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Extending Carlino-Mills Models to Examine Urban Size and Growth Impacts on Proximate Rural Areas

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ABSTRACT A modification of the Boarnet model of local economic change is developed that links the growth of urban nodes in functional economic regions to employment and population change in the rural hinterlands of these regions. The two-equation model uses labor market and residential zone observations that are consistent with commuter fields around each rural community in the regions studied. The model parameters are estimated for 204 Danish rural municipalities, for 3515 rural communes in six regions of Eastern France, and for 268 rural census tracts in South Carolina. Results indicate that urban nodal spread effects are often significant and tend to dominate urban backwash impacts on rural communities. Accordingly, rural communities need to be concerned with the economic fortunes of their urban nodes and with policies that affect the pattern of urban growth between urban center and the urban fringe.

Introduction

Recent empirical work uses a core-periphery framework to analyze rural change. For example, Hughes and Holland (1994) built a core-periphery input-output model to examine how urban core industries are linked to periphery sectors in Washington State. Barkley et al. (1996) studied rural population density in relation to distance from the urban center. Henry et al. (1997) and Kristensen and Henry (1997) extended the models of Carlino-Mills (1987) and Boarnet (1994a) to analyze the influence of urban growth on population and employment change in the rural hinterland. Shaffer and Deller (1997) suggested

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that Krugman's unified view of a new economic geography (NEG) and traditional growth center theory (e.g., Berry 1972) both imply that rural areas will grow from a sort of urban 'residual' effect. In this view, urban agglomeration economies will focus growth in urban areas with some spinoff to nearby rural places. Do urban centers act as growth centers for nearby rural areas? If so, what is the mechanism that links rural area change to urban growth? The empirical evidence reported in this paper suggests that urban to rural 'spinoffs' are present in three regions of advanced economies (Denmark, France, and the United States)—each with different social, economic and political settings. However, urban growth affects rural places in different ways depending on the urban core and fringe patterns of change and on the size of the local labor and residential zones near the rural place. Finally, rural places are influenced by urban growth and size through both residential choices by households and new firm location (or expansion) decisions.

Urban growth and rural areas—Some channels of influence. The forces which cause dispersion of population and jobs to rural areas may differ according to the geographical scope of the analysis (Schmitt 1996). Near cities, the dynamics of rural areas may be explained by the increase in land rent brought about by competition for residential land use near the urban center. The ensuing population spread to the urban fringe induces employment growth from an increase in the market for residentiary goods. Jobs in firms distributing consumer goods and personal services would be responsible for much of this growth in rural employment. Land rent near the urban center tends to increase with city size and growth. Thus, it is expected that larger urban centers will promote larger movements of the urban population towards nearby rural areas.

A second level of urban-rural interaction involves the competition between rural areas and their urban centers for jobs in industries that serve external markets. Urban areas offer agglomeration economies which can be limited by congestion effects. Rural areas offer relatively low land and labor costs but may increase the transportation costs of moving goods to markets. From a Functional Economic Region (FER) perspective, it is the urban center and its rural hinterland that compete for jobs created inside the FER. Employment spread from the urban center to nearby rural areas can be viewed as an outcome of congestion effects, which increase with city size and growth. At the same time, rural employment change can be influenced by favorable characteristics of the rural work force—low wage rates, work ethic, etc.,—that may provide lower unit labor costs in rural areas than urban centers.

The distinction between these two levels of analysis can be useful for analyzing rural dynamics. However, many places can be affected by both forces—competition for land at the urban fringe and core and competition for new firms and households between rural places and urban places in a FER.

To analyze population and employment changes in rural areas and to reveal which kind of forces are dominant, an extension of the Boarnet model is developed (Henry et al. 1997). This model allows for linkages between local population and employment changes and examines how urban growth affects rural hinterland population and employment change. In this paper, the work in Henry et al. 1997 is extended by comparing empirical results across three countries (Denmark, France, and the United States) to evaluate how country differences in the local socioeconomic milieu affect linkages between urban growth and rural change.

In the next section, the extension of the Boarnet model is described. In the third section, the data needed to estimate the model are discussed. In the fourth section, empirical results for Danish, and selected French and U.S. regions are examined. A summary of findings and rural policy implications are provided in the last section.

Model

Empirical models of regional development often reflect the interdependencies between household residential choices and firm location decisions. This view is well established as a result of work on identification of the direction of causality in the 'jobs follow people' or 'people follow jobs' literature (Steinnes and Fischer 1974). To account for this interdependency, Carlino and Mills 1987 constructed the location equations as a two-equation simultaneous system. Underlying wage and land price structural equations are not specified since variation in amenities across space are assumed to be capitalized into local wages and rents (Roback 1982). Use of amenity variables in the two-equation system reflects these wage and rent effects across space. Boarnet (1994a) refined the Carlino-Mills approach by incorporating residential and employment zones in the two equation model. As shown in Henry et al. (1997), Boarnet's model can be modified to include urban growth influences on nearby rural places to test for the presence of urban spread (backwash) effects on proximate rural communities.

There are several key concepts that Henry et al., Carlino-Mills and Boarnet share. First, they are models with two endogenous variables, population and employment, that reflect the interplay within regions between job and population change. Second, each assumes that there is a lagged adjustment process between change in one of these variables, say regional employment, and the corresponding change in the other variable, say population, in the region. This is because population does not adjust instantaneously to the new set of regional employment opportunities but approaches the desired (equilibrium) level over time. At this juncture, a third key concept is introduced by Boarnet and in Henry, et al., to modify Carlino-Mills. This concept is a view of local labor market areas that allows population to be influenced by employment change both in their place of residence and within commuting zones. And employers can be attracted to labor pools near potential sites not just the labor force in the community where they locate. This common set of concepts is depicted in equations (1) - (4).

$$P^*_{1,t} = \psi(C_1, EMP^*_{i,t}, g_1, g_2) \quad (1)$$

$$E^*_{i,t} = \theta(D_i, POP^*_{i,t}, h_1, h_2) \quad (2)$$

where $P^*_{i,t}$ and $E^*_{i,t}$ are equilibrium population and employment in the ith rural community at time period t; $EMP_{i,t}$ and $POP_{i,t}$ are equilibrium *local labor market* and *residential zones* - not single communities; g_1 (g_2) is the urban center (urban fringe) employment growth rate for the FER to which the ith rural community belongs; h_1 (h_2) is the urban center (urban fringe) population growth rate for the FER to which the ith rural community belongs. C_i and D_i are vectors of residential and firm related 'amenities' that the ith rural community has to offer.

Partial adjustment equations to the equilibrium levels for the ith rural community are:

$$dP_i = P_{1,t} - P_{i,t-1} = \lambda_p (P^*_{i,t} - P_{i,t-1}) \quad (3)$$

$$dE_i = E_{1,t} - E_{i,t-1} = \lambda_e (E^*_{i,t} - E_{i,t-1}) \quad (4)$$

where, dP_i and dE_i are rural community population and employment changes; λ_p and λ_e are the rates of adjustment to desired levels for population and employment respectively.

Adopting linear forms of (1) and (2) with interaction terms yields equations (5) and (6). Here, ε_1 and ε_2 are random disturbance terms that are assumed to be normally and independently distributed with zero mean and constant variance. Note that θ_1 and τ_1 are vectors of 'amenity' parameters.

$$P^*_{i,t} = \theta_0 + C_i\,\theta_1 + \theta_2\ EMP^*_{i,t} + \theta_3 (EMP^*_{i,t}\ g_1) + \theta_4\ (EMP^*_{i,t}\ g_2) + \varepsilon_1 \quad (5)$$

$$E^*_{i,t} = \tau_0 + D_i\,\tau_1 + \tau_2\ POP^*_{i,t} + \tau_3 (POP^*_{i,t}\ h_1) + \tau_4\ (POP^*_{i,t}\ h_2) + \varepsilon_2 \quad (6)$$

Interaction terms are introduced so that the pattern of urban growth as reflected in the growth rates of the urban core and fringe can be reflected in the empirical model to be estimated. This procedure is useful because urban growth patterns ranging from rapid 'urban sprawl' to 'smart growth' patterns of higher densities can be hypothesized and the likely effects on proximate rural areas examined.

By substituting (5) and (6) into (3) and (4), and introducing partial adjustment equations to the desired levels for *local labor markets* and *residential zones* in both equations, the desired levels of population and employment are determined. Next, by substitution where needed and simplification, the changes in population and employment in each rural community are obtained in (7) and (8).

$$dP_i = \gamma_0 + C_i\, \gamma_1 - \lambda p\, P_{i,t-1} + [\gamma_2 + \gamma_3\, g_1 + \gamma_4\, g_2]\, EMP_{i,t-1} + \left[\frac{\gamma_2}{\lambda_e} + \frac{\gamma_3}{\lambda_e}\, g_1 + \frac{\gamma_4}{\lambda_e}\, g_2\right](EMP_{i,t} - EMP_{i,t-1}) + \varepsilon_1 \tag{7}$$

$$dE_i = \delta_0 + D_i\, \delta_1 - \lambda_e\, E_{i,t-1} + [\delta_2 + \delta_3\, h_1 + \delta_4\, h_2]\, POP_{i,t-1} + \left[\frac{\delta_2}{\lambda_p} + \frac{\delta_3}{\lambda p}\, h_1 + \frac{\delta_4}{\lambda p}\, h_2\right](POP_{i,t} - POP_{i,t-1}) + \varepsilon_2 \quad \cdots (8)$$

Next, a spatial 'linkage' matrix, W, is introduced that has non-zero elements, w_{ij}, for communities that are within the same zone (local labor market or residential zone). The W matrix has a dimension of n x n where n is the number of communities in the region. In this form, w_{ii} is always equal to zero. Thus, $w_{ij}=1$ if communities i and j are within the same commuter shed of each other; and $w_{ij} = 0$ otherwise. Including the 'own-community' for w_{ii} is achieved by adding the identity matrix, I, to W to form (I+W). Population and employment in the sets of communities defined by the (I+W) matrix can be thought of as *clusters* of population or employment near the rural community. Accordingly, *local labor market and residential zone* variables are defined as: $EMP_{i,t-1}=(I+W)E_{i,t-1}$; $POP_{i,t-1}=(I+W)P_{i,t-1}$; $(EMP_{i,t}-EMP_{i,t-}=(I+W)dE_i$ and $(POP_{i,t}-POP_{i,t-1})=(I+W)dP_i$. Substitution of these commuting zone variables into equations (7) and (8) and dropping the community i subscripts yields the empirical model used to estimate potential spatial linkages between the urban centers, urban fringe and rural hinterland in equations (9) and (10):

$$dE=\beta_0 - \lambda_e E_{t-1} + [\beta_2 + \beta_3\, h_1 + \beta_4\, h_2](I+W)P_{t-1} + [\beta_5 + \beta_6\, h_1 + \beta_7\, h_2]\,(I+W)\,d\hat{P} + D\,\delta_1 + \varepsilon_2 \tag{9}$$

$$dP=\alpha_0 - \lambda p\, P_{t-1} + [\alpha_2 + \alpha_3\, g_1 + \alpha_4\, g_2](I+W)E_{t-1} + [\alpha_5 + \alpha_6\, g_1 + \alpha_7\, g_2]\,(I+W)\,d\hat{E} + C\,\gamma_1 + \varepsilon_1 \tag{10}$$

Note that the α's and the β's are reduced form parameters that are products of the structural model parameters in equations (5) and (6) and the rate of adjustment coefficients, λ_p and λ_e. The vectors of 'amenity' parameters are $\gamma_1=\lambda_p\,\theta_1$ and $\delta_1=\lambda_e\,\tau_1$. Finally, *dE* and *dP* on the right hand side of (9) and (10) are estimated values from a first stage regression to correct for simultaneity bias.[1]

Model Summary The difference between the model in equations (9) and (10) and the Boarnet (1994) model is the introduction of urban core and fringe growth effects. Thus, in the Boarnet specification, some right-side equation terms do not appear: the $(\alpha_3 g_1 + \alpha_4 g_2)(I+W)E_{t-1}$ and $(\alpha_6 g_1 + \alpha_7 g_2)(I+W)\,\mathrm{d}\hat{E}$ terms in the population change equation and the $(\beta_3 h_1 + \beta_4 h_2)(I+W)P_{t-1}$ and $(\beta_6 h_1 + \beta_7 h_2)(I+W)\,\mathrm{d}\hat{P}$ terms in the employment change equation. The Carlino and Mills (1987) model does not allow for the spatial lag effect that Boarnet introduced. That is, the Carlino-Mills model, in part, differs from Boarnet and Henry et al. by the absence of all (I+W) terms.

The labor market zone variables should represent the locus of employment opportunities within a commuting range of each rural community that a household is considering as a place of residence—not just the employment opportunities in that same community. From a firm's perspective, the size of the residential zone (potential pool of labor) around each rural community that the firm is considering for a new plant or business is the proper geographical unit—not simply the population of the rural community it is considering. The Boarnet model, in our view, corrects for this specification problem in Carlino/Mills. However, Boarnet ignores the possible urban spread and backwash effects on rural areas from cities of differing size and growth rates. Thus, the Boarnet model is modified to capture these possible urban size and growth effects on rural communities. A summary of *urban influence parameter estimates* across each country is presented in the Results section.[2]

Data

Using data from regions in Denmark, France, and the United States, parameters in equations (9) and (10) are estimated. Data sources and variable definitions for each country follow.

Denmark Danish data are organized around 46 Functional Economic Regions (FERs) and the 275 municipalities of Denmark presented in Figure 1. These FERs are delineated on the basis of commuting data and within each FER an *urban center* and *rural hinterland* are identified. Data are assembled from Statistics Denmark (see *Statistics Denmark* 1985) the Danish Ministry of the Interior (see Ministry of the Interior 1985a and 1985b) and the Institute of Local Government Studies. Population and employment data for 1985 and 1993 are from the annual series available from *Statistics Denmark* for each of the 275 municipalities in Denmark. Data on rural amenities in 1985 are gathered from all three sources.

Population and employment. The spatial linkage matrix, W, is constructed that has non-zero elements, w_{ij}, for municipalities that are within the same commuting zone (labor market or residential zone). The zones are defined by an upper bound on typical travel costs of a commute—about 90 Danish Kroner per day. The population and employment in the sets of municipalities defined by the W matrix can be thought of as *clusters* of population or employment near the rural municipality. Labor market and residential area variables for Denmark are:

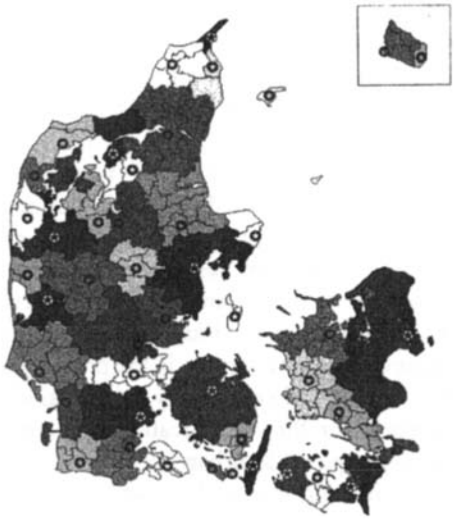

FIGURE 1. THE 46 FUNCTIONAL ECONOMIC REGIONS IN DENMARK
Source: Dept of County Planning (1994), p.47. Notes: Municipalities indicated with a star are Centers of Functional Economic Regions.

$EMP_{i,t}$ = (I+W)E85, $POP_{i,t-1}$ = (I+W) P85, where P85 [E85] is the 1985 total population [employment] in a municipality; and thus, (I+W)P85 [(I+W)E85] is the 1985 total population [employment] of the municipalities within the commuter shed of the hinterland municipality; $(EMP_{i,t}-EMP_{i,t-1})$=(I+W)dE, $(POP_{i,t}-POP_{i,t-1})$=(I+W)dP (I+W)dP [(I+W)dE] is the change from 1985 to 1993 in total population [employment] of the municipalities within the commuter shed of the ith rural municipality; g_1 (g_2) is a vector constructed from the ratios of 1993 to 1985 employment (population) for the urban centers of the 46 FERs in Denmark. Danish local amenities used in the C and D vectors are described in the Appendix.

France. French data are organized across communes (French municipalities) in six regions (see Figure 2). As before, the commune data are aligned into different Functional Economic Regions (FERs) using commuting flows between communes. In the case of France, the typical commute is about 15 KM one-way. In contrast to Denmark, where there is only an urban center and a rural hinterland in each FER, in France we identify an employment center (the core), a periurban area (the fringe) and a peripheral rural area (the hinterland). The data are assembled from several French statistical sources including: *Census Files for Population and Job Data* 1975, 1982, and 1990; *Commercial Inventory* 1980, 1988; and *Taxable Income File*, General Director of Taxes 1984.

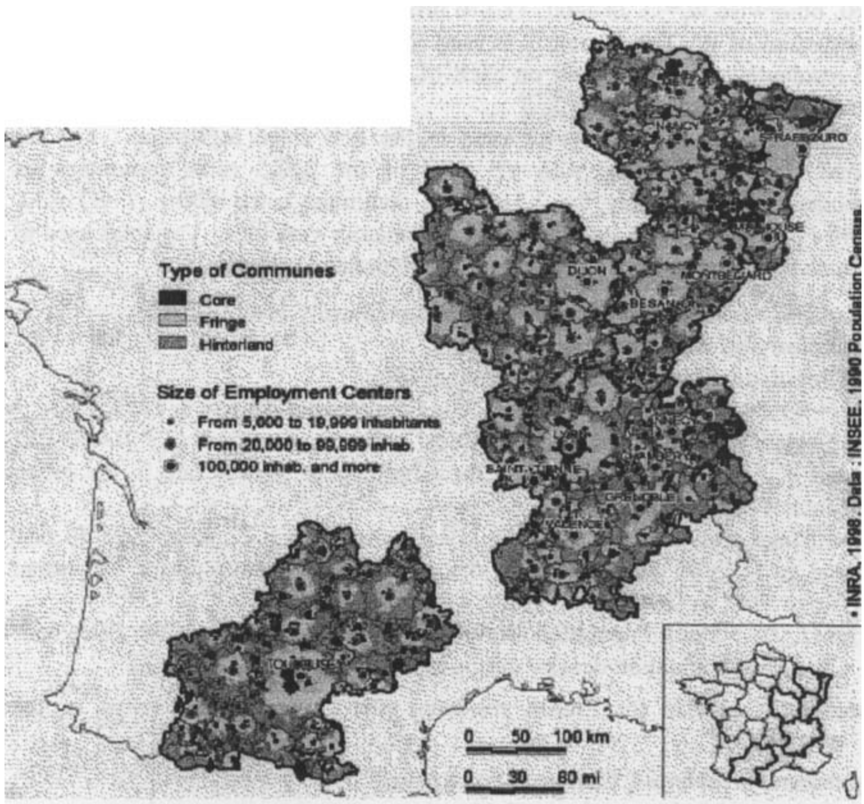

FIGURE 2. RURAL HINTERLAND OF LMAS IN SIX FRENCH REGIONS

The rural communes that are analyzed are the communes in periphery zones of the six regions—each with an urban center in their FER of at least 5,000 inhabitants, except the communes less than 50 km from a national boundary. There are 3,515 rural communes that meet these criteria. The distance for the W matrix is fixed at 15 km (if the distance between i and j is higher than 15 then $w_{ij}=0$, otherwise $w_{ij}=1$). In total, 11,170 urban and rural communes are used in construction of W. The W matrix is used to construct local labor market zones and residential zones centered on each of the 3,515 rural communes. These zones are illustrated in Figure 3.

The 11,170 communes were used in the first stage regression. For the second stage regressions, with *dP [dE]* of the 3,515 rural communes as dependent variables, only the 3,515 rural commune rows of the *(I+W) E82, (I+W) P82* , *etc.* vectors are retained as explanatory variables. Variables used to estimate equations (9) and (10) for France are defined below:

Dependent variable*: *dP: Change in population density 1982 to 1990;
***Population and Labor market variables*:**
P82: Population density in each commune, 1982;
(I+W) E82: Local Labor Market Zone Employment density in 1982;
Urban center growth interaction with Local Labor market Zone: g_1 * *(I+W) E82* and g_1 * *(I+W) dE* where g_1 is the employment growth rate in the urban center 1982 to 1990;
Urban fringe growth interaction with Local Labor market Zone: g_2 * *(I+W) E82* and g_2 * *(I+W) dE* where g_2 is the employment growth rate in the urban fringe 1982 to 1990;
NATBAL_P : Natural Population Growth(births-deaths)1982 to 1990; *VDP7582*: Change in population density during previous period (1975-1982).

'Amenity' variables for French residents (the C vector) are listed in the appendix.

Dependent variable: dE Change in employment density 1982-1990;
Population and Labor market variables:
E82 Employment density in 1982;
(I+W) P82 Residential Zone: Population density in 1982;
Urban center growth rate interaction with Local Residential Zone: h_1*(I+W) P82* and h_1 * *(I+W) dP* where h_1 is the population growth rate in the urban center 1982 to 1990;
Urban fringe growth rate interaction with Local Residential Zone : h_2 * *(I+W) P82* and h_2 * *(I+W) dP* where h_2 is the population growth rate in the urban core 1982 to 1990;
VDE7582: Change in employment density during previous period (1975-1982)
Business amenities in France (the D vector) are listed in the appendix.

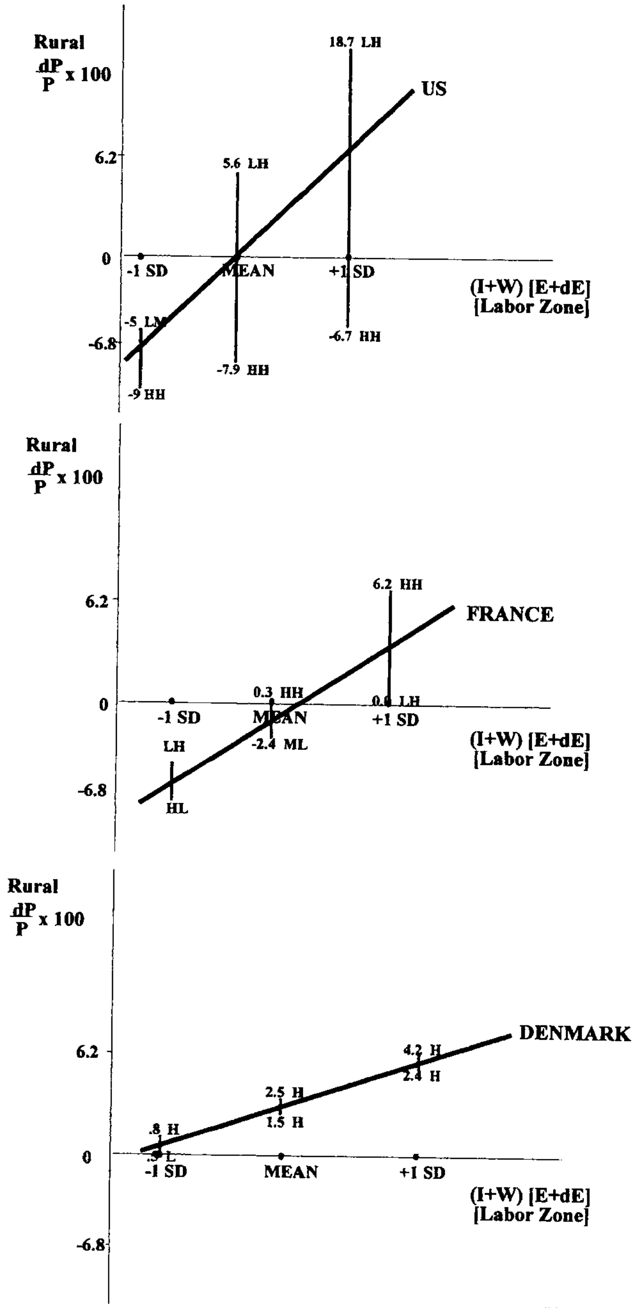

FIGURE 3. IMPACTS ON RURAL POPULATION FROM URBAN EMPLOYMENT GROWTH

United States. Within each Functional Economic Region in South Carolina, and border areas of Georgia and North Carolina (see Henry et al. 1997), urban core tracts, urban fringe tracts and hinterland tracts are identified. The *urban core* is defined as the Census Urbanized Area in 1990 and the surrounding tracts with population density over 1000 persons/square mile. The *urban fringe* captures all tracts outside the core but within a 30 mile (centroid to centroid) distance from the center of the urban core area. The remaining tracts in each FER are the *rural hinterland* tracts.

Variables include:

P80 [E80]= 1980 total population [employment] in a hinterland tract.

(I+W)P80 [(I+W)E80] = 1980 total population [employment] of the tracts within 30 miles of the hinterland tract. $w_{ij} = 1$ if tract i and j are within 30 miles (centroid to centroid) of each other; and $w_{ij} = 0$ otherwise.

(I+W) dP [(I+W) dE] = Changes from 1980 to 1990 in total population [employment] of the tracts within 30 miles of the ith rural tract.

g1[g2] = the ratio of 1990 to 1980 population for the urban core [fringe].

C [D] = vectors of local amenities influencing population[employment].

Amenity variables selected for the C and D vectors for the U.S. are listed in the Appendix. See Henry et al. 1997 for expected relations and discussion of results for the amenity variables. Note that a wide range in geographic areas of rural communes in France suggested the need to employ population and employment densities. In the U.S. and Danish cases, rural tracts/communities were more uniform in size. For Denmark, beginning period population density was used to proxy possible congestion effects (see Kristensen and Henry 1997).

Estimation Results

In this section, key findings are reported on the relationships between urban size and growth and rural population and employment change. To test for the presence of urban spread or backwash effects, joint t-tests are used for the significance of the α_i parameters within equation (9) and the β_i parameters within equation (10). These test results are listed in the appendix. In the appendix tables, three alternative growth rates are assumed for the urban core and fringe: the mean growth rates for all urban cores and fringes; and the mean plus or minus one standard deviation. Joint t tests for the interaction parameters in the brackets of equation (9) are then made for each of the combinations of low, mean, and high urban core and fringe growth rates. There are two sets of these estimates—one for the interactions with the beginning size of the local labor market zone, e.g., (I+W)E82, and one for the change in employment from 1982 to 1990 in the local labor market zone, (I+W)dE.

Holding the rural amenity values constant, estimates of the change in rural population (dP) are made for each combination of urban growth rates. These

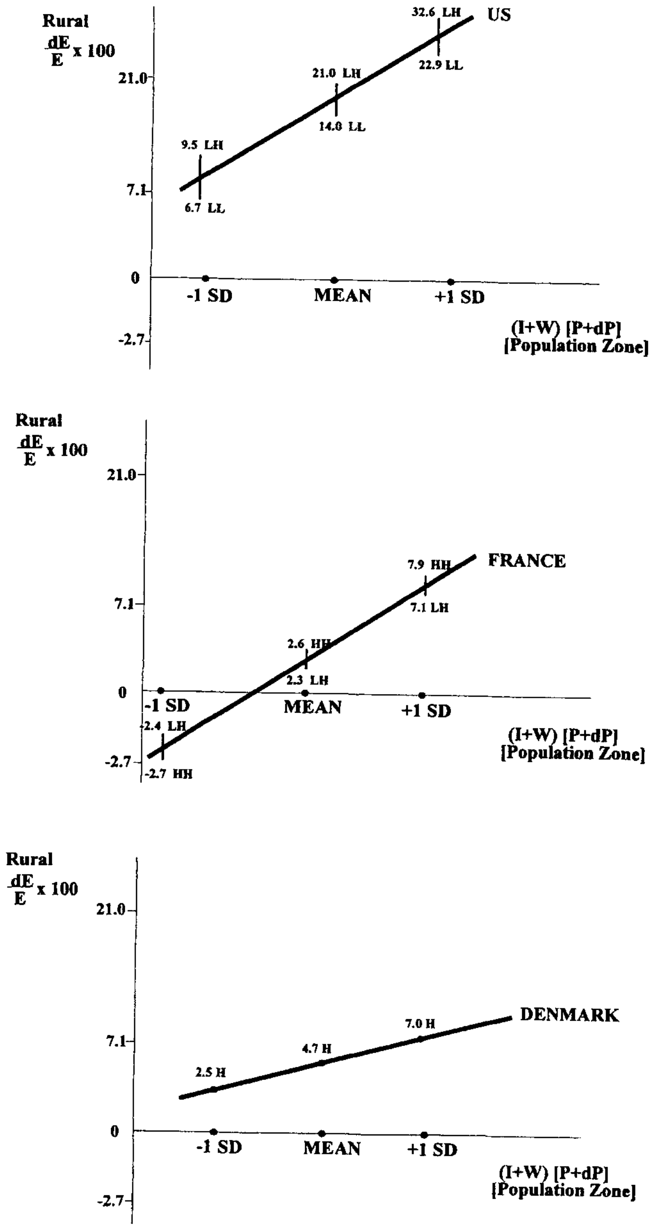

FIGURE 4. IMPACTS ON RURAL EMPLOYMENT FROM URBAN POPULATION GROWTH

estimates of dP are divided by the mean rural population, P, in the beginning period and used in Figure 3 to illustrate the impact of alternative urban growth scenarios. A symmetric procedure is used to estimate alternative values of the change in rural employment, dE, needed for Figure 4. Full model results including second stage regressions of equations (9) and (10) and a discussion of amenity effects are available in Henry et al. (1997) for the United States, Schmitt and Henry (1997) for France, and Kristensen and Henry (1997) for Denmark.

Estimating equations (9) and (10) captures three facets of urban size and change operating on proximate rural places: beginning size of the urban complex (through (I+W) E80 or P80), change in the size of the urban complex (through (I+W)dE or dP), and the growth patterns of the urban complex (urban core and fringe growth rates). As the size and growth in the labor (residential) zone increase, rural response may vary from a backwash effect, no effect to urban spread effects. Faster urban center growth rates with positive (negative) spread effects would increase the positive (negative) impact of urban areas on rural communities beyond the 'Boarnet effect' of growth only within a given labor market area. For example, urban sprawl may be thought of as a spatial development process where the urban fringe is growing rapidly. This could be associated with urban core decline or stagnation—a pattern of urban decentralization. Or the sprawl could be associated with both core and fringe growth where the relative rates of core and fringe growth determine the density of activity between core and fringe. What do the interaction terms in the model suggest happens to rural areas as urban growth patterns range from rapid 'urban sprawl' to 'smart growth' patterns of higher urban densities?

Using statistically significant (10 percent level) regression results from estimating equations (9) and (10) reported in the appendix, the three key concepts that differentiate this model from Carlino-Mills are examined. First, the beginning period size (I+W)E80 or P80 and change in the size (I+W)dE or dP of the local labor market for a given rural community are considered jointly. A range of urban size and change effects are examined by allowing (I+W) E80 and (I+W)dE to vary from plus to minus one standard deviation(sd) of the means for these variables. In Figure 3, the term (I+W) [E+dE] reflects these values. Second, the urban core and fringe growth rates interactions with the local labor market areas are captured in the simulations. Only statistically significant (10 percent level) urban growth rate parameters in the appendix tables are used. Again, urban growth rates are allowed to vary over a range (-1 standard deviation to + 1 standard deviation from the mean urban core and fringe growth rates). These growth rates are depicted in Figure 3 as either L (one sd below the mean), M (the mean urban growth rate) or H (one sd above the mean). In Figure 3, the first letter (L, M, or H) refers to the urban center growth rate and the second letter in a pair is the urban fringe growth rate. For example, a rural community with a Labor Zone of average size and a Low core/High fringe (LH) urban growth rate combination (one 'sprawl scenario') is expected to experience a population spillover effect of 5.6 percent over the decade. However, if both the core and fringe are rapidly growing (HH), there is a 7.9 percent population backwash effect on the rural community.

Rural community population (employment) effects are estimated for each combination of urban sizes and growth rates. Consider first the effects of urban employment patterns on rural population across the three countries.

***Rural population*.** Looking first at Figure 3, generally, as the size of the 'Labor Zone–(I+W)[E + dE]' increases along the horizontal axis, the impact on rural Population increases in absolute terms. In Denmark, there are small to modest spread effects (recall there is only one urban area–not a core and fringe–for the Danish case) in all sizes of Labor Zones. If the urban area has high rates of employment growth, the rural population growth is about double what it is for Low urban rates of employment growth. For example, in large Labor Zones, High urban employment growth yields 4.2 percent more residents to a rural municipality while Low urban employment growth is associated with a 2.4 percent increase in rural municipality population change.

***Urban core and fringe employment growth rates in the FER*.** In the U.S. for the mean size Labor Zone and mean Labor Zone growth, rural tract population grew about 5.6 percent faster from urban spread effects—if the urban core had Low growth and the fringe had High growth—the urban decentralization (LH in Figure 3) scenario in the FER. In contrast, if the U.S. urban core was High growth along with High urban fringe growth rates, there was a rural population backwash effect of about 7.9 percent over the 1980-90 period. In the U.S., this pattern persists as the size of the labor zones increases. This urban 'High/High' (HH in Figure 3) case results in rural population decline from -9.0 percent for small labor zones to -6.7 percent for large labor zones.

In France, the absolute impacts on rural places also increase with the size of the labor zone. However, the urban growth rate impacts in France are a bit different. High urban core and High fringe employment growth rates result in larger population effects on rural communes—from 0.3 percent to 6.2 percent for mean or large Labor zones. However, for small Labor zones, the High urban core and Low urban fringe employment growth rates (urban concentration scenario) result in a 6.8 percent loss in rural population over the 1982-90 period. When looking at the labor market zone, (I+W) dE, that experienced growing employment opportunities, there is compelling evidence that urban employment growth is spreading population to rural communes for almost all combinations of urban core/fringe growth rates and sizes of French urban centers. Accordingly, rural population change is strongly and positively affected by the employment growth performance of the urban core and fringe in French FERs.

Rural employment. Looking next at Figure 4, in Denmark, only the FERs with High rates of urban population growth had impacts on rural municipality employment change. These impacts increased steadily from 2.5 percent in small Population Zones to 7 percent in large population zones. Rural U.S. employment benefited from the Low urban core and High urban fringe 'decentralization' process; rural employment gains from the 'L/H' urban scenario ranged from 9.5 percent in small population zones to 32.6 percent in large population zones. The Low /Low combination of urban core/fringe growth yields a similar pattern of rural benefits—albeit at lower rates than the 'low/high' scenario. In France, high urban fringe population growth rates—in combination with high or low urban core growth rates—yield added employment to nearby rural communes. Employment in the mean French rural commune increased by 2.3 to 7.9 percent over the period with average or large size of Population zones. In contrast, rural communes with small Population zones experienced employment declines of -2.4 to -2.7 percent with LH or HH patterns of urban population growth.

Summary. Rural population and employment changes in the regions of the U.S., France and in Denmark are sensitive to the performance of the urban core/fringe that is nearby. The patterns that emerge are generally of urban spread to rural places that have average or large Labor and Population zones. And the spread effects increase with the sizes of these zones. Backwash effects from urban growth are more likely in rural places with small labor or population zones and in FERs with low rates of growth in the urban fringe.

Conclusions

Estimation of the impacts that urban growth had on rural places in Functional Economic Regions suggests the following general conclusions about urban size and growth impacts on nearby rural areas. First, there are statistically significant impacts of urban growth on both population and employment change in rural areas in these regions. As shown in Figures 3 and 4, the magnitude of these impacts varies from a few tenths of a percentage point per year to annual rates of 3 percent or more per year—depending on the combined fringe and core growth rates and the sizes of the labor and population zones. In particular, support is found in the U.S. sample for a classic urban core to fringe to rural hinterland spread effect in average or large labor zones and in all sizes of population zones. The patterns that emerge are generally of urban spread to rural places that have average or large Labor and Population zones. And the spread effects increase with the sizes of these zones. Backwash effects from urban growth are more likely in rural places with small labor or population zones and in FERs with low rates of growth in the urban fringe.

During the 1982-1990 period, both size of the urban center and the growth rates of employment and population of the urban core and its fringe affect the extent of population and employment change in rural French commune places. As such, economic development policy for rural areas needs to go beyond policy that is focused on farming or other traditional rural sectors. Urban policy or policy that stimulates employment in sectors that tend to favor urban locations may have more impact on rural communes than traditional rural policies to support farm prices. While there is little evidence of urban backwash, the spread effects *to* rural commune population *from* employment growth in urban places vary in importance by size of the urban center and the pattern of urban core and fringe employment growth rates. The same thing is observed for rural employment change from urban population growth.

Within Functional Economic Regions and over the 1985 to 1993 time period, there is evidence of urban to rural spread effects and no support for an urban backwash effect on rural municipalities in Denmark. This conclusion is supported by several findings in this paper. First, urban spread effects on *rural population* growth, over this relatively short time period, are most apparent for the rural municipalities near larger urban centers experiencing high rates of employment growth. Perhaps, like many areas in the United States, jobs are spreading from the old city center to the outer border of the urban municipalities and people are commuting from rural municipalities to the outer border rather than to the old urban core. Second, urban spread effects on *rural employment growth*, over the eight years examined, were strongest in rural municipalities near urban centers with the most rapid ratios of population growth. These fast growing populations in urban centers may be providing larger pools of new Labor for nearby rural firms or they may be generating new employment in proximate rural areas as the growing urban population consumes goods and services in nearby rural communities. In sum, rural employment and population changes in Denmark, in differing degrees, are affected by growth in nearby urban places. Thus, rural areas are functionally related to nearby urban centers, and a typology of rural areas is needed that reflects these urban influences on rural areas. These results support the view that a revised rural typology that identifies the strength of urban spread effects on rural communities would be useful in targeting structural adjustment funds to the rural communities most in need of public intervention.

NOTES

1. A two-stage process is used with a set of exogenous (mainly beginning period) variables used as instruments to estimate dP and dE in the first stage. The first stage results are available in Henry et al. (1997) for the U.S., in Kristensen and Henry (1997) for Denmark and in Schmitt and Henry (1997) for France.
2. In this model, like Carlino-Mills (1987) and Boarnet (1994), employment and population change are interdependent. The 'chicken-egg' direction of causality between population and employment change is revealed in the empirical estimates of

the relative strength of employment change on population change and population change on employment change. One alternative for examining urban spread(or backwash) effects on nearby rural places is to examine population and employment trends over space separately in single equation models. However, as Rey and Boarnet (1998, p. 2) argue, "since Steinnes and Fisher's work [1974] it has been commonly accepted that population and employment are both endogenous in urban models(e.g., Boarnet 1994a and 1994b; Dietz 1998; Steinnes 1977)." The model in this article is an example of a spatial cross-regressive model. However, it is only one of several options for including both spatial interaction and multiple endogenous variables in urban econometric models (See Rey and Boarnet 1998, for a recent taxonomy of models in this spirit). The advantage of the model used in this article is that impacts on rural areas from alternative rates of urban growth can be specified for both the urban core and the urban fringe. This is the motivation for the interaction term approach instead of a simple spatial autoregressive process that could likewise test for urban spread (backwash) effects in a model with multiple endogenous variables.

REFERENCES

Aiken, L.S. and S.G. West. 1991. *Multiple regression: testing and interpreting interactions*. Newbury Park NJ: Sage Publications.

Barkley, D.L., M.S. Henry and S.Bao. 1996. Identifying spread vs. backwash effects in regional economic areas: a density function approach. *Land Economics* 72(3): 336-357.

Barkley, D.L., M.S. Henry, and S. Bao. 1995. How functional are economic areas? Tests for intra-regional spatial association using spatial data analysis. *Papers in Regional Science* 74(4):1- 20.

Berry, B.J.L. 1973. *Growth centers in the American system*, Volume I. Cambridge MA: Ballinger Publishing Company.

Boarnet, M.G. 1994a. An empirical model of intrametropolitan population and employment growth. *Papers in Regional Science* 73: 135-153.

Boarnet, Marlon G. 1994b. The monocentric .model and employment location. *Journal of Urban Economics* 36: 79-97.

Carlino, G.A., and E.S. Mills. 1987. The determinants of county growth. *Journal of Regional Science* 27: 39-54.

Department of County Planning. 1994. *Commuting in Denmark*, Copenhagen: Ministry of Environment & Energy. (In Danish).

Dietz, R. 1998. A joint model of residential and urban location in urban areas. *Journal of Urban Economics* 44: 197-215.

Henry, M.S., D.L. Barkley, and S. Bao. 1997. The hinterland's stake in metropolitan growth: evidence from selected southern regions. *Journal of Regional Science* 37(3): 479-501.

Hughes, D., and D. Holland. 1994. Core-periphery economic linkage: a measure of spread and possible backwash effects for the Washington economy. *Land Economics* 70(3): 364-377.

Kristensen, K., and M.S. Henry. 1997. Hinterland population and employment change in Denmark's functional economic regions: does the hinterland have a stake in urban growth? Paper for the European Association of Agricultural Economists Seminar, Rural restructuring within developed economies. Dijon, France, March 20-21.

Krugman, P. 1991. Increasing returns and economic geography. *Journal of Political Economy* 99 (3): 483- 499.

Ministry of the Interior. 1985a. *Key figures of the Ministry of the Interior: Jutland*, Copenhagen: Ministry of the Interior. (In Danish).

———. 1985b. *Key Figures of the Ministry of the Interior: The Islands*, Copenhagen: Ministry of the Interior. (In Danish)

———. 1997. *Report no. 1333 on the development prospects of rural areas.* Copenhagen: Ministry of the Interior. (In Danish)

Rey, S., and M. Boarnet. 1998. A taxonomy of spatial econometric models for simultaneous equations systems. Paper presented at the 45th North American Meetings of the Regional Science Association, International, Sante Fe, NM Nov. 13.

Roback, J. 1982. Wages, rents, and the quality of life. *Journal of Political Economy* 90(6): 1257-1278.

SAS Institute, Inc. 1985. *SAS Users Guide.*

Schmitt, B.. 1996. Avantages comparatifs, dynamique de population et dynamique d'emploi des espaces ruraux. *Revue d'Economie Regionale et Urbaine*, No. 2: 362-382.

Schmitt, B. and M.S. Henry. 1997. Size of employment centers in French labor market areas: Consequences for the rural village economy. Paper, Regional Science Association, North America. Buffalo NY, Nov. 6-9.

Shaffer, R. and S. Deller. 1997. Krugman's economic geography: Does traditional growth pole theory help us understand the implications for rural areas? Paper Presented at the Meeting of the Southern Regional Science Association, Memphis TN, April.

Statistics Denmark. 1985. *KSDB and ABBA - Description of matrices 1985*, Copenhagen: Statistics Denmark. (In Danish)

Steinnes, D., and W. Fisher. 1974. An econometric model of intraurban location. *Journal of Regional Science* 14: 65-80.

APPENDIX A

The results below are sets of parameter estimates derived from two stage least squares regressions of equations (9) and (10) in the text. They are used to estimate the change in rural place population (dP) and employment (dE) presented in Figures 3 and 4 of the text.

Rural Population Change. In Tables 1A to 3A, three alternative population growth rates for the urban core and fringe are assumed: the mean growth rates for all urban cores and fringes; and, the mean plus or minus one standard deviation. Joint t tests for the interaction parameters in the brackets are then made for each of the combinations of low, mean and high urban core and fringe growth rates. *Boldfaced numbers indicate a rejection of the null hypothesis that the term in brackets is zero for $\alpha = .10$.*

TABLE 1A. EFFECTS OF URBAN EMPLOYMENT GROWTH ON RURAL POPULATION CHANGE, dP - FRANCE

		URBAN FRINGE GROWTH (g_2)					
		LOW		MEAN		HIGH	
		Coef.	T-value	Coef.	T-value	Coef.	T-value
			$[\alpha_2+\alpha_3 g_1+\alpha_4 g_2]$ (I+W) E82				
All communes of FERs with center greater than 5,000 inhabitants							
URBAN	LOW	-0.0023	*(-0.238)*	0.0058	*(0.678)*	0.0140	*(1.504)*
CORE (g_1)	MEAN	0.0131	***(1.382)***	**0.0214**	***(2.870)***	**0.0295**	***(3.954)***
GROWTH	HIGH	**0.0287**	***(2.348)***	**0.0369**	***(3.659)***	**0.0451**	***(4.757)***
			$[\alpha_5+\alpha_6 g_1+\alpha_7 g_2]$ (I+W) dE				
All communes of FERs with center greater than 5,000 inhabitants							
URBAN	LOW	**0.803**	***(5.105)***	**0.716**	***(5.044)***	**0.628**	***(3.925)***
CORE (g_1)	MEAN	**0.958**	***(6.747)***	**0.871**	***(7.849)***	**0.783**	***(6.496)***
GROWTH	HIGH	**1.114**	***(6.457)***	**1.026**	***(7.516)***	**0.938**	***(7.068)***

Together, the results in parts a and b of Table 2 indicate that hinterland population change is affected by urban growth and the size and change in employment opportunities near rural tracts. Greatest expected rural population change occurs in hinterland tracts near smaller, (I+W) E80, but rapid growth, (I+W) dE, labor market areas; if the urban complex is 'decentralizing'—rapid fringe population growth and slow urban core population growth—rural population growth will be enhanced. Slower rural population change occurs in tracts with large but slow growing labor market areas—especially if the urban complex is 'centralizing'—high urban core population growth and slow urban fringe population growth.

Denmark. As noted in the second section, Denmark has few urban centers with a suburban fringe so the model in (9) and (10) was modified to delete urban fringe variables. Accordingly, rural places are associated only with the urban core in each of the 46 Danish functional economic regions.

Rural Employment Change In Tables 4A to 6A, three alternative employment growth rates for the urban core and fringe are assumed: the mean growth rates for all urban cores and fringes; and, the mean plus or minus one standard deviation. Joint t tests for the interaction parameters in the brackets are then made for each of the combinations of low, mean and high urban core and fringe growth rates. Shaded blocks indicate a rejection of the null hypothesis that the term in parentheses is zero for $\alpha = .10$.

TABLE 2A. EFFECTS OF URBAN GROWTH ON RURAL POPULATION, dP - U.S.

a. Effect of Urban Growth on Hinterlands
(for Population Equation - $[\alpha_2+\alpha_3 g_1+\alpha_4 g_2]$ (I+W) E82

		URBAN FRINGE GROWTH g_2		
		HIGH	MEAN	LOW
URBAN	HIGH	**-0.14052 (-2.08)**	-0.10284 (-1.53)	-0.06516 (-0.85)
CORE (g_1)	MEAN	**-0.12744 (-2.96)**	**-0.08977 (-3.20)**	-0.05209 (-1.44)
GROWTH	LOW	**-0.11437 (-1.82)**	**-0.07669 (-1.78)**	-0.03901 (-1.05)

b. Effect of Urban Growth on Hinterlands
(for Population Equation - $[\alpha_5+\alpha_6 g_1+\alpha_7 g_2]$ (I+W) dE

		URBAN FRINGE GROWTH g_2		
		HIGH	MEAN	LOW
URBAN	HIGH	**0.47846 (1.99)**	0.23873 (1.04)	-0.00099 (-0.003)
CORE g_1)	MEAN	**0.53101 (2.85)**	**0.29129 (3.33)**	0.05156 (0.39)
GROWTH	LOW	**0.58357 (2.07)**	**0.34185 (1.96)**	0.10412 (0.76)

TABLE 3A. URBAN GROWTH AND RURAL POPULATION CHANGE – DENMARK

a. Effects of Urban Employment Growth Ratios (g_1) on Rural *Population* Change: dP

		$[\alpha_2 + \alpha_4 g_1]$ (I+W)E85	$[\alpha_3 + \alpha_5 g_1]$ (I+W) dE
Urban	LOW	**0.0006* (2.813)**	0.0028 (0.902)
Core (g_1)	MEAN	**0.0008* (4.250)**	0.0028 (0.912)
Growth	HIGH	**0.0010* (4.333)**	0.0029 (0.922)

France. High core growth rates of population in medium size cities spread jobs to rural communes as shown in Table 4A. And if the residential zone, (I+W)dP, is expanding along with high urban fringe growth rates (an urban decentralization pattern), then rural commune employment will increase too. Thus, fast urban population growth rates, combined with residential zone growth, increases rural employment.

United States. Estimated impacts of urban growth on rural employment in the southern U.S. are shown in Table 5A. The results from evaluating the term in brackets over a range of g1 and g2 are listed in part a of Table 5A. In the cases of high or mean fringe population growth rates (g2) and a low core population growth rate (g1), there is a spread from urban to rural. Other combinations have no significant impact on rural employment change—except for a weak negative impact in the low core/ low fringe case.

Moreover, the findings listed in part b of Table 5A give no support to a spread or backwash effect working through the change in population clusters near hinterland tracts. In tandem, these results suggest a much more footloose location pattern in the FERs for firms than for population.

TABLE 4A. URBAN POPULATION GROWTH AND RURAL EMPLOYMENT CHANGE, dE - FRANCE

		URBAN FRINGE GROWTH (h_2).					
		LOW		MEAN		HIGH	
Urban Core	Urban Fringe	Coef.	T-value	Coef.	T-value	Coef.	T-value
		$[\beta_2+\beta_3h_1+\beta_4h_{2}]$ (I+W) P82					
All communes of FERs with center greater than 5,000 inhabitants							
URBAN	LOW	**-0.0068**	***(-1.546)***	**-0.0049**	***(-1.310)***	-0.0029	*(-0.722)*
CORE (h_1)	MEAN	-0.0031	*(-0.689)*	-0.0011	*(-0.352)*	0.0008	*(0.283)*
GROWTH	HIGH	0.0007	*(0.126)*	0.0026	*(0.653)*	**0.0046**	***(1.397)***
		$[\beta_5+\beta_6h_1+\beta_7h_2]$ (I+W) dP					
All communes of FERs with center greater than 5,000 inhabitants							
URBAN	LOW	0.019	*(0.289)*	**0.087**	***(1.392)***	**0.155**	***(2.092)***
CORE (h_1)	MEAN	0.028	*(0.420)*	**0.096**	***(1.877)***	**0.164**	***(3.074)***
GROWTH	HIGH	0.037	*(0.420)*	**0.105**	***(1.589)***	**0.173**	***(2.932)***

TABLE 5A. URBAN POPULATION GROWTH AND RURAL EMPLOYMENT CHANGE, dE – UNITED STATES

		$[\beta_2+\beta_3h_1+\beta_4h_{2}]$ (I+W) P80		
	Urban Fringe	URBAN FRINGE GROWTH (h_2)		
Urban Core		HIGH	MEAN	LOW
URBAN	HIGH	-4.3E-05 (-0.02)	-0.00029 (-0.18)	-0.00054 (-0.32)
CORE (h_1)	MEAN	0.00081 (0.25)	0.00056 (0.86)	0.00031 (0.49)
GROWTH	LOW	**0.00166 (2.17)**	**0.00141 (3.33)**	**0.00120 (3.63)**
		$[\beta_5+\beta_6h_1+\beta_7h_2]$ (I+W) dP		
		URBAN FRINGE GROWTH h_2		
Urban Core		HIGH	MEAN	LOW
URBAN	HIGH	0.002109 (0.12)	0.00029 (0.13)	0.00207 (0.13)
CORE (h_1)	MEAN	-0.00019 (-0.02)	-0.00021 (-0.02)	-0.00022 (-0.03)
GROWTH	LOW	-0.00248 (-0.23)	0.00209 (0.19)	-0.00252 (-0.20)

Denmark. Urban population growth effects on rural municipal employment change in Denmark are reported in Table 6.

TABLE 6A. URBAN GROWTH AND RURAL EMPLOYMENT, dE – DENMARK.

		Size of Residential Zone $[\beta_2+\beta_4 h_{2l}]$ (I+W) P85	Growth of Residential Zone $[\beta_5+\beta_6 h_1]$ (I+W) dP
Urban	LOW	0.0000 (0.031)	-0.0110 (-0.968)
Core	MEAN	0.0005 (1.319)	-0.0110 (0.969)
Growth	HIGH	**0.0009* (1.621)**	-0.0110 (-0.970)

Notes: * indicates rejection of the null hypothesis that the bracketed term is equal to zero at the 0.10 level.

Calculation of standard errors for the joint tests are described in the appendix; t-statistics are in parentheses.

The results for Danish rural municipality employment change indicate urban spread effects from fast growing population in larger urban centers.

Joint t tests. Inspection of the t-values for the parameters in equations (15) and (16) may be misleading since there are interaction variables. These t-values are from the second stage regressions and are derived from the asymptotic variance/covariance matrix. At this juncture, what is interesting is to look at several values for g_1, g_2, h_1 or h_2 - the urban growth rates - and test their effect on rural growth. The terms in brackets require a joint t-test and thus a standard error that reflects covariance between both terms in the parentheses. In turn, this requires that the variance/covariance matrix is obtained from the regressions. See Aiken and West (1991, p. 24-26).

APPENDIX B. LOCAL AMENITIES

DENMARK

Population Density = the number of inhabitants per square kilometer;

Income per Person = yearly (average) gross income (in Danish kroner) per person in the labor force;

Number of Low Incomes = number of persons in the rural municipality earning a gross income per year less than 100,000 Danish kroner;

School Quality = teacher-hours per pupil in primary school;

Greenspace per Inhabitant = hectares of 'greenspace' per 1000 inhabitants in the rural municipality;

Distance to Urban Core = distance (in kilometers) from the centroid of the rural municipality to the centroid of the urban core of the FER to which the rural municipality belongs.

French residents (the C vector) are:
DPBAS90C = distance to the employment center (centroid to centroid);
D2PBAS90C = distance to the employment center squared;
HOU.S.82_P = percentage in 1982 of commune houses built before 1975 ;
NOT80 = frequency of twenty-eight types of residentiary services in 1980;
SCHOLDIST = distance to the nearest secondary school in 1980;
HOSPDIST = distance to the nearest hospital in 1980;
D1AUTOR = distance to the nearest freeway entrance point in 1988;
RNMOY84 = household taxable income in 1984.

Business amenities in France (the D vector):
DPBAS90C = distance to the urban employment center;
D2PBAS90C = distance to the urban employment center squared;
DAGGLO = distance to the nearest urban agglomeration greater than 200,000 inhabitants;
DIAUTOR = distance to the nearest freeway entrance point;
WNOBLU82 = ratio of active population of executive and intermediate occupations by active population of manual and clerical workers in 1982 [multiplied by (I+W)];
WSKIWO82 = ratio active population of skilled manual workers by unskilled manual workers in 1982 [multiplied by (I+W)];
WSELFJ82 = percentage of non-salaried jobs in non agricultural sectors in 1982 [multiplied by (I+W)];
WRCHOM82 = unemployment rate in 1982 [multiplied by (I+W)];
WTAXIN84 = household taxable income in 1984 [multiplied by (I+W)];

Amenity variables for the C and D vectors for the U.S. are:
DIST = distance(miles) from the hinterland tract (centroid) to the urban core.
RSEW80 = the percentage of houses with public sewer facilities (1980 census data).
WSL80 = the 1980 water/sewer line density (miles of lines / square miles of land area).
PHL80 = the 1980 highway density(miles of four lane highways / square miles land).
POV80 = the percentage of people in households with incomes below the poverty level (1980 census data).
RHOU78 = percentage of all houses in the tract built from 1970-80.
DEC80C = the quality of the local labor market pool as measured by the percentage of the adult population with a two year college degree or above residing within a 30 mile radius of the hinterland tract centroid in 1980.
PUPTEA80 = the mean ratio of pupils per teacher in hinterland tract high schools in 1980.