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Modeling Strategic Interactions in Land-Use Decision Models

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“Open space has been often cited as a primary attractor of urban and suburban residents to exurban areas located just beyond the metropolitan fringe”

--Irwin and Bockstael, 2001, p. 691

For residents deciding where to locate their homes, areas with wide availability of open space are much coveted as they are rich in rural and natural amenities, scenic landscapes, and because such areas provide diverse opportunities for amenity based recreational activities. Perhaps more importantly, as observed by Irwin and Bockstael, areas endowed with open space are perceived to be dissociated from many environmental disamenities, like vehicular congestion and air pollution, that are associated with more developed areas (Irwin and Bockstael, 2001). In essence, open space is representative of all that which is natural and untouched by the negative externalities that are taken to be the by-product of commercial development and urbanization. It is an important characteristic of the bundle of attributes that defines residential goods and over which residential consumers have preferences.

Spurred on by the importance of open space as a source of residential amenities, and with urban sprawl relentlessly encroaching upon prime agricultural lands, governments and other land use and land management authorities are increasingly aware of the need to conserve open space lands. Faushold and Lilieholm describe the motivations behind this “drive to conserve” from three perspectives. First, they observe that open space areas are integral to the production of certain public goods and services such as food, fiber, recreation, natural hazards mitigation, and ecosystem services, and may in addition possess important geological and biological features (Faushold and

Lilieholm,1996). Secondly, they characterize the heightened drive for conservation of open space as an attempt to counter the adverse effects of the socioeconomic and land use changes that come in the wake of declining urban cores and exurban sprawl (Faushold and Lilieholm, 1996). They also point out that open space preservation has significant fiscal implications for local governments that rely upon property tax revenues, so involvement in the decision-making process is critical for local authorities (Faushold and Lilieholm,1996).

In the recent past, the growing literature on open space has followed one of several different paths. The most pursued research has been on hedonic studies that focus on the effect of open space and its associated amenities on property values (Irwin and Bockstael, 2001; Irwin and Bockstael, 2000). The methodology of this approach follows from the body of work on hedonic studies that examine the effects of locational/environmental characteristics on property values (Palmquist, 1992; Leggett and Bockstael, 2000; Tyrvaïnen and Miettinen, 2000). Although several willingness- to-pay studies have demonstrated the positive amenity value of open space (Halstead, 1984; Beasley et al, 1986), evidence from the hedonic studies are limited and mixed (Acharya and Bennett, 2001).

An alternative approach to valuing open space has been that of directly estimating the public demand for open space (Bates and Santerra, 2002) with research in this area drawing heavily from the broad literature in public economics on demand for public goods(Bergstrom and Goodman, 1973; Santerra, 1985).

Other research, not specific to open space, has concentrated on developing methodologies for investigating spatial interdependence among counties with respect to

land-use changes (Hsieh et al, 2000) and land-use regulation (Hsieh et al, 2001). Findings from this research suggest that land-use models that fail to recognize the presence of certain types of spatial interdependence will suffer from specification error (Irwin and Bockstael, 2000).

Strategic interaction, especially in the presence of externalities, has emerged as an important component in models of policy and government choice, because in the presence of externalities policy choices become interdependent, and such interactions must be explicitly accounted for in reaching optimal policy decisions (Brueckner, 1998). Much of the literature on strategic interaction is to be found in tax competition literature (Revelli, 2001); one close application in urban economics is found in the study of strategic interaction in the choice of urban growth control measures (Brueckner, 1995; Helsey and Strange, 1994).

This paper integrates the methodology on strategic interactions in the public economics literature with the literature on the spillover benefits of open space by developing a theoretical framework for conceptualizing the problem of spatial interaction in land-use allocation decisions. It presents an amenity-based model of land-use decisions that is then used to examine micro level decision-making regarding land use in the presence of spillover open-space benefits and determine whether there are any benefits to be gained from strategic decision making across municipalities.

The Model: An Amenity Based Model of Land Use decisions

The detailed assumptions of the model are as follows. The decision-making unit of the local government is the municipality, denoted by i . For simplicity we begin with the assumption that there are two municipalities under consideration, $i=1,2$.

Each municipality under consideration has unsettled, unoccupied land of area A_i and it must decide how to allocate this land between two alternative land uses-residential space (z_i) and land that provides environmental amenities-which we call 'open space.' Let (b_i) denote the proportion of available land that is provided as open space. Open space is assumed to be homogenous land with no distinction made between land that provides different type of environmental amenities. The model therefore, sticks to the restrictive assumption of featureless landscape that is found in many standard spatial equilibrium models (Solow, 1973).

Each municipality has a fixed population of households (N_i) with similar preferences and income (Y_i). Therefore each municipality can be characterized using the notion of a representative household. Population is mobile across the municipalities, and there are several constraints that each municipality faces:

- fixed utility
- a resource constraint dictating that resources used can not exceed income.
- a population constraint dictating that a given population of households must be accommodated and housed within the geographical boundaries of the municipalities.
- a land constraint requiring that the demand for residential space be equal to the supply in the municipalities.

The representative household in each municipality chooses its most preferred combination of residential space (z_i), proportion of the total land area that is provided as open space (b_i) and a composite good (c_i) to maximize its utility subject to a budget constraint (Y_i).

The representative household takes the rental price of the residential space denoted by r_i as exogenous, but within the model rent is endogenously determined as a function of how much land remains for residential use and the size of the population that space has to support.

Our purpose is to explore whether there are gains to be made if municipalities act strategically in the allocation of open space when they are making their land use decisions. To investigate the possibility of gains, we need to compare the results of a more regional, strategic decision making process with the ones obtained when those decisions are made nonstrategically.

Therefore, there are several cases of the same optimizing behavior of the municipalities that are presented here; the difference between the three cases arises from the differences in the perspective that the decision-making agents have when they conduct the optimization procedure.

Case 1: Model with no consideration of spillover effects

In order to introduce the model, we first consider the case where the municipality assumes that the utility of its representative member depends only on the open space available within its geographical limit and makes its choice of z_i and b_i to maximize that resident's utility.

Mathematically,

$$(1) \quad \underset{z_i, b_i, c_i, \lambda}{Max} L(z_i, b_i, c_i, \lambda) \equiv U_i(z_i, c_i, \delta_i(b_i A_i)) + \lambda(Y_i - P_c c_i - r_i z_i)$$

where,

$U_i(z_i, c_i, \delta_i(b_i))$ is the representative household's utility function;

$\delta_i(b_i A_i)$ is an index of the environmental amenities from provision of open space;

Y_i is the gross household income;

P_c is the price of the composite good;

r_i is the rental price

and λ is the Lagrangian multiplier.

The household utility function adapted is as used in Solow (1973), but it is also modified as in Wu (2001) to depend on environmental amenities:

$$(2) \quad U_i(z_i, c_i, \delta_i(b_i)) = \alpha \ln[\delta_i(b_i A_i) z_i] + (1 - \alpha) \ln c_i$$

This specification implies that environmental amenities and residential space are substitutable: a small house in a good 'green' locality can provide the same level of utility as a larger house in a less desirable area.

The first order conditions for the maximization problem can be distilled into the following system of equations:

$$(3a) \quad \frac{\alpha}{z_i} - \lambda r_i = 0$$

$$(3b) \quad \frac{(1 - \alpha)}{c_i} - \lambda P_c = 0$$

$$(3c) \quad \frac{\alpha}{\delta_i(b_i A_i)} \frac{\partial \delta_i(b_i A_i)}{\partial b_i} - \lambda z_i \frac{\partial r_i}{\partial b_i} = 0$$

$$(3d) \quad Y_i - P_c c_i - r_i z_i = 0$$

Solution of this system of equation gives us the optimal choice of b_i for municipality i .

Combining equation (3a) and (3b) gives us the representative households demand for residential space z_i .

$$(4a) \quad z_i = \frac{\alpha Y_i}{r_i}$$

The spatial equilibrium condition can be solved using equation (4a). In each municipality the demand for residential space must equal supply.

$$(4b) \quad N_i z_i = (1 - b_i) A_i$$

Using (4a) and (4b) the bid-rent price for housing is

$$(4c) \quad r_i = \frac{N_i \alpha Y_i}{(1 - b_i) A_i}$$

Differentiating equation (4c) with respect to b_i and substituting it and equation (4b) in equation (3c) gives us the following differential equation, which must be satisfied for the municipality to be maximizing the representative resident's utility:

$$(5) \quad \frac{\alpha}{\delta_i(b_i A_i)} \frac{\partial \delta_i(b_i A_i)}{\partial b_i} - \frac{\alpha}{(1 - b_i)} = 0$$

The equilibrium system can be solved only when the precise form of the environmental amenities index $\delta_i(b_i A_i)$ is specified. Previous hedonic studies of property values assume that amenities at a given site depend on distance to the nearest recreational

area. Looking for simplicity in the context of the proposed model, assume that environmental amenity index for households in the i^{th} municipality is

$$(6) \quad \delta_i(b_i) = (b_i A_i)^\gamma, \quad 0 < \gamma < 1$$

Where γ is the elasticity of the environmental amenity index with respect to proportion of land allocated to open space. This specification implies that what contributes to utility is only the absolute amount of land that is provided as open space within each municipality. Where within the municipality it is located is of no consequence, for current purposes i.e. the spatial location of the amenity is not considered.

Corresponding to this functional form for the amenity index, equation (5) changes to

$$(5a) \quad \frac{\alpha\gamma}{b_i} - \frac{\alpha}{(1-b_i)} = 0$$

Solution to the above equation gives the proportion of land that the municipality would choose to allocate to open space in equilibrium i.e. (b_i^*).

In this case, it works out that

$$(6) \quad b_1^* = b_2^* = \frac{\gamma}{1+\gamma}$$

The equilibrium allocation of land to open space depends exclusively on the environmental amenity index parameter. For $\gamma = 0.5$, we find $b_i^* = 0.33$. The higher the value of γ , the greater is the allocation of land to open space for either municipality. This makes intuitive sense as it tells us that the higher the amenity value of preserved land, the more is the land that is allocated to generate those amenities.

Case 2: Model with Spillover Effects and Non-Strategic Decision-Making

We now alter the model to account for the spillover utility effect of open space. This expanded model will also be used to investigate the effects, and possible benefits derived from, strategic decision-making with respect to land-use allocation. The added spillover effect in this model is captured in an extra argument in the utility function that was not included in the previous case.

Households living within a community get utility not only from the environmental amenities available within their own backyard but also from living next to communities that are green. Each household within a municipality therefore receives benefits not only from the open space that is provided within that municipality but also from all the open space that is provided in all other municipalities surrounding that particular municipality. In deciding on its allocation of open space, municipality i must now take into account the amount of open space provided for in the adjoining municipality j , $j=1,2$ and $i \neq j$.

Therefore in contrast to the first case, municipality i now assumes that the utility of its representative member depends not only on the open space available within its own geographical limit but also on that which is available within the neighboring units (b_j , $i \neq j$) and makes its choice of z_i and b_i given exogenous values of b_j . Each municipality now alters their optimization procedure to account for this spatial interdependence.

Mathematically,

$$(1^{\wedge}) \quad \underset{z_i, b_i, c_i, \lambda}{\text{Max}} L(z_i, b_i, b_j, c_i, \lambda) \equiv U_i(z_i, c_i, \delta_i(b_i A_i, b_j A_j)) + \lambda(Y_i - P_c c_i - r_i z_i)$$

where,

$U_i(z_i, c_i, \delta_i(b_i A_i, b_j A_j))$ is the representative household's utility function;

$\delta_i(b_i A_i, b_j A_j)$ is an index of the environmental amenities from provision of b_i and

b_j amount of open space;

r_i is the bid-rent price for housing which now depends on both b_i and b_j

and everything else is unchanged.

The household utility function now evolves to

$$(2^\wedge) \quad U(z_i, c_i, \delta_i(b_i, b_j)) = \alpha \ln[\delta_i(b_i A_i, b_j A_j) z_i] + (1 - \alpha) \ln c_i$$

As before, this specification again implies that environmental amenities and residential space are substitutable: a small house in a good 'green' locality (where the locality under consideration now extends over the geographical jurisdiction of the neighboring municipality) can provide the same level of utility as a larger house in a less desirable area.

The first order conditions for this maximization problem can be distilled into the following system of equations:

$$(3a^\wedge) \quad \frac{\alpha}{z_i} - \lambda r_i = 0$$

$$(3b^\wedge) \quad \frac{(1 - \alpha)}{c_i} - \lambda P_c = 0$$

$$(3c^\wedge) \quad \frac{\alpha}{\delta_i(b_i A_i, b_j A_j)} \frac{\partial \delta_i(b_i A_i, b_j A_j)}{\partial b_i} - \lambda z_i \frac{\partial r_i}{\partial b_i} = 0$$

$$(3d^\wedge) \quad Y_i - P_c c_i - r_i z_i = 0$$

Solution of this system of equations gives the optimal choice of b_i for municipality i for exogenously determined values of b_j .

Combining equation (3a[^]) and (3b[^]) gives the representative household's demand for residential space z_i .

$$(4a^{\wedge}) \quad z_i = \frac{\alpha Y_i}{r_i}$$

The spatial equilibrium condition for municipality i — i.e. the constraint that demand for residential space must equal supply— implies:

$$(4b^{\wedge}) \quad N_i z_i = (1 - b_i) A_i$$

As before, using (4a[^]) and (4b[^]), the bid-rent price for housing in each municipality is given by:

$$(4c^{\wedge}) \quad r_i = \frac{N_i \alpha Y_i}{(1 - b_i) A_i}$$

Differentiating equation (4c[^]) with respect to b_i and substituting it, together with equation (4b[^]) back into equation (3c[^]) gives the following differential equation:

$$(5^{\wedge}) \quad \frac{\alpha}{\delta_i(b_i A_i, b_j A_j)} \frac{\partial \delta_i(b_i A_i, b_j A_j)}{\partial b_i} - \frac{\alpha}{(1 - b_i)} = 0$$

The only difference between this scenario and the one described in case 1 is that the environmental amenity index for households in the i th municipality now has b_j as an argument. Intuitively, one might expect households to receive greater pleasure from amenities that are closer to their homes than farther away. Based on this, the environmental amenity index is defined to be:

$$(5a^{\wedge}) \quad \delta_i(b_i A_i, b_j A_j) = (b_i A_i + \theta b_j A_j)^{\gamma} \quad 0 < \theta, \gamma < 1,$$

where γ is the elasticity of the environmental amenity index with respect to proportion of land allocated to open space, as before, and θ is the response parameter that determines how exogenously determined values of b_j affect the environmental amenity index for municipality i . Higher the value of θ , the greater will be the amenity benefits derived by municipality 1 from a given amount of open space in municipality 2.

Corresponding to this functional form for the amenity index, equation (5[^]) changes to

$$(5b^{\wedge}) \quad \frac{\alpha\gamma A_i}{b_i A_i + \theta b_j A_j} - \frac{\alpha}{(1 - b_i)} = 0$$

Solution to the above equation gives the proportion of land that municipality i would choose to allocate to open space in equilibrium given predetermined values of b_j :

$$(6^{\wedge}) \quad b_i = \frac{A_i \gamma - \theta b_j A_j}{A_i (1 + \gamma)}$$

As expected, a comparison of (6) and (6[^]) demonstrates that in the latter case, where spillover utility effects are taken into account from a neighboring municipality, land-use planners would choose to allocated less land to open space than when all utility is presumed to come from open space within one's own municipality. The greater the amount of open space available in an adjacent municipality, or the higher the weight placed on that open space, the lower the amount of open space an optimizing decision-maker will choose to allocate to open space in their own municipality. Reaction functions for each of the municipalities under a baseline parameter scenario ($\alpha = \theta = \gamma = 0.5, A_i = A_j = 8000$) are illustrated in Figure 1 below.

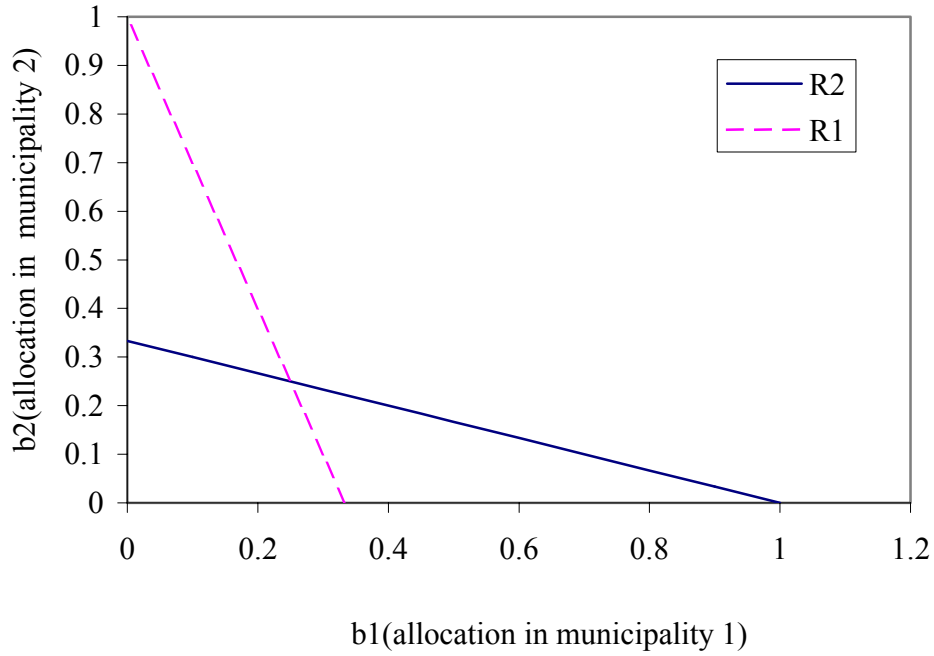


Figure1: Non Strategic equilibrium under symmetry

Equation (6[^]) determines municipality 1's optimal choice of land in open space as a function of it's belief about municipality 2's choice of land in open space; this relationship gives municipality 1's reaction curve (R1), and an analogous relationship determines municipality 2's reaction curve (R2). As both curves are downward sloping, they indicate that b_1 and b_2 are “strategic substitutes”-the more b_i is, the less will be b_j and vice versa. The intersection of the functions constitutes the Nash equilibrium of the land allocation game. The closed form solution for the Nash equilibrium works out to be:

$$b_i = \frac{\gamma((1 + \gamma)A_i - A_j\theta)}{A_i(1 + 2\gamma + \gamma^2 - \theta^2)} \quad i=1,2 ; j=1,2,$$

With the parameters set to the previous baseline values the Nash equilibrium allocation works out to be $b_i=b_j=0.25$.

Case 3: Decision-making that incorporates spill-over utility effects and strategic decision-making

Consideration of the spill-over effects of adjacent open space when making utility-maximizing land-use allocation decisions may be considered a type of strategic decision-making. In this section, however, we are interested in a different type of strategic consideration when making land-use decisions. In case 2, land-use allocation decisions considered the municipalities to be independent; each municipality decided, based on what adjacent municipalities allocated to open space, how much to allocate to open space in order to maximize the utility of their own residents. This structure, however, neglects that municipal boundaries are not impermeable; it is likely that residents will flow across the boundary in response to the different land-use decisions made in adjacent counties. This is a stylized illustration of Tiebout's theory that residents will "vote with their feet" in choosing the residential jurisdiction that offers them their most preferred bundle of services and public goods. Residents on our landscape are not differentiated by their preferences, but the landscape may become differentiated if the two municipalities offer different "bundles" of rent and open space. In this study, we consider a strategic decision-maker to be one who considers the effects of their land-use allocation on the residential choice decisions of adjacent municipalities and allocates land accordingly.

Under this scenario, the land-use planner will again choose an open space allocation to maximize the utility of a representative resident whose utility function

incorporates the spill-over effects of open space in adjacent municipalities. Therefore, equations (1[^]) through (4a[^]) continue to apply to this optimization problem. However, under this scenario, the spatial equilibrium condition that each municipality faces differs. Under this scenario, the land-use planners assume that both municipalities together, rather than simply their own municipality, represent a closed system with exogenously given population size ($\sum_{i=1}^2 N_i$) but endogenously determined utility. Here N_i is the initial or pre-equilibrium population in municipality i prior to any movement. In other words, the planners take into account that once they make a land-use allocation decision, the population between the two municipalities will redistribute so as to equalize utility between them. We are interested in exploring how this consideration will affect a land-use planner's decisions about open space allocation.

To characterize an equilibrium of this sort, we need two further conditions. The first is a modified land constraint, which states that total demand for residential land across the two municipalities post all population movement must be equal to the total supply of land:

$$(4b1^{\wedge}) \quad \sum_i^2 n_i z_i = \sum_i^2 (1-b_i) A_i$$

where n_i is the final size of the population that chooses to live in municipality i or the post equilibrium population of municipality i and where n_i satisfies the following conditions:

$$\begin{aligned} \text{I.} \quad & \sum_{i=1}^2 N_i = \sum_{i=1}^2 n_i \quad . \\ \text{II.} \quad & n_i = \frac{(1-b_i)A_i}{z_i} = \frac{r_i(1-b_i)A_i}{\alpha Y_i} \end{aligned}$$

The first condition reinforces the fact that the system is closed and initial population must match the post equilibrium population. The second condition indicates that in equilibrium there will be no unused space i.e. there is no wastage of land.

A final constraint requires that the utility of representative households in each municipality must be equal. This reflects the fact that under the new equilibrium assumptions, representative households are assumed to have no incentive to relocate to the other municipality.

For our two municipality case, this means

$$(4b2^{\wedge}) \quad \alpha \ln[\delta_1(b_1 A_1, b_2 A_2)z_1] + (1 - \alpha) \ln c_1 = \alpha \ln[\delta_2(b_1 A_1, b_2 A_2)z_2] + (1 - \alpha) \ln c_2$$

As before,

using (4a[^]) and (4b1[^] and 4b2[^]) the bid-rent price for housing can be calculated as:

$$(4c^{\wedge})$$

$$r_i = \frac{\alpha(N_i + N_j)(Y_i - \alpha Y_i)^{1/\alpha} Y_j (Y_j - \alpha Y_j)^{-1/\alpha} \frac{\delta_i}{\delta_j}}{(A_i b_i + A_j b_j - A_i - A_j) \left[\frac{A_i(1 - b_i)(Y_j - \alpha Y_j)^{-1/\alpha} [\delta_i((1 - \alpha)Y_i)^{1/\alpha} - \delta_j Y_i(1 - \alpha)Y_j]^{1/\alpha}}{(A_i b_i + A_j b_j - A_i - A_j)Y_j} - 1 \right]}$$

Differentiating equation (4c[^]) and (5a[^]) with respect to b_i , we substitute it and equations (4b1[^] and 4b2[^]) into equation (3c[^]). This gives us an equation (see Appendix A) that determines the new equilibrium values of b_i given exogenously provided values of b_j . The environmental amenity index denoted by delta is as defined earlier in equation (5a[^]).

An algebraic analytical closed form solution for b_i is not possible in this case, so we calculated numerical solutions to the reaction functions derived from the above



equation. That gives the proportion of land that municipality i would choose to allocate to open space in equilibrium (denoted by b_i^{**}) given predetermined values of (b_j) and certain predetermined (baseline) parameter values for all other relevant parameters. These numerical solutions show how reaction values of b_i vary as b_j varies, under different parameter values of a , γ , and θ and different values of N_i , Y_i and A_i . Both reaction functions are depicted in Fig. 2 for the symmetric case, in which parameters are assigned the following baseline values: $a=0.5$, $\gamma=0.5$, $\theta=0.5$, $Y_i=50,000$, $N_i=6000$, $A_i=8000$.

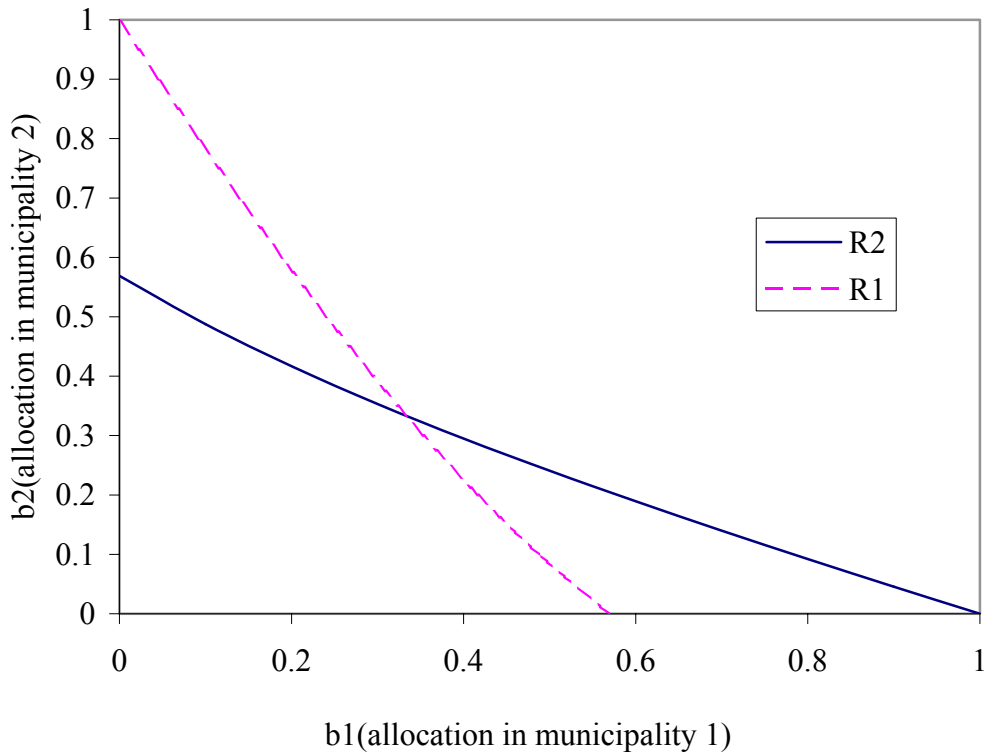


Figure 2. Reaction curves for $\alpha=0.5$, $\gamma=0.5$, and $\theta=0.5$

In the presence of both spillover utility effects and strategic land-allocation behavior, the Nash equilibrium allocation occurs where $b_1=b_2= .33$. This equilibrium involves considerably more land set aside as open space than was set aside as a result of the non-strategic decision-making illustrated in Case 2 and Figure 2.

When a land-use planner acknowledges the mobility of local residents, the allocation of land for every exogenously given value of adjacent open space will be greater than when that mobility is not considered. Under the strategic scenario, the land-use planner is forced to consider not only the effect of their land-use allocation decision on their own residents, but on the residents of neighboring municipalities as well. This can be considered an example of the planner “internalizing a positive externality” which results in more of the good being provided. A land-use planner who fails to take into account the effect of open space on the utility of neighboring municipalities “under provides” open space. This decision results in lower rent in their own municipality because rent is directly proportional to the available open space. Under provision lowers both the amenity effect of open space on rent and the supply restriction for residential land.

Municipal residents however continue to enjoy the benefits of open space from their neighbors. Such a situation is not stable if, as neighbor residents may have the incentive to move into the low-rent municipality, where they will continue to enjoy the benefits of the open space from their old municipality, albeit from slightly farther away. Land-use planners who consider this dynamic in their allocation decisions find that it is strategically optimal to increase their provision of open space, thereby perhaps forestalling major re-distributions of population and rent adjustments.

Under symmetry both municipalities will choose that value of b_i for which the absolute amount of land that is set aside as open space is identical for both municipalities. Then the environmental amenity index faced by all residents, irrespective of where they are located within the two municipalities, will be the same. This is because the

environmental amenity index as designed depends on the absolute amount of land that is allocated to open space. Under symmetry, relocation is no longer a possibility as there is no scope of any transfer of benefits between the two competing needs of amenities and residential space.

It is to be noted that the resulting allocation is the same as the allocation that would result should both municipalities engage in the independent, non-strategic decision-making illustrated in case A. This result emerges from the symmetry of the problem; when two identical municipalities with symmetrical spillover effects maximize their joint utility, the resulting decisions are the same as those they would have made in isolation.

Reaction Functions under asymmetry

In real life, municipalities tend to be dissimilar in their geographical, demographical and income layout. In cases 1 and 2, differences between the municipalities had no effect on a municipality's optimal allocation. When a land-use planner adopts a more regional perspective in their land-use allocation decisions, however, and acknowledges the mobility of all regional residents, differences between municipalities can be quite significant in determining how land should be allocated.

Area Asymmetry

When asymmetry in area is incorporated into the model, the resulting equilibrium values for b_1 and b_2 are different from the previous asymmetrical case. For the case where the area of municipality 2 ($A_2 = 8000$) is greater than the area of municipality 1 (A_1

= 4000), the equilibrium values turn out to be $b_1=0.282$ and $b_2=0.355$. This is illustrated in Figure 3.

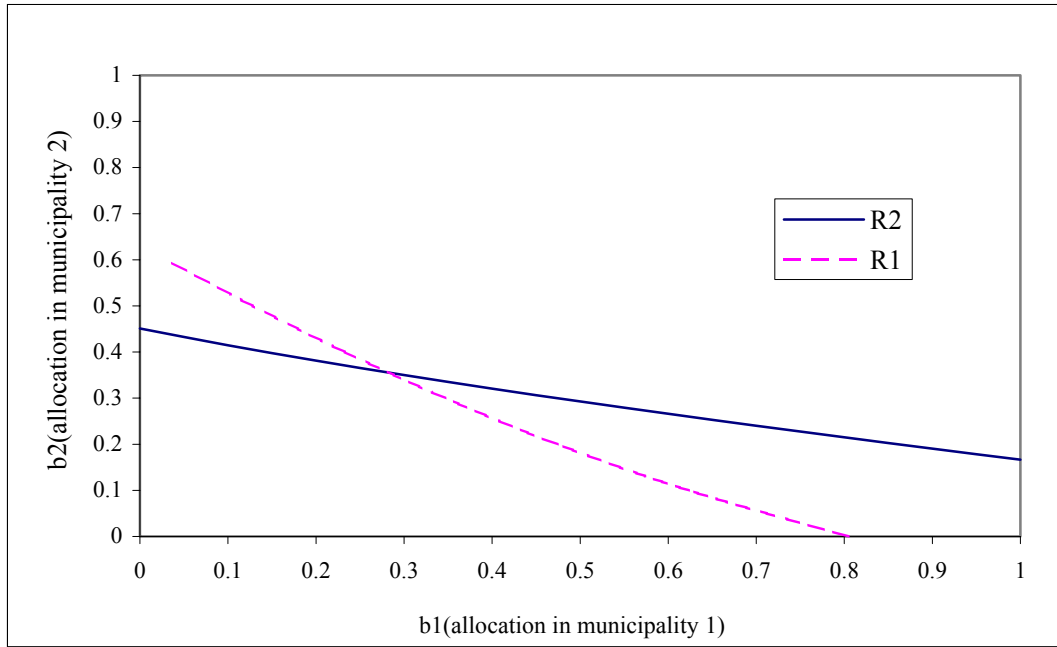


Figure 3. Equilibrium intersection under area asymmetry.

When the municipalities differ significantly in size, the optimization procedure results in the smaller municipality allocating a smaller proportion of land to open space. The presence of strategic interaction is most evident. The land endowment of municipality 2 is so enormous ($A_2= 8000$) that municipality 2 knows that even if municipality 1 was not to allocate any land to open space, it will not provide any more for open space than .45 of its total land endowment. There is therefore ample scope here for the smaller municipality to be strategic about its disadvantage in land endowment. Had they engaged in non-strategic decision making, then both municipalities, taking advantage of the large land endowment, would have ended up with poor allocations to open space, the larger municipality still providing more than the smaller one, though not

as high as it does in the equilibrium that is finally obtained. With population having the option to relocate to the municipality in which they wish to reside, such allocation would not have resulted in an equilibrium.

If under such circumstance, the smaller municipality also provides too low an amount in open space and thereby makes more land available as residential space, the amenity effect on rents being low along with decreased supply restriction on land, the rents will also be much lower in the smaller municipality. This will attract migration of neighboring residents into the smaller municipality.

Increased congestion pressures results in higher rents in the smaller municipality. By allocating less to open space, the municipality has to host additional population without being able to enjoy additional residential space. The best strategy for the smaller municipality, since it cannot match the amenity benefits provided by the larger municipality will be to provide higher residential space. So while the larger municipality specializes in providing open space, the smaller specializes in creating residential space.

Both municipalities are aware that residents will continue to move between the two municipalities till the utility they obtain from either municipality is equal i.e. that is they have no incentive to move from wherever they are located. Residents will continue relocating themselves from the larger municipality 2 to the smaller one till the loss in benefits they obtain from the lower amenities of municipality 1 equate the increase in benefits they obtain from the additional residential space they obtain in municipality 1.

In equilibrium, in terms of absolute amount of land that is set aside as open space, the smaller municipality allows for 1129.08 units of land as open space while municipality 2 allows for a much larger 2843.37 units of land as open space. The

amenity index for municipality 1 ($\delta_1=50.502$) is lower than that of municipality 2 ($\delta_2=58.377$). The amenity effects of rent lead to rents being higher for municipality 2 than municipality 1. However in equilibrium residents of municipality 1 enjoy a greater amount of residential space ($z_1=0.735 > z_2 = 0.636$) than residents of municipality 2. The larger municipality supports the greater portion of the total population in the closed system.

Residents of the larger municipality are therefore paying a higher rent for a much lower amount of residential space but they are willing to do so because by locating in the larger municipality, they are getting to enjoy higher amenity benefits. They trade off additional residential space for increased amenity benefits. On the other hand, the residents of the smaller municipality pay a lower rent than the larger municipality but they get to enjoy more residential space than that they would have enjoyed in the larger municipality. The trade off they make is reduced amenity benefits for additional living space.

The larger portion of the population will locate themselves in the larger municipality while residents who choose to live in the smaller one are the ones who choose the combination of low amenity benefits but more residential space.

Income Asymmetry

Income asymmetry refers to the case where, due to differences in municipal development or proximity to an urban area, representative income levels differ between the two municipalities under consideration. Figure 4 illustrates the case where the income of residents of municipality 1 is increased to \$90,000, with all other parameters held constant as in the base case.

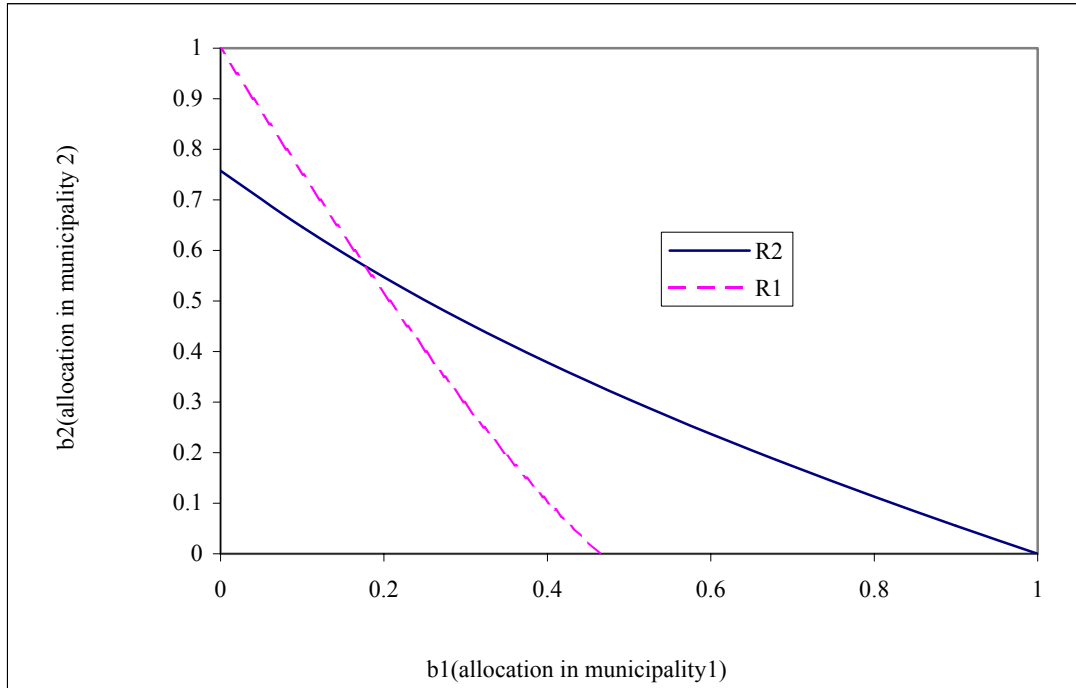


Figure 4. Allocation under income asymmetry.

As a result of asymmetry in income, the Nash equilibrium occurs at an allocation where the relatively less affluent municipality sets aside more open space ($b_2=0.568$) than the relatively richer one ($b_1=0.177$). In terms of absolute land allotted as open space this means that the more affluent allocates only 1417 units of the available 8000 to open space while the less affluent allocates 4551 units of the available 8000 to the same. In this case, we find that the less affluent municipality ends up allocating more to open space in comparison to the more affluent municipality. Similar strategic considerations as those that played under area asymmetry also work here. If in view of the income disadvantage, the less affluent municipality ignoring demographic dynamics tries to over provide residential space for its residents (relative to the equilibrium), it will end up allocating less land to open space. The reduced amenity effect on rent and the reduced

restrictions on supply of residential space will lower rents in the less affluent municipality. This will attract neighboring residents into municipality 2. Congestion will increase rents in municipality 2 in turn. Municipality 2 then faces increased rents without the benefit of additional residential space.

The less affluent will therefore strategically always choose b_i such that the environmental amenity index faced by residents who choose to locate themselves in that municipality is higher than that faced by residents in the more affluent municipality. In equilibrium, the less affluent municipality 2 enjoys a higher amenity index ($\delta_2=72.524 > \delta_1=60.768$), higher per unit residential space ($z_2=1.114 > z_1=0.739$) and faces a lower rent than the more affluent municipality 2. Municipality 1 provides a much lower combination of amenity benefits and residential space but it allows the residents more income to be spent on 'all other goods' or the composite good of our model ($c_1=45000 > c_2=25000$). In equilibrium therefore the larger portion of the initial population settles in the more affluent municipality, the demographic effect on rent resulting in a higher rent for lower amenity benefits and lower residential space but greater consumption of 'all other goods'.

Extensions

Further extensions planned include foremost an extension of the two-municipality model into a multi municipality model so that a better and more realistic regional perspective can be obtained. The effect of varying initial endowment of open space on the land planners' decisions will also be considered.

Conclusions

Our results suggest that when land-use planners adopt a more regional perspective in their land allocation decisions, their utility optimization process results in greater consideration of open space benefits and a greater allocation of land to open space. This regional perspective is the logical consequence of the assumption that discontinuous utility levels are unlikely to exist on an otherwise homogeneous landscape in which residents are free to relocate. Each municipality's optimal allocation is therefore also sensitive to asymmetries in characteristics such as municipal area or income, or any other characteristic that affects the utility level of current residents. We are currently working on more in-depth analysis of the effects of municipal asymmetries on asymmetries in optimal open space allocation patterns, as well as on extensions of the model to multiple municipalities.

Appendix A

$$\alpha A_i \left[\frac{\gamma}{A_i b_i + \theta A_j b_j} + \frac{(A_i b_i + \theta A_j b_j)^\gamma \left(\frac{y_i - \alpha y_i}{p} \right)^{\frac{1}{\alpha}} y_j + \frac{A_j^\gamma \gamma (b_j - 1) b_j (A_j b_j + \theta A_i b_i)^{\gamma-1} (\theta^2 - 1) y_i \left(\frac{y_j - \alpha y_j}{p} \right)^{\frac{1}{\alpha}}}{A_i b_i + \theta A_j b_j}}{A_i (b_i - 1) (A_i b_i + \theta A_j b_j)^\gamma \left(\frac{y_i - \alpha y_i}{p} \right)^{\frac{1}{\alpha}} y_j + A_j (b_j - 1) (A_j b_j + \theta A_i b_i)^\gamma y_i \left(\frac{y_j - \alpha y_j}{p} \right)^{\frac{1}{\alpha}}} \right] = 0$$

This equation implicitly defines cell i's response to an exogenously given value of b_j . Solving two equations simultaneously for cell i's response to b_j and cell j's response to b_i generates the solution that represents the equilibrium solution in this analysis.

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