2003).[1]

Moving Beyond the NEG Framework

Explaining modern day core-periphery population dynamics requires extending the NEG framework to accommodate emerging forces impacting the nature of the predicted relationships. In contrast to Krugman's NEG growth shadow, current economic realities imply a positive relationship between population growth and *close* proximity to the largest agglomeration centers.

In their city model, Lucas and Rossi-Hansberg (2002) postulate that firms weigh the benefits derived from spatially concentrating to achieve closer input-output linkages against the gains of dispersing into residential areas to reduce commuting costs for their workforce. Extending this model to allow commuting and input-output externalities beyond the city captures more extensive spatial interactions (in

[1] Some NEG theories suggest catastrophic shocks could generate realignments of the entire urban system (Fujita and Mori 1997). However, Davis and Weinstein (2002) show that even the ruinous Allied bombing campaigns against Japan during WW II did not significantly alter its urban system.

which commuting costs rise and externalities decay over distance). Within this spatial contour, population growth is *inversely* related to distance from the urban center rather than *directly* related as predicted by many NEG models. Besides transport costs, transactions costs such as information costs about demand and locating trusted suppliers also increase with distance from the core.[2] Congestion costs, higher crime, pollution, and land prices (Glaeser 1997) may push growth to nearby areas. Allowing for interregional migration would further extend the spatial reach of agglomeration.

In this framework, households locate to maximize utility in the consumption of amenities (HHAMEN) and traded goods (X) at price *p* (normalized to unity across regions):

(1) $U_i = U_i(HHAMEN_i, X_i)$,

where *i* denotes region of residence. Amenity consumption relies on the stock of amenities in region *i* ($AMENITY_i$), as well as a vector of amenities accessible in *j* proximate regions ($AMENITY_j$). Urban amenities include diverse consumption opportunities available in higher-tiered urban areas (Glaeser et al., 2001). The cost of accessing these amenities outside the region increases in terms of a vector of distances (d_{ij}) between region *i* and each of the *jth* proximate higher-tier regions. Labor income *w* influences the amount of goods that can be purchased, and reflects both the wage rate in region *i* and that within commuting distances to regions *j*. Commuting costs also increase with distance to job location.

The resulting indirect utility function can be written as:

(2) $V_i = V_i(\mathbf{AMENITY_i}, \mathbf{AMENITY_j}, w_i, \mathbf{w_j}, \mathbf{d_{ij}})$.

Utility is higher where there is access to greater and more diverse economic opportunities and to more possibilities for consuming amenities. Interregional equilibrium requires equalized utility across space. Information constraints and moving costs mean that migration may only partially adjust in a given period to utility differentials. Thus, net migration (NM) into region *i* in a representative period relates to the difference in regional household utility from the rest of the U.S. (V_{ROUS}):

(3) $NM_i = \alpha_i(V_i - V_{ROUS}),\ 0 \le \alpha_i \le 1$,

where α is the adjustment rate.

[2] Wolf (1997) finds that U.S. domestic goods are shipped an average of 255 miles.

Synthesis of NEG and Extensions for Spatial Population Dynamics

The predicted population dynamics of NEG models are altered by these extensions. Following the tradition of CPT, NEG predicts a hierarchy of cities, in which the availability of services increases when moving towards the top of the hierarchy. This occurs because of rising demand thresholds for higher-order services and spatial competition among firms, the latter acting as a nearby dispersal force. Each tier of city has services that are available in lower-tier cities plus those for which threshold requirements are first met at that tier. The top tier (n) in the hierarchy offers the full range of services including the highest-order financial and legal services, with the first or lowest tier, offering only the most basic such as gasoline. Residents and businesses in the first tier travel to the nearest higher-tier cities for second, third, and higher orders of services.

In NEG models, this hierarchy generates agglomeration growth shadows, where spatial competition near higher-tiered centers constrains the growth of local businesses. Yet, because of the extensions discussed above, spatial-competition shadows may be overcome. Rural areas and smaller urban centers can benefit from close proximity to successively higher-tiered centers, while incurring penalties for increasing remoteness, having to travel incrementally farther to access increasingly higher-orders of services and to access employment through commuting.

The distance penalties/benefits for community i in tier j of n tiers of cities in the urban hierarchy evolve as follows. Each consecutive higher-tier urban area (t, t+1, t+2…n) has successively higher orders of services and urban amenities. Consistent with marginal costs, the incremental distance is defined as the difference in the distances to places t+1 and t, both measured from place i. For each i, beyond the 'own' level j of urban center ($j<t\leq n$), let the incremental distance to the nearest higher-tier t place equal d^t and the marginal 'penalty' for job growth of greater incremental distance from a tier t place equal φ^t.[3] The different φ^t across tiers allows the total distance response to have different segments (not just one linear response for the entire hierarchy). The sum (over all tiers) of the accessibility penalties for population growth at location i in the jth tier can be depicted as:

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[3] For the nearest higher-tier place $t \geq j$+1, the incremental distance equals the ***actual*** distance between t and c. Section 3 provides specific examples. If there are growth shadows, the 'penalty' could revert to a benefit.

(4) $Penalty_{ij} = \sum_t d^t \varphi^t$,

where the summation is over $t = j+1$ to the n^{th} tier. The penalty term reflects the total cost a region faces due to cumulative incremental distances as a result of traveling up the hierarchy to access progressively higher-order services. Appendix Figure 1 shows a visual representation of the distance penalty.

3. Empirical Implementation

The underlying agglomeration mechanisms discussed above vary in their predictions regarding the effect of distances from agglomerated core areas on performance in peripheral areas. Our primary interest is the impact on growth processes of geographic position relative to nearby cities (differentiated by hierarchical level).

We regress population growth between periods 0 and *t* on initial period (0) conditions to allow for transitions from one equilibrium to another, consistent with related literature (Eeckhout 2004; Partridge et al. 2007a).[4] Specifying subsequent population growth as a function of the (pre-determined) initial-period characteristics mitigates concerns with statistical endogeneity. Regarding the key distance variables, we assume that the U.S. urban hierarchy was well established by 1990. This assumption follows Tabuchi and Thisse (2006) in a theoretical NEG framework, as well as empirical evidence that suggests that the urban hierarchy has been very stable over time (e.g., Eeckhout, 2004; Duranton, 2007). Thus, distances from a location to its higher-tiered urban areas are predetermined and set by prior development of the U.S. urban system. Yet, statistical endogeneity in other variables may bias the distance results, a topic we consider in more detail below.

Population change is examined primarily over the 1990-2000 period, in which sensitivity analysis is conducted for 1990-2006. Counties in the lower 48 states and the District of Columbia are our units of observation.[5] We use multiple sub-samples to examine the different transmission mechanisms across the urban hierarchy. Counties that are not part of either a micropolitan area (MICRO) or a larger metropolitan area (MA) are referred to as rural/hinterlands, which occupy the lowest tier in the urban hierarchy.

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[4]Examining growth rates has the advantage of differencing out fixed effects associated with levels or the scale of the locality (Hanson 2001).

[5]Following the U.S. BEA, there are cases where independent cities are merged with the surrounding county to form a more functional economic area (especially in Virginia). Forty-three mostly small rural counties are omitted due to the lack of economic data. For details, see Partridge and Rickman (2006).

MICROs, small 'urban' center of 10,000–50,000 people and counties with tight commuting linkages, are considered the next tier.[6] Moving up the urban hierarchy, we next divide the sample into counties in MAs of less than and more than 250 thousand people. NEG theory posits that small and medium-sized urban centers need distance protection from the higher-order centers to reduce spatial competition (Fujita et al. 1999). The 250 thousand population threshold (we conduct sensitivity analysis using different thresholds) splits the metro sample into two approximately equal groups. .

The most complete reduced-form specification for county *i*, located in state *s* is depicted as:

(5) $\%\Delta POP_{is(t-0)} = \alpha + \delta\ POPDEN_{is0} + \boldsymbol{\varphi}\ \mathbf{GEOG}_{is0} + \theta\ \mathbf{DEMOG}_{is0} + \boldsymbol{\psi}\mathbf{ECON}_{is0} + \boldsymbol{\gamma}\mathbf{AMENITY}_{is0} + \sigma_s + \varepsilon_{is(t-0)}$,

where *POPDEN* is initial-period population density to control for own-county agglomeration or congestion effects. **GEOG**, **DEMOG**, **ECON**, and **AMENITY** are vectors that represent: geographic attributes including distance to different tiers in the urban hierarchy; demographic characteristics; economic characteristics; and amenities. The regression coefficients are α, δ, $\boldsymbol{\varphi}$, $\boldsymbol{\theta}$, $\boldsymbol{\psi}$, and $\boldsymbol{\gamma}$; σ_s are state fixed effects that account for common factors within a state; and ε is the residual.

Our analysis begins with more parsimonious models than equation (5) to assess whether potential multicollinearity and endogeneity affect the key results. The most parsimonious models include only variables that are clearly exogenous (e.g., climate) or predetermined (distance), while additional factors are added in successive models to assess robustness. The county residual is assumed to be spatially correlated with residuals for neighboring counties, with the strength of the correlation being inversely related to the distance between the two counties. We use a generalized method of moments (GMM) procedure to produce t-statistics that are robust to cross-sectional spillovers (Conley 1999).[7] Appendix Table 1 presents detailed variable definitions, sources, and descriptive statistics.

GEOG contains several measures of proximity to higher-tiered urban areas. The first measure is distance to the nearest urban center of any size, which can be either a MA or MICRO. If the county is

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[6]We generally use the 2003 MA/MICRO definitions, as MICROs were first defined in 2003. An inclusive definition of MAs is desired to isolate growth due to changing commuting patterns versus *intra* urban center interactions due to other factors. Note, ***excluding*** the fastest growing recently-acquired outer MA counties from the rural sample, ***weakens*** any underlying negative rural-distance to urban center response (actually strengthening our results). Sensitivity analyses use earlier 1999 definitions mostly based on 1980s commuting patterns to establish boundaries for the existing (1990) MAs, along with MAs newly defined in the 1990s.

[7]The bandwidth extends 200 kms, after which zero correlation in county residuals is assumed.

already part of an urban area, this is the distance from the population-weighted center of the county to that of the urban area.[8] If the county is not part of a MA or MICRO, it is the distance from its center to that of the nearest urban place. Outer counties *within* MAs or MICROs areas could grow faster due to urban sprawl and suburbanization. Yet, greater remoteness to the next *higher* urban tier may promote or detract from growth depending on whether distance is costly or offers protection from spatial competition.

To reflect 'penalties' to additional tiers, we include incremental distance to higher-tiered urban centers for counties whose nearest city is not the highest tier. First, we include the incremental distance from the county to reach a MA.[9] Next we include variables that measure the incremental distance to reach an urban center of at least 250 thousand, at least 500 thousand, and >1.5 million people.[10] The incremental distances reflect the additional penalty (or benefit) a resident/business of a county encounters because they have additional travel costs to access progressively higher-ordered urban centers. The largest urban tier represents top-tier regional/national centers, while the other smaller-center sizes capture different-size labor markets (for commuting) and access to personal and business services.

In some MICRO and MA samples, we include distance to the nearest urban center *within* the same tier. For a given MICRO, this would be the distance to the nearest other MICRO. The sign of this coefficient shows the net effect of two offsetting possibilities: (1) spatial competition among urban centers *within the same tier* (akin to a growth shadow), or (2) close proximity to another urban center in the same tier enhancing the regional agglomeration effect. For large MAs, the own-tier distances are calculated for population categories of 250- 500 thousand, 500 thousand-1.5 million, and >1.5 million.

Other variables in the **GEOG** vector include population of the nearest (if a rural county) or own (if

[8]The population weighted centroid of each county is from the U.S. Census Bureau. The population category for MAs is based on initial 1990 population. If the urban center only has one county, this distance is zero.

[9]For example, if rural county A is 40 kms from a MICRO and is 70 kms from the nearest MA, the incremental distance to the nearest MA would be 30 kms. Conversely assume county B is located in a MICRO, being 25 kms from the center of its MICRO and 70 kms from the nearest MA. The corresponding incremental value to the nearest MA would be 45 kms (70-25). For a MA county, the incremental value is zero.

[10]Incremental distance is calculated as before. If the county is already nearest to a MA that is in either a larger or same size classification, then the incremental value is zero. For example, if the county's nearest urban center of any size (or MA of any size) is already over 500k, then the incremental values for the at least 250k and at least 500k categories are both equal to zero. In another example, if say rural county A is 30 kms from a MICRO (its nearest urban center), 70 kms from its nearest MA of any size (say 150k population), 120 kms from a MA >250k people (say 400k population), 160 kms from a MA >500k (say 2 million). Then the incremental distances are 30 kms to the nearest urban center, 40 incremental kms to the nearest MA (70-30), 50 incremental kms to a MA >250k (120-70), 40 incremental kms to a MA >500k (160-120), and 0 incremental kms to a MA >1.5million (160-160).

MICRO or MA county) urban center. A county may benefit from proximity to a larger nearby urban center if more positive agglomeration effects spill over (labor market effects for commuting and proximity to amenities and higher-order services). The existence of growth shadows would produce offsetting responses.

Analogous to the distance variables, we also include incremental population variables for the nearest MA, a MA of at least 250 thousand, at least 500 thousand and at least 1.5 million, people.[11] Because we already include the incremental *distance*, these population terms account for any *marginal* population impact. That is, they account for *within* tier effects of urban size, while the incremental distance terms account for the penalties of reaching an urban center of at least the specified size.[12] Other specifications (below) use the actual rather than incremental population, as well as models that omit incremental population altogether, but there was almost no change in the key incremental distance results. Finally, some models control for the population in surrounding counties within the county's BEA economic region (see footnote a, Appendix Table 1) to account for factors such as agglomeration spillovers and market potential (Head and Mayer 2004, 2006).

The remaining control variables capture potential causes of population change aside from geographic location. First, we account for natural **AMENITIES** as measured by climate, topography, percent water area, and a related amenity scale constructed by U.S. Department of Agriculture (see Appendix Table 1). Amenities are included in all models as they reflect natural location advantages.

To examine robustness, we also include numerous demographic and economic variables (in 1990) in some models. To account for human capital migration effects, we include initial-period **DEMOG** measures of racial composition, past immigration, age, and educational attainment. To control for disequilibrium economic migration, some models incorporate the following **ECON** measures: 1989 median household income, 1990 unemployment rate, 1990 employment shares in agriculture and in goods production. We also include the 1990-2000 industry mix job growth, a common exogenous measure of demand shifts.[13] To

[11]For example, if the nearest/actual urban center is 45 thousand (MICRO), the next closest urban center is 600 thousand, the third closest urban center is 2 million people, then the incremental population of nearest MA is 555k the incremental population of a MA that is >250k is 0, the incremental population of a MA >500 thousand is 0, and the incremental population of a MA that is at least 1.5 million is 1.4 million (2-0.6 million).

[12]For example, for the 250 thousand cutoff, the incremental distance to an urban center variable accounts for penalties to reach an urban center of at least 250 thousand. The incremental population variable accounts for any marginal spillovers due to this urban center/tier having a population in *excess* of 250 thousand.

[13]Industry mix employment growth is the sum of the county's initial industry employment shares multiplied by

account for nearby county economic spillovers, some models include BEA-region values of median income, unemployment, and industry-mix growth measures (excluding the county of interest).

In other models, state fixed effects are included to account for factors such as policy differences, geographic location with respect to coasts, and settlement period.[14] When state fixed effects are included, the other regression coefficients are interpreted as the responses after *within* state changes in the explanatory variables.

4. Empirical Results

Descriptive statistics are reported in Appendix Table 1, whereas Appendix Table 2 has selected sub-sample statistics. Table 1 contains the results for the 1990-2000 period for counties located in noncore rural areas, MICRO areas, small MAs with less than 250 thousand people, and large MAs with population over 250 thousand. Sensitivity analysis follows thereafter.

4.1 Base Regression Models

With the exception of the large MA group, we start with a very parsimonious model that only includes distance and amenity measures, followed by a second model that adds the urban population, economic, and demographic variables, and a third model that adds state fixed effects. These models successively test the robustness of the results to alternative causes of population change such as initial economic conditions, or econometric concerns regarding omitted variables, multicollinearity, endogeneity, or omitted autoregressive processes. Stability of our key results across these varied specifications will show that our findings are not an artifact of a particular econometric misspecification.

In Table 1, the key distance results across columns (1)-(3) for rural counties, (4)-(6) for MICRO counties, and (7)-(9) for small MA counties are very similar, indicating the robustness of the results.[15] Given their robustness, we describe the results of the fully specified models in columns (3), (6), (9), and (10). We start with the rural area results, then the smaller urban centers, followed by the largest MAs. We

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the corresponding national industry growth rates for the period. Because national industry growth should be exogenous to county industry growth, it is a common instrument for local job growth (Blanchard and Katz 1992).

[14] We experimented with also including three indicators for being within 50 kilometers to the Atlantic Ocean, Pacific Ocean, and the Great Lakes. However, our results were essentially unaffected and the ocean/lake proximity variables were generally insignificant suggesting that state fixed effects adequately represent these natural advantage effects.

[15] The large MA sample results are also robust, but we do not report all of them for brevity.

focus our discussion on the distance results due to their first-order importance.

Urban-Hinterland Interactions

The distance to the nearest urban center coefficient (column 3) suggests that for a rural county, every kilometer increase in distance from its nearest urban center (of any size) is associated with 0.1% less population growth. When measured at the mean distance of 60 kilometers (Appendix Table 2), this translates into 6.1% less population growth than a rural county adjacent to the urban center's core. The influence of the urban hierarchy does not end there. If the nearest urban center is only a MICRO area, the rural county loses an additional 0.038% of population growth per incremental kilometer to reach a MA of any size. If this urban center is a small MA of less than 250 thousand people, there is another penalty of 0.03% per incremental kilometer to reach a MA of at least 250 thousand. There are corresponding population growth penalties of about 0.02% and 0.01% per kilometer to reach MAs of at least 500 thousand and 1.5 million people. At the mean incremental distances (Appendix Table 2), the typical rural county incurs a distance penalty of 11.9% in population growth during the 1990s for its remoteness from all of the urban tiers.[16]

Although it is notable that there are incremental penalties for a hinterland county not having access to urban centers up to 1.5 million, the largest marginal penalty is for remoteness from *any* urban center greater than 10,000. This suggests that accessibility for commuting and basic urban services may be of over-riding importance. These results are inconsistent with an urban growth shadow, as well as with a long-run CPT equilibrium with uniform population growth in the hinterlands. Such settlement patterns illustrate the strong far-reaching regional forces that can encourage rural sprawl.

The results for the 1990-2006 period are similar, generally being larger in proportion to the years added to the analysis (Appendix Table 3). Exceptions include the coefficient for population of the nearest urban center becoming significantly positive and the coefficient for population density becoming insignificant.

Small Urban Center Spatial Interactions

[16]A one standard deviation increase in the distance to the nearest urban center is associated with an expected 3.1% decline in rural county population growth, while a one-standard deviation increase in all of the incremental distance terms is associated with 10.5% less growth.

The MICRO and small MA results in columns (6) and (9) reveal that more distant counties *within* an urban center are growing faster, consistent with sprawl and suburbanization (though the small MA result is only marginally significant). This pattern applies even after accounting for a host of other characteristics. For MICROs, the incremental distance to the nearest MA coefficient implies a 0.026% population penalty per every kilometer farther away. Beyond that, only the incremental distance to an urban center greater than 250 thousand has a statistically significant negative impact.

For small MAs, the estimates suggest that for increased incremental distance from urban centers greater than 250 thousand, 500 thousand, and 1.5 million people, small MAs are marginally penalized even more than rural counties. For example, at the mean incremental distances (Appendix Table 2), small MAs *ceteris paribus* incur growth penalties of 8.3%. This penalty likely relates to a lack of access to higher order services and amenities.

The sole evidence of a distance-based growth shadow is for small MAs being too close to other small MAs *within* their tier. So, greater distance of a small MA from other small MAs allows it to grow more. For the mean distance between small MAs, population growth is 2% slower, in which a one standard deviation increase in the distance increases growth by 2%.

The urban-center *population* results are more ambiguous. For both MICROs and small MAs, county population growth is inversely related to own initial population density. Inconsistent with growth shadows, the incremental population variables are mostly insignificant. In fact, for small MAs, the incremental population of the nearest MA greater than 250 thousand positively and significantly affects population growth. Yet, neighboring region population is insignificant in the MICRO and small MA models.

Expanding the sample to 2006 generally produced comparable results (Appendix Table 3). For micropolitan areas, population density became insignificant. The urban hierarchy coefficients for small metropolitan areas became more negative by magnitudes which are greater than the proportion of the sample period expansion, and much greater than what occurred for noncore rural areas and micropolitan areas. Thus, not only were small metropolitan areas penalized more for greater distances from high-tiered metropolitan areas, the relative penalty appears to be increasing in the most recent years.

Large Urban Center Spatial Interactions

Column (10) of Table 1 shows the corresponding results for the counties located in large MAs (population >250 thousand). With the exception of the positive *within* MA distance coefficient, none of the proximity variables are significant. Thus, the general pattern is one of sprawl, while proximity to higher-tiered MAs and other same-tiered MAs plays little role.

The positive own-county population density variable suggests that there are favorable local agglomeration effects at the 10% level, consistent with a size threshold where own agglomeration effects become more important for larger urban centers. The positive and significant (at the 10% level) neighboring-county population coefficient suggests that agglomeration benefits are also derived regionally. There is now evidence of a growth-shadow effect for counties located in MAs of between 250 thousand and 1.5 million people when they are close to a MA with population over 1.5 million (evidenced by the negative effect of increased population of the large MA).[17] Given the corresponding insignificant distance effects, it may be that only the largest MAs in the top tier cast a growth shadow consistent with NEG. The insignificant incremental distance findings are still most consistent with no clear spatial interactions between neighboring cities (Ioannides and Overman 2004).[18]

The results for the expanded period of 1990-2006 suggest that urban sprawl appears to be pervasive. Population density also has a more significant positive effect on growth, while population in surrounding counties is now insignificant. Yet, the general pattern is very similar to the shorter 1990-2000 period.

Further Search for Growth Shadows

To further search for the existence of growth shadows, we added interactions of the distance variables with the corresponding urban center population (not shown). This tests whether growth shadow effects attenuate with distance. These interaction variables were jointly insignificant in the MICRO and small MA models, but significant at the 5% level in the rural and large MA cases.

For rural counties, the negative distance-population interaction coefficients generally suggest less population growth the more distant the county is from an urban center of a given size, which is the opposite

[17]Dividing small and large MAs at 500 thousand was considered in sensitivity analysis, but without much affect.

[18]We considered whether using earlier 1999 MA boundaries to define our sample (MICRO areas were not defined in 1999) affected our key distance results (not shown). These boundaries would have included only commuting patterns from the 1980s identified in the 1990 Census (along with any new MAs defined in the 1990s). Nonetheless, the distance results were generally robust. In defining these small and large MA samples, 1999 boundaries are used in determining the MA's particular population category (e.g., less than or greater than 250 thousand).

of an agglomeration growth shadow. For the 'smaller' large MAs with between 250 thousand and 1.5 million people, the positive interaction coefficient suggests that greater distance from an urban center of >1.5 million mitigates the adverse population effects described above, consistent with the growth shadow interpretation above.

4.2 Summary of Findings

We generally find that proximity to a higher-tier urban center is positively related to population growth for counties in rural areas, MICROs, and small MAs. This is inconsistent with growth shadows of CPT and NEG models. There is less evidence that (regional) market potential is a good explanation for population change because the own population density and the neighboring county population coefficients have the wrong sign or are insignificant. One reason for the mixed pattern could be 'exports' from smaller urban centers and the hinterlands are more directed to national and international markets than those nearby.

For larger MAs, we find surprisingly little evidence that proximity to (even) higher-tier urban centers affects their growth. The pattern is consistent with offsetting effects from decaying agglomeration effects and CPT factors. There is evidence of growth shadow effects between small MAs *within* the same tier. There also is some evidence that among 'medium' MAs of 250 thousand to 1.5 million, there are adverse competition effects (growth shadows) from proximity to the very largest urban centers.

Examination of 1990-2006 confirms the continued negative effects of a county's distance from higher-tiered urban areas. In fact, the effects for small MAs became more-than-proportionately negative (relative to the length of the time period expansion)—i.e., they appear to be intensifying after 2000. Sprawl also appears to be continuing at the outer fringe of MAs with greater than 250,000 people. However, generally the patterns are similar over the longer period.

4.3 Commuting Linkages

The lack of urban growth shadows could relate to tight commuting links between cities, rather than geographically-widespread input-output linkages. [19] Most agglomeration models suggest that urban input/output externalities are a function of thresholds and the size of the urban center (Black and Henderson 2003). Marginal growth in an urban center would not measurably affect the size of its input-output

[19] For example, past research suggests that knowledge spillovers have a much smaller geographic scope, perhaps less than a few miles because of their highly personalized nature (Rosenthal and Strange 2001, 2003).

externalities—e.g., New York MA's input-output externalities would be only marginally affected if it grew by (say) 5%. Yet, if it created 5% more jobs, this may create commuting opportunities in nearby counties, increasing their population growth.

By controlling for job growth in the urban center, we can ascertain how much of its job growth spills over and creates opportunities in neighboring counties. Thus, if the incremental (urban center) distance coefficients are much smaller in magnitude when the urban commuting measures (employment growth) are included in the model, this would suggest that the incremental distance attenuation affects are mostly due to commuting. Any remaining distance effects would more likely be related to spillovers from threshold effects (input/output externalities and access to urban amenities).

To assess this issue, we include measures of urban center job growth for the same urban-tier categories used above. Because commuting effects likely die out after 160 kilometers (100 miles), we set the corresponding nearest urban center employment growth equal to zero if it is farther than 160 kilometers from the county. Even within 160 kilometers, commuting effects likely decay with distance. Hence, we also include interactions of the nearest urban center's job growth with the county's distance from it. Finally, population and job growth may be simultaneously determined. To account for this, we substitute the relevant 1990-2000 industry mix employment growth as an exogenous proxy for local job growth.

The results for the four size groupings are reported in Table 2. For each group, the first set of results is for the slightly-adjusted base model from Table 1, which is reported only for comparative purposes.[20] The second model for each group adds the industry mix growth rates for the nearest/actual urban center in each size category and the corresponding industry mix-distance interactions.

In the noncore rural model, the industry mix terms for the nearest urban center are consistently positive and jointly significant at the 5% level, suggesting nearby urban job growth creates rural commuting opportunities.[21] Likewise, the urban center distance × industry mix interaction terms are all negative and jointly significant at the 5% level. As expected, positive urban employment growth effects attenuate with distance. Yet, the incremental distance to urban center coefficients are still jointly significant at the 5%

[20]With the exception of the noncore rural sample, the own-county industry mix measure is also omitted from these models as the urban center's overall industry mix job growth accounts for localized employment growth.

[21]For the variables reported in the other tables, the coefficients are similar to the base model in Table 1, and are not reported for brevity, while the distance to the nearest tier variable is omitted.

level, while their magnitude declined only modestly. The rural pattern suggests that urban job growth spreads out and lifts rural population growth through commuting opportunities. However, because the incremental distance coefficients remain large, there appear to be important backward-forward externalities that affect rural population growth.

Regarding the urban centers, the industry mix employment growth terms and corresponding distance interactions are almost universally insignificant. So job growth in nearby higher-tier urban centers generally has little statistical influence on smaller urban center growth—suggesting that commuting ties do not underlie the interactions between urban centers. The pattern remains that growth in MICROs and small MAs is inversely related to distance from higher-order urban centers, consistent with accessibility to urban centers (rather than growth shadows) playing the most important role. For larger urban centers, the results still suggest relatively little spatial interaction. Since commuting does not appear to be a strong contributing factor, one of our conclusions is that there are geographically far-reaching backward-forward externalities.[22]

5. Conclusion

Despite the development of many variants of New Economic Geography, few studies have empirically examined its ability to explain population dynamics in a stable mature urban system. In particular, there has been little investigation of the spatial interactions among urban areas and between the urban core and peripheral regions. This study addressed this issue by examining U.S. population dynamics across the urban hierarchy, specifically the link between county population growth and geographic proximity to successively higher-tiered urban areas as well as between areas within the same tier of the hierarchy.

We find that rural counties and smaller urban centers have significant positive interactions with their nearest higher-tiered urban areas. We found successive *penalties* in terms of lower growth the farther a rural or smaller urban county was from each higher tier of urban center. Further analysis suggested that urban job growth stimulated rural population growth in part through commuting opportunities, illustrating the strong forces supporting rural sprawl. We found little evidence consistent with NEG growth shadows, the exception being spatial competition among small MAs.

[22]The insignificance of the industry mix employment growth variables for the urban samples supports our interpretation that they reflect commuting linkages and not static spatial input-output linkages, the latter expected to exist *between* urban areas rather than *between* urban and less-populated rural areas.

For counties located in larger MAs, spatial interactions with higher-tiered urban areas were much less evident. We found evidence of urban growth shadows only around the highest-tier MAs, which were being cast on proximate MAs with between 250,000 and 1.5 million population. The general lack of growth shadows suggest that some predictions of NEG and CPT are not particularly germane for describing the continued evolution of the American urban system. Likewise, commuting linkages likely play only a small role in describing interactions for the smallest MAs and no role for describing the interactions between larger MAs. Instead, the evidence is most consistent with lower-ordered places benefiting from closer accessibility in their backward-forward linkages and access to urban amenities. Finally, we found that deconcentration and sprawl remain key features of *intra* urban area settlement patterns for large MAs (ceteris paribus).

In terms of policy, these findings have implications for understanding land-use and settlement patterns. Proximity to larger urban areas is critical in shaping the size and growth of rural counties and urban areas with less than 1.5 million people. Indeed, these proximity effects are large, appearing to trump other factors such as own size and even amenities. Further analysis for the most recent years revealed that these trends show no signs of abating. Clearly, planners should consider these much broader regional interactions in their development strategies.

References

Black, D. & Henderson, V. (2003). Urban evolution in the USA. *Journal of Economic Geography*, *3*, 342-372.

Blanchard, O.J. & Katz, L.F. (1992). Regional evolutions. *Brookings Papers on Economic Activity*, *1*, 1-75.

Brülhart, M. (1998). Economic geography, industry location and trade: The evidence. *World Economy, 21(6),* 775-801.

Brülhart, M. & Koenig, P. (2006). New economic geography meets Comecon. *Economics of Transition, 14(2)*, 245-267.

Christaller, W. (1933). Central places in Southern Germany. Translated from *Die Zentralen Orte in Süddeutschland* by Charles W. Baskin. Englewood Cliffs, N.J. Prentice Hall.

Combes, P-P. (2000). Economic structure and local growth: France, 1984-1993. *Journal of Urban Economics, 47*, 329-355.

Conley, T.G. (1999). GMM estimation with cross sectional dependence. *Journal of Econometrics, 92*, 1-45.

Davis, D. & Weinstein, D. (2002). Bones, bombs, and break points: The geography of economic activity. *American Economic Review, 92*, 1269-1289.

Desmet, K., & Fafchamps, M. (2005). Changes in the spatial concentration of employment across US counties: A sectoral analysis 1972-2000. *Journal of Economic Geography, 5(3)*, 261-84.

Dobkins, L. H. & Ioannides, Y. M. (2001). Spatial interactions among cities. *Regional Science and Urban Economics, 31*, 701-731.

Duranton, G. (2007). Urban evolutions: The fast, the slow, and the still. *American Economic Review, 97(1)*, 197-221.

Eaton, J. & Eckstein, Z. (1997). Cities and growth: Theory and evidence from France and Japan. *Regional Science and Urban Economics, 27(4-5),* 443-74.

Eeckhout, J. (2004). Gibrat's law for (all) cities. *American Economic Review, 94*, 1429-1451.

Fujita, M. (1988). A monopolistic competition model of spatial agglomeration. *Regional Science and Urban Economics, 18(February)*, 87-124.

Fujita, M. & Mori, T. (1997). Structural stability and evolution of urban systems. *Regional Science and Urban Economics,* 27, 399-442.

Fujita, M., Krugman, P. & Mori, T. (1999). On the evolution of hierarchical urban systems. *European Economic Review, 43*, 209-251.

Fujita, M. & Thisse, J-F. (1996). Economics of agglomeration. *Journal of the Japanese and International Economies, 10(4),* 339-78.

Glaeser, E. L. (1997). Are cities dying? *Journal of Economic Perspectives, 12(2)*, 139-60.

Glaeser, E. L. & Maré, D.C. (2001). Cities and skills. *Journal of Labor Economics, 19(2)*, 316-42.

Glaeser, E. L. & Kohlhase, J.E. (2004). Cities, regions and the decline of transport costs. *Papers in Regional Science, 83(1)*, 197-228.

Glaeser, E.L., J. Kolko, and A. Saiz (2001). "Consumer City," *Journal of Economic Geograp*hy 1, 27-50.

Hanson, G. H. (1997). Increasing returns, trade and the regional structure of wages. *Economic Journal, 107*, 113-33.

_____.(2001). Scale economies and geographic concentration of industry. *Journal of Economic Geography, 1*, 255-276.

Head, K. & Mayer, T. (2004). The empirics of agglomeration and trade. In J.V. Henderson & J.F. Thisse (Eds.), *Handbook of regional and urban economics, Vol. 4.* (pp. 2609-69). Elsevier: San Diego.

_____, (2006). Regional wage and employment responses to market potential in the EU. *Regional Science* *and Urban Economics, 36*, 573-594.

Ioannides, Y. M. & Overman, H.G. (2004). Spatial evolution of the US urban system. *Journal of Economic Geography*, *4,* 131-56.

Knaap, T. (2006). Trade, location, and wages in the United States. *Regional Science and Urban Economics, 36*, 595-612.

Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy, 99*, 483-499.

Lucas, R. E. & Rossi-Hansberg, E. (2002). On the internal structure of cities. *Econometrica, 70*, 1445-1476.

McCann, Philip and Daniel Shefer, 2004. "Location, agglomeration and infrastructure," *Papers in Regional Science* 83, 177-196.

McCann, Philip, 2007. "Sketching Out a Model of Innovation, Face-to-face Interaction and Economic Geography." *Spatial Economic Analysis* 2(2), 117-34.

Partridge, M.D., Bollman, R., Olfert, M.R. & Alasia, A. (2007a). Riding the wave of urban growth in the countryside: Spread, backwash, or stagnation. *Land Economics, 83*, 128-152.

Partridge, M.D., D.S. Rickman, K. Ali, and M. Rose Olfert (2007b). Lost in Space: Population Dynamics in the American Hinterlands and Small Cities. Unpublished manuscript available at **http://economy.okstate.edu/rickman/lostinspace.pdf**.

Partridge, M. D. & Rickman, D.S. (2006). *The spatial dimension of economic performance and American poverty.* Kalamazoo, MI: W.E. Upjohn Employment Institute.

Rosenthal, S. S. & Strange, W.C. (2001). The determinants of agglomeration. *Journal of Urban Economics*, *50*, 191-229.

_____. (2003). Evidence on the nature and sources of agglomeration economies. Prepared for the *Handbook of urban and regional economics*, *Vol. 4*. Accessed from www.rotman.utoronto.ca/~strange on November 22, 2005.

Tabuchi, Takatoshi and Jacques-François Thisse. 2006. "Regional Specialization, Urban Hierarchy, and Commuting Costs." *International Economic Review* 47: 1295-1317.

Venables, A.J. (1996). Equilibrium locations of vertically linked industries. *International Economic Review, 37*, 341-359.

Wolf, H.C. (1997). Patterns of intra- and inter-state trade. *NBER Working Paper No. 5939*.

Table 1. Dependent variable: Percentage Change in U.S. County Population 1990-2000

	Noncore Rural Area			Micropolitan Area			Inside MA with pop ≤250,000			MA >250,000
Variables/var groups	Dist	Add other **X**	Add State FE	Dist	Add other **X**	Add State FE	Dist	Add other **X**	Add State FE	Full model
Intercept	-0.508	17.344	19.482	2.200	29.742	45.870*	-3.489	46.031	11.409	55.262**
	(-0.10)	(0.87)	(1.09)	(0.38)	(1.04)	(1.82)	(-0.43)	(1.43)	(0.39)	(2.09)
Distance to nearest or actual urban center	-0.075**	-0.092**	-0.102**	0.054	0.216**	0.137**	0.092**	0.082	0.064	0.188**
	(-4.32)	(-5.98)	(-7.62)	(0.97)	(3.31)	(2.14)	(2.17)	(1.53)	(1.55)	(4.26)
Inc Dist to MA	-0.050**	-0.040**	-0.038**	-0.039**	-0.037**	-0.026**	n.a.	n.a.	n.a.	n.a.
	(-4.87)	(-4.51)	(-4.79)	(-2.99)	(-3.25)	(-2.02)				
Inc Dist to MA>250k	-0.026**	-0.025**	-0.030**	-0.028**	-0.036**	-0.029**	-0.028**	-0.038**	-0.057**	n.a.
	(-4.91)	(-5.67)	(-5.17)	(-3.43)	(-4.95)	(-3.24)	(-2.95)	(-4.17)	(-5.53)	
Inc Dist to MA>500k	-0.006	-0.004	-0.018**	-0.003	-0.008	-0.009	0.004	0.002	-0.027**	0.011
	(-0.71)	(-0.50)	(-2.42)	(-0.25)	(-0.75)	(-0.78)	(0.24)	(0.18)	(-2.23)	(0.72)
Inc Dist to MA>1500k	-0.006	-0.007	-0.011**	-2.1E-05	0.004	0.003	-0.001	-0.007	-0.026**	-3.3E-04
	(-1.22)	(-1.32)	(-2.50)	(0.00)	(0.73)	(0.51)	(-0.09)	(-0.92)	(-2.66)	(-0.04)
Dist to nearest own tier	0.021	-0.019	0.003	0.026	0.026	0.015	0.020	0.045**	0.044**	0.013
	(0.75)	(-0.83)	(0.15)	(0.87)	(1.30)	(0.85)	(0.99)	(2.69)	(3.14)	(0.74)
Population density	N	-0.066**	-0.054*	N	-0.013	-0.023*	N	-0.018**	-0.022**	4.2E-04*
		(-2.19)	(-1.95)		(-1.06)	(-1.81)		(-3.17)	(-4.07)	(1.74)
Pop of nearest or actual urban center	N	9.3E-07	6.8E-06	N	-5.8E-05**	-2.3E-05	N	1.6E-05	4.6E-05**	-5.0E-07
		(0.18)	(1.49)		(-2.75)	(-1.18)		(1.07)	(3.45)	(-1.50)
Inc pop of nearest MA	N	-1.7E-06*	-1.4E-07	N	-1.4E-06	-9.6E-07	N	n.a.	n.a.	n.a.
		(-1.86)	(-0.18)		(-1.47)	(-1.14)				
Inc pop of MA>250k	N	-1.2E-06*	-5.5E-07	N	-6.4E-07	-4.9E-07	N	6.2E-07	8.9E-07*	n.a.
		(-1.94)	(-0.95)		(-0.93)	(-0.76)		(1.08)	(1.79)	
Inc pop of MA>500k	N	-1.1E-06**	-4.6E-07	N	-4.3E-07	-2.6E-07	N	-1.0E-06**	-2.1E-07	-3.1E-07
		(-2.00)	(-0.96)		(-1.13)	(-0.66)		(-2.25)	(-0.50)	(-0.98)
Inc pop of MA>1500k	N	-6.9E-07**	-2.3E-07	N	-6.2E-07**	-2.3E-07	N	-8.8E-07**	2.2E-07	-5.0E-07**
		(-3.62)	(-1.07)		(-4.03)	(-1.44)		(-2.39)	(0.57)	(-2.69)
Pop in surrounding counties	N	2.4E-07	-2.0E-07	N	4.1E-08	2.5E-07	N	-7.6E-08	-4.5E-07	4.0E-07*
		(0.77)	(-0.74)		(0.08)	(0.52)		(-0.19)	(-1.34)	(1.93)
Weather/Amenity[a]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Economic/Demographic[b]	N	Y	Y	N	Y	Y	N	Y	Y	Y
Surrounding Econ/Demog[c]	N	Y	Y	N	Y	Y	N	Y	Y	Y
State fixed effects (FE)	N	N	Y	N	N	Y	N	N	Y	Y
R^2	0.33	0.49	0.60	0.24	0.52	0.63	0.17	0.51	0.64	0.63
No. of counties	1300	1300	1300	672	672	672	416	416	416	641
F-statistic										
All MA pop = 0	N	3.10**	2.00*	N	3.99**	0.53	N	2.87**	2.79**	1.15
Inc MA pop = 0	N	3.70**	0.53	N	2.69**	0.39	N	3.69**	1.03	1.66
Inc distance to MA = 0	27.88**	17.19**	12.27**	8.90**	12.23**	4.33**	4.73**	6.04**	7.53**	0.36

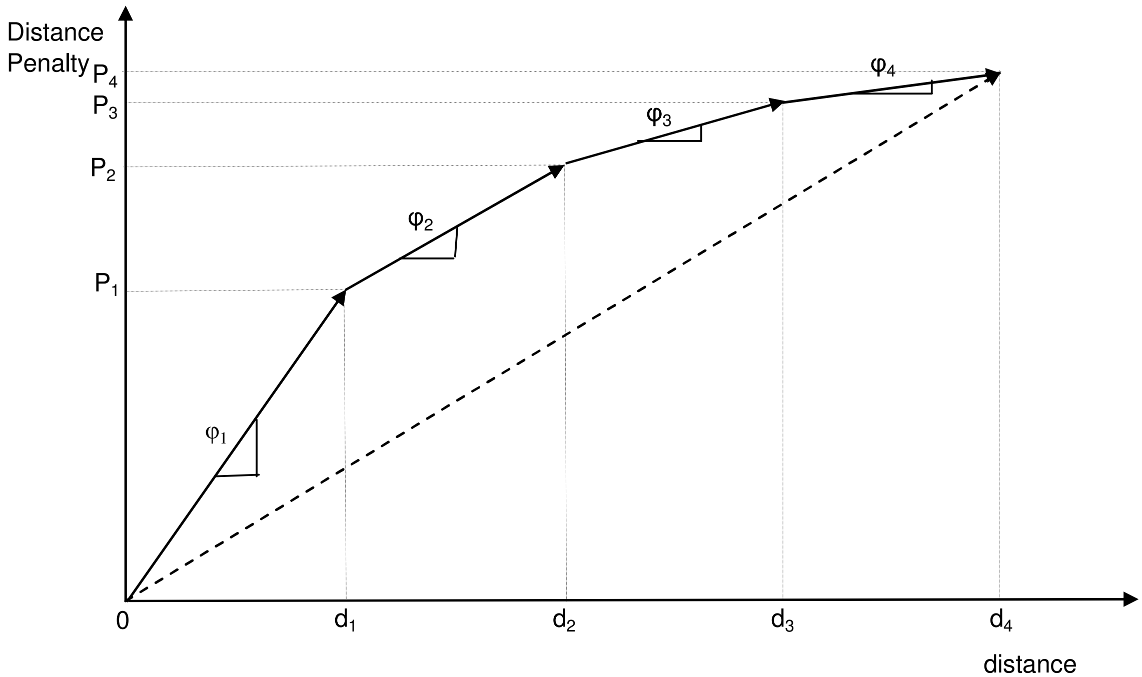
Notes: Robust t-statistics from Conley (1999) estimator are in the parentheses. A ** or * indicates significance at ≤ 5% or ≤ 10% level respectively. N=not included, Y=included. a = sunshine hours, January temp, July humidity, typography, amenity ranking, and percent water area.
b = 1989 median household income, 1990-2000 industry mix emp. growth, 1990 unemp. rate, 1990 share ag. emp., 1990 share goods emp., 6 age-distribution variables for 1990, 4 education categories for 1990, 5 race/ethnicity variables for 1990, and percentage of population immigrated during 1985-90.
c = weighted average 1989 median household income, 1990-2000 industry mix emp. growth, and 1990 unemp. rate in surrounding counties within a BEA region.

Table 2. Dependent variable: Percentage Change in U.S. County Population 1990-2000

Variables/var groups	Noncore Rural		Micropolitan area		Inside MA ≤ 250,000		Inside MA > 250,000	
	Base Model	Full Model	Base Model	Full Model	Base Model	Full Model	Base Model	Full Model
Intercept	24.225	25.195	92.418**	62.614**	32.797	28.226	84.577**	77.256**
	(1.32)	(1.39)	(3.66)	(2.79)	(0.95)	(0.85)	(2.93)	(2.64)
Dist to nearest or actual urban center	-0.103**	-0.070**	0.006	-0.144	0.054	0.033	0.173**	0.198**
	(-7.96)	(-3.50)	(0.09)	(-0.56)	(1.33)	(0.63)	(3.92)	(4.15)
Inc Dist to MA	-0.039**	-0.015*	-0.034**	-0.043**	n.a.	n.a.	n.a.	n.a.
	(-5.27)	(-1.67)	(-2.61)	(-2.39)				
Inc Dist to MA>250k pop	-0.030**	-0.026**	-0.033**	-0.026**	-0.065**	-0.084**	n.a.	n.a.
	(-5.77)	(-4.79)	(-3.40)	(-2.54)	(-5.66)	(-5.42)		
Inc Dist to MA>500k pop	-0.019**	-0.013	-0.009	-0.017	-0.024*	-0.034*	-0.005	0.005
	(-2.68)	(-1.63)	(-0.69)	(-1.22)	(-1.70)	(-1.90)	(-0.42)	(0.22)
Inc Dist to MA>1500k pop	-0.011**	-0.007	0.006	-0.001	-0.021*	-0.022	-0.004	-0.008
	(-2.64)	(-1.62)	(0.89)	(-0.12)	(-1.75)	(-1.45)	(-0.54)	(-0.70)
Industry mix growth 1990-2000	98.669**	95.338**	N	N	N	N	N	N
	(6.79)	(6.67)						
Indmixgr of micropolitan area	N	4.675	N	152.214**	N	N	N	N
		(0.33)		(5.99)				
Indmixgr of MA <250k	N	29.895**	N	-20.727	N	9.184	N	N
		(2.70)		(-1.29)		(0.33)		
Indmixgr of MA 250k to 500k	N	18.638**	N	15.974	N	-26.325	N	12.958
		(1.99)		(1.18)		(-1.42)		(0.96)
Indmixgr of MA 500k to 1500k	N	27.499**	N	14.853	N	-36.693	N	26.755
		(2.38)		(1.11)		(-1.45)		(1.40)
Indmixgr of MA>1500k	N	61.689**	N	4.084	N	-13.440	N	8.441
		(3.13)		(0.23)		(-0.61)		(0.41)
Dist x Indmixgr of micropolitan area	N	-0.083	N	0.420	N	N	N	N
		(-0.85)		(0.27)				
Dist x Indmixgr of MA <250k	N	-0.217**	N	0.152	N	-0.055	N	N
		(-2.92)		(1.50)		(-0.28)		
Dist x Indmixgr of MA 250k to 500k	N	-0.080	N	-0.150*	N	0.157	N	-0.011
		(-1.04)		(-1.71)		(1.11)		(-0.11)
Dist x Indmixgr of MA 500k to 1500k	N	-0.198**	N	-0.150*	N	0.246*	N	-0.109
		(-2.46)		(-1.70)		(1.68)		(-0.87)
Dist x Indmixgr of MA >1500k	N	-0.376**	N	-0.067	N	-0.021	N	-0.030
		(-2.64)		(-0.53)		(-0.13)		(-0.25)
R^2	0.60	0.61	0.59	0.63	0.62	0.62	0.62	0.62
N	1300	1300	672	672	416	416	641	641
F-statistic								
Inc distance to MA = 0	12.72**	5.45**	6.21**	3.20**	8.06**	9.71**	0.13	0.28
Indmixgr of MA = 0	N	5.37**	N	11.42**	N	1.27	N	0.97
Dist x Indmixgr of MA = 0	N	4.56**	N	1.86	N	1.04	N	0.27

Notes: t-statistics are in parentheses. They are derived from the Conley (1999) estimator which allows spatial correlation in errors and uses a quadratically declining weighting scheme that becomes zero beyond 200 km. ** and * indicate significant at ≤ 5% and ≤ 10% level respectively. N=not included.
See the notes to Table 1 for more details.

Appendix Figure 1. Representation of the Distance Penalties for a Lower-Tiered Center.



Note: The figure illustrates the distance penalty for a location *i* that is assumed to be at the lowest tier, four levels below the highest urban tier (or tier 4). Location *i* is situated distance d_1 from the next higher-level (tier 1) center; distance d_2 from a tier 2 center (incremental distance $d_2 – d_1$); distance d_3 from tier 3 (incremental distance $d_3 – d_2$); and distance d_4 from tier 4 (incremental distance $d_4 – d_3$). These distances could be taken from a map, in which the higher-tiered cities could fall in any 360° direction from location *i*. These distances are then placed on the horizontal axis. The φ terms show the respective marginal penalties to access the successively higher levels of services, where for simplicity, the marginal penalties decline with successively higher urban tiers. The P terms reflect various levels of distance penalties with P_4 representing the cumulative penalty. The figure shows the nonlinear nature of distance effects in the urban hierarchy and the intervening effects of more proximate higher-tiered urban areas that are below the highest tier.

Appendix Table 1. Variable Definitions and Descriptive Statistics (full sample)

Variable	**Description**	**Source**	**Mean**	**St. dev.**
Population change	Percentage change in population over 1990-2000	1990 2000 Census	11.22	16.00
Dist to nearest/actual urban center (micropolitan or metropolitan area)	Distance (in km) between centroid of a county and population weighted centroid of the nearest urban center, if the county is not in an urban center. It is the distance to the centroid of its own urban center if the county is a member of an urban center (in kms).	1990 Census, C-RERL	34.61	32.44
Inc dist to metro	Incremental dist. to the nearest/actual MA in kms	Authors' est.	36.68	49.06
Inc dist to metro>250k	Incremental distance to the nearest/actual MA with > 250,000 population, in 1990 in kms	Authors' est.	56.29	97.27
Inc dist to metro>500k	Incremental distance to the nearest/actual MA with > 500,000 population in 1990 in kms	Authors' est.	40.67	66.83
Inc dist to metro>1500k	Incremental distance to the nearest/actual MA with > 1,500,000 population in 1990 in kms	Authors' est.	89.77	111.47
Dist to nearest own tier	Distance in kms to the nearest own tier county/urban area. For an urban area, this is the distance from the center of the urban county to the population-weighted center of the nearest own-tier urban area.	Authors' est.	42.85	32.18
Population density	1990 county population per square mile	1990 Census	207.83	1,593.40
Nearest/Actual Urban Center pop	1990 population of the nearest/actual urban center measured as a MICRO or MA.	Authors' est.	374,271.3	1,377,909.3
Inc pop of nearest metro	Incremental pop. of the nearest/actual MA, 1990	Authors' est.	186,155.0	457,600.8
Inc pop of metro>250k Inc pop of metro>500k Inc pop of metro>1500k	Incremental population of the nearest/actual MA with > 250,000 population; with > 500,000 population; or >1.5million population in 1990.	Authors' est.	N.A.	N.A.
Weather/Amenity	Vector includes: mean January sun hours; mean January temperature (degree F); mean July relative humidity (%);typography score 1 to 24, in which 24 represents the most mountainous; natural amenity rank 1 to 7, with 7 being the highest; % of county area covered by water	ERS, USDA	N.A.	N.A.
Economic/Demographic				
Median HH inc	Median household income 1989	1990 Census	23,842.7	6,388.8
Industry mix growth	Industry mix employment growth, calculated by multiplying each industry's national employment growth (between 1990 and 2000) by the initial period (1990) industry employ. shares in each sector	1990, 2000 BEA, Authors' est.	0.16	0.04
Unemployment rate	1990 Civilian unemployment rate (%)	1990 Census	6.67	3.02
Agriculture share	1990 Percent employed in agriculture sector	1990 Census	8.45	8.20
Goods share	1990 Percent empl. in (nonfarm) goods sector	1990 Census	27.28	10.19
Age Shares	Percent of 1990 population <6 years; 7-17 years; 18-24 years; 55-59 years; 60-64 years; and > 65 years.	1990 Census	N.A.	N.A.
Educational Attainment	% of 1990 population 25 years and over that are high school graduates; have some college; have an associate degree; and are 4 year college graduates.	1990 Census	N.A.	N.A.
Race/Ethnic	% of 1990 population Hispanic; Black; Asian and Pacific Islands; Native American; other race.	1990 Census	N.A.	N.A.
Percent immig 1985-90	Percent of 1990 pop. immigrated over 1985-90	1990 Census	0.48	0.96
Surrounding Variables				
Population density_surr	Weighted average population density in surrounding counties within a BEA region[a]	1990 Census, Authors' est.	663.44	1,553.27
Median HH inc_surr	Weighted average median household income in surrounding counties within a BEA region[a]	1990 Census, Authors' est.	26,753.7	4795.7
Industry mix growth_surr	Weighted average industry mix employment growth in surrounding counties within a BEA region[a]	1990 BEA, Authors' est.	0.19	0.02
Unemployment rate_surr	Weighted average total civilian unemployment rate in surrounding counties within a BEA region[a]	1990 Census, Authors' est.	6.25	1.55
N			3029	

Notes: Centroids are population weighted. The metropolitan/micropolitan definitions follow from the 2003 definitions. BEA = Bureau of Economic Analysis, Regional Economic Information Service; ERS, USDA = Economic Research Services, U.S. Department of Agriculture; C-RERL = Canada Rural Economy Research Lab, University of Saskatchewan. See Partridge and Rickman (2006) for more details of the variable sources and sample selection.

a. The surrounding BEA region variables are calculated as the average of the region net of the county in question. The BEA economic regions are 177 functional economic areas constructed by the BEA.

Appendix Table 2. Mean (Standard Deviations) of Major Variables by Population Group

Variables	Noncore Rural	Micropolitan	MA≤ 250,000	MA>250,000
Distance to nearest or actual urban center	59.91	4.63	17.76	28.60
	(30.56)	(9.63)	(18.60)	(19.52)
Inc dist to MA	43.47	78.46	n.a.	n.a.
	(49.93)	(46.97)		
Inc dist to MA>250k	76.02	48.96	93.23	n.a.
	(115.19)	(83.41)	(93.26)	
Inc dist to MA>500k	45.32	38.17	36.87	36.29
	(68.95)	(59.87)	(59.07)	(73.34)
Inc dist to MA>1500k	83.45	99.81	78.54	99.37
	(106.24)	(119.29)	(115.44)	(139.88)
Dist to nearest own tier	42.60	50.26	45.99	33.53
	(22.43)	(34.47)	(44.38)	(34.69)
Population density	23.01	61.14	119.96	793.46
	(20.06)	(45.95)	(123.82)	(3,399.82)
No. of counties	1300	672	416	641

Notes: The categories are determined using 2003 definitions.

Appendix Table 3. Dependent Variable: 1990-2006 %Δ in U.S. County Population

	Noncore Rural Areas	Micropolitan Areas	Small MAs	Large MAs
Intercept	8.628	4.609	-12.677	65.602
	(0.31)	(0.12)	(-0.24)	(1.45)
Distance to nearest or actual urban center	-0.150**	0.200**	0.107	0.303**
	(-7.85)	(2.13)	(1.28)	(3.61)
Inc Dist to MA	-0.053**	-0.039**	n.a.	n.a.
	(-4.82)	(-2.05)		
Inc Dist to MA>250k	-0.041**	-0.037**	-0.095**	n.a.
	(-4.72)	(-2.98)	(-5.16)	
Inc Dist to MA>500k	-0.027**	-0.021	-0.050**	0.015
	(-2.28)	(-1.26)	(-2.46)	(0.53)
Inc Dist to MA>1500k	-0.015**	0.006	-0.060**	-0.008
	(-2.45)	(0.63)	(-3.27)	(-0.55)
Dist to nearest own tier	-0.014	0.034	0.065**	0.013
	(-0.53)	(1.25)	(2.63)	(0.36)
Population density	-0.014	-0.027	-0.037**	0.001**
	(-0.30)	(-1.22)	(-3.85)	(2.30)
Pop of nearest or actual urban center	1.2E-05*	-3.2E-05	7.4E-05**	-9.3E-07
	(1.93)	(-0.98)	(3.13)	(-1.37)
Inc pop of nearest MA	7.5E-07	-3.8E-07	n.a.	n.a.
	(0.61)	(-0.28)		
Inc pop of MA>250k	-5.1E-08	-6.3E-07	1.4E-06	n.a.
	(-0.05)	(-0.63)	(1.64)	
Inc pop of MA>500k	-4.4E-07	-2.1E-07	-5.0E-07	-9.1E-07
	(-0.67)	(-0.35)	(-0.66)	(-1.44)
Inc pop of MA>1500k	-2.8E-07	-3.0E-07	4.9E-07	-8.6E-07**
	(-0.90)	(-1.13)	(0.78)	(-2.25)
Pop in surrounding counties	-4.8E-07	1.9E-07	-8.4E-07	5.5E-07
	(-1.23)	(0.25)	(-1.41)	(1.20)
Weather/Amenity[a]	Y	Y	Y	Y
Economic/Demographic[b]	Y	Y	Y	Y
Surrounding Econ/Demog[c]	Y	Y	Y	Y
State fixed effects (FE)	Y	Y	Y	Y
R^2	0.61	0.61	0.61	0.60
No. of counties	1300	672	416	641
F-statistic				
All MA pop = 0	2.43**	0.31	2.26*	0.94
Inc MA pop = 0	0.46	0.17	0.92	1.39
Inc distance to MA = 0	10.85**	3.14**	6.99**	0.43

Notes: Robust t-statistics from Conley (1999) estimator are in the parentheses.
A ** or * indicates significant at ≤ 5% or ≤ 10% level respectively.
N=not included, Y=included.
a = sunshine hours, January temp, July humidity, typography, amenity ranking, and percent water area.
b = 1989 median household income, 1990-2000 industry mix emp. growth, 1990 unemp. rate, 1990 share ag. emp., 1990 share goods emp., 6 age-distribution variables for 1990, 4 education categories for 1990, 5 race/ethnicity variables for 1990, and percentage of population immigrated during 1985-90.
c = weighted average 1989 median household income, 1990-2000 industry mix emp. growth, and 1990 unemp. rate in surrounding counties within a BEA region.