Regional Housing Supply Elasticity in Spatial Equilibrium Growth Analysis

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by

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Abstract

The spatial equilibrium growth model of Glaeser and Tobio (2008) is built upon the traditional static Rosen-Roback spatial equilibrium model. A distinguishing feature is the addition of a regionally-varying elasticity of housing supply, which was found empirically for the U.S. in a number of studies. Applications of the framework have been limited. But it is sufficiently flexible to be used in a wide variety of settings. Numerous policies and site characteristics of areas have the potential to simultaneously influence household amenity demand, firm productivity and elasticity of housing supply. The spatial equilibrium growth model not only ascertains the growth effects of policies and site characteristics, but it also assesses the channels through which they affect regional growth.

1. Introduction

Land is featured prominently in the canonical Rosen-Roback spatial equilibrium model (Rosen, 1974, Roback 1982). Land is used by both households and firms, and can be transferred between uses without frictions. Perfect mobility of households and firms equalizes utility and profits across space. Therefore, in spatial equilibrium wages and land rents reflect relative location advantages for firms and households. Land rents increase (decrease) in response to higher (lower) household amenity attractiveness and firm productivity.

The spatial equilibrium model has been used extensively to estimate both the regional quality of life and the regional quality of the business environment in countries including China (Zheng et al., 2014b), Germany (Buettner and Ebertz, 2009), Russia (Berger et al., 2008) and the United States (e.g., Roback, 1982; Blomquist et al., 1988; Beeson and Eberts, 1989; Gabriel and Rosenthal, 2004). Assuming that spatial equilibrium holds continuously, the effects of changing household amenity attractiveness of regions and productivity can be examined (Gabriel et al., 2003; Partridge et al., 2010). However, Rickman (2014) notes the passive role of the housing sector in the traditional spatial equilibrium model, where regionally-uniform elasticities of housing supply are assumed and innovations in housing supply are not allowed in spatial equilibrium growth analyses. Considerable evidence exists that housing supply elasticities are not constant across space (Glaeser et al., 2008).

Studies then have begun to incorporate differing elasticities of housing supply within a spatial equilibrium model. Glaeser et al. (2006) retain the assumption of spatial equalization of utility but do not impose equalization of profits. They then allow the elasticity of housing to vary spatially and demonstrate empirically that labor demand shocks have larger housing price effects in areas with less elastic housing supply and lower population growth. This can explain why in declining U.S. cities there are larger responses in housing prices and lower population outflows (Glaeser and Gyourko, 2005); houses are built more quickly than they depreciate, making housing supply relatively inelastic in declining areas. Krupka and Donaldson (2013) likewise expand the Rosen-Roback model such that household amenity attractiveness and firm productivity do not solely determine wages and rents. Hence, they impose additional labor market equilibrium conditions for the labor and housing markets. Of particular note, Krupka and

Donaldson show that *all else equal* the Rosen-Roback model will estimate natural amenities that restrict housing supply as more attractive than amenities that do not.

Glaeser and Tobio (2008) take the spatial equilibrium model one step further by incorporating innovations in housing supply. Local areas may enact restrictive housing development policies in response to concerns with adverse effects of growth. Therefore, the model becomes fairly comprehensive in its ability to account for the various possible sources of growth.

The first use of the model by Glaeser and Tobio (GT) (2008) was to examine the sources of growth in the southern region of the United States over the last half of the twentieth century. A notable finding of the study was that rather than increased demand by households for natural amenities, such as a favorable climate, the most important growth factor in the most recent decades was a more favorable housing regulatory environment in southern states that made housing supply more elastic. In earlier decades, it was productivity growth that underpinned stronger growth in southern states.

Rickman and Rickman (2011) used the theoretical model of GT to assess the changing role of natural amenity demand in nonmetropolitan county growth for 1990-2000, while accounting for the elasticity of housing supply and labor demand. They found household amenity demand as underlying stronger population growth in areas with higher levels of natural amenities. However, they found amenities becoming fully capitalized in the most amenity attractive areas, which reduced their relative population growth. In fact, they also found some evidence that quality of life deteriorated in areas possessing high levels of natural amenities, presumably because of adverse effects of population growth on the quality of life.

Rickman and Wang (forthcoming) found that both differences in natural amenities and urban agglomeration underpinned U.S. regional growth differences post-2000. However, rather than household amenity demand, it was productivity growth that was stronger in areas with high levels of natural amenities. And rather than urban agglomeration economies, it was increased household amenity attractiveness that underpinned stronger population growth in larger metropolitan areas.

Davidsson and Rickman (2011) used the framework to examine growth differences in micropolitan areas across the U.S. from 1990-2000. The important factor was industry composition of the micropolitan areas, in which the GT framework allowed them to detect negative household amenity effects for mining and manufacturing employment shares. The second most important factor was Census Division effects. Using the growth decomposition provided by GT, they assessed the differences across Census Divisions as primarily derived from productivity growth differences, followed by amenity demand, with innovations in household housing supply the least important. The third most influential factor was policy variables, where county spending on highways and education were reported to positively influence both productivity and amenity attractiveness over the period.

Therefore, this paper presents and discusses the Glaeser and Tobio (2008) model, illustrating the past uses and potential uses in other settings. The next section presents the theoretical framework of the model. Section 3 presents and discusses empirical implementation of the model and includes discussion of approaches used in previous studies using the model. Also included is discussion of the applicability of the model to countries such as China that have limited labor mobility. Section 4 discusses the findings of past applications of the model. Concluding statements are in the final section of the paper.

2. Theoretical Framework

The spatial hedonic growth model of Glaeser and Tobio (2008) has its roots in the static spatial general equilibrium framework (Rosen, 1979; Roback, 1982). Below is a presentation of the model that closely follows those contained in Glaeser and Tobio (2008) and Rickman and Rickman (2011).

The model contains two optimizing agents: the household and the firm. The household supplies one unit of labor and is assumed completely mobile across regions. Subject to a budget constraint, the household consumes a composite traded good with a normalized price of unity and housing (H) with price P_h to maximize utility. Amenities (A_h) serve as a utility shifter across regions. Utility of the household is assumed to be represented by the Cobb-Douglas constant-returns-to-scale function, with housing expenditure share α, and is equalized across regions in equilibrium because of perfect household mobility. Equalized indirect utility (V_0) can be written as:

$$V_0 = \alpha^{\alpha}(1-\alpha)^{(1-\alpha)} A_h w P_h^{-\alpha} \qquad (1)$$

The firm produces a nationally traded good, with normalized price equal to unity, according to a constant-returns-to-scale Cobb-Douglas function using labor (N), nationally mobile capital (K), and locally fixed capital (Z), with input expenditure shares equal to β, γ, and (1- β-γ), respectively. In addition, site-specific characteristics cause productivity (A_f) to vary regionally. Profit maximization yields the following inverse labor demand function:

$$w = \beta\gamma^{(\gamma/(1-\gamma))}A_f^{1/(1-\gamma)}N^{(\beta+\gamma-1)/(1-\gamma)}Z^{(1-\beta-\gamma)/(1-\gamma)} \quad (2)$$

Equation (2) stands in contrast with the formulation in the standard spatial equilibrium model. First, land is not used in production of the traded good. So, only households are affected by land prices. Second, profits are not constrained to be equal across regions. As such, spatial differences in productivity do not directly affect land prices, which they do in the traditional spatial equilibrium model. In the traditional spatial equilibrium model, with land transferable between residential and firm uses, the assumptions of equalization of utility and profits across space are sufficient to derive equilibrium wages and rents and the level of population.

The supply of housing is given by the fixed level of land (L) and housing structure (h) on the land. The cost per unit of land is P_l; the cost of housing structure is $\xi_0 h^\delta$ where ξ_0 is a constant and $\delta>1$. Free entry and zero economic profits are assumed in the housing sector in equilibrium. Using the first-order profit maximizing level of h, total housing supply is given as: $h\underline{L}=(ph/\xi_0\delta)^{(1/(\delta-1))}$. Equating housing demand with housing supply in equilibrium yields the following equilibrium expression for housing prices:

$$ph=((N/\underline{L})\alpha w)^{((\delta-1)/\delta)}\delta^{(1/\delta)}\xi_0^{(1/\delta)} \quad (3)$$

The housing equilibrium condition is required because of the absence of land as an input into production and the absence of a firm profit constraint.

In natural logarithms, the static equilibrium conditions for population (assuming full employment), wages and housing prices from the above are as follows (Glaeser and Tobio, 2008; Rickman and Rickman, 2011):

$$\ln(N) = K_N + (\delta + \alpha - \alpha\delta)\ln(\boldsymbol{A}_f) + (1-\gamma)(\delta\ln(\boldsymbol{A}_h) + \alpha(\delta-1)\ln(L))/\Delta \quad (4)$$

$$\ln(w) = K_w + (\delta - 1)\alpha\ln(\boldsymbol{A}_f) + (1-\beta-\gamma)(\delta\ln(\boldsymbol{A}_h) + \alpha(\delta-1)\ln(L))/\Delta \quad (5)$$

$$\ln(P_h) = K_H + (\delta-1)\ln(\boldsymbol{A}_f) + \beta\ln(\boldsymbol{A}_h) - (1-\beta-\gamma)\ln(L))/\Delta \quad (6)$$

where K_N, K_w and K_H are constant terms derived from the solutions and $\Delta = \delta(1-\beta-\gamma) + \alpha\beta(\delta-1)$.

Equations (4)-(6) can be used to assess the influence of housing supply elasticity on regional outcomes by estimating regressions for the three variables, and include measures of shocks that are interacted with proxies for housing supply elasticity (Glaeser et al., 2006). Labor demand shocks will increase housing prices more relative to population in areas with less elastic housing supply. Other sources of growth can come from increased household amenity attractiveness through life cycle factors and increased national income (Graves, 1979; Gyourko et al., 2013).

To derive corresponding growth equations, unanticipated exogenous shocks to amenity demand, firm productivity and housing supply elasticity are added to equations (4) to (6) (Rickman and Rickman, 2011). Assuming that the static equilibrium conditions hold between periods t and t+1, equations (4) to (6) can be transformed into growth equations:

$$\ln(N_{t+1}/N_t) = \pounds_N + \Delta^{-1}\left((\delta+\alpha-\alpha\delta)\lambda_f + (1-\gamma)(\delta\lambda_h + \alpha(\delta-1)\lambda_L)\right)\boldsymbol{R} + \varepsilon_N \quad (7)$$

$$\ln(w_{t+1}/w_t) = \pounds_W + \Delta^{-1}\left((\delta-1)\alpha\lambda_f - (1-\beta-\gamma)(\delta\lambda_h + \alpha(\delta-1)\lambda_L)\right)\boldsymbol{R} + \varepsilon_W \quad (8)$$

$$\ln\left(P_{h,t+1}/P_{h,t}\right) = £_H + \Delta^{-1}\left((\delta - 1)(\lambda_f + \beta\lambda_h - (1 - \beta - \gamma)\lambda_L\right)\boldsymbol{R} + \varepsilon_H \tag{9}$$

where λ_f, λ_h and λ_L are the shocks to firm productivity, household amenity attractiveness and land supply common within regional category $\boldsymbol{R}$. The £ represent shocks common to all regions, while the ε represent shocks idiosyncratic to areas. $\boldsymbol{R}$ represents the South in Glaeser and Tobio (2008), natural amenity classification in Rickman and Rickman (2011), all independent variables more generally in Davidsson and Rickman (2011), and both natural amenities and urban agglomeration in Rickman and Wang (forthcoming).

Let $\boldsymbol{B_N}$, $\boldsymbol{B_W}$ and $\boldsymbol{B_H}$ represent the expressions multiplied by $\boldsymbol{R}$ in Equations (7) to (9), respectively. The expressions associated with them can then be solved simultaneously to obtain the innovations in productivity, amenity attractiveness and land supply.

Productivity growth (λ_f) is revealed by

$$(1-\gamma-\beta)\mathbf{B_N}+(1-\gamma)\mathbf{B_W} \tag{10}$$

Strong population growth combined with wage growth is evidence of relative productivity gains. Increased productivity attracts firms, increasing labor demand, which increases both employment and wages. This contrasts with the traditional spatial equilibrium model where higher productivity is revealed by higher wages and land prices.

The change in amenity attractiveness (λ_h) then is obtained as

$$(\alpha\mathbf{B_H}-\mathbf{B_W}) \tag{11}$$

The negative of the decrease in real labor earnings reveals increased amenity attractiveness, which is consistent with the static equilibrium expression of Roback (1982) because of the assumption of equalization of utility and same arguments in the household utility function. α can be increased based on the correlation of housing prices and other non-traded goods prices to account for real wage effects of non-traded goods prices (Shapiro, 2006).

Relative growth in land supply (λ_L) is obtained as

$$\mathbf{B_N} + \mathbf{B_W} - (\delta \mathbf{B_H}/(\delta - 1)) \tag{12}$$

Strong population and wage growth relative to housing price growth is evidence of greater elasticity of land supply. Less elastic supply of land restricts population growth and increases housing prices relative to wages.

To estimate the impacts of the shocks on growth, we derive the multiplier effects of the shocks on each of the three variables from Equations (7) to (9).

A one percent change in amenity demand causes a:

$(1-\gamma)\delta\Delta^{-1}$ percent change in population (13a)

$-(1-\beta-\gamma)\delta\Delta^{-1}$ percent change in wages (13b)

$(\delta-1)\beta\Delta^{-1}$ percent change in housing prices (13c)

where Δ^{-1} equals 1/ $\delta(1-\beta-\gamma)+\alpha\beta(\delta-1)$.

A one percent change in productivity leads to a

$(\delta + \alpha - \alpha\delta)\Delta^{-1}$ percent change in population (14a)

$(\delta - 1)\alpha\Delta^{-1}$ percent change in wages (14b)

$(\delta - 1)\Delta^{-1}$ percent change in housing costs. (14c)

A one percent change of land supply causes a

$\alpha(\delta - 1)(1 - \gamma)\Delta^{-1}$ percent change in population (15a)

$-\alpha(\delta - 1)(1 - \beta - \gamma)\Delta^{-1}$ percent change in wages (15b)

$-(\delta - 1)(1 - \beta - \gamma)\,\Delta^{-1}$ percent change in housing prices. (15c)

3. Empirical Implementation

Aggregate measures such as the average annual wage rate or median income can be used for the wage measure, while aggregate housing prices or housing rental rates can be used for the price of housing (Glaeser and Tobio, 2008; Davidsson and Rickman, 2011; Rickman and Rickman, 2011). Where micro-data (survey data) are available, characteristic wage rates and housing costs can be derived, which makes them more comparable over time (Rickman and Wang, forthcoming). Aggregate measures can be adjusted for differences in characteristics, but because they are measured as aggregate shares there is a potential endogeneity problem. Population is routinely available for different levels of geography.

3.1 Characteristic-adjusting wages and housing prices

To characteristic-adjust wages and housing costs, one can perform an ordinary least squares regression of the natural logarithm of individual wages on fixed effects for the geographic areas considered, while controlling for characteristics of individuals (Rickman and Wang, forthcoming). The basic regression equation is given by the following:

$$lnw_{ij} = \boldsymbol{\kappa X}_{ij} + \theta_j + \varepsilon_{ij} \qquad (16)$$

where lnw_{ij} is the natural log wage of individual *i* in CONSPUMA *j*. $\boldsymbol{X}_{ij}$ represents the vector of characteristics of individual *i* in area *j*. Characteristics in wage equations typically include age, gender, ethnicity, education, marital status, family status, occupation and industry of employment, hours worked per period of interest, and immigrant status. θ_j is the fixed effect of area *j*. ε_{ij} is the error term.

The baseline characteristic-adjusted wages can be obtained as $ln\widehat{w}_j = \widehat{\boldsymbol{\kappa}}\overline{\boldsymbol{X}} + \hat{\theta}_j$ where $ln\widehat{w}_j$ represents baseline characteristics adjusted wages in area *j*. $(\widehat{\boldsymbol{\kappa}}\overline{\boldsymbol{X}} + \hat{\theta}_j)$ is predicted average wage whereas $\overline{\boldsymbol{X}}$ represents the national mean of characteristics for individuals. In fact, the regressions can be run separately for males and females to capture labor market differences between them:

$$ln\widehat{w}_j = \omega\, ln\widehat{w}_j^m + (1-\omega) ln\widehat{w}_j^f \qquad (17)$$

where ω represents the proportion of males in the sample, while $(1-\omega)$ is the proportion of females in the sample. $ln\widehat{w}_j^m$ represents the baseline characteristics adjusted wages of male; $ln\widehat{w}_j^f$ represents the baseline characteristics adjusted wages of female.

Housing costs refer to housing rents or a housing-price-based imputed rent for homeowners plus the costs of utilities, water, electricity, gas, and the costs of fuel, oil, coal, kerosene, wood, etc. Following previous studies (Beeson and Eberts, 1989; Blomquist et al., 1988; Gabriel and Rosenthal, 2004; Partridge et al., 2010), one can convert owner-occupied median housing prices into imputed annual rent using a discount rate. The basic housing regression is given by the following:

$$lnh_{ij} = \boldsymbol{\varphi Z}_{ij} + \eta_j + \mu_{ij} \tag{18}$$

where lnh_{ij} is natural log of housing cost for individual i in j. $\boldsymbol{Z}_{ij}$ represents the vector of housing characteristics, which can include whether housing units contain a business on the property, the amount of land the house is located on, binary indicators for the number of rooms in the housing unit, whether the residence contained complete plumbing facilities, whether it contained kitchen facilities, the bedroom-to-room ratio, and age of the structure. η_j is the area fixed effect and μ_{ij} is the error term.

One can run the regression for home owners and renters separately to obtain the estimated housing owner cost, $ln\hat{h}_j^o = \boldsymbol{\varphi \overline{Z}}^o + \hat{\eta}_j^o$, and rental housing cost, $ln\hat{h}_j^r = \boldsymbol{\varphi \overline{Z}}^r + \hat{\eta}_j^r$. The two estimates can be combined to obtain the weighted housing cost of each area j as follows

$$ln\hat{h}_j = \tau\, ln\hat{h}_j^o + (1-\tau) ln\hat{h}_j^r \tag{19}$$

where $ln\hat{h}_j$ denotes baseline characteristics-adjusted housing cost in area j. τ is the percent of a house unit owned by household; $(1-\tau)$ is the percent of rented housing units.

3.2 Empirical Model

Equations (7) to (9) are implemented as natural log-differences in population, wages and housing costs between years t and t+1:

$$\ln(pop_{t+1}/pop_t) = £_N + \boldsymbol{B_N R} + \boldsymbol{\theta Control} + \varepsilon_N \qquad (20)$$

$$\ln(wage_{t+1}/wage_t) = £_W + \boldsymbol{B_W R} + \boldsymbol{\theta Control} + \varepsilon_W \qquad (21)$$

$$\ln(hous_{t+1}/hous_t) = £_H + \boldsymbol{B_H R} + \boldsymbol{\theta Control} + \varepsilon_H \qquad (22)$$

where $£_N$, $£_W$ and $£_H$ are constants. $\boldsymbol{B_N}$, $\boldsymbol{B_W}$ and $\boldsymbol{B_H}$ are the coefficient vectors of binary indicator variables to be estimated. ε_N, ε_W and ε_H are error terms. **R** is the matrix of variables of interest to assess their roles in regional growth through the three channels of household amenity attractiveness, firm productivity and housing supply elasticity.

One can test the assumption of continuous spatial equilibrium by including a beginning period measure of disequilibrium in Equations (20)-(22). Rickman and Rickman (2011) use the residuals from a beginning period levels hedonic equation to represent initial disequilibrium (Clark et al., 2003), finding that allowing for potential equilibrium did not much affect the estimated results. For Equation (21) they include the wage residuals, whereas, the housing cost residuals are used in Equation (22). For population growth in Equation (20), both the wage and housing cost residuals were included. Accounting for disequilibrium at the beginning of the growth period may much more important for countries such as China, where its *hukou* system limits labor mobility.

For Glaeser and Tobio (2008), **R** represented whether a U.S. metropolitan area was located in one of the eleven former confederate states. In the base regressions, only an intercept was included with a binary variable indicating location in a former confederate state. In subsequent regressions, temperature variables were added to separate the influence of temperature from other influences in the eleven states.

In Rickman and Rickman (2011), **R** corresponded to a vector of binary variables for the amenity ranking of U.S. counties produced by Economic Research Service (ERS) of the United States Department of Agriculture. The ranking ranges from 1 to 7, with 7 representing the most natural amenity rich areas. The amenity ranking is based on the natural amenity scale composed by the combination of six measures: average January temperature, average January days of sun, average July temperature, average July humidity, topographic variation and water area-to-county area ratio (McGranahan, 1999). Only **R** appears in the base regressions, where subsequent regressions included control variables in sensitivity analysis: worker characteristic shares in the wage regression; housing characteristic shares in the housing cost regression; Census division dummy variables; and measures of county remoteness from larger urban centers.

In Rickman and Wang (forthcoming), **R** represented both binary variables for natural amenity attractiveness and binary variables for the area's position along the rural-urban continuum based on the classification by ERS. This allowed for testing the relative importance of natural amenities versus urban agglomeration in the growth differences across the United States.

In addition to representing binary indicator variables as in the other studies, in Davidsson and Rickman (2011) **R** also represented time varying variables. Such variables included: measures of natural amenities; location in the U.S. rural-urban hierarchy; industry composition; and state and local tax and expenditure variables. Binary variables included Census Division, location of a land grant university, and right-to-work status. Only the binary variable coefficient estimates were decomposed into the innovations using expression equivalent to Equations (10) to (12). The time varying slopes estimates simply were used to assess which pattern most fit the coefficients in terms of the pattern, where no decomposition was performed. Such decompositions could be performed if reference values are chosen such as mean values.

Industry composition variables based on the classification by ERS also can be included as control variables ($\boldsymbol{Control}$). The variables represent whether the area is primarily dependent on: farming, mining, manufacturing, federal or state government, or services. The reference category would be sectorally-diversified areas.

4. Application Results

The first use of the model by Glaeser and Tobio (GT) (2008) was to examine the sources of growth in the southern region of the United States over the last half of the twentieth century. It was commonly argued that warm weather of the southern states was responsible for their strong population growth. Other arguments for the strong growth include convergence related to movement of capital from the north to the south and rising levels of human capital. However, understudied was the potential role of more elastic supply of land and housing.

GT examined the growth of population, median income and housing prices by decade from 1950 to 2000 for 135 U.S. metropolitan areas. From the 1950s through the 1970s, the South enjoyed productivity growth advantages. Perhaps surprisingly, there were negative effects on population growth of climate throughout the five decades. This occurred despite advances in air conditioning and improvement in fighting diseases correlated with the climate of the South. The South began enjoying a growth advantage from a more favorable housing regulatory environment in the 1970s and 1980s. In examining the influence of hot summers versus warm winters in place of the South dummy variable, GT find that areas with warm winters sometimes enjoyed increased amenity demand, while those with hot summers never have been associated with increased amenity valuation.

Rickman and Rickman (2011) used the theoretical model of GT to assess the changing role of natural amenity demand in nonmetropolitan county growth for 1990-2000, while accounting for the elasticity of housing supply and labor demand. Historically stronger growth in nonmetropolitan areas with the highest levels of natural amenities began to converge to that of areas with lesser, though above average, levels of natural amenities. A number of factors could have underpinned the growth convergence. First, amenities could become capitalized into higher housing prices and lower nominal wages, offsetting the amenity-growth advantages. Second, it could be that restrictions imposed by public lands affect resource extractive activities and residential land supply. Thirdly, local areas may impose growth controls, adversely affecting productivity and residential land supply.

Rickman and Rickman (2011) found amenities becoming fully capitalized in the most amenity attractive areas, which reduced their population growth. In fact, they also found some evidence that quality of life deteriorated in areas possessing high levels of natural amenities, presumably because of adverse effects of population growth on the quality of life. Finally, they also found evidence of slower productivity growth in the highest amenity nonmetropolitan areas. Perhaps surprisingly, they did not find evidence of land becoming less elastically supplied in the high natural amenity areas.

Rickman and Wang (forthcoming) found that both differences in natural amenities and urban agglomeration underpinned U.S. regional growth differences post-2000. However, rather than household amenity demand, it was productivity growth that was stronger in high amenity areas, though household amenity demand also was important in non-metropolitan areas. This could result from firms choosing to locate in high natural amenity areas, or workers with unmeasured productive skills sorting into natural amenity-attractive areas. And rather than urban agglomeration economies, it was increased household amenity attractiveness that drove stronger population growth in larger metropolitan areas.

Davidsson and Rickman (2011) used the framework to examine growth differences in micropolitan areas across the U.S. from 1990-2000. Micropolitan areas are defined similarly to metropolitan areas, except that the population level requirement is for a city between 10 and fifty thousand. They may have differing growth patterns than either metropolitan or other nonmetropolitan areas (Partridge et al., 2008).

A distinguishing methodological feature of Davidsson and Rickman (2011) is the use of time varying variables in **R** in Equations (20)-(22), whereas, in previous studies only binary indicator variables were included in **R**. The important growth factor for micropolitan areas for the 1990s was found to be industry composition. The GT framework allowed the authors to detect negative household amenity effects for mining and manufacturing employment shares. The second most important factor was Census Division effects, obtained with the use of binary indicator variables. Using the growth decomposition framework, differences across Census Divisions were primarily attributed to productivity growth differences, followed by amenity demand, with innovations in household housing supply the least important. The third most influential factor was policy variables, where county spending on highways and education were reported to positively influence both productivity and amenity attractiveness over the period.

5. Conclusion

The spatial equilibrium growth framework can be applied in a wide variety of settings. Innumerable factors can underlie productivity and household amenity differences across regions, and the general structure of the spatial equilibrium framework can account for them (Ottaviano and Pinelli, 2006; Tabuchi and Thisse, 2006). For China, the relaxing of *hukou* restrictions would increase household demand for cities with higher amenities, increasing their population growth; Zheng et al. (2014a) find lower pollution to be more fully capitalized into housing prices in cities with less restrictive *hukou* regulations on labor mobility. Relaxing of housing regulations likewise would increase population growth relative to the change in housing prices. The spatial equilibrium growth framework is well-suited to examine the growth effects of changes in these types of policies, while also accounting for the effects of restrictive policies in preventing full spatial equilibrium.

REFERENCES

Beeson, Patricia E. and Randall W. Eberts, 1989. "Identifying Productivity and Amenity Effects in Interurban Wage Differentials," *Review of Economics and Statistics* 71(3), 443-452.

Berger, Mark C., Glenn C. Blomquist, and Klara Sabirianova Peter, 2008. "Compensating Differentials in Emerging Labor and Housing Markets: Estimates of Quality of Life in Russian Cities," *Journal of Urban Economics* 63, 25–55.

Blomquist, Glenn, Mark Berger, and John Hoehn, 1988. "New Estimates of the Quality of Life in Urban Areas," *American Economic Review* 78, 89-107.

Buettner, Thiess and Alexander Ebertz, 2009. "Quality of Life in the Regions: Results for German Counties," *Annals of Regional Science* 43, 89–112.

Clark, David E., William E. Herrin, Thomas A. Knapp and Nancy E. White, 2003. "Migration and Implicit Amenity Markets: Does Incomplete Compensation Matter?" *Journal of Economic Geography* 3(3), 289-307.

Davidsson, Michael and Dan S. Rickman, 2011. "U.S. Micropolitan Growth: A Spatial Equilibrium Growth Analysis," *The Review of Regional Studies* 41, 179-203.

Gabriel, Stuart A., Joe P. Mattey and William L. Wascher, 2003. "Compensating Differentials and Evolution in the Quality-of-Life among U.S. states," *Regional Science and Urban Economics 33*(5), 619-649.

Gabriel, Stuart A. and Stuart S. Rosenthal, 2004. "Quality of the Business Environment versus Quality of Life: Do Firms and Households Like the Same Cities?" *Review of Economics and Statistics* 86(1), 438-444.

Glaeser, Edward L., Gyourko, J., 2005. "Urban Decline and Durable Housing," *Journal of Political Economy* 113 (2), 345–375.

Glaeser, Edward L., Joseph Gyourko, and Albert Saiz, 2008. "Housing Supply and Housing Bubbles," *Journal of Urban Economics*, 64, 198–217.

Glaeser, Edward L., Joseph Gyourko, and Raven E. Saks, 2006. "Urban Growth and Housing Supply," *Journal of Economic Geography* 6, 71-89.

Glaeser, Edward L. and Kristina Tobio, 2008. "The Rise of the Sunbelt," *Southern Economic Journal* 74(3), 610-643.

Graves, Phillip E, 1979. "A Life Cycle Empirical Analysis of Migration and Climate, by Race," *Journal of Urban Economics* 6(2), 135-47.

Gyourko, Joseph, Christopher Mayer, and Todd Sinai, 2013. "Superstar Cities," *American Economic Journal: Economic Policy*, 5(4): 167-99.

Krupka, Douglas and Kwame Donaldson, 2013. "Wages, Rents and Heterogeneous Moving Costs," *Economic Inquiry* 51(1), 844–864.

McGranahan, David A., 1999. *Natural Amenities Drive Rural Population Change*, AER 781. Washington D.C.: Economic Research Service, U.S. Department of Agriculture.

Ottaviano, G. and Pinelli, D., 2006. "Market Potential and Productivity: Evidence from Finnish Regions," *Regional Science and Urban Economics* 36, 636–657.

Partridge, Mark D., Dan S. Rickman, Kamar Ali and M. Rose Olfert, 2008. "Lost in Space: Population Growth in the American Hinterlands and Small Cities, *Journal of Economic Geography* 8, 727–757.

_____, 2010. “Recent Spatial Growth Dynamics in Wages and Housing Costs: Proximity to Urban Production Externalities and Consumer Amenities,” *Regional Science and Urban Economics* 40, 440-452.

Rickman, Dan S., 2014. “Assessing Regional Quality of Life: A Call for Action in Regional Science,” *The Review of Regional Studies* 44(1), 1-12.

Rickman, Dan S. and Shane D. Rickman, 2011. “Population Growth in High? Amenity Nonmetropolitan: What’s the Prognosis?” *Journal of Regional Science* 51(5), 863-879.

Rickman, Dan S. and Hongbo Wang, 2015. "U.S. Regional Population Growth 2000-2010: Natural Amenities or Urban Agglomeration?" MPRA Paper 61051, University Library of Munich, Germany.

Roback, Jennifer, 1982. “Wages, Rents, and the Quality of Life,” *Journal of Political Economy* 90, 1257-1278.

Rosen, Sherwin. 1979. “Wage-based Indexes of Urban Quality of Life,” In *Current Issues in Urban Economics,* edited by Peter Mieszkowski and Mahlon Straszheim. Baltimore: Johns Hopkins University Press, pp. 74-104.

Shapiro, Jesse M., 2006. “Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital,” *Review of Economics and Statistics* 88(2), 324-335.

Tabuchi, Takatoshi and Thisse, Jacques F., 2006. “Regional Specialization, Urban Hierarchy, and Commuting Costs,” *International Regional Economic Review* 47, 1295–1317.

Zheng, Siqi Q., Jing Cao, Matthew E. Kahn and Cong Sun, 2014a. “Real Estate Valuation and Cross-Boundary Air Pollution Externalities: Evidence from Chinese Cities,” *The Journal of Real Estate Finance and Economics* 48(3), 398-414.

Zheng, Siqi, Sun, Cong, Qi, Ye and Matthew E. Kahn, 2014b. “The Evolving Geography of China's Industrial Production: Implications for Pollution Dynamics and Urban Quality of Life,” *Journal of Economic Surveys* 28(4), pp. 709-24.