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Harnessing growth spillovers for rural development: The effects of regional spatial structure

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HARNESSING GROWTH SPILLOVERS FOR RURAL DEVELOPMENT: THE EFFECTS OF REGIONAL SPATIAL STRUCTURE

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Summary: Many rural development strategies seek to leverage urban-to-rural growth spillovers. This paper concludes that their success depends on the spatial structure surrounding the target rural counties. We develop a county-level spatial growth model to identify the positive spread and negative backwash effects of urban to rural spillovers in the lower 48 states over the 1990-2000 period. Instead of the conventional, fallacious substitution of metropolitan and non-metropolitan for urban and rural, we consider the urban and rural character of each county. Most counties have both urban and rural populations, and we classify each as urban, mixed urban, or rural depending on the relative sizes of its urban and rural populations, the absolute size of its urban population, and its overall population density. We then develop a generalized simultaneous cross-regressive model that permits a flexible array of tests for spillover influences among the three county types and over various distances. We find evidence of positive spread effects on rural county employment growth from growth originating in nearby highly urbanized counties, but rural counties appear to suffer negative backwash effects from employment growth in nearby mixed urban/rural counties, and they do not benefit from nearby rural growth. Our results can be interpreted in the context of six classic regional development scenarios, each of which posits a unique regional spatial structure within which rural economies are embedded: the expanding monocentric city, the declining urban core, the sprawling low-density city, the large multi-centered urban region, the central place and its hinterland, and the isolated resource-dependent rural area. The research demonstrates that the prospects of urban-rural growth diffusion vary by scenario, and it cautions strongly against basing rural development programs on any single archetypal understanding of urban-rural growth diffusion.

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1 Overview

Why do some rural areas prosper while others do not? Proximity to urban areas—a long-standing subject of inquiry in the rural and regional development literatures—is one possible piece of the puzzle. Are successful rural places those in the geographic orbit of large and growing urban areas? Or, does proximity to growing urban centers retard a rural community's economic development prospects and growth? The academic literature is replete with colorful terms to characterize the hypothesized spillover relationships between big and small places: spread-backwash, generative-parasitic, trickling down-polarization (Gaile, 1980). While the terminology varies, the predominant model of urban-rural growth diffusion postulates a clear hierarchy in the relationship between places characterized as "core" and those defined as "periphery," with the former viewed as either imposing or conferring outcomes on the latter. In this context, the nature of urban-rural economic growth diffusion seemingly reduces to a simple empirical question: Are the spillovers from urban to rural places positive or negative? Is it spread or backwash?

Such parsimony does not square with the rich variation in the pattern of regional economic development in the United States. Indeed, we can identify at least six common spatial development scenarios, each of which posits a unique regional spatial structure within which rural economies are situated and under which forces of urban-rural growth diffusion occur: the expanding monocentric city, the declining urban core, the sprawling low-density city, the large multi-centered urban region, the central place and its hinterland, and the isolated resource-dependent rural community. Since the six scenarios reflect different regional spatial structures and urban-rural economic growth experiences, they also imply differences in hypothesized diffusion relationships and impose specific demands on empirical research designed to shed light on urban-rural growth dynamics. Properly accounting for the complexity of U.S. regional spatial structure within the context of a generalized growth model becomes the principal methodological and empirical challenge.

Six Growth Scenarios. The first of the six scenarios—the expanding monocentric city characterized by a densely settled core, less dense suburbs, and a vast, sparsely populated hinterland—is the spatial development scenario most commonly envisioned in classical models of urban spread-backwash, where the growth of economic activity in the core is viewed as either benefiting or harming the economic prospects of the suburbs and nearby rural communities. In this case, core growth is presumed to drive broader regional economic development outcomes. In reality, growth spillover relationships are not that simple, as the second scenario—the declining urban core surrounded by an expanding ring of suburbs and differentially growing rural places—illustrates. In the case of the declining urban core, characteristic of cities like Detroit and Cleveland in the 1980s and early 1990s, suburban and rural growth may be occurring at the expense of economic growth in the center. Economic growth *around* the core may produce negative spillovers for economic growth *in* the core, a pattern consistent with the flight of businesses from congestion, crime, land costs and other maladies in the urban center. More generally, the reality of growth spillovers is that they are not uni-directional, occurring from one type of region to another (e.g., core to periphery, or urban to rural), but multi-directional, occurring among proximate regions of varying characteristics.

The third scenario—the sprawling low-density city—represents a development pattern common in the Southwest and much of the West as a whole, and is partly a creature of the arbitrary nature of the geographical data often available for modeling spatial growth (i.e., county-level data). Cities such as Phoenix lack the kind of dominant economic center characteristic of older cities in the Midwest and East, while also being situated in large counties with significant room to grow. Linkages with neighboring counties are likely to be weak in such cases, since neighbors are typically very sparsely populated. Rural counties in such contexts are juxtaposed next to "urban" counties that, in fact, are capable of considerable expansion before any spillover to rural areas is likely to occur. In contrast, the fourth scenario—the multi-centered urban region—reflects both the multi-nucleated region and the massive conurbations common to the upper Eastern seaboard where highly dense, urban centers are nearby one another. In this case, spillovers are likely to be strong, particularly when measured at the county scale, but cannot be easily interpreted using the monocentric city as a frame of reference, since the spillovers may be between two urban places. Two or more independent urban centers, together with their less dense suburban and partially rural rings, may be close enough to either compete or compliment one another's growth. Highly urbanized places may abut or nearly abut other highly urbanized places, with less urbanized regions and rural spaces between them effectively linked to more than one center.

The fifth and sixth scenarios have received much attention in the rural development literature, as they present some of the most significant rural economic development challenges. The central place is characteristic of much of the Midwestern farmbelt: one, or occasionally two, moderately urbanized, steadily growing counties surrounded by a broad band of predominantly agricultural counties. Better highways and reduced transportation costs have helped the employment base of Midwestern urban centers grow larger through the capture of retail and service functions formerly provided by thousands of small, independent farm towns, implying a negative relationship between urban and rural growth, as in the conventional spread-backwash model. The sixth and final scenario is the isolated resource-dependent rural community, most common to Appalachia, the Lower Mississippi Delta, and the Northern Plains. It is a rural place surrounded by other rural places, with few linkages to any urban center. The growth spillovers in such regions, such as they exist, are therefore between rural communities, and may be competitive or complimentary. Indeed, an important and neglected empirical question in rural development research is whether a rural county's economy generally benefits or suffers when it is located near another rural county with an expanding economic base.

Any effort to disentangle the nature of interregional economic growth spillovers to and from rural economies in the U.S. must be undertaken in a manner that accounts for the complexity that the six different scenarios we have described represent. A successful study along these lines would yield valuable information for public policy. If large and growing urban centers exert a positive influence on economic growth in nearby rural communities (a spread dynamic), rural development strategies aimed toward establishing, strengthening, and leveraging urban-rural linkages make sense. An effective "rural development" prosperity strategy conceivably might include "urban development" programs and initiatives. If urban growth is detrimental to the sustained prosperity of rural places (a backwash dynamic), policies emphasizing the endogenous development of rural communities together with efforts to mitigate the worst impacts of nearby urban growth would be more appropriate. Alternatively, if economic growth in one rural community tends to occur at the expense of the economic development of its rural neighbors, the direction of rural development resources by state or federal governments must be very carefully considered in light of the broader regional consequences such assistance may have. In reality, places may exert both positive and negative influences on the growth of other places, and a good rural development strategy must leverage the former while mitigating the latter.

Working out the practical details of such a strategy requires a good understanding of 1) the *net* influence of the spillover effects between places of different types and 2) the specific *mechanisms* by which offsetting negative and positive influences manifest themselves. This paper focuses on the first problem—measurement of net spatial growth spillovers—as a necessary precursor to more extensive research on the determinants of such spillovers. Specifically, we develop and estimate a highly general spatial cross-regressive model that decomposes employment growth spillovers between U.S. counties of different levels of development and urbanization. The framework allows us to assess inter-regional growth effects not just uni-directionally as is common in the literature (e.g., the influence of urban on rural growth), but bi-directionally (including the influence of rural on urban growth). Moreover, we strive to acknowledge the complexity of spatial development patterns by distinguishing among dense, highly urbanized counties, less dense counties that contain both urban and rural portions, and predominantly rural counties. By measuring bi-directional growth spillovers between rural and highly urban counties, between rural and mixed urban/rural counties, and between urban and mixed urban/rural counties, we are able to produce a rich picture of regional growth diffusion for the specific period of study (1990-2000). In effect, we are able to capture the heterogeneity of U.S. regional spatial structure and shed light on rural growth in the context of the six major spatial development scenarios. Our work builds logically on the burgeoning spatial growth modeling literature (e.g., Boarnet, 1994; Henry, Barkley et al., 1997; Henry, Schmitt et al., 1999; Henry, Schmitt et al., 2001; Bao, Henry et al., 2004; Rey and Boarnet, 2004) and is motivated by current rural development policy concerns and classical research on spread-backwash and core-periphery relations (Hoselitz, 1955; Myrdal, 1957; Hirschman, 1958).

Findings. Across a range of different spatial scales, we find evidence of negative employment growth spillovers between counties at the *same* level of development (alternatively, in the same category or type) over the 1990 to 2000 period. Employment growth in highly urbanized counties appears to exert a negative effect on the employment growth of proximate counties that are also highly urbanized. Likewise, spillovers among rural counties, as well as among mixed urban/rural counties, are generally negative. These findings suggest—at least with respect to our study period—a kind of "competitive" relationship between proximate counties of similar levels of development and urbanization. In the rural case, the average rural county fared better in terms of employment gains between 1990 and 2000 if it did *not* have rapidly growing rural neighbors.

At the same time, the spillovers between counties of *different* levels of development are sometimes competitive and sometimes "complementary." Most notably, urban county employment growth between 1990 and 2000 exerted a positive and statistically significant influence on nearby rural employment growth in six of the eight distance scale assumptions we tested. This result suggests that the urban to rural employment spillover dynamic over the study period was one of spread rather than backwash; rural counties located nearby growing *highly* urbanized counties generally fared well. The most significant backwash to rural counties originated from mixed urban/rural counties. In five of the distance specifications tested, employment growth in mixed counties exerted a negative effect on rural county growth.

The results make sense in the context of development potentials in different types of counties and the dynamics of the six spatial development scenarios. Because our urban counties are densely settled, their internal opportunities for expansion are limited. The growth that spills over their borders into nearby mixed counties is residential rather than employment based, but rural counties abutting the mixed counties enjoy employment growth. This is consistent with the scenario of an expanding urban core that is creating bedroom communities in its suburbs, but employment opportunities in adjacent rural counties that are serving those suburbs. At the same time, a declining urban core implies employment growth in surrounding mixed rings (the declining core scenario), and adjacent rural counties seem to suffer. Mixed counties have a moderate degree of urbanization and a lower density, and, therefore, have considerable room to grow internally. Rural counties near growing mixed counties may fare poorly because growth spillovers remain internal to the mixed urban/rural counties and do not cross their borders. Such a result is consistent with the rural growth experience in much of the Midwest (the central place scenario) and the Southwest (the sprawling low density city). Potential rural growth is "captured" internally by the growing mixed counties in a kind of competition on the fringe of urban areas that can even retard economic growth of the nearby rural counties. Finally, our finding that employment growth spillovers between rural counties tends to be competitive is indicative of much of the experience in places like Appalachia and the Mississippi Delta, where isolated economic development successes have not managed to diffuse more widely. In such contexts, economic development success in one place may be a harbinger of development failure nearby.

Overall, our results fail to reinforce the general emphasis in the literature on urban backwash to rural places. The actual spatial dynamics are much more varied. The answer to the question of whether urban growth influences rural prosperity is "yes," though the direction of that influence—positive or negative—depends on how "urban" is defined. Over the 1990-2000 period, large and dense urbanized counties exerted spread effects to rural counties while mixed urban/rural counties exerted backwash effects. In general, while the conventional view is that growth spillovers arise from inequality—in regional size, level of development, infrastructure, etc.—we find as much evidence of spillovers between counties of roughly equal size and level of development as we do between counties of radically differing sizes and development.

Organization of the Paper. We have organized the discussion as follows. Section 2 lays the groundwork for our modeling effort by highlighting developments in the empirical spatial growth literature. Section 3 details our modeling strategy, Section 4 presents variable definitions and basic econometric procedures, and Section 5 presents the basic findings. We conclude the paper in Section 6 with a discussion of policy implications and further research needed to continue to advance understanding of the growth spillover issue.

2 Small Area Growth Modeling Antecedents

Prior to the early 1990s, the typical approach to modeling local economic growth was ad hoc. Researchers used a variety of dependent variables, including relocating firms (Wasylenko, 1980), personal income (Helms, 1985), new branch plant openings (Bartik, 1985; Schmenner, Huber et al., 1987), growth in value added (Plaut and Pluta, 1983), and employment change (Newman, 1983; Wasylenko and McGuire, 1985; Munnell, 1990).[1] Theoretical frameworks were mostly informal, with only partial consideration of equilibrium versus disequilibrium adjustment issues.[2]

The approach of Carlino and Mills' (1987)—the simultaneous modeling of population and employment within a disequilibrium adjustment framework—has heavily influenced local growth modeling research over the last 15 years. With work by Boarnet (1994) and Henry, Barkley and Bao (1997), researchers are including explicit consideration of spatial linkages and interaction together with population and employment simultaneity.[3] Continued advances in the econometrics of simultaneous spatial modeling is opening up additional avenues for understanding spatial diffusion and spread-backwash (Rey and Boarnet, 2004). In this section we provide a brief review of the Carlino-Mills, Boarnet, and Henry-Barkley-Bao contributions in order to clarify the origins of our own approach to measuring growth spillovers.

Carlino and Mills (1987, hereafter CM) took a model in Steinnes and Fisher (1974) as a point of departure, assuming that production costs vary among regions due to differences in accessibility, labor supply, land use regulation, taxes, amenities, and agglomeration economies. Profit maximizing firms adjust their locations until profits are equalized everywhere. Likewise, households migrate to maximize their utility such that utility levels are the same at all locations in equilibrium. Firms and households are in disequilibrium in period *t-1* and adjustment toward equilibrium occurs with a lag.

In the basic model, population and employment are determined simultaneously in equilibrium:

$$P_i^* = \alpha_1 E_{it} + \alpha_2 C_{it} \qquad (1)$$

$$E_i^* = \beta_1 P_{it} + \beta_2 D_{it} \qquad (2)$$

where P and E are area population and employment in period t in county i, C and D are vectors of exogenous variables influencing P and E, and the asterisks denote equilibrium values. CM propose a distributed-lag adjustment (suppressing the county i subscript) originally suggested by Mills and Price (1984):

$$P_t = P_{t-1} + \lambda_P (P^* - P_{t-1}) \tag{3}$$

$$E_t = E_{t-1} + \lambda_E (E^* - E_{t-1}) \tag{4}$$

where $0 \le \lambda_E, \lambda_P \le 1$. Substitution of (1) and (2) into (3) and (4) yields the simultaneous equations that form the basis of the econometric estimation:

$$P_t = \lambda_P \alpha_1 E_t + \lambda_P \alpha_2 C + (1 - \lambda_P) P_{t-1} \tag{5}$$

$$E_t = \lambda_E \beta_1 P_t + \lambda_E \beta_2 D + (1 - \lambda_E) E_{t-1} \tag{6}$$

In implementation, CM specify P and E as density variables (population and employment density in county i, respectively). All non-dummy independent variables take either beginning or middle-of-period values. Appendix Table 1 lists the CM model specification and summarizes their results.

Boarnet (1994) analyzed employment and population at the municipality level, using the potentials approach of Steinnes and Fisher (1974) and Fisher and Fisher (1975) to extend the CM model to include consideration of the influence of neighboring regions on own-region growth. In the Boarnet framework, local area i equilibrium population and employment levels are determined by area i characteristics (C, D) and equilibrium population and employment in a commuter shed centered on $i\,(\bar{P}^*,\ \bar{E}^*)$:

$$P^* = f(C_i, \bar{E}^*) \tag{7}$$

$$E^* = g(D_i, \bar{P}^*) \tag{8}$$

Assuming linear relationships between variables in (7) and (8) and utilizing the lagged adjustment of (3) and (4) in differences form gives:

$$\Delta P = P_t - P_{t-1} = \alpha_0 \lambda_P + \alpha_1 \lambda_P C + \alpha_2 \lambda_P \bar{E}^* - \lambda_P P_{t-1} + \mu \lambda_P \tag{9}$$

$$\Delta E = E_t - E_{t-1} = \beta_0 \lambda_E + \beta_1 \lambda_E D + \beta_2 \lambda_E \bar{P}^* - \lambda_E E_{t-1} + \varepsilon \lambda_E \tag{10}$$

or, simplifying:

$$\Delta P = P_t - P_{t-1} = \gamma_0 + \gamma_1 C + \gamma_2 \bar{E}^* - \lambda_P P_{t-1} + \mu' \tag{11}$$

$$\Delta E = E_t - E_{t-1} = \delta_0 + \delta_1 D + \delta_2 \bar{P}^* - \lambda_E E_{t-1} + \varepsilon' \tag{12}$$

Boarnet assumes that the labor market variables $\bar{P}$ and $\bar{E}$ follow the same additive lagged adjustment specification as area level population and employment:

$$\bar{P}_t - \bar{P}_{t-1} = \lambda_P (\bar{P}_t^* - \bar{P}_{t-1}) \tag{13}$$

$$\bar{E}_t - \bar{E}_{t-1} = \lambda_E (\bar{E}_t^* - \bar{E}_{t-1}) \tag{14}$$

Expressing (13) and (14) in observables and substituting into (11) and (12) then yields the estimating equations:

$$\Delta P = P_t - P_{t-1} = \gamma_0 + \gamma_1 C + \gamma_2 \bar{E}_{t-1} + \frac{\gamma_2}{\lambda_E} (\bar{E}_t - \bar{E}_{t-1}) - \lambda_P P_{t-1} + \mu' \tag{15}$$

$$\Delta E = E_t - E_{t-1} = \delta_0 + \delta_1 D + \delta_2 \bar{P}_{t-1} + \frac{\delta_2}{\lambda_P} (\bar{P}_t - \bar{P}_{t-1}) - \lambda_E E_{t-1} + \varepsilon' \tag{16}$$

$\bar{P}_t$, $\bar{P}_{t-t}$, $\bar{E}_t$, and $\bar{E}_{t-t}$ are all expressed as potential variables of the following form:

$$\bar{P}_{i,t} = \sum_{j \neq i} \frac{P_{j,t}}{\left(d_{ij}\right)^{\alpha}} + P_{i,t} \tag{17}$$

$$\bar{E}_{i,t} = \sum_{j \neq i} \frac{E_{j,t}}{\left(d_{ij}\right)^{\alpha}} + E_{i,t} \tag{18}$$

where d_{ij} = 1 for municipalities less than one mile apart and d_{ii} = 0. In matrix notation:

$$\bar{\mathbf{P}} = (\mathbf{I} + \mathbf{W})\mathbf{P}, \quad \bar{\mathbf{E}} = (\mathbf{I} + \mathbf{W})\mathbf{E}, \tag{19}$$

where **W** is a matrix with elements $1/(d_{ij})^{\alpha}$. Following CM, Boarnet lagged all local area *i* exogenous variables in order to identify (15) and (16):

$$\Delta\mathbf{P} = \gamma_0 + \gamma_1 \mathbf{C_{t-1}} + \gamma_2 (\mathbf{I} + \mathbf{W})\mathbf{E_{t-1}} + \gamma_3 (\mathbf{I} + \mathbf{W})\Delta\mathbf{E} - \lambda_P \mathbf{P_{t-1}} + \mu' \tag{20}$$

$$\Delta\mathbf{E} = \delta_0 + \delta_1 \mathbf{D_{t-1}} + \delta_2 (\mathbf{I} + \mathbf{W})\mathbf{P_{t-1}} + \delta_3 (\mathbf{I} + \mathbf{W})\Delta\mathbf{P} - \lambda_E \mathbf{E_{t-1}} + \varepsilon' \tag{21}$$

Boarnet's interest was not directly spread-backwash or growth diffusion. However, the model in (20) and (21) can be used to study local growth spillover dynamics via inspection of the parameters γ_3 and δ_3.

A third key contribution—Henry, Barkley and Bao (1997; hereafter HBB)—focuses specifically on spread-backwash dynamics. HBB outline three hypotheses: first, that "urban spillovers to rural areas vary with the growth of population in the proximate metropolitan area" (p. 481); second, that "rural communities that provide quality public services, amenities and lower public-sector costs will capture more spillover from a proximate metropolitan area than less attractive rural places" (p. 482); and third, that "the net effect of the spread-backwash process on rural areas varies according to the beginning period or existing spatial distribution of population and employment within a Functional Economic Area" (p. 482). HBB argue that a Boarnet-type model can be used to test the third hypothesis since the location of an area (e.g., Census tract) would be specified by the **W** matrix (weighted employment or population complex). The second hypothesis could also be studied by examining the coefficients on **C** and **D**. It is the test of how urban areas influence rural growth, a central issue in spread-backwash analysis, that requires some adjustment of the model.

HBB begin by classifying census tracts into one of three types within mutually exclusive functional economic areas (FEAs): *urban core* (Census Urbanized Area in 1990 and surrounding tracts with population density of over 1,000 persons per square mile), *urban fringe* (all tracts outside the core but within 30-mile centroid-to-centroid distance of the center of the core of FEA *i*, and *rural hinterland* (all other tracts in FEA *i*). They then specify equilibrium population and employment within the *rural hinterland* as functions of urban core and fringe growth:

$$P^*_{ikt} = f(\mathbf{C}_i, \bar{E}^*_{it}, gc_k, gf_k) \qquad (22)$$

$$E^*_{ikt} = f(\mathbf{D}_i, \bar{P}^*_{it}, gc_k, gf_k) \qquad (23)$$

Where P^*_{ikt} and P^*_{ikt} are equilibrium population and employment in tract *i*, time period *t*, FEA *k*; $\bar{E}^*_{it}$ and $\bar{P}^*_{it}$ are equilibrium labor market and residential areas; gc_k and gf_k are urban core and fringe population growth rates in FEA *k*; and $\mathbf{C}_i$ and $\mathbf{D}_i$ are vectors of residential and firm-related amenities. Using CM partial adjustment equations for rural fringe tract *i* in FEA *k*, labor market area adjustment equations as in (13) and (14), and linear versions of (22) and (23) gives

$$\Delta P_{ik} = \gamma_0 + \mathbf{C}_i\gamma_1 - \lambda_P P_{ik,t-1} + [\gamma_2 + \gamma_3 gc_k + \gamma_4 gf_k]\bar{E}_{ik,t-1} + [\frac{\gamma_2}{\lambda_E} + gc_k\frac{\gamma_3}{\lambda_E} + gf_k\frac{\gamma_4}{\lambda_E}]\Delta\bar{E}_{ik} + u' \quad (24)$$

$$\Delta E_{ik} = \delta_0 + \mathbf{D}_i\delta_1 - \lambda_E E_{ik,t-1} + [\delta_2 + \delta_3 gc_k + \delta_4 gf]\bar{P}_{ik,t-1} + [\frac{\delta_2}{\lambda_P} + gc_k\frac{\delta_3}{\lambda_P} + gf_k\frac{\delta_4}{\lambda_P}]\Delta\bar{P}_{ik} + v' \quad (25)$$

Then letting

$$\bar{E}_{i,t-1} = \mathbf{(I + W)E}_{t-1} \quad (26)$$

$$\bar{P}_{i,t-1} = \mathbf{(I + W)P}_{t-1} \quad (27)$$

$$\Delta\bar{E}_{i} = \mathbf{(I + W)\Delta E} \quad (28)$$

$$\Delta\bar{P}_{i} = \mathbf{(I + W)\Delta P} \quad (29)$$

and simplifying gives the HBB estimating equations:

$$\Delta\mathbf{P} = \alpha_0 - \alpha_1\mathbf{P}_{t-1} + [\alpha_2 + \alpha_3\mathbf{gc_k} + \alpha_4\mathbf{gf_k}](\mathbf{I}+\mathbf{W})\mathbf{E}_{t-1} + [\alpha_5 + \alpha_6\mathbf{gc_k} + \alpha_7\mathbf{gf_k}](\mathbf{I}+\mathbf{W})\Delta\mathbf{E} + \mathbf{F}_1\mathbf{C} + u' \quad (30)$$

$$\Delta\mathbf{E} = \beta_0 - \beta_1\mathbf{E}_{t-1} + [\beta_2 + \beta_3\mathbf{gc_k} + \beta_4\mathbf{gf_k}](\mathbf{I}+\mathbf{W})\mathbf{P}_{t-1} + [\beta_5 + \beta_6\mathbf{gc_k} + \beta_7\mathbf{gf_k}](\mathbf{I}+\mathbf{W})\Delta\mathbf{P} + \mathbf{F}_2\mathbf{D} + v' \quad (31)$$

The term $\mathbf{(I + W)P}_{t-1}$ is total population of tracts within 30 miles of the hinterland tract (analogously for employment). The term $\mathbf{(I + W)\Delta P}$ is change in population (analogously for employment) of tracts within 30 miles of *i*th rural/hinterland tract. Factor $\mathbf{gc_k}$ ($\mathbf{gf_k}$) is the ratio of *t* population in the core (fringe), FEA *k*, to *t*-1 population in the core (fringe).

To find spread-backwash effects, HBB estimate the parameters in (24) and (25) and then use the mean, the mean plus one standard deviation, and the mean minus one standard deviation of $\mathbf{gc_k}$ and $\mathbf{gf_k}$, to calculate the following:

$$\alpha_2(\mathbf{I}+\mathbf{W})\mathbf{E}_{t-1} + \alpha_3\mathbf{gc_k}(\mathbf{I}+\mathbf{W})\mathbf{E}_{t-1} + \alpha_4\mathbf{gf_k}(\mathbf{I}+\mathbf{W})\mathbf{E}_{t-1} \quad (32)$$

$$\alpha_5(\mathbf{I}+\mathbf{W})\Delta\mathbf{E} + \alpha_6\mathbf{gc_k}(\mathbf{I}+\mathbf{W})\Delta\mathbf{E} + \alpha_7\mathbf{gf_k}(\mathbf{I}+\mathbf{W})\Delta\mathbf{E} \quad (33)$$

$$\beta_2(\mathbf{I}+\mathbf{W})\mathbf{P}_{t-1} + \beta_3\mathbf{gc_k}(\mathbf{I}+\mathbf{W})\mathbf{P}_{t-1} + \beta_4\mathbf{gf_k}(\mathbf{I}+\mathbf{W})\mathbf{P}_{t-1} \quad (34)$$

$$\beta_5(\mathbf{I}+\mathbf{W})\Delta\mathbf{P} + \beta_6\mathbf{gc_k}(\mathbf{I}+\mathbf{W})\Delta\mathbf{P} + \beta_7\mathbf{gf_k}(\mathbf{I}+\mathbf{W})\Delta\mathbf{P} \quad (35)$$

Positive (negative) alpha and beta parameters in equations (32) **–** (35) indicate urban spread (backwash) effects. With urban core and fringe treated separately it is the joint effects that determine the net of effect of urban areas on hinterlands.

The Boarnet and HBB approaches build on the growth framework of CM to provide a useful basis for a general study of growth spillovers. However, both approaches also have key limitations. The Boarnet framework assumes that sub-regions within regional commuter sheds are homogenous in their influence on the population and employment growth of individual municipalities. The plausibility of such an assumption is tenuous, though it may increase with greater disaggregation in the spatial unit of analysis *together with* a reduction in the geographic scale for which commuter sheds are defined. Ceteris paribus, the two factors taken in concert would tend to increase the similarity of sub-areas within a given regional commuter shed.

An assumption of homogeneity of the commuting region around a given county would seem to be less plausible. Consider rural county *i* adjacent to both a rapidly growing urban county *j* as well as a rural county *k*. The likely spillover dynamics, whether spread or backwash, between county *i* and county *j* (rural versus urban) are likely to be substantially different than between *i* and *k* (rural versus rural). Defining a commuting region around *i* that simply aggregates *j* and *k* ignores those differences. Therefore, for a county-level analysis it would seem to make sense to disaggregate the Boarnet model in a manner that captures heterogeneity in neighboring counties.

The HBB approach avoids the shed homogeneity problem by estimating a model for hinterland tracts alone, with core and fringe population growth indicators interacted against population and employment variables defined for homogenous commuting sheds around those hinterland tracts. The HBB model investigates whether a given hinterland tract's growth is influenced by the level and growth of activity in its surrounding region (the hinterland's hinterland, as it were). The spillover effect is allowed to vary with the population growth of urban core and urban fringe within the functional economic area within which the given hinterland tract is located. Put differently, with the HBB approach we can learn whether the influence a location's surrounding region has on that location's growth trajectory depends on urban core and urban fringe growth trends *within* the location's FEA. One notion is that a hinterland tract within an FEA with a rapidly growing core may enjoy greater spread (or suffer greater backwash) effects from surrounding tract growth than a tract within an FEA with a slowly growing (or declining) urban core.

The HBB approach cannot, however, reveal the *direct effect* of urban versus fringe growth on hinterland growth. More problematic may be that each hinterland tract must be assigned to a single FEA. It is the nature of hinterland areas that their linkages with any other single region are weak, or, conversely, that they enjoy very modest linkages with many different neighboring regions. The identification of the single urban core to which a hinterland location is linked is therefore likely to be largely arbitrary, even if journey-to-work flows are the basis of the assignment. After all, hinterland regions are essentially "hinterland" because their commuting flows are modest with other regions. That implies that urban growth influences may originate from many directions and not any single pre-defined core. Again, the approach may be more defensible for highly disaggregate areal units and smaller regional scales, as indeed implemented by HBB. It is probably not appropriate when counties are used as the unit of analysis.

Our own strategy is motivated by two specific aims. First, we are keenly interested in understanding how regional growth diffusion differs among regions of varying levels of development. As a point of departure we expect that the nature of the bi-directional spillovers between highly- and moderately-developed regions will be different than those between highly- and less-developed regions. Perhaps more important is potential difference between the influence of highly urban places on rural regions on the one hand, and the influence of moderately urban (or mixed or suburban) places on rural regions on the other. Second, we want to return to a complete analysis of the coterminous U.S., as in Carlino and Mills (1987). The national scale extends the external validity of the analysis and permits a wide variety of sub-regional investigations. In addition, to our knowledge the CM framework modified to address spillover dynamics has not yet been applied at the national scale. There is value to utilizing the latest thinking on spread-backwash and simultaneous spatial modeling to revisit national small area growth dynamics. Clearly, working at the national scale means that counties are the most plausible units of analysis, with all that implies for the appropriateness of a given model.

4 A Generalized Small Area Growth Model

Following Boarnet, we postulate a model that decomposes own-area and neighboring area effects:

$$P^* = f(C_i, E^*, \bar{E}^*) \tag{36}$$

$$E^* = g(D_i, P^*, \bar{P}^*) \tag{37}$$

Here E^* and P^* represent equilibrium employment in county *i* and $\bar{P}^*$ and $\bar{E}^*$ equilibrium population and employment within specified distances *d* of county *i*, not including county *i* itself. Thus, a county's equilibrium population is determined by its own equilibrium level of employment as distinct from equilibrium employment in neighboring locations. Note that Boarnet's definitions of his shed variables (17) and (18) effectively combine own and neighboring area effects in a single parameter in a given estimating equation.

Assuming linear relationships in (36) and (37) and lagged adjustment to equilibrium:

$$\Delta P = P_t - P_{t-1} = \lambda_P (P_t^* - P_{t-1}) \tag{38}$$

$$\Delta E = E_t - E_{t-1} = \lambda_E (E_t^* - E_{t-1}) \tag{39}$$

$$\Delta \overline{P} = \overline{P}_t - \overline{P}_{t-1} = \lambda_p (\overline{P}_t^* - \overline{P}_{t-1}) \tag{40}$$

$$\Delta E = \overline{E}_t - \overline{E}_{t-1} = \lambda_E (\overline{E}_t^* - \overline{E}_{t-1}) \tag{41}$$

Then, substituting and simplifying yields:

$$\begin{aligned} \Delta P = P_t - P_{t-1} = \lambda_P \alpha_0 + \lambda_P \alpha_1 C_{t-1} + \lambda_P \alpha_2 \left(E_{t-1} + \frac{1}{\lambda_E}(E_t - E_{t-1}) \right) \\ + \lambda_P \alpha_3 \left(\overline{E}_{t-1} + \frac{1}{\lambda_E}(\overline{E}_t - \overline{E}_{t-1}) \right) - \lambda_P P_{t-1} + \lambda_P \mu \end{aligned} \tag{42}$$

$$\begin{aligned} \Delta E = E_t - E_{t-1} = \lambda_E \beta_0 + \lambda_E \beta_1 D_{t-1} + \lambda_E \beta_2 \left(P_{t-1} + \frac{1}{\lambda_P}(P_t - P_{t-1}) \right) \\ + \lambda_E \beta_3 \left(\overline{P}_{t-1} + \frac{1}{\lambda_P}(\overline{P}_t - \overline{P}_{t-1}) \right) - \lambda_E E_{t-1} + \lambda_E \varepsilon \end{aligned} \tag{43}$$

The model in equations (42) and (43) differs from Boarnet's in the separate specification of parameters for own and neighboring growth. Here we make a further departure, which is to decompose neighboring spillover effects into three categories, i.e., that associated with urban growth (*U*), mixed urban/rural growth (*M*), and rural growth (*R*).

$$P^* = f(C_i, E^*, \overline{UE}^*, \overline{ME}^*, \overline{RE}^*) \tag{44}$$

$$E^* = g(D_i, P^*, \overline{UP}^*, \overline{MP}^*, \overline{RP}^*) \tag{45}$$

Including rural and urban dummy variables (*V*) along with their interactions on regional population and employment change permits us to decompose spillover effects by county type (treating mixed counties as the base case):

$$
\begin{array}{c}
V_U,\ V_R \\
\Delta\overline{UE}*V_U,\quad \Delta\overline{ME}*V_U,\quad \Delta\overline{RE}*V_U \\
\Delta\overline{UE}*V_R,\quad \Delta\overline{ME}*V_R,\quad \Delta\overline{RE}*V_R \\
\Delta\overline{UP}*V_U,\quad \Delta\overline{MP}*V_U,\quad \Delta\overline{RP}*V_U \\
\Delta\overline{UP}*V_R,\quad \Delta\overline{MP}*V_R,\quad \Delta\overline{RP}*V_R
\end{array}
\tag{46}
$$

One possible set of estimating equations is then:

$$
\begin{aligned}
\Delta P = {} & \gamma_0 + \gamma_1 C_{t\text{-}1} + \gamma_2 E_{t\text{-}1} + \gamma_3 \Delta E + \\
& \gamma_4 \overline{UE}_{t\text{-}1} + \gamma_5 \overline{ME}_{t\text{-}1} + \gamma_6 \overline{RE}_{t\text{-}1} + \gamma_7 \Delta\overline{UE} + \gamma_8 \Delta\overline{ME} + \gamma_9 \Delta\overline{RE} + \\
& \phi_1 V_U + \phi_2 \Delta\overline{UE}*V_U + \phi_3 \Delta\overline{ME}*V_U + \phi_4 \Delta\overline{RE}*V_U + \\
& \phi_5 V_R + \phi_6 \Delta\overline{UE}*V_R + \phi_7 \Delta\overline{ME}*V_R + \phi_8 \Delta\overline{RE}*V_R - \\
& \lambda_P P_{t\text{-}1} + u'
\end{aligned}
\tag{47}
$$

$$
\begin{aligned}
\Delta E = {} & \delta_0 + \delta_1 D_{t\text{-}1} + \delta_2 P_{t\text{-}1} + \delta_3 \Delta P + \\
& \delta_4 \overline{UP}_{t\text{-}1} + \delta_5 \overline{MP}_{t\text{-}1} + \delta_6 \overline{RP}_{t\text{-}1} + \delta_7 \Delta\overline{UP} + \delta_8 \Delta\overline{MP} + \delta_9 \Delta\overline{RP} + \\
& \xi_1 V_U + \xi_2 \Delta\overline{UP}*V_U + \xi_3 \Delta\overline{MP}*V_U + \xi_4 \Delta\overline{RP}*V_U + \\
& \xi_5 V_R + \xi_6 \Delta\overline{UP}*V_R + \xi_7 \Delta\overline{MP}*V_R + \xi_8 \Delta\overline{RP}*V_R - \\
& \lambda_E E_{t\text{-}1} + v'
\end{aligned}
\tag{48}
$$

The framework in (47) and (48) permits a direct test of the influence of population growth in *neighboring* urban, mixed, and rural counties on *county-level* employment growth (decomposed by county type as urban, mixed and rural).

In the present context, however, we would prefer to investigate the influence of neighborhood employment growth on county *i* employment growth (rather than county *i* population growth). Thus, we modify the model to express equilibrium population as a function of own county equilibrium employment and neighboring county population:

$$P^* = f(C_i, E^*, \overline{UP}^*, \overline{MP}^*, \overline{RP}^*) \tag{49}$$

$$E^* = g(D_i, P^*, \overline{UE}^*, \overline{ME}^*, \overline{RE}^*) \tag{50}$$

Using the same basic assumptions, (49) and (50) yield the following estimating equations:

$$\begin{aligned}\Delta P = {} & \gamma_0 + \gamma_1 C_{t\text{-}1} + \gamma_2 E_{t\text{-}1} + \gamma_3 \Delta E + \\ & \gamma_4 \overline{UP}_{t\text{-}1} + \gamma_5 \overline{MP}_{t\text{-}1} + \gamma_6 \overline{RP}_{t\text{-}1} + \gamma_7 \Delta \overline{UP} + \gamma_8 \Delta \overline{MP} + \gamma_9 \Delta \overline{RP} + \\ & \phi_1 V_U + \phi_2 \Delta \overline{PU} * V_U + \phi_3 \Delta \overline{PM} * V_U + \phi_4 \Delta \overline{PR} * V_U + \\ & \phi_5 V_R + \phi_6 \Delta \overline{PU} * V_R + \phi_7 \Delta \overline{PU} * V_R + \phi_8 \Delta \overline{PU} * V_R - \\ & \lambda_P P_{t\text{-}1} + u' \end{aligned} \qquad (51)$$

$$\begin{aligned}\Delta E = {} & \delta_0 + \delta_1 D_{t\text{-}1} + \delta_2 P_{t\text{-}1} + \delta_3 \Delta P + \\ & \delta_4 \overline{UE}_{t\text{-}1} + \delta_5 \overline{ME}_{t\text{-}1} + \delta_6 \overline{RE}_{t\text{-}1} + \delta_7 \Delta \overline{UE} + \delta_8 \Delta \overline{ME} + \delta_9 \Delta \overline{RE} + \\ & \xi_1 D_u + \xi_2 \Delta \overline{UE} * V_U + \xi_3 \Delta \overline{ME} * V_U + \xi_4 \Delta \overline{RE} * V_U + \\ & \xi_5 D_r + \xi_6 \Delta \overline{UE} * V_R + \xi_7 \Delta \overline{ME} * V_R + \xi_8 \Delta \overline{RE} * V_R - \\ & \lambda_E E_{t\text{-}1} + v' \end{aligned} \qquad (52)$$

Using the model in equations (51) and (52), we can directly evaluate the influence of urban, mixed and rural spillover employment growth on own-county employment growth, the issue at the heart of spread-backwash. Still a third model might admit full generality in the linkage between spillovers and own-area performance:

$$P^* = f(C_i, E^*, \overline{UP}^*, \overline{MP}^*, \overline{RP}^*, \overline{UE}^*, \overline{ME}^*, \overline{RE}^*) \qquad (53)$$

$$E^* = g(D_i, P^*, \overline{UE}^*, \overline{ME}^*, \overline{RE}^*, \overline{UP}^*, \overline{MP}^*, \overline{RP}^*) \qquad (54)$$

The model in equations (53) and (54) would include all lagged spillover variables—both levels and changes in employment and population—on the right-hand side of both estimating equations. While theoretically attractive, the model is econometrically infeasible due to the very high correlations between the population and employment spillover variables, the major indicators of interest.

Table 1 summarizes the treatment of growth spillovers in the employment equation in each of the three possible models. We focus on employment because it is an indicator of regional prosperity that is especially important to rural development policy makers. In the first model (equations 44-45), county *i* employment growth is influenced by county *i* population growth—as part of the simultaneous treatment of population and employment at the county level—and hypothesized spillovers are driven by *surrounding region population growth*. The second model (equations 49-50) investigates the influence of *surrounding region employment growth* on county *i* employment growth. The third model (equations 53-54) admits that both population and employment growth in county *i*'s surrounding region may influence that county *i*'s employment growth trajectory. Note that regional spillovers are handled in a mirrored fashion in the population growth equation in each of the three models. Thus, from the estimation of the two equation system we can generate a highly detailed set of regional spillover parameters for both population and employment growth at the county level. In this paper, we estimate the second model and focus on the results for the employment growth equation.

5 Operations: Definitions, Variables and Estimation

Estimating equations (51) and (52) constitute a spatial cross-regressive model (Rey and Boarnet 2004). The urban, mixed and rural change variables on the right-hand side are essentially spatial lags of the endogenous variables in the opposite equations (a type of spatial simultaneity). The equations are also obviously simultaneous in population and employment change (what Rey and Boarnet call feedback simultaneity), consistent with the Carlino-Mills framework. Proper estimation of the model requires instrumentation of both the basic and additional endogenous variables (i.e., the cross-regressive terms). We also require a definition of urban, mixed, and rural counties; a specification of the "neighborhood" or shed around county *i* (effectively the geographic extent over which spillovers are expected to occur); and a set of exogenous county *i* determinants of population and employment change (**C** and **D**). The following sections detail how we address these.

County Typology. The purpose of our decomposition of counties into urban, mixed and rural categories is, first, to acknowledge the substantial degree of variation in the "urban-ness" of the counties that make up U.S. metropolitan areas; second, to investigate spillovers exerted by regions of widely varying levels of development; and, third, to avoid the common but fundamentally flawed practice of equating rural counties with non-metropolitan counties. We seek to distinguish among sparsely populated counties that are clearly predominantly rural, densely settled urban counties, and counties that are partially urban but with substantial territory available for additional urban development. The latter counties often surround highly dense and urbanized counties and might be suburban in nature, but also often they are free-standing counties with an urban core surrounded by considerable rural area. Because they have "room to grow," they may have a different influence on neighboring rural counties than would mostly urbanized counties. Official metropolitan/non-metropolitan definitions are poor proxies for level of development because many metropolitan areas contain sparsely populated, predominantly rural counties. Indeed, more than half the U.S. rural population as defined by the Census Bureau is found within metropolitan areas (Isserman, 2005).

We define rural counties as those that have 1) an urban population of 10 percent or less *or* with 10,000 or fewer in total urban population; *and* 2) a population density of fewer than 500 per square mile. Urban counties as those with 1) a population that is at least 90 percent urban; 2) a minimum of 50,000 in urban population; *and* 3) a population density of at least 500 people per square mile. By our definition, highly urbanized Mecklenburg County in North Carolina (the principle location of the City of Charlotte) is urban while Maricopa County in Arizona—home to Phoenix but also substantial rural territory—is not. Maricopa is a mixed urban/rural county, a category that accurately its urban and rural combination, low density, and, thus, potential for continued urban expansion within the county itself. Mixed counties are defined simply as counties that are neither urban nor rural. As the Phoenix example makes clear, mixed counties should not be viewed only as suburban counties, although many are located on the immediate fringe of urban counties. An extensive rationale for the basic approach to the county designation we use, including the selection of threshold values, is provided in Isserman (2005).

We identify a total of 3,079 "county" units in the coterminous U.S. after making two decisions. First, following the practice of the Bureau of Economic Analysis (BEA), we combine Virginia's independent cities that are wholly contained within a particular county and that county before classifying the combined entity as a single county. Doing so makes such cities more directly comparable to other U.S. municipalities whose values are incorporated in the data of their home county and, most importantly, makes possible the use of BEA's Regional Economic Information System. It provides annual county population and employment with more comprehensive employment coverage by place of work than any other source. Second, we hold county units and boundaries constant at their definitions applicable between 1990 and 2000, our study period. Doing so means ignoring the 2003 creation of Broomfield County in Colorado. The county types are mapped in Figure 2, and summary statistics for each type of county are in Table 2.

Spillover Attenuation. We define the neighboring region of county *i* as all counties whose centroids are within pre-specified distances. This strategy has several advantages over using adjacency to define neighborhoods. In portions of the U.S., several rings of counties are within the defined distances, not just the adjacent ring. In other parts of the country, the counties are so large that adjacent counties may fall within the specified distances, meaning that they would not be identified as neighbors. Using distances allows us to account, if imperfectly, for different county sizes in definition of the scale over which spillovers are likely to occur. Note that, ideally, we would have preferred the use of a population-weighted centroid over a geographical centroid to capture counties potential interaction, but the Census Bureau no longer calculates population centroids.

We simply sum the values of population and employment for counties within the distance bands:

$$\begin{aligned}\bar{\mathbf{p}}_{\mathbf{t,r}} &= \mathbf{W}\mathbf{p}_{\mathbf{t,r}} \\ \bar{\mathbf{e}}_{\mathbf{t,r}} &= \mathbf{W}\mathbf{e}_{\mathbf{t,r}} \\ \Delta\bar{\mathbf{p}}_{\mathbf{r}} &= \bar{\mathbf{p}}_{\mathbf{t,r}} - \bar{\mathbf{p}}_{\mathbf{t-1,r}} \\ \Delta\bar{\mathbf{e}}_{\mathbf{r}} &= \bar{\mathbf{e}}_{\mathbf{t,r}} - \bar{\mathbf{e}}_{\mathbf{t-1,r}}\end{aligned} \tag{55}$$

where **W** is a matrix with elements w_{ij} =1 if distance m_{ij} between the geographic centroids of *i* and *j* is less than or equal to some threshold α and zero otherwise (also, $m_{ii} = 0$). The subscript *r* indexes the county type (urban, mixed, and rural). We specify the threshold *d* at a distance of 45 miles as a reasonable approximation of maximum commuting distance. However, we also evaluate the robustness of the spatial results in two basic ways. The first is by calculating and comparing findings for four additional maximum distance thresholds: 30, 60, 75, and 90 miles. The second is by computing neighborhood effects for three distance "bands" around county *i*, where d_1 = 0-30, d_2 = 30-60, and d_3 = 60-90. Figure 3 illustrates the distance bands definitions for a single rural county in Georgia (Greene).

County Specific Location Factors. Our sets of exogenous location factors (**C** and **D**) are derived from the theories of residential and industrial location as well as a careful review of the findings of similar simultaneous small area growth models (primarily CM, HBB, and Boarnet, but also Leichenko, 2001 and Clark and Murphy, 1996). We measure our dependent variables in the population and employment equations as the change in working age population (population aged 18-65) and private nonfarm employment, respectively. This narrows the scope of the model to private sector economic activity and obviates the need to identify local factors driving migration of retirees or the location of government and non-profit facilities. Table 2 organizes the large and rather diffuse body of location theory into several major categories of factors potentially influencing residential and private sector industrial location decisions.

The current empirical simultaneous growth literature can at best be described as inconclusive with regard to the relative importance of the different dimensions in Table 2. Many exogenous location factors have proven to be extremely weak, unstable, or altogether statistically insignificant in studies similar to this one. If one excludes regional dummies, Carlino and Mills' (1987) models include only two significant location factors in each of the population and employment equations (see Appendix Table 1). Boarnet's model is somewhat more successful (see Appendix Table 2), with measures of accessibility, race, ethnicity, poverty, crime and housing stock age proving significant in the population change equation and accessibility, transit availability, crime, manufacturing potential, and retail potential proving statistically significant in the employment change equation. Nothing aside from local spillovers is statistically significant in HBB's employment equation (see Appendix Table 3). HBB have more luck with their population equation, where variables measuring infrastructure, poverty, housing stock age, and school quality all prove to be significant determinants.

We assembled a parsimonious set of exogenous factors that reflect the most significant influences on county-level growth as evidenced in the empirical literature. Unless otherwise indicated, all variables are measured at the county level and beginning-of-period. In the population equation we include a measure of environmental amenities (AVGSUN; mean hours of January sunlight over the period 1941-70), housing cost (MHV90; median house value in 1990), housing stock age (HSGSTK90; percent of housing units in 1990 built before 1939), school quality (STRATIO; ratio of students to teachers in 1989/90), health care accessibility (HMSA89; 1 if all or part of the county was designated as a health maintenance shortage area in 1989), neighborhood characteristics (POVERT90; 1990 poverty rate), highway accessibility (IHWY; 1 if there are at least nine miles of interstate highway in the county), and personal crime (VCRIME90; violent crimes per 100,000 population, 1990). Local growth factors in the employment equation include IHWY, property crime (PCRIME90), labor cost in the labor market area centered on county *i* (WAGE90), industrial diversity (DIVERS90), unionization (UMEM90; percent private sector workers unionized in state *j*, 1990), labor force quality (HISCH90; percent population aged 25 or over with at least a high school degree), airport access (LRGHUB; distance in miles to a large airport hub), innovation activity (PATENT; average utility patents over the 1990-95 period in region around county *i*), and university research activity (URD50; total research expenditures in hard sciences in universities in region of county *i*, 1992).[4] Table 4 provides the full list of spillover and growth factor variables, specific definitions and data sources. Median values of each non-dichotomous local growth factor variable are reported in Table 5.

Estimation. As noted above, our model includes traditional feedback simultaneity and spatial simultaneity, the latter via the inclusion spatial cross-regressive terms in the form of the neighboring county growth variables. Pre-determined and exogenous variables include our neighboring county levels variables, county *i* levels variables, and location factors **C** and **D**. Conventional two-stage least squares estimation to handle the traditional simultaneity would be inappropriate in this context given the spatial cross-regressive terms. Therefore, we follow the spatial Generalized Methods of Moments approach outlined by Kelejian and Robinson (1993) and evaluated by Rey and Boarnet (2004) in a Monte Carlo analysis of alternative approaches to modeling spatial simultaneity. Procedurally, the GMM strategy calls for the first stage estimation of each basic endogenous variable (population and employment change) and additional endogenous variable (the cross-regressive terms) on *both* the full set of predetermined variables and spatial lags of the predetermined variables. Predicted values for the basic and additional endogenous variables from the first stage are then entered as the appropriate right hand side variables in a second stage ordinary least squares regression to obtain the final results. Rey and Boarnet (2004) found that this strategy yielded maximum consistency over both traditional and spatial two stage least squares.[5]

Heteroskedasticity is common in county-level growth models that employ absolute change in population, employment or other aggregate indicators as the dependent variable, particularly when the entire U.S. is the subject of study. This is because the size of counties varies significantly across the country, from very large urban counties to extremely small rural counties. Both visual plots and formal tests (a modified Levene test) confirmed heteroskedastic errors in an initial estimation of the model. A simple variable transformation (e.g., to logs) is precluded in this instance given that many of our independent variables take zero values. After our initial attempts to model the form of the heteroskedasticity proved unsuccessful, we chose to utilize White's (1980) result and calculate heteroskedasticity-robust standard errors for the second stage estimates. We estimated the model using the SYSLIN procedure in SAS software. We programmed the calculation of White's variance-covariance matrix and the decomposition of the spillovers by county type (the dummy-growth interaction effects and joint standard errors) in SAS's interactive matrix language (IML) module.

6 Results

Table 6 reports the second stage regression results for both the population and employment equations where the regional spillover variables are calculated for a distance of 45 miles (d = 45). Before discussing the spillover results, we briefly summarize the parameters on the local growth factor variables, beginning with the population change equation. Although the parameters on most variables take an expected sign, not all are statistically significant. The parameters on mean hours of January sunlight (AVGSUN) and the student-teacher ratio (STRATIO) are both positive and significant. The sign on the STRATIO reflects the difficulty of capturing school quality—or service delivery—even when a time lag is introduced. The pairwise correlation of 1990-2000 population change with STRATIO is strongly positive; the counties that grew robustly over the 1990s were also those with larger primary and secondary school class sizes at the beginning of the period. The parameters on housing cost (MHV90), housing stock age (HSGSTK90) and poverty (POVERT90) are all negative as expected but they are only barely significant at conventional levels (at between 10 and 11 percent). The parameters on the health care shortage and violent crime indicators (HMSA89 and VCRIME90) are negative and highly insignificant. The negative and significant parameter on the interstate highway variable is hard to explain if IHWY is regarded as a measure of accessibility. However, the negative coefficient has to be understood as an average parameter over a wide range of regions.[6] The nature of the interstate highway system is that it stretches across much sparsely populated territory in the U.S. as it connects urban centers, through many counties that are growing slowly or not at all. In this context, with all coterminous U.S. counties as the units of analysis, it is not surprising that the *average* relationship between highways and population growth is a negative one.

In the employment change equation, significant (or marginally significant) local explanatory factors include innovation activity in the region around the county (PATENT, positive), the level of educational attainment in the county (HISCH90, positive), the union membership rate in state *i* (UMEM90, positive), and average wages (WAGE90, positive). Other variables such as highways, distance to a large hub airport, the level of industrial diversity, and property crime take expected signs but are insignificant. The parameter on university research expenditures in the region around county *i* takes an unexpected negative sign but is highly insignificant.

The unionization variable is perhaps the most significant anomaly; most existing studies find employment growth negatively related to unionization rates (Kusmin, 1994). We see two possible explanations. The first is that most existing studies are for significantly earlier periods (e.g., before 1990) in which unions were much larger and more influential in selected states. They also covered a period (the 1970s and 1980s) of significant manufacturing decline in the nation's industrial heartland. Unionization may not be the negative influence on business activity that it was through the 1970s and 1980s. The second explanation relates to the first in that our variable, measured at the state level, may be picking up more general differences in state characteristics unrelated to unionization. Metropolitan areas in a number of states with relatively high rates of private sector unionization generated strong job gains over the 1990s. Some fast growing, technology-oriented states like Massachusetts and California have relatively high levels of unionization.

We now turn to the net growth spillover effects. The level, direction and statistical significance of the spillovers are difficult to discern from investigation of individual parameters in Table 6, given our use of urban and rural dummy variables and interaction terms. The results have to be interpreted with reference to mixed urban counties as the base case. Table 7 simplifies the interpretation by reporting the spillover parameters for mixed, rural and urban counties calculated from the estimated own and interaction effects (along with their joint standard errors). Specifically, the cells in Table 7 report the parameters measuring the influence of *neighboring region* urban/mixed/rural employment growth (down the rows) on urban/mixed/rural *county i* employment growth (across the columns). The result is a detailed and rich picture of spillovers among counties of differing levels of urbanization. There are a total of nine possible effects, as diagrammed in the top panel of Figure 4. The lower panel of Figure 4 illustrates the statistically significant estimated effects along with the direction of the relationship (negative or positive).

The uppermost-left parameter (-0.193) in Table 7 indicates that the employment growth of urban counties within 45 miles exerts a negative influence on urban county *i* employment growth over the 1990 to 2000 period. This result may be interpreted as a "competitive" relationship between proximate urban counties. Although the growth of urban counties also exerts a negative influence on mixed counties (at -0.051), the influence of urban growth on rural county growth is positive (at 0.071). The latter implies that rural counties proximate to robustly growing urban counties fared well over the 1990s, at least in terms of their own employment performance, evidence of a classic urban "spread" effect.

If there is a general pattern to the spillovers, it is that employment growth in *more* urbanized counties can be a liability for growth in *less* urbanized counties, but *level* of urbanization is a key intervening factor. We also find that the employment growth of *less* urbanized counties generally contributes positively to growth in *more* urbanized counties: we detect net positive spillover effects from mixed *to* urban counties, from rural *to* mixed counties, and from rural *to* urban counties, although the last relationship is not statistically significant. These results are not wholly unexpected given the way we segmented different types of counties. Recall that urban counties are highly urbanized and dense; they have little room to expand in a physical sense. By contrast, mixed counties have both urban and rural characteristics and thus much undeveloped territory.

Mixed counties are generally situated around highly urbanized counties, though in some cases they may constitute entire metropolitan areas (e.g., in the case of Phoenix).

As we noted in the introduction, the observed spillover effects are broadly consistent with the six classic spatial development scenarios. In the case of the growing metropolitan area with expanding employment in a dynamic urban core and growing residential development in the suburbs, the urban core is capturing much of the region's employment growth while neighboring mixed counties are serving as bedroom communities and therefore do not receive employment spillovers. Mixed counties do enjoy some employment gains from the residential development as local consumer and recreational services sectors expand, but the suburban mixed counties' employment trajectories fare poorly *in a relative sense*—that is, in comparison to other mixed counties with diverse and expanding industrial bases. The employment bases of rural counties, on the other hand, tend to benefit from nearby urban county growth in relative terms—again, in comparison to other rural counties. The relative employment gains from services sector expansion tied to residential growth is much more significant for small, rural counties than for mixed urban/rural counties. Rural counties may also enjoy employment gains from the expansion of demand for traditional rural industries (e.g., agricultural and other natural resource goods) or the location of branch plant manufacturing on greenfield sites.

We also see the case of the declining urban core in our results, where urban county employment growth is associated with positive employment gains for mixed counties—a scenario particularly common to deindustrializing urban centers in the Midwest and Northeast—and negative employment gains for rural counties. In this case, employment gains are captured in the suburbs, both at the expense of the urban core and nearby rural counties. The negative spillover between urbanized counties is consistent with the scenario of a large multi-centered region, where the employment dynamic between such centers is a competitive one, while the spillovers from mixed to rural places (negative) and from rural to mixed places follow the sprawling city pattern of the Southwest and the central place experience of much of the Midwest. In the empirical question of whether rural employment growth is a boon or bust for neighboring rural counties, our results imply the latter, with significant implications for rural policy.

Targeting the growth of one rural community may very well help retard the growth of a neighboring rural place, a finding that puts a further nail in the coffin of old notions that rural places can serve as growth poles for other rural places.

It is possible the results in Table 7 depend heavily on our distance assumption of 45 miles. Table 8 reports spillover parameters after re-estimating the model an additional six times, using centroid-to-centroid distance assumptions on spillover variables of 30, 60, 75, and 90 miles and distance band assumptions of 30-60 and 60-90 miles. There are two key results in Table 8. First, spillover effects tend to decline with distance, although not always continuously. For example, we find the strongest urban-to-urban spillovers when we specify neighboring regions at a distance of 60 miles from county *i*. The decay with respect to spillovers to rural counties is illustrated clearly in Figure 5. The strongest influence on rural counties of neighboring county growth is at distances of 45 miles or less. Second, with one exception, the direction of the spillovers to rural counties is consistent regardless of the distance assumption we use. The exception is when we define county *i*'s neighboring region as 60 miles from its centroid; at this distance assumption, urban county employment growth exerts a negative influence on rural county employment growth. In fact, that is the only urban-to-rural "backwash" effect we detect.

7 Summary, Policy Implications and Further Research

In this paper we use a small area spatial growth model that accounts for population and employment simultaneity to study spillovers between counties of varying levels of development. With respect to rural counties, we find evidence of net positive employment growth spillovers from proximate urban counties ("spread effects") but net negative spillovers from growth in nearby mixed urban/rural counties ("backwash effects"). We also find that employment growth in rural counties themselves may exert a net backwash effect on other rural counties nearby. It is important to realize that the effects are reversed in an employment decline context. Decline in an urban county is associated with decline in proximate rural counties while decline in mixed urban/rural counties is associated with growth in proximate rural counties.

As to the question of whether urban spillovers influence rural prosperity—at least when prosperity is measured by job growth—the answer is a conditional "yes." The conditionality depends on how we define “urban”—and, by extension—“rural.” In this study, we have been careful to distinguish overwhelmingly rural places—those that are sparsely populated and largely non-urbanized—from counties that are a significant mixture of urbanized and rural. Over the 1990-2000 period, rural counties proximate to growing, *highly* urbanized counties fared better than rural counties proximate to growing but as yet *less* urbanized counties. In general, we do not find evidence of universal spread or backwash effects. Rather, net spread-backwash effects vary by type of county. They also vary by geographical scale, although more in terms of magnitude than direction.

An important lesson for the formation of rural development policy is that growth spillover opportunities and liabilities facing a given rural county differ depending on the characteristics of the larger territorial complex within which the county is located. Note that by “territorial complex” we do not mean metropolitan area. Most rural counties are not a significant component of any one metropolitan area; many exist on the periphery of one or more metropolitan regions. Rural development strategies designed to leverage urban growth and mitigate backwash are likely to be more effective if they are tailored according to the broader regional spatial structure surrounding targeted rural communities. For example, effective rural development strategies for counties on the periphery of the comparatively dense metropolitan centers of the northeastern U.S. will necessarily differ from strategies that work well in the much less dense Southwest where urbanized areas are primarily comprised of mixed counties with considerable room to grow.

Progress along two specific research fronts is needed if we are to fully understand the influence that urban growth has on rural development trajectories, such that we might actually formulate tangible and administratively feasible strategies aimed at mitigating, capturing or leveraging urban-to-rural spillovers. The first concerns the causes of positive and negative spillovers. While there is an extensive theoretical literature that speculates what those causes might be, systematic empirical studies are surprisingly few. Instead, most rural development research has focused on relating local conditions or characteristics to net growth outcomes. What is needed is research that studies the linkage between inter-county flows (people, commodities, finance, etc.) and spread-backwash effects directly. This will likely require not just application of more sophisticated spatial econometric models, but also deft use of qualitative research techniques that can tease out detailed contextual factors that explain why certain linkages produce negative outcomes while others yield positive outcomes.

Also requiring much more attention is the study of spillovers over longer time horizons, namely 50 to 100 years. In this study we estimate net employment growth spillovers over an extremely short time horizon from an economic development standpoint: a mere ten years. There are many good reasons to suspect that long run spillover dynamics are different than short run dynamics. It is possible, for example, that some of the negative spillover effects we are observing are temporary; perhaps the net result turns positive after some period of time. Alternatively, the factors driving our observed positive spillovers may be temporary or may represent an unsound foundation for long run economic development in rural places. While rural research is benefiting from advances in spatial econometrics that are permitting more robust consideration of geography, and especially concepts such as interregional spillover attenuation over distance, we must also investigate variation in the causes of rural development outcomes over time horizons that better reflect long run development trajectories.

Notes

1. These references reflect the most frequently cited papers covered in Kusmin's (1994) review of 35 empirical studies of local and regional growth. Kusmin reviewed major studies completed up to 1991.
2. The most detailed discussion of equilibrium in an industrial location context remains Chalmers and Beckhelm (1976).
3. See also Henry et al. (1999); Henry, Schmitt and Piguet (2001), and Bao, Henry and Barkley (2004).

4. The wage and industrial diversity measures are calculated for labor market areas centered on county *i*. We used 1990 county-to-county journey-to-work flows to identify each county's unique LMA. Specifically, LMA_i is defined as all counties *j* (that supply through commutation—or own county supply where $i = j$—at least five percent of *i*'s total workforce.
5. Rey and Boarnet (2004) investigated an additional issue, namely the specific form of the first stage spatial lags. Perhaps the most common approach is to include in the second stage regression the spatial lags of the predicted value of the dependent variable from the first stage ($W\hat{y}$). The alternative is to substitute the predicted value of the spatial lag $\widehat{Wy}$. In other words, in the first case, the *endogenous variable* is regressed against the pre-determined variables and their spatial lags. In the second case, the *spatial lag of the endogenous variable* is regressed. The Rey and Boarnet simulations demonstrate the latter strategy is preferred and we therefore follow their recommendation. In specifying the first stage spatial lags themselves we have used a first order contiguity matrix (queen) extracted from GeoDa software. Note that since some of our exogenous variables are spatially lagged by design, albeit in a different form, the first stage estimation includes spatial lags on spatial lags for those predictors.
6. A more conventional highway density variable (miles of Interstate roadway per square mile) also yielded a negative and significant coefficient.

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Table 1. Alternative model treatment of spillovers

Model	Dependent variable	Population growth, region in proximity *d* to county *i*			Employment growth, region in proximity *d* to county *i*		
		Urban	Mixed	Rural	Urban	Mixed	Rural
Model 1	Population growth, county *i*				x	x	x
	Employment growth, county *i*	x	x	x			
Model 2	Population growth, county i	x	x	x			
	Employment growth, county i				x	x	x
Model 3	Population growth, county i	x	x	x	x	x	x
	Employment growth county i	x	x	x	x	x	x

Table 2

Basic characteristics: Urban, mixed and rural counties

Type		All	Urban	Mixed	Rural
Total		3,079	115	1,185	1,779
Working age	Median	15,128	431,351	42,898	7,789
population	Std Dev	184,266	686,899	105,905	7,315
Private sector	Median	9,380	392,874	29,057	4,224
employment	Std Dev	165,591	612,870	92,070	4,860
Pct population	Median	14.4	14.0	16.5	12.9
change, '90-'00	Std Dev	26.8	15.4	26.4	27.4
Pct employment	Median	21.1	18.8	22.6	20.1
change, '90-'00	Std Dev	34.7	15.7	22.6	41.4

Table 3

Summary of residential/industrial location factors

Environmental amenities (primarily residential location)	• Weather • Landscape/topography
Cultural amenities (residential location/population)	• High culture (arts) • Popular culture • Local personal services (retail, restaurants) • Safety (absence of crime)
Employment opportunity (residential location/population)	• Job availability, in location *i* • Wage relative to cost of living, in location *i* • Job accessibility, connectivity of *i* to other employment centers, LMA
Housing (residential location/population)	• Quality (including age of stock), location *i* • Cost, location *i*
Neighborhood choice (residential location/population)	• Racial preference (e.g., percent black, Hispanic) • Poverty • Income
Security (residential and industrial location)	• Bodily harm (violent crime) • Property harm (property crime) • Police and fire services
Workforce (industrial location/employment)	• Skills, in labor market area • Education, in labor market area • Labor pool (skill to industry match, size of pool) • Flexibility (unionization), labor market area
Agglomeration economies (industrial location/employment)	• Supplier availability, distance attenuation • Knowledge spillovers (proxied by universities, R&D houses, localization economies), distance attenuation • Industrial diversity, labor market area or shed • Raw area/industry size, labor market area or shed
Infrastructure (industrial location/employment)	• Highways, location *i* • Airports, connectivity of *i* (number of independent carriers, daily flights, enplanements)
Public service versus tax bundle (residential/industrial location)	• Particularly education for population • Developmental activities for employment

Table 4
Variable names, definitions and data sources

Name	Description	ΔP	ΔE	Source
Endogenous				
PCH9000	Absolute change in population aged 18-65, 1990-2000, county *i*		♦	CCDB
ECH9000	Absolute change in private nonfarm employment, 1990-2000, county *i*	♦		BEA/REIS
E, P				
POP90	Population, 1990, county *i*	♦	♦	CCDB
EMP90	Employment, 1990, county *i*	♦	♦	BEA/REIS
$\overline{P}$, $\overline{E}$				
PU90*d*	Urban population, 1990, counties within radius *d*	♦		CCDB
PM90*d*	Mixed population, 1990, counties within radius *d*	♦		CCDB
PR90*d*	Rural population, 1990, counties within radius *d*	♦		CCDB
EU90*d*	Urban employment, 1990, counties within radius *d*		♦	BEA/REIS
EM90*d*	Mixed employment, 1990, counties within radius *d*		♦	BEA/REIS
ER90*d*	Rural employment, 1990, counties within radius *d*		♦	BEA/REIS
$\Delta\overline{P}$, $\Delta\overline{E}$				
PUCH*d*	Abs change in urban pop, 1990-00, counties w/in radius *d*	♦		CCDB
PMCH*d*	Abs change in mixed pop, 1990-00, counties w/in radius *d*	♦		CCDB
PRCH*d*	Abs change in rural pop, 1990-00, counties w/in radius *d*	♦		CCDB
EUCH*d*	Abs change in urban emp, 1990-00, counties w/in radius *d*		♦	BEA/REIS
EMCH*d*	Abs change in mixed emp, 1990-00, counties w/in radius *d*		♦	BEA/REIS
ERCH*d*	Abs change in rural emp, 1990-00, counties w/in radius *d*		♦	BEA/REIS
Dummy variables, interaction terms				
URBAN	1 if county *i* is designated urban, 0 otherwise	♦	♦	Authors
RURAL	1 if county *i* is designated rural, 0 otherwise	♦	♦	Authors
PUCH*d* _U	Interaction term, URBAN x PUCHd	♦		n/a
PMCH*d* _U	Interaction term, URBAN x PMCHd	♦		n/a
PRCH*d* _U	Interaction term, URBAN x PRCHd	♦		n/a
PUCH*d* _R	Interaction term, RURAL x PUCHd	♦		n/a
PMCH*d* _R	Interaction term, RURAL x PMCHd	♦		n/a
PRCH*d* _R	Interaction term, RURAL x PRCHd	♦		n/a
EUCH*d* _U	Interaction term, URBAN x EUCHd		♦	n/a
EMCH*d* _U	Interaction term, URBAN x EMCHd		♦	n/a
ERCH*d* _U	Interaction term, URBAN x ERCHd		♦	n/a
EUCH*d* _R	Interaction term, RURAL x EUCHd		♦	n/a
EMCH*d* _R	Interaction term, RURAL x EMCHd		♦	n/a
ERCH*d* _R	Interaction term, RURAL x ERCHd		♦	n/a
C, D				
AVGSUN	Mean hours of sunlight January, 1941-70, county *i*	♦		ERS
HMSA89	1 if health maintenance shortage county in 1989, 0 otherwise	♦		HHS
HSGSTK90	Percent housing units built before 1939, 1990, county *i*	♦		CCDB
IHWY	1 if interstate of at least 9 miles in county, 0 otherwise	♦	♦	GDT
MHV90	Median housing value, 1990, county *i*	♦		CCDB
POVERT90	Poverty rate, 1990, county *i*	♦		CCDB
ST_RATIO	K-12 student-teacher ratio, 1989/90 school year, county *i*	♦		NCES
VCRIME90	Violent crimes per 100,000 population, 1990, county *i*	♦		FBI

Table 4

Variable names, definitions and data sources

Name	Description	ΔP	ΔE	Source
HISCH90	Pct pop 25 yr+ w/ HS degree or more, 1990, county *i* LMA		♦	CCDB
WGSHED90	Average annual wage, 1990, county *i* LMA		♦	BEA/REIS
DIVERS90	1 - Herfindahl on 1 digit SIC emp, 1990, county *i* LMA		♦	BEA/REIS
LRGHUB	Distance in miles to large hub airport, county *i*		♦	FAA
PATENT	Average utility patents 1990-95, county *i* 50 mile shed		♦	USPTO
PCRIME90	Property crimes per 100,000 population, 1990, county *i*		♦	FBI
UMEM90	Percent private sector workers unionized, state *j* , 1990		♦	HM
URD50	University R&D dollars, 1992, county *i* 50 mile shed (mil)		♦	NSF

Notes. Acronyms are the following: City and County Databook (CCDB), U.S. Bureau of Economic Analysis Regional Economic Information System (BEA/REIS), Federal Bureau of Investigation (FBI), U.S. Department of Agriculture Economic Research Service (ERS), labor market area defined based on 1990 U.S. Census county-to-county journey-to-work flows (LMA; see footnote 4), National Center for Education Statistics (NCES), U.S. Patent and Trademark Office (USPTO), Hirsch and Macpherson's UNIONSTATS.COM (Hirsch and Macpherson 2003), Federal Aviation Administration (FAA), U.S. Department of Health and Human Services (HHS) . The parameter *d* is defined for an initial county centroid-to-centroid distance of 45 miles and then sensitivity tested for distances of 30, 60, 75, and 90 miles, as well as centroid-to-centroid distance bands of 0-30, 30-60, and 60-90 miles around county *i* (county *i* 's values excluded; see text for further explanation).

Table 5

Median values, exogenous local characteristics variables

Variable	Description	All	Urban	Mixed	Rural
AVGSUN	Mean hours of sunlight January, 1941-70, county *i*	152	151	148	153
DIVERS90	1 - Herfindahl on 1 digit SIC emp, 1990, county *i* LMA	0.823	0.824	0.823	0.824
HISCH90	Pct pop 25 yr+ w/ HS degree or more, 1990, county *i* LMA	71.4	78.8	74.2	67.8
HSGSTK90	Percent housing units built before 1939, 1990, county *i*	18.2	14.9	15.1	20.9
LRGHUB	Distance in miles to large hub airport, county *i*	152.7	20.0	124.5	174.2
MHV90	Median housing value, 1990, county *i*	$45,000	$86,900	$55,600	$39,300
PATENT	Average utility patents 1990-95, county *i* 50 mile shed	33.0	822.7	76.0	19.0
PCRIME90	Property crimes per 100,000 population, 1990, county *i*	519.9	1017.6	747.4	348.8
POVERT90	Poverty rate, 1990, county *i*	0.115	0.087	0.098	0.131
ST_RATIO	K-12 student-teacher ratio, 1989/90 school year, county *i*	16.0	17.1	16.8	15.3
UMEM90	Percent private sector workers unionized, state *j* , 1990	9.40	11.30	10.40	8.70
URD50	University R&D dollars, 1992, county *i* 50 mile shed (mil)	$70.7	$28,087.0	$456.1	$1.6
VCRIME90	Violent crimes per 100,000 population, 1990, county *i*	115.2	278.6	142.5	90.9
WGSHED90	Average annual wage, 1990, county *i* LMA	$17,852	$24,664	$19,396	$16,162

Table 6

Two-stage least squares estimates

Growth spillover variables specified as *d* = 45 miles

	Population change, '90-'00			*Employment change, '90-'00*		
Variable	Parameter	Standard error	p-value	Parameter	Standard error	p-value
Intercept	-8,659.101	5,366.616	0.107	-2,176.956	4,835.128	0.653
PCH9000				0.729	0.041	0.000
ECH9000	1.175	0.115	0.000			
POP90	0.190	0.035	0.000	-0.123	0.032	0.000
EMP90	-0.163	0.035	0.000	0.114	0.024	0.000
PU90*d*	-0.017	0.003	0.000			
PM90*d*	0.010	0.003	0.003			
PR90*d*	-0.018	0.011	0.094			
EU90*d*				-0.001	0.002	0.725
EM90*d*				-0.005	0.003	0.106
ER90*d*				0.004	0.010	0.665
PUCH*d*	0.259	0.025	0.000			
PMCH*d*	-0.004	0.022	0.838			
PRCH*d*	-0.688	0.098	0.000			
EUCH*d*				-0.051	0.010	0.000
EMCH*d*				-0.067	0.015	0.000
ERCH*d*				0.425	0.064	0.000
URBAN	-16,230.256	10,038.690	0.106	20,458.237	9,688.151	0.035
RURAL	-43.894	1,035.892	0.966	-1,084.302	702.463	0.123
PUCH*d* _U	0.063	0.035	0.068			
PMCH*d* _U	-0.324	0.091	0.000			
PRCH*d* _U	2.102	0.540	0.000			
PUCH*d* _R	0.027	0.044	0.546			
PMCH*d* _R	-0.134	0.025	0.000			
PRCH*d* _R	1.180	0.098	0.000			
EUCH*d* _U				-0.142	0.032	0.000
EMCH*d* _U				0.265	0.067	0.000
ERCH*d* _U				-0.171	0.420	0.684
EUCH*d* _R				0.120	0.016	0.000
EMCH*d* _R				0.018	0.013	0.165
ERCH*d* _R				-0.641	0.064	0.000
IHWY	-840.617	460.364	0.068	316.418	334.181	0.344
VCRIME90	-1.494	2.575	0.562			
AVGSUN01	49.543	11.961	0.000			
MHV90	-0.054	0.033	0.102			
ST_RATIO	347.787	145.999	0.017			
HMSA89	-745.447	584.617	0.202			
HSGSTK90	-65.014	40.710	0.110			
POVERT90	-9,968.085	6,384.415	0.119			
PCRIME90				-0.611	0.693	0.378
LRGHUB				-2.798	2.019	0.166
UMEM90				88.832	46.150	0.054
WAGE90				0.159	0.098	0.106
DIVERS90				256.020	5,238.111	0.961

Table 6

Two-stage least squares estimates

Growth spillover variables specified as *d* = 45 miles

	Population change, '90-'00			*Employment change, '90-'00*		
Variable	Parameter	Standard error	p-value	Parameter	Standard error	p-value
HISCH90				32.844	19.723	0.096
PATENT				12.825	3.146	0.000
URD50				-0.009	0.011	0.385
Observations	3,079			3,079		

Note: Second stage results of Generalized Methods of Moments Estimator (Kelejian and Robinson 1993, Rey and Boarnet 2004) with White's heteroscedasticity-robust standard errors (White 1980, Wooldridge 2002). Implemented in SAS software using PROC SYSLIN and the IML (Interactive Matrix Language) module; first stage spatial lags created with a first order contiguity matrix extracted from GeoDa software.

Table 7

Influence of neighboring employment growth on county employment growth

Parameter estimates, dependent variable = Absolute change in employment, 1990-2000, county *i*

	Influence on employment growth of counties of type:		
Neighboring employment growth in counties of type:	Urban	Mixed urban/rural	Rural
Urban	-0.193	-0.051	0.070
Mixed	0.199	-0.067	-0.049
Rural	0.254	0.425	-0.216

Note: Shaded cells are statistically significant at the 5 percent level.

Table 8

Sensitivity test: Influence of neighboring employment growth on county employment growth

Parameter estimates, dependent variable = Absolute change in employment, 1990-2000, county *i*

	Influence on employment growth of counties of type:		
Urban county employment growth within:	Urban	Mixed urban/rural	Rural
30 miles	-0.170	-0.066	0.116
45 miles	-0.193	-0.051	0.070
60 miles	-0.218	0.010	-0.020
75 miles	-0.129	0.017	0.026
90 miles	-0.016	0.000	0.031
30 miles	-0.170	-0.066	0.116
30 to 60 miles	0.083	0.111	0.008
60 to 90 miles	0.340	0.085	0.072
Mixed urban/rural county employment within:	Urban	Mixed urban/rural	Rural
30 miles	0.083	0.137	-0.268
45 miles	0.199	-0.067	-0.049
60 miles	0.253	-0.139	0.012
75 miles	0.114	-0.099	-0.033
90 miles	-0.064	-0.081	-0.036
30 miles	0.083	0.137	-0.268
30 to 60 miles	-0.027	0.253	-0.138
60 to 90 miles	-0.301	-0.092	-0.072
Rural county employment growth within:	Urban	Mixed urban/rural	Rural
30 miles	7.157	-1.606	-0.544
45 miles	0.254	0.425	-0.216
60 miles	-0.804	0.852	0.028
75 miles	-0.327	0.535	0.036
90 miles	0.588	0.473	0.006
30 miles	7.157	-1.606	-0.544
30 to 60 miles	-0.132	-1.181	0.621
60 to 90 miles	1.477	0.135	-0.039

Note: Shaded cells are statistically significant at the 5 percent level.

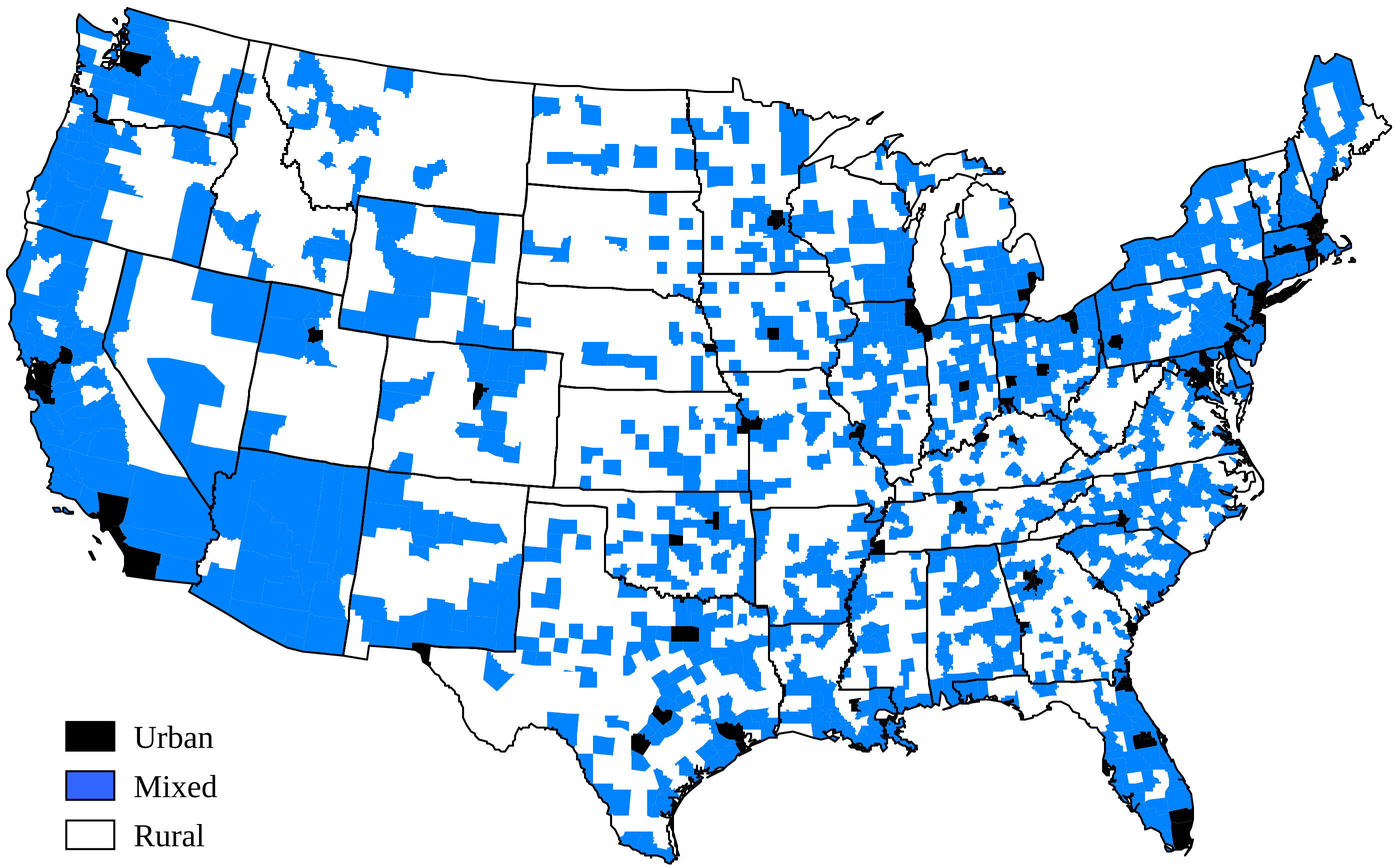


Figure 1. County designations based on population size, percent urban and density

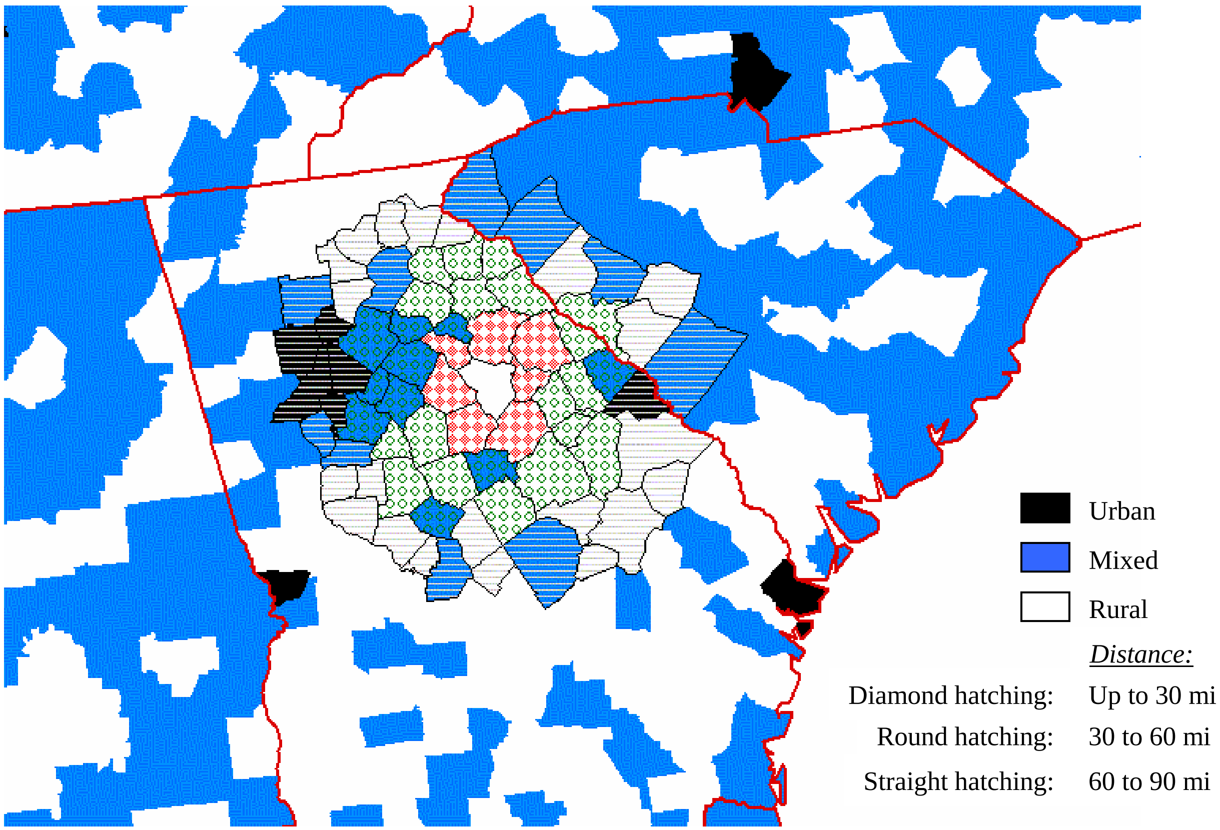
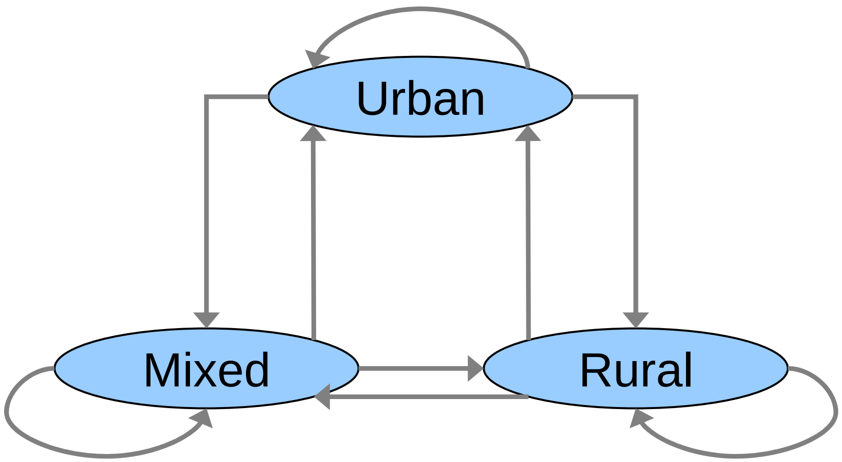
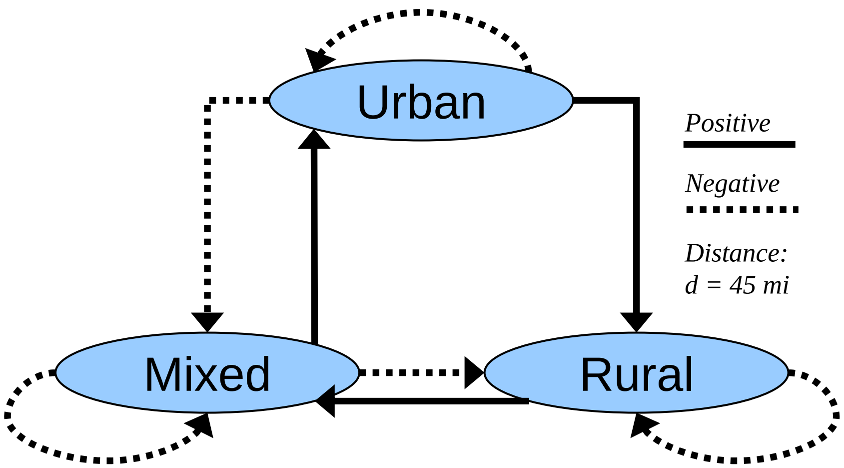


Figure 2. Three distance bands from Greene County, Georgia



I. Set of possible growth spillovers between three county types



II. Estimated employment growth spillovers among county types

Figure 3. Spillovers among urban, mixed & rural counties

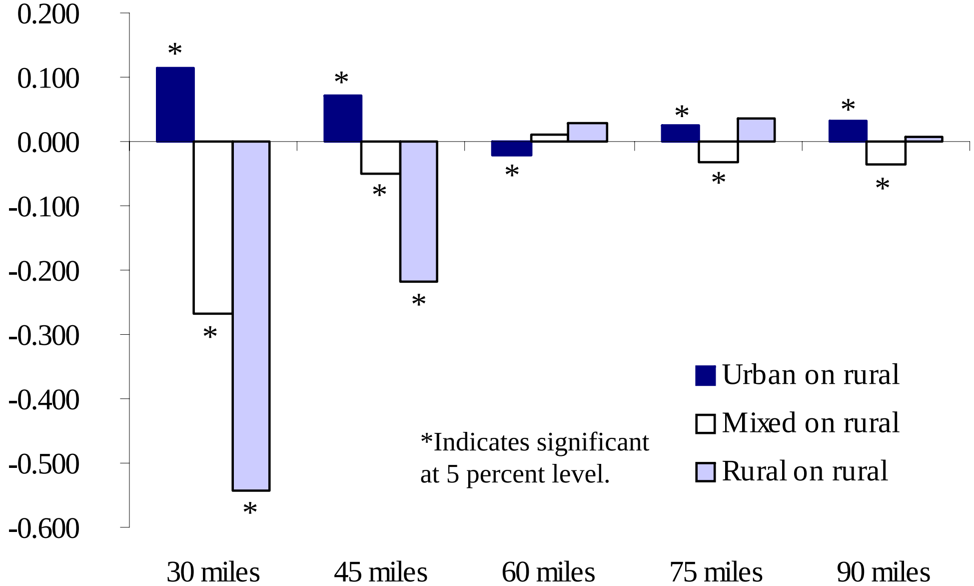


Figure 4. Spillovers *from* urban, mixed & rural counties *to* rural counties

Table A1. Carlino and Mills (1987, *Journal of Regional Science*)

Population equation (population density, 1980, counties)			**Employment equation (employment density, 1979, counties)**		
Employment in *i*, 1979	E_{it}	+			
			Population in *i*, 1980	P_{it}	+
			Employment in *i*, 1969	$E_{i,t-1}$	+
Population in *i*, 1970	$P_{i,t-1}$	+			
S			*T*		
Desc.	Acr.	Res.	Desc.	Acr.	Res.
Percent black in *i*, 1970	PB_i		Percent black in *i*, 1970	PB_i	
Interstate hwy density in *i*, 1982	I_i	+	Interstate hwy density in *i*, 1982	I_i	+
Local gov taxes per capita in *i*, 1972	T_i				
Median family income in *i*, 1970	Y_i	+	Median family income in *i*, 1970	Y_i	+
			Union membership as pct of non-ag emp in state *j*, 1970	U_j	
			Value industrial revenue bonds issued through 1981, state *j*	IDB_i	
Crime rate per 100k people in *i*, 1975	CR_i				
Median school yrs attained in *i*, 1970	MS_i				
Dummy 1 if county contains central city	CC_i	+	Dummy 1 if county contains central city	CC_i	+
Dummy 1 if *i* adjacent to metro area	NM_{10}	-	Dummy 1 if *i* adjacent to metro area	NM_{10}	
Dummy 1 if *i* non-metro, non-adjacent	NM_{11}	-	Dummy 1 if *i* non-metro, non-adjacent	NM_{11}	
Dummy 1 if *i* in New England	NE_i	-	Dummy 1 if *i* in New England	NE_i	
Dummy 1 if *i* in Middle Atlantic	MA_i		Dummy 1 if *i* in Middle Atlantic	MA_i	-
Dummy 1 if *i* in East North Central	ENC_i	-	Dummy 1 if *i* in East North Central	ENC_i	-
Dummy 1 if *i* in West North Central	WNC_i	-	Dummy 1 if *i* in West North Central	WNC_i	-
Dummy 1 if *i* in East South Central	ESC_i		Dummy 1 if *i* in East South Central	ESC_i	
Dummy 1 if *i* in West South Central	WSC_i	-	Dummy 1 if *i* in West South Central	WSC_i	
Dummy 1 if *i* in Mountain	M_i	-	Dummy 1 if *i* in Mountain	M_i	-
Dummy 1 if *i* in Pacific	PAC_i	-	Dummy 1 if *i* in Pacific	PAC_i	

Table A2. Boarnet (1994, *Papers in Regional Science*), summary of results

Population equation (absolute change 80-88, municipalities)			***Employment equation (absolute change 80-88, municipalities)***		
Spatially lagged employment, 1980					
Spatially lagged employment change, 80-88		+			
			Spatially lagged population, 1980		
			Spatially lagged population change, 80-88		?
(Lagged) population in *i*, 1980		?			
			(Lagged) employment in *i*, 1980		
T, A			τ, a		
Desc.	Acr.	Res.	Desc.	Acr.	Res.
Distance to core	*NYCDIST*	?	Distance from New York City	*NYCDIST*	+
Square of distance from New York City	*NYCDISTSQ*	?	Square of distance from New York City	*NYCDISTSQ*	+
Dummy, 1 if *i* on a major highway	*ANYHIWAY*	?	Dummy, 1 if *i* on a major highway	*ANYHIWAY*	?
			Dummy, 1 if *i* contains commuter rail stn	*NJTRNSIT*	?
Land area in 1980 in *i*	*LANDAR80*	?	Land area in 1980 in *i*	*LANDAR80*	?
Proportion black population in *i*	*PRBLCK80*	+			
Proportion Hispanic population in *i*	*PRHISP80*	?			
Poverty rate in *i*	*POVRAT80*	+			
Violent crimes per 100K pop in *i*	*VIORAT80*	+	Violent crimes per 100K pop in *i*	*VIORAT80*	?
Property crimes per 100K pop in *i*	*PRPRAT80*	+	Property crimes per 100K pop in *i*	*PRPRAT80*	+
			No. of farm property parcels in *i*	*FRMPAR80*	-
			Per emp exp on streets, drainage, sewage in *i*	*PEBUSEXP*	
			Equalized property tax rate in *i*	*EQZDTX80*	
Proportion housing stock built before 1940 in *i*	*HOUPRE40*	+			
			Manufacturing employment potential, 1982	*TOTMAN82*	?
			Retail employment potential, 1982	*TOTRET82*	?
Per capita municipal expenditures in *i*	*PCNECEXP*				
Per capita municipal taxes in *i*	*PCTAX80*				

Table A3. Henry, Barkley and Bao (1997, *Journal of Regional Science*), summary of results

Population equation (absolute change 80-90, hinterland tracts)			***Employment equation (absolute change 80-90, hinterland tracts)***		
Spatially lagged employment, 1980					
Spatially lagged employment change, 80-90		-			
			Spatially lagged population, 1980		
			Spatially lagged population change, 80-90		
(Time lagged) population in *i*, 1980		+			
			(Time lagged) employment in *i*, 1980		+
Cross, core growth 80-90 on lagged emp 80					
Cross, fringe growth 80-90 on lagged emp 80					
Cross, core growth on lagged emp chng					
Cross, fringe growth on lagged emp chng		+			
			Cross, core growth 80-90 on lagged pop 80		
			Cross, fringe growth 80-90 on lagged pop 80		
			Cross, core growth on lagged pop chng		
			Cross, fringe growth on lagged pop chng		
T, *A*			*τ*, *a*		
Desc.	Acr.	Res.	Desc.	Acr.	Res.
Distance from hinterland to core centroid	*DIST*		Distance from hinterland to core centroid	*DIST*	
Percent households w/public sewer, 1980	*RSEW80*	+			
			Water/sewer line density, 1980	*WSL80*	
Percent households below poverty, 1980	*POV80*	-	Percent households below poverty, 1980	*POV80*	
Four lane highway density, 1980	*PHL80*				
Percent houses in tract built between 70-80	*RHOU78*	+			
			Percent adult pop with at least 2 yr degree, 80	*DEC80C*	
Ratio of pupils per teacher hinterland HSs, 80	*PUPTEA80*	-	Ratio of pupils per teacher hinterland HSs, 80	*PUPTEA80*	

Highway density (PHL80) was dropped from the employment equation because it was highly correlated with water/sewer line density.