Development Patterns and the Recreation Value of Amenities

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1 Introduction

Public open space offers many benefits to the residents of cities including recreational opportunities, environmental and ecosystem benefits, and visual amenities. Evidence that the benefits of open space are substantial is clear from the support the public has given to ballot measures to conserve, create, and rehabilitate open space. In 2003 and 2002, ballot measures generated \$1.8 billion and \$10 billion respectively for local and state land conservation bringing the full tally of funds since 2000 to \$16.8 billion (Land Trust Alliance, 2004).

A substantial proportion of the benefits from public open space are from recreation since an enormous number of people in the United States engage in basic outdoor recreation. Eighty-three percent of the 250 million people in the United States do walking for pleasure, 74% have family gatherings, 54% do picnicking, 52% do sightseeing, and 45% go wildlife viewing. Further, participation in these activities is growing. In the last nine years, 40 million more people began walking for pleasure, family gathering grew by 36 million, picnicking grew by 20 million, and sightseeing grew by 24 million (National Survey on Recreation and the Environment, 2003).

Unfortunately, there is an increasing level of public open space loss each year. In the past 20 years, thirty-four million acres were converted to developed uses - an area roughly the size of Illinois. From 1997 to 2001, forty-six percent of the converted land was forested, twenty percent was cropland, and sixteen percent was pastureland (U.S. Department of Agriculture). The significant benefits that the public receives from open space coupled with the steady demise of public open space around urban areas is likely to make issues about open space an increasingly more important topic for environmental policy and research.

Most commonly, open space refers to either public or private land that is undeveloped. However, different demographics of people have different views of the definition of open space. While rural residents only view farmland as open space if the land is publicly accessible, farmers view all farmland as open space providing wildlife habitat and clean air (ARE Update, May/June 2003). Open space in my research is public open space since the public is assumed able to do recreation on the land. There is no debate among the different demographic groups that public open space is open space.

Economists have examined the influence of open space on urban areas since the late 1970s. Economic theory models examining open space largely fall into two categories. The first category is the emphasis taken in this paper. This category uses the monocentric city model to examine the interaction between urban spatial structure and open space (Polinsky and Shavell 1976; Yang and Fujita 1983; Fujita 1989; Yang 1990; Lee and Fujita 1997; Wu and Plantinga 2003). These studies put open space of different sizes and shapes into a city with an influential Central Business District (CBD) to see how land rents, lot sizes, and the area of the city change. The second category examines competition among the municipalities in the provision of public goods, such as open space, to maximize the utility of its residents (Tiebout 1956; Correll, Lillydahl et al. 1978; Wile 1978; Marshall 2004). Residents move between municipalities depending on their preference for either a larger house or more open space.

A significant strand of empirical research on open space examines the influence of open space on housing prices. The hedonic property price method has been applied to the housing market to learn the value of proximity to urban parks and forests (Weicher and Zerbst February 1973; Tyrvainen and Miettinen March 2000), lakes and rivers (Lansford and Jones July 1995; Leggett and Bockstael March 2000), and urban wetlands (Doss and Taff 1996; Mahan, Polasky et al. 2000). The marginal willingness to pay to have more of or live closer to these different types of open space is identified.

Recently stated preference techniques, such as contingent valuation and conjoint analysis, have been used to learn about the interactions between open space, housing values, and residential development (Johnston, Swallow et al. 2002; Roe, Irwin et al. 2004). Further, there is a trend towards analyzing the general equilibrium relationships determining the urban spatial structure of a city. By modeling housing prices, development densities and house sizes as a system, both estimates and inferences are improved (Wu, Adams et al. 2004).

2 Model

The basic model for investigating the influence of amenities, including the recreation value of those amenities, on residential development and density is examined in this chapter. Extensions to the basic model are presented at the end of the chapter.

In the Alonso-Muth-Mills tradition, the urban area containing the residential developments of interest has a single central business district (CBD) which households commute to for employment. The households have identical incomes and preferences, and the commuting cost depends on the distance between the residence and the CBD. Land developers utilize identical constant returns to scale technology for residential development. The market for residential development is perfectly competitive, and the development profits are zero.

Households choose a residential location from preferences defined over home size, *recreation* at the amenities, the ambient level of the amenities, and a non-housing (numeraire) good with the commuting cost represented in the budget constraint. Land developers choose the location, home size, and density of development to maximize profits. The interaction of the preferences of households for housing and the profit motives of the land developers results in a spatial market equilibrium of housing prices, which equates the demand for and supply of housing at each location.

The spatial market equilibrium is influenced by the choice of whether to model a city as open or closed. An open city model assumes that households migrate between cities to maintain an exogenous level of utility. The closed city model assumes that the population of the households is fixed and the utility of the households fluctuate in response to changes in the framework of the city.

The choice of an open or closed city model hinges on whether the urban model is meant to represent a short or long run spatial market equilibrium. The closed city model is better suited for short run analysis since the population of a city is largely fixed in the short run while the open city model is better suited for the long run analysis where households have had the chance to migrate across cities. Since the influence of policies on both the short and long run equilibriums of a city is of interest, both the closed and open city models are examined.

2.1 The household location decision

The landscape of the model is represented by the Cartesian plane $(u, v) \in \mathbf{R}^2$, and the CBD is represented by a single point located at the origin (0,0). The u-axis is the west-east direction in miles, and the v-axis is the south-north direction in miles. All of the landscape other than the origin is available for residential development.

The population of households has identical income and preferences. A household located at the residential site (u, v) has a commuting distance in miles to the CBD of $x(u,v) = \sqrt{u^2 + v^2}$. The distance of most commutes is longer than the shortest distance between a residential site and the CBD. However, the common use of highways in urban areas for commuting makes the assumption not a bad approximation.

Residential sites are differentiated by their proximity to the amenities. Heterogeneity in the ambient level of amenities is represented by the distribution function $a((u,v), rd)$ defined over the landscape. The proximity and physical size, represented by the radius rd, of the circular amenities near the residential site (u,v) influences the magnitude of $a((u,v), rd)$. The magnitude of $a((u,v), rd)$ asymptotically approaches the base value of 1 for residential sites sufficiently far away from all of the amenities. Examples of how the proximity of an amenity to a residential site influences the ambient level of amenities at the site include improvements in views of the amenities from the site and cleaner air at the site.

Heterogeneity in the cost of a recreation trip over the landscape is represented in the household budget constraint by $k(u,v)$. The proximity of the amenity closest to the residential site (u,v) influences the magnitude of $k(u,v)$ since trips require travel costs. Since each amenity is identical by assumption, the proximity of amenities other than the amenity closest to the residential site (u,v) does not influence the magnitude of $k(u,v)$.

The magnitude of $k(u,v)$ does not rise proportionally with distance from an amenity since the city streets usually traversed to reach an amenity often contain additional barriers to travel. For instance, a household twice the distance away from an amenity incurs more than twice the travel cost for a recreation trip. Households at residential sites directly adjacent to an amenity have zero travel cost for a recreation trip, but there is an admission fee, af, for access to the amenity.

Each household takes the price per square foot of residential space, $p(u,v)$, the commuting distance in miles, $x(u,v)$, the ambient level of amenities, $a(u,v)$, and the cost of a recreation trip, $k(u,v)$, as given. Accordingly, by selecting the residential site (u,v), the household is simultaneously choosing a housing price, a commuting distance, an ambient level of amenities, and a cost of a recreation trip.

2.1.1 Positive number of recreation trips

Each household chooses among residential space q, recreation trips T, residential site (u,v), and a numeraire "all other consumption" good g to maximize utility $U(q, T, g, a((u,v), rd))$. The budget constraint of the household is $p(u,v)q + k(u,v)T + g + tx(u,v) = y$, where y is the gross household income, and t is the round-trip commuting cost per mile. The utility function specification chosen is Stone-Geary since the demand for recreation trips is believed to have a finite choke price.

$$U(q, T, g, a((u,v), rd)) = a((u,v), rd)^{\gamma} q^{\alpha} (T+1)^{\beta} g^{1-\alpha-\beta}, \tag{1}$$
$$\text{where } 0 < \alpha < 1,\ 0 < \beta < 1, \text{and } \gamma > 0.$$

The first order conditions for the utility maximization problem specify the optimal choices of residential space, recreation trips, and the numeraire good for the locations where households take a positive number of recreation trips:

$$q^*(u,v) = \frac{\alpha(y - tx(u,v) + k(u,v))}{p(u,v)} \tag{2}$$

$$T^*(u,v) = \frac{\beta(y - tx(u,v) + k(u,v))}{k(u,v)} - 1 \tag{3}$$

$$g^*(u,v) = (y - tx(u,v) + k(u,v))(1 - \alpha - \beta) \tag{4}$$

Competition for housing bids up the prices of housing in desirable locations. In the closed city, utility adjusts to changes in the framework of the city. However, in equilibrium, household utility $\overline{V}$ is identical across households. Households far away from the CBD have longer commutes but pay less for housing than households closer to the CBD. In the open city, the equilibrium utility is exogenous from the standpoint of a single city since migration equalizes utility $\overline{V}$ across cities.

Substituting (2)-(4) into the utility function (1) and setting utility equal to $\overline{V}$ yields the bid price of housing for the locations where households take a positive number of recreation trips:

$$p^*(u,v) = \left[\frac{a((u,v), rd)^{\gamma} \alpha^{\alpha} (1-\alpha-\beta)^{1-\alpha-\beta} (y - tx(u,v) + k(u,v))}{\overline{V}} \left(\frac{\beta}{k(u,v)} \right)^{\beta} \right]^{\frac{1}{\alpha}} \tag{5}$$

The bid price equation (5) reveals the influence of amenities on the household's maximum willingness to pay for housing at location (u,v). The heterogeneity in the ambient level of amenities across the landscape, represented by $a((u,v),rd)^\gamma$, directly influences the bid price of housing. If the ambient level of amenities is high enough, households may be willing to pay more for housing close to an amenity than housing close to the CBD.

The proportion of household income spent after commuting costs on recreation, β, and the cost per trip of recreation, $k(u,v)$, operate together to influence the bid price of housing. If there is spatial variation in $k(u,v)$, then the cost per trip of recreation produces spatial variation in the bid price of housing. If there is no spatial variation in the cost per trip, $k(u,v) = k$, then all households benefit(lose) equally from a fall(rise) in the cost per trip of recreation, and no spatial variation is produced from the recreation costs on the bid price of housing.

The magnitude of the proportion of household spending on recreation, i.e β, influences the sensitivity of housing prices to spatial variation in the cost per trip of recreation. For instance, if recreation is a large proportion of household spending, i.e. high β, then even slight spatial variation in the cost per trip of recreation produces significant spatial variation in the bid price of housing. Naturally, changes in recreation costs have a stronger influence on housing prices if recreation is a large component of household spending. The issues surrounding the influence of amenities on housing prices are analyzed in more detail later in the chapter.

2.1.2 Zero recreation trips

For households at a distance far enough away from every amenity, zero recreation trips to any amenity is optimal. As the distance from an amenity increases, the travel cost component of the cost per trip rises until the choke price of recreation trips is reached. Setting (3) equal to zero and rearranging yields the choke price of recreation trips, $\hat{k}(u,v) = \beta(y - tx(u,v) + k(u,v))$. The proportion of household spending on recreation defines the choke price. A higher proportion of household spending on recreation implies households at greater distances from an amenity will still take recreation trips.

If the cost per trip exceeds $\hat{k}(u,v)$, then no recreation trips are taken by the household, and the utility maximization problem of the household changes. Now, the household maximizes $U(q,g,a((u,v),rd)) = a((u,v),rd)^\gamma q^\alpha g^{1-\alpha-\beta}$ subject to $p(u,v)q + g + tx(u,v) = y$.

From the first order conditions of the new utility maximization problem and from setting utility equal to $\overline{V}$, the bid price of housing for the locations where households take zero recreation trips is:

$$p^*(u,v) = \left[\frac{a((u,v),rd)^\gamma \alpha^\alpha (1-\alpha-\beta)^{1-\alpha-\beta}}{\overline{V}} \left(\frac{y - tx(u,v)}{1-\beta} \right)^{1-\beta} \right]^{\frac{1}{\alpha}}. \quad (6)$$

The cost of a recreation trip $k(u,v)$ no longer influences the bid price of housing equation (6). However, the preference for recreation still influences the bid price of housing through the parameter β. The ambient level of amenities potentially still influences the bid price of housing although the influence is likely non-existent since the ambient level of amenities disappears very quickly with distance from an amenity.

2.2 The residential development decision

The model of the supply side of residential development comes from Wu and Plantinga (2003). Residential developers choose the location (u,v) and density s (total residential space per acre) of development to maximize profits per acre $\pi((u,v),s)$. The profit per acre $\pi((u,v),s) = p(u,v)s - c((u,v),s)$, where $p(u,v)$ is the price of residential space and $c((u,v),s) = r(u,v) + c(s)$ are total costs that include the price per acre of land $r(u,v)$ and the building costs $c(s)$. The building costs $c(s) = c_0 + s^\delta$ include laying the foundation c_0 and the construction s^δ, with $\delta > 1$.

The first order condition for profit maximization implies that

$$s^*(u,v) = [p^{**}(u,v)/\delta]^{1/\delta}. \quad (7)$$

Equation (7) shows that the density of housing at (u,v) increases with the price of residential space at (u,v). $p^{**}(u,v)$ is the minimum selling price for residential space at (u,v). Combining together equation (7) with the knowledge that profits must be zero in competitive market equilibrium obtains the developer's bid price for land

$$r^*(u,v) = \left[\frac{(\delta-1)^{\frac{\delta-1}{\delta}}}{\delta} \, p^{**}(u,v) \right]^{\frac{\delta}{\delta-1}} - c_0. \quad (8)$$

Equation (8) shows that the price of land at (u,v) increases with the price of residential space at (u,v).

2.3 Conditions of spatial market equilibrium

Five conditions combining the household location decision and residential development decision characterize the spatial market equilibrium. The first equilibrium condition is that housing prices are bid up until no household has the incentive to move. This condition is satisfied when housing prices are represented by (5) since the household's bid function is the maximum willingness to pay for housing.

The second equilibrium condition is that at each location the price households are willing to pay for housing equals the price developers are willing to accept for housing. This second condition is satisfied when $p^*(u,v) = p^{**}(u,v)$. The third equilibrium condition is that land price are bid up until the profits are zero everywhere and developers are indifferent to the location of development. The third condition is satisfied when land prices are represented by (8) since the developer's bid function is the maximum willing to pay for land.

The fourth equilibrium condition is that all households are accommodated such that the total supply of housing equals the total demand of housing. The household density $n(u,v)$ (households per acre) is the development density (residential space per acre) divided by the housing demand per household (residential space per household). Since land is developed if the developer's bid price for land exceeds the agricultural rent r_{ag}, the developed area is the set $\{(u,v)|r^*(u,v) \geq r_{ag}\}$.

$$\int\int_{r^*(u,v)>r_{ag}} 640\frac{s^*(u,v)}{q^*(u,v)}\, du\; dv = N, \tag{9}$$

determines the equilibrium utility of the households $\overline{V}$ in the closed city model or the total number of households N in the open city model. The 640 is the conversion factor from acres to square miles since household density is per acre but u and v are measured in miles.

The fifth equilibrium condition is that the city boundary is the set of locations where the land price equals the agricultural rent, $\{(u,v)|r^*(u,v) = r_{ag}\}$.

The mechanisms of the model are illustrated here briefly through comparative statics. First, suppose an open city model. A rise in income, a fall in commuting costs, or a fall in recreation costs cause in-migration and increases in housing and land prices throughout the city. To convince yourself, note from (5) and (8) that $\partial p^*/\partial y > 0$, $\partial p^*/\partial t < 0$, $\partial r^*/\partial y > 0$, and $\partial r^*/\partial t < 0$

for any (u,v), and $\partial p^*/\partial k < 0$ and $\partial r^*/\partial k < 0$ for all (u,v) where there is a positive number of recreation trips. Wherever housing prices increase, (2) and (7) illustrate that the demand for residential space q falls and the density of development s rises. The rise in land prices increases the developed area defined by $\{(u,v)|r^*(u,v) \geq r_{ag}\}$. Bringing these results together indicates that the left-hand side of (9) increases, and the number of households N must rise to restore equilibrium.

Now, suppose a closed city model. Since the level of utility readjusts in response to changes in the parameters, the mechanics of the closed city version of the model are a good deal more complex. The comparative statics were first fully laid out by William Wheaton (1974). A rise in income, a fall in commuting costs, or a fall in the recreation costs (for the special case of no spatial variation in the recreation costs, i.e. $k(u,v) = k$) cause the utility level to rise, the developed area to increase, and the housing and land price gradients to flatten.

Following the logic from the open city model derivation, to roughly illustrate the derivation by Wheaton of the closed city model, a rise in income, a fall in commuting costs, or a fall in recreation costs make housing and land prices rise, the demand for residential space fall, the density of development rise, and the developed area expand. The difference from the open city model is that the number of households is fixed, and the utility level imbedded within the left-hand side of (9) adjusts to restore equilibrium.

A rise of the utility level simultaneously increases the demand for residential space and lowers the density of development in order to equate the left-hand side of (9) to N. Note from (5) that the rise in the utility level causes housing and land prices to fall faster near the city center than at the city boundary since the numerator of (5) is larger near the city center. The result is that the housing and land price gradients flatten. The fall in land prices at the city boundary in the utility adjustment process suggests that the developed area expands less than in open city model.

The comparative statics for a fall in the recreation costs, where there is spatial variation in the recreation costs, for the closed city case are not fully worked out. The areas of the city where recreation costs are important are likely to exhibit a greater expansion in the developed area and flatter housing and land price gradients. The areas of the city where recreation costs have no importance are likely to exhibit a contraction in developed area and a steepening of housing and land price gradients. However, these predictions are based upon economic intuition rather than analytical derivation, and the numerical simulations later in this chapter better illustrate the influence of recreation costs on the urban spatial structure.

2.4 Amenities, recreation, and property values in an open city – A general formulation

The specification of a utility function's functional form is necessary for the simulations, but further insights into the influence of amenities and recreation on urban spatial structure are possible with a fully general utility function.

By substituting the optimal choices of residential space, recreation trips, and the numeraire good into the direct utility function U, the indirect utility function V expressed as a function of the price of residential space, income net of transportation costs, amenities, and the cost of recreation at that location is formed. In an open city, the common level of utility $\overline{V}$ is exogenous since households are free to migrate at no cost between cities.

$$\overline{V} = V(p(u,v), y - tx(u,v), a(u,v), k(u,v)). \tag{10}$$

Utility is equalized because the price of a square foot of housing adjusts across locations to leave households equally well off. The higher the attractiveness of a location the higher the price of a square foot of housing at that location to equalize utility. The attractiveness of a location depends on its proximity to the CBD and other amenities. Differentiating (10) with respect to u or v and then solving for p', the housing price gradient is,

$$p' = \frac{V_2}{V_1}\, tx' - \frac{V_3}{V_1}\, a' - \frac{V_4}{V_1}\, k', \tag{11}$$

where the subscripts denote partial derivatives.

$V_1 < 0$, since, ceteris paribus, an increase in the price of a square foot of housing decreases utility;

$V_2 > 0$, since, ceteris paribus, an increase in income net commuting costs increases utility;

$V_3 > 0$, since, ceteris paribus, an increase in amenities increase utility;

$V_4 < 0$, since, ceteris paribus, an increase in the cost of recreation decreases utility.

The housing price gradient may be either upward or downward sloping. The first term, which is negative since $x' > 0$, shows the rate at which the housing price gradient slopes downward, as one moves further from the CBD, to keep housing attractive enough to compensate for the increase in commuting costs. The second term, which is the same sign as a', expresses the change in amenities and their effect on utility. The higher that the marginal utility of amenities, V_3, is the more that housing prices adjust to a change in the level of amenities. A significantly large change in a' may result in an upward sloping housing price gradient over some range.

The third term, which is the opposite sign of k', expresses the change in the recreation costs and their effect on utility. The higher the marginal utility of recreation, V_4, is the more that housing prices adjust to a change in the level of recreation costs. Since amenities fall and the recreation costs rise with distance from an amenity, the sign of a' and k' are opposite each other. A moderate change in a' and k' may result in a housing price gradient with a positive slope over some range since the second and third terms of (11) complement each other.

The condition to observe an upward sloping housing price gradient while moving further away from the CBD is,

$$V_3\ a' + V_4\ k' > V_2\ tx'. \tag{12}$$

Equation (12) states that the housing price gradient rises if a movement away from the CBD results in a greater utility gain from improved amenities and lower recreation costs than the loss of utility from higher commuting costs.

The demand for residential space for this general utility function is derived from Roy's Identity,

$$q(u,v) = -\frac{\partial V/\partial p}{\partial V/\partial y} = -\frac{V_1(p(u,v), y - tx(u,v), a(u,v), k(u,v))}{V_2(p(u,v), y - tx(u,v), a(u,v), k(u,v))}. \tag{13}$$

From (11) a fall in recreation costs everywhere shifts up the housing price gradient. However, (13) illustrates that the demand for housing could remain unchanged or even rise if the fall in recreation costs outweighs the rise in the price of residential space. However, the separability of utility used for the simulations, since the functional form is Stone-Geary, ensures that a fall in recreation costs results in a decline in the demand for housing.

Equation (11) illustrates that in an open city the price of housing at any location depends only on the level of amenities and the costs of recreation *at that location.* The reason is that in an open city each location yields the fixed level of utility $\overline{V}$. Since the level of amenities and recreation costs at other locations do not influence the level of utility, the price of housing at a particular location is only influenced by the level of amenities and recreation costs at that location. Since the supply of housing of a single city is tiny in comparison to the supply of housing available across all cities, a change in the supply of housing at other locations of a city brought about by a change in the level of amenities or the recreation costs does not influence the price of housing at locations where no change in the level of amenities or the recreation costs occurred.

If sufficient assumptions are made about preferences, information about the preferences for amenities and recreation may be obtained from the equilibrium bid price for housing. Consider the case of the Stone-Geary utility for the simulations. The bid function (5) can be rewritten as,

$$p^*(u,v) = \left(\frac{C}{\overline{V}}\right)^{\frac{1}{\alpha}} a((u,v),rd)^{\frac{\gamma}{\alpha}} \; [\, y - tx(u,v) + k(u,v)]^{\frac{1}{\alpha}} \; k(u,v)^{-\frac{\beta}{\alpha}}, \quad (14)$$

where $C = \alpha^\alpha \beta^\beta (1-\alpha-\beta)^{1-\alpha-\beta}$. To see that these parameters can be identified by standard estimation techniques, take natural logs to convert (14) into a linear relationship,

$$p^*_{uv} = m_0 + m_1 y_{uv} + m_2 a_{uv} + m_3 k_{uv}, \quad (15)$$

where

$$\begin{array}{ll} p_{uv} = log\ p(u,v), & y_{uv} = log\ (\ y - tx(u,v) + k(u,v)), \\ a_{uv} = log\ a(u,v), & k_{uv} = log\ k(u,v), \\ m_0 = (1/\alpha)\ log\ (C/\overline{V}), & m_1 = 1/\alpha, \\ m_2 = \gamma/\alpha, & m_3 = -\beta/\alpha. \end{array}$$

Equation (15) expresses the determinants of the equilibrium bid price of housing in the form of a regression equation. The coefficients estimates of m_1, m_2, and m_3 together allow for identification of α, γ, and β.

2.5 Amenities, recreation, and property values in a closed city – A general formulation

In a closed city, the population is fixed, and the common level of utility $\overline{\overline{V}}$ is endogenous since households are no longer able to migrate between cities. The equilibrium bid price condition similar to (10) is,

$$\overline{\overline{V}} = V(p(u,v), y - tx(u,v), a(u,v), k(u,v)). \tag{16}$$

A fall in recreation costs may lead to either an increase or decrease in $\overline{\overline{V}}$. A decrease in $\overline{\overline{V}}$ would occur if a fall in recreation costs made the demand for housing increase enough (despite the rise in housing prices) that residential density declines throughout the city. A possible explanation is that recreation and housing are complements. However, the expectation is that a fall in recreation costs would increase $\overline{\overline{V}}$ since a rise in housing prices typically increases residential density. A sufficient condition to have $\overline{\overline{V}}$ increase is that utility is separable. The Stone-Geary specification of utility used for the simulations is a separable form of utility. Thus, for the simulations of the closed city, a fall in recreation costs results in an increase of $\overline{\overline{V}}$. Unlike the open city case, the price of housing at $(\overline{u}, \overline{v})$ is influenced by a change in the recreation costs anywhere in the city, through their effect on $\overline{\overline{V}}$.

Suppose two scenarios for a change in recreation costs. The first scenario has recreation costs fall everywhere except at $(\overline{u}, \overline{v})$. The second has recreation costs fall everywhere, including at $(\overline{u}, \overline{v})$. For both scenarios, the resulting change in housing prices at $(\overline{u}, \overline{v})$ is examined.

A fall in recreation costs everywhere except at $(\overline{u}, \overline{v})$ increases $\overline{\overline{V}}$ causing $p(\overline{u}, \overline{v})$ to fall. All locations except $(\overline{u}, \overline{v})$ have become relatively more attractive. Since households are drawn away from $(\overline{u}, \overline{v})$, $p(\overline{u}, \overline{v})$ must fall to restore equilibrium. The fall in $p(\overline{u}, \overline{v})$ because of the rise in $\overline{\overline{V}}$ is the indirect effect of recreation costs on $p(\overline{u}, \overline{v})$. Suppose that recreation costs fall at $(\overline{u}, \overline{v})$ too. The rise in $p(\overline{u}, \overline{v})$ that results is the direct effect of recreation costs on $p(\overline{u}, \overline{v})$.

A fall in recreation cost everywhere, including at $(\overline{u}, \overline{v})$, is represented through a shift parameter ρ such that $k_\rho = \partial k((u,v),\rho)/\partial\rho < 0$, for all (u,v). Since utility is endogenous in a closed city, $\overline{\overline{V}}$ is dependent on recreation costs throughout the city, and is thus a function of ρ. For the Stone-Geary form of utility, a downward shift in recreation costs raises $\overline{\overline{V}}$, i.e. $\overline{\overline{V}}_\rho > 0$. The influence of a downward shift in recreation costs on the bid price for housing is illustrated by differentiating (15) with respect to ρ. The result is that

$$\partial p(u,v)/\partial \rho > 0 \quad \text{if} \quad \varepsilon_{y\rho} k_\rho - \beta \varepsilon_{k\rho} > \varepsilon_{\overline{\overline{V}}\rho}\ , \tag{17}$$

where $\varepsilon_{y\rho} = k_\rho \left(\frac{\rho}{(y - tx(u,v) + k(u,v))} \right)$, $\varepsilon_{k\rho} = k_\rho \left(\frac{\rho}{k} \right)$, and $\varepsilon_{\overline{\overline{V}}\rho} = \overline{\overline{V}}_\rho \left(\frac{\rho}{\overline{\overline{V}}} \right)$.

A downward shift in recreation costs raises the bid price for housing if the elasticity of recreation costs with respect to ρ (weighted by β) exceeds the elasticity of utility with respect to ρ. The elasticity of net income with respect to ρ is close to zero since recreation costs are a tiny share of net income. The sensitivity of recreation costs to ρ, that is $\varepsilon_{k\rho}$, and the importance of recreation β embody together the direct effect of recreation costs on housing prices. The sensitivity of the common level of utility to ρ, that is $\varepsilon_{\overline{\overline{V}}\rho}$, embodies the indirect effect of recreation costs on housing prices. At each (u,v), these effects work in opposite directions to determine how housing bid prices change in response to an increase in ρ.

Less information about the preferences for amenities and recreation is available from the equilibrium bid price of housing if a closed city is assumed. There is an identification problem since net income, amenities, and recreation costs all change the common level of utility, $\overline{\overline{V}}$. Similar to (15) the new linear relationship is

$$p^*_{uv} = m_0^{'} + m_1^{'} y_{uv} + m_2^{'} a_{uv} + m_3^{'} k_{uv}, \tag{18}$$

where

$$\begin{aligned} p_{uv} &= log\ p(u,v), & y_{uv} &= log\ (\ y - tx(u,v) + k(u,v)), \\ a_{uv} &= log\ a(u,v), & k_{uv} &= log\ k(u,v), \\ m_0^{'} &= (1/\alpha)\ log\ (C/\overline{\overline{V}}), & m_1^{'} &= 1/\alpha, \\ m_2^{'} &= \gamma/\alpha, & m_3^{'} &= -\beta/\alpha. \end{aligned}$$

Since $\overline{\overline{V}}$ is endogenous, the term $m_0^{'}$ is no longer a constant. Any incorrect measurement of $m_0^{'}$ generates bias in the coefficient estimates since the error is correlated with y_{uv}, a_{uv}, and k_{uv}. Although $m_1^{'}$, $m_2^{'}$, and $m_3^{'}$ capture the direct effects of net income, amenities, and recreation costs on housing bid prices, the indirect effect through $m_0^{'}$ is lost. The biased coefficient estimates for $m_1^{'}$, $m_2^{'}$, and $m_3^{'}$ prevent the identification of α, γ, and β.

There is no way to know from standard real estate data if the city is closed or open. The cost of mobility between cities is the best measure of the degree of openness of a city. Unfortunately, since the cost of mobility varies across households, only those unobservables about the households could determine if the data reflect a closed or open city.

3 Amenities, recreation, and property values in a closed city – Simulations

Simulations of the spatial city model with amenities enable an examination of the effect of open space policies on urban spatial structure. A government agency purchases land for public open space. The land is immediately perceived by the public as an amenity. Since the residents of the city have public access to the open space, one principal type of benefit to the households from the open space is recreation. Another principal type of benefit is ambient amenities in the form of pleasant views of the open space or cleaner air from the vegetation at the open space. The agency is able to change the quality of the open space in ways that influence particular types of benefits (e.g., recreation) but not others (e.g., the views of the open space).

The comparison of spatial equilibria for a city with no open space and for cities with open spaces in different locations identifies how different spatial configurations of open space influence recreation and urban spatial structure. Two types of spatial configurations of open space are explored. In the first type, the land acquired for public open spaces is at different proximities to each other. The first type of open space locations enable an investigation of the importance public open space concentration. In the second type, the land acquired for public open spaces is at different proximities to the CBD. In this case, the importance of public open spaces outside the city boundary for development density and recreation is examined. Both types of spatial configurations of open space are simulated with and without the presence of ambient amenities. The comparison of the spatial equilibria for cities with and without ambient amenities identifies how recreation benefits versus ambient amenity benefits influence recreation and urban spatial structure.

Table 1 lists the parameter values used in the simulations. Since the specification of household utility and the developer's cost function are largely for analytical convenience, the parameter values are to a certain extent arbitrarily chosen to help illustrate the influence of public open spaces on urban spatial structure and recreation. However, most of the parameter values are consistent with empirical evidence from the US. Since households spend about 30-35% of income on housing and 20-25% of income on commuting, setting $\alpha = 0.4$ is appropriate since households spend about 40% of income after commuting costs on housing. The intra-city travel cost per mile for recreation trips is consistent with the annual commuting cost per mile. The difference between the travel costs is because travel for commuting is often along freeways while intra-city travel is often along streets with traffic lights. The parameter value units are based upon the assumption that each point (u, v) on the landscape is an acre of land.

In the spatial equilibrium of a city with no public open space, the city is circular and all the land within the city boundary is developed. There are no recreation opportunities for households, and the ambient amenities are uniformly distributed across the city and normalized to one (i.e., $a(u, v) = 1$). The city is circular since land prices depend only on the distance to the CBD. In panel (a) of Figure 1, the city with no public open space is shown. For all the figures, the contours represent the level of the land prices within the city. Recall that housing and land prices are directly related to each other through (8). The darkest contour indicates the region of the highest land prices while the lighter contours indicate progressively lower land prices. The white contours represents undeveloped land.

In the spatial equilibria of cities with public open space, the city no longer has a circular shape since land prices depend on the distance to the amenities as well as the CBD. Not all the land within the city boundary is developed since some land is public open space surrounded by development.

Suppose there is a circular amount of public open space located at $(ac1, ac2)$. The cost of a recreation trip is assumed to have the form $k(u, v) = \theta z^{\psi}$, where $z = \left(\left(u - ac1 + \frac{(u-ac1)*rd}{\sqrt{(u-ac1)^2+(v-ac2)^2}} \right)^2 + \left(v - ac2 + \frac{(v-ac2)*rd}{\sqrt{(u-ac1)^2+(v-ac2)^2}} \right)^2 \right)^{0.5}$ is the distance between the household location (u, v) and the closest edge of the closest circular public open space, θ is the cost of a recreation trip for a household living one mile away, and ψ determines the rate at which intra-city travel costs increase the further away a household is from the amenity. Since the cost of a recreation trip increases the further away a household is from the open space, the attractiveness of a housing location declines the further the home is from the open space. Note this by substituting $k(u, v) = \theta z^{\psi}$ into the household's bid price (5). Since each circular amount of public open space is assumed identical, a household takes all its recreation trips to the closest park.

The ambient amenity function is assumed to have the form $a(u,v) = 1 + a_d(e^{\phi rd+\lambda(0.1-rd)(1+(rd-0.1))^2} - 1)(e^{-\eta\mathbf{z}} \cdot \mathbf{1})$, where $\mathbf{z}$ is a vector of distances between the household location (u,v) and the closest edge of each circular park in the city, a_d is the level of ambient amenities provided to a household located at the edge of a park, ϕ and λ determine how much the size of each park influences the ambient amenity level, and η determines the rate at which ambient amenity level declines the further a household is from each amenity.

Unlike benefits households receive from recreation, where only the closest public open space matters, every public open space potentially has an influence on the ambient amenity level at location (u,v). However, only public open space very close to (u,v) raises the ambient amenity level since $a(u,v)$ falls off very quickly to the normalized value of one with distance from a public open space. Since the ambient amenity level declines the further a home is from open space, here is another reason that the attractiveness of housing location dissipates with distance from open space. Note this by substituting $a(u,v) = 1 + a_d(e^{\phi rd+\lambda(0.1-rd)(1+(rd-0.1))^2} - 1)(e^{-\eta\mathbf{z}} \cdot \mathbf{1})$ into the household's bid price (5).

3.1 Open space locations and their proximity to each other

3.1.1 Ambient Amenities Present

Panels (b)-(d) of Figure 1 illustrate how the proximity of open spaces to each other influence the urban spatial structure for the closed city model with ambient amenities. Panel (b) shows two public open spaces opposite each other across the CBD at $(0,1)$ and $(0,-1)$. In panels (c)-(d), the open space initially at $(0,1)$ is brought clockwise around the city towards the open space at $(0,-1)$. The open spaces are kept at the same distance from the CBD in panels (b)-(d) to examine solely the influence of public open space proximity to each other.

Figure 1 illustrates that the proximity of open spaces to each other influence the concentration of high land rents. The closer the open spaces are to each other the greater the proportion of the city area having the darkest shading for land rents. The reason for this is that both open spaces influence the level of ambient amenities at a location. Since the locations between the open spaces enjoy two doses of ambient amenities, those locations are especially attractive, and land prices increase even more there.

Another observation about Figure 1 is that the closer the open spaces are to each other the more that the city is developed away from the CBD. The commuting costs of the households increase the further that the households locate away from the CBD. Higher commuting costs reduce the income available for the consumption of housing, recreation trips, and the numeraire good.

Comparing a city with no open space in panel (a) to the cities with open space in panels (b)-(d), the presence of open space steepens the land rent gradient. In particular, the ambient amenities make the locations close to the open spaces very attractive, and the land prices there are elevated significantly above the land price at the city boundary r_{ag}. Since the locations between the open spaces are even more attractive the closer the open spaces are to each other, the land rent gradient is the steepest in panel (d).

Table 2 lists equilibrium features of the urban spatial structure of the cities in Figure 1. Comparing the city with no open space to the cities with open space in Figure 1, the equilibrium utility level is lower, the developed area is larger, the housing density is lower, and the total land rents are lower in the city with no open space. Since public open space increases utility through recreation trips and ambient amenities, utility is higher in the cities with open space. The rise in land rents that open space generates in cities stimulates greater housing density in those cities. Since the number of households is fixed in the closed city model, the greater housing density for cities with open space reduces the developed area of those cities. In contrast, in the open city model, the in-migration caused by the open space results in an increase of the developed area.

To evaluate open space policies in the short-run, the closed city model is appropriate. The open space policy of focus in this section is judging the appropriate proximity of open spaces to each other in cities. Perhaps most important among the equilibrium features of a city in the short-run to policy makers is the equilibrium utility. The equilibrium utility rises then drops as the open space above the CBD is rotated clockwise towards the open space below the CBD. The equilibrium utility rises initially because the double dose of ambient amenities benefits households. However, as the open spaces get very close to each other, the area between the open spaces disappears, and the developed area of the city is drawn away from the CBD resulting in greater commuting costs.

As the public open spaces get closer to each other, the developed area of the city falls, the average housing density rises, and the total land rents rise. By bringing the open spaces together, the land surrounding the open spaces becomes extremely attractive. Whenever a localized area is made very attractive, high density development occurs in that area, and the developed area of the city falls. In a city with no open space, the CBD is the most attractive location in a city. However, for cities with open space, the land surrounding the open spaces are the most attractive locations in the city. The first reason the land around the open space is so attractive is because of the choice of a high value for the parameter γ. The second reason is that the level of the ambient amenities tapers off very quickly with distance from the open space. Since the high level of ambient amenities is only available to households located on a small section of land around the open space, the land around the open space is especially attractive relative to all other locations in the city.

Table 3 lists equilibrium features of the recreation done at the public open spaces in Figure 1. As the public open spaces get closer to each other, the total net benefits of recreation steadily falls, but the ratio of recreation trips to travel costs initially rises then drops. Although this result appears puzzling, the reason that the net benefits of recreation fall is that household income less commuting costs fall since the developed area of the city is getting further from the CBD. The ratio of recreation trips to travel costs initially rises since more people live nearer to the public open spaces. Only the rise in commuting costs keeps the net benefits of recreation from rising. When the open spaces are closest to each other, many households still live close to open spaces, but the recreation trips are less since the higher commuting costs have shrunk recreation demand significantly.

3.1.2 Ambient Amenities Absent

Panels (b)-(d) of Figure 2 illustrate how the proximity of open spaces to each other influence the urban spatial structure for the closed city model without ambient amenities. The simulations are of the same spatial configurations of public open space in Figure 1 except that the open spaces no longer offer ambient amenities to households.

There is much less distortion of the land rents if the open spaces do not offer ambient amenities. Not until panel (c) do three contours in the land rents gradient appear. In panel (d) the three contours are more pronounced. There

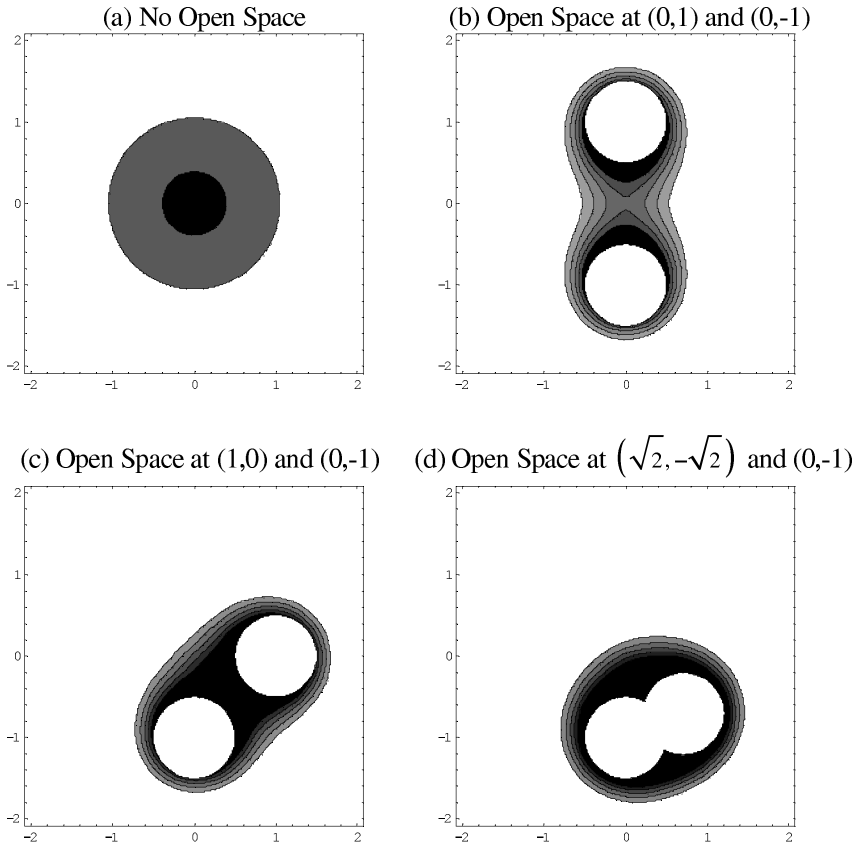

Figure 1: Open spaces at different proximities to each other for a closed city model with ambient amenities. (a) No open space; (b) open space at $(0, 1)$ and $(0, -1)$; (c) open space at $(1, 0)$ and $(0, -1)$; (d) open space at $(\sqrt{2}, -\sqrt{2})$ and $(0, -1)$.

is no high density development around the open spaces since the recreation trip costs do not rise dramatically with distance from the open space. The most attractive location is the CBD, but the recreation benefits do stimulate some attraction to the open spaces raising land rents moderately around the open spaces. Since the greater proximity of the open spaces to each other does not make the locations around the open spaces more attractive than the CBD, the developed area of the city shifts little away from the CBD.

Table 2 lists equilibrium features of the urban spatial structure of the cities in Figure 3. The cities with open space in Figure 2 have higher equilibrium utility levels, fewer developed acres, higher housing density, and the total land rents are lower than the city with no open space. Since public open space increases utility through recreation trips, utility is higher in cities with open space and no ambient amenities than in cities with no open space. Since the open space generates a steeper land rent gradient and the number of households is fixed, the developed area of cities with open space falls. Another outcome of the steeper land rent gradient is that the average housing density of the city rises.

The net result of land rents rising moderately and the developed area falling is that the total land rents of those cities falls. For the cities with ambient amenities, total land rents are higher because the ambient amenities raise the attractiveness of the locations around the open space at no cost to the households. Unlike recreation benefits, where there is a cost of a recreation trip leaving less income available for housing, ambient amenities make locations nearby open space attractive at no cost.

For the simulations in Figure 2, as the public open spaces are brought closer together, the equilibrium utility steadily drops. Since there is no double dosage of ambient amenities the closer that the open spaces are brought to each other, the clumping of the open spaces merely increases the travel costs of recreation for households on the far side of the city. Higher total costs of recreation and no ambient amenity benefits results in lower equilibrium utility in the city.

The attraction of households to the recreation benefits of open spaces makes the locations near the open spaces more attractive than the locations are when there is no open space. The rise in the number of attractive locations for cities with open space increases the housing density, and the developed area of the city falls. The closer the open spaces are to each other the more that the city develops in a single direction spatially–in the direction of the open space. If a city develops more in a single direction spatially, the land rent gradient steepens, and the developed area of the city falls. In other words, the more that a small region of the landscape becomes very attractive the more that total land rents rise, since the households bid high to live at the top locations, and the more that the developed area of the city falls.

Table 3 lists equilibrium features of the recreation done at the public open spaces in Figure 2. Unlike in the simulations in Figure 1, the developed area of the city does not shift away from the CBD the closer the open spaces get to each other. As a consequence, recreation demand (3) does not shift downward due to the rise in commuting costs. However, the closer that the open spaces get to each other the more that total recreation costs rise since the travel costs per recreation trip for households at the far side of the city increase. The result is that as the public open spaces get closer to each other both the total net benefits of recreation and the ratio of recreation trips to travel costs steadily fall. Since households do not crowd closer to the open spaces in the Figure 2 simulations, as the the open spaces get closer to each other, the decline in the total net benefits of recreation is faster for the Figure 2 simulations than the Figure 1 simulations.

3.2 Open space locations and their proximity to the CBD

3.2.1 Ambient Amenities Present

Panels (a)-(f) of Figure 3 illustrate how the proximity of open spaces to the CBD influence the urban spatial structure for the closed city model with ambient amenities. Panels (a)-(d) show a public open space progressively further from the CBD until commuting costs are so high that no development occurs around the open space. In panels (e)-(f), there are two open spaces. While one open space is held fixed at $(0, -1)$, the other open space is placed progressively further from the CBD. In panels (e)-(f), both the proximity of the open spaces to each other and their distance from the CBD is changing. Since the influence of the proximity of open spaces to each other was examined in the prior section, the information from that section should allow for the identification of the separate influence of the distance of the open space from the CBD.

Figure 3 illustrates that the proximity of open space to the CBD influences the land rent gradient. The further the open space is from the CBD the flatter is the land rent gradient around the open space until there is no development

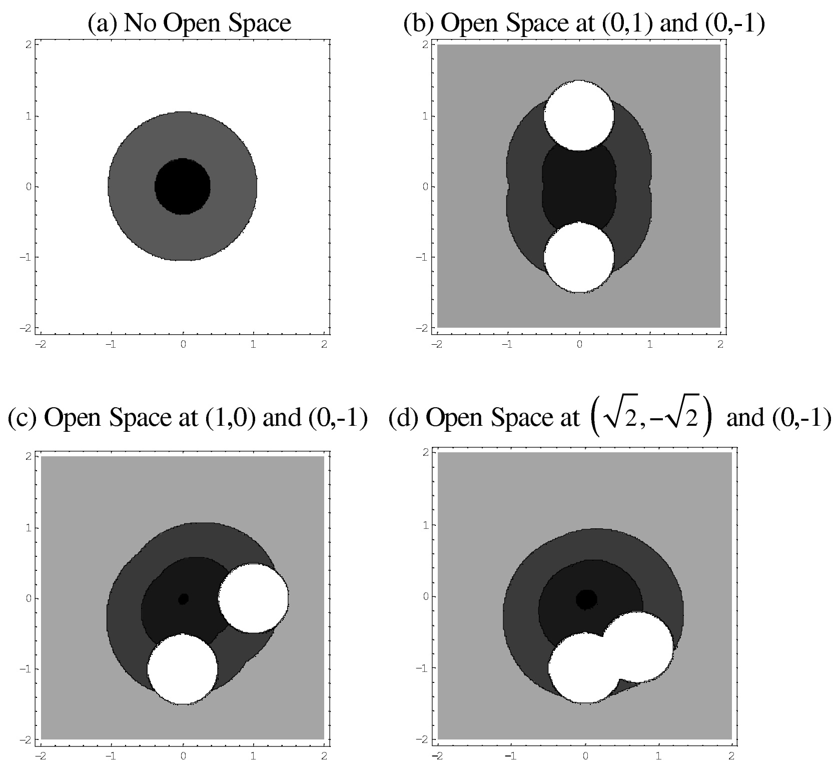

Figure 2: Open spaces at different proximities to each other for a closed city model without ambient amenities. (a) No open space; (b) open space at (0,1) and (0,-1); (c) open space at (1,0) and (0,-1); (d) open space at $(\sqrt{2}, -\sqrt{2})$ and $(0, -1)$.

around it. When the open space is close to the CBD, the attractiveness of the locations around the open space far exceed the attractiveness of the CBD. In fact, in panel (b), there is no development at all around the CBD because of the strong attraction to the open space.

Table 2 lists equilibrium features of the urban spatial structure of the cities in Figure 1. The open space policy of focus in this section is judging the appropriate proximity of open spaces to the CBD. The equilibrium utility falls the further the open space is from the CBD since households cannot locate close to both work and to the open space.

The developed area of the cities with open space is always less the developed area of a city with no open space because the open space is such a strong attraction that high density development is built around it. However, the further that the open space is from the CBD the less attractive the locations around the open space become, and the more that the developed area of the city rises. The only exception is in panel (b) where development is only around the open space. Since the open space has a complete grasp on the city, there is no additional development that a nearby CBD is stimulating that would increase the developed area of the city.

The total land rents of the cities with open space far away from the CBD are often less than the total land rents of cities with no open space. The reason is that when the households locate near an open space far away from the CBD to enjoy the ambient amenities of the open space there are high commuting costs that prevent substantial payment for housing. The low bid prices for housing result in low total land rents.

Table 3 lists equilibrium features of the recreation done at the public open spaces in Figure 3. The further the public open space gets from the CBD the more that the net benefits of recreation fall. From panel (a) to panel (b), the ratio of trips to travel costs barely falls, but the net benefits of recreation falls significantly. The reason is that recreation demand shifts downward because of the rise in commuting costs, but households still live the same distance away from the open space. In panels (c)-(d), the development near the CBD raises the total travel costs of recreation dramatically. However, the net benefits of recreation do not fall dramatically since recreation demand shifts upward for those households near the CBD. In panels (e)-(f), the net benefits of recreation fall even though households live closer to the open space in panel (f) because of the downward shift in recreation demand for the households located around the open space at $(0, 3)$.

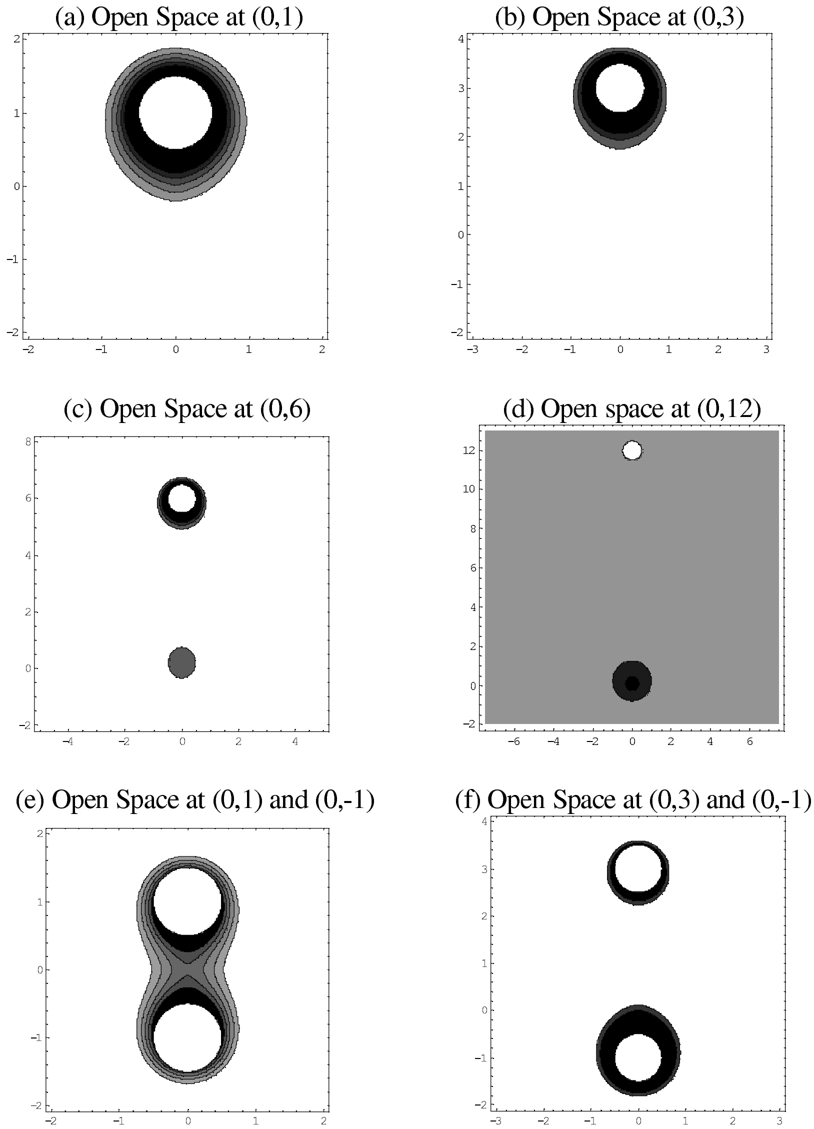

Figure 3: Open space at different proximities to the central business district (CBD) for a closed city model with ambient amenities. (a) open space at $(0,1)$; (b) open space at $(0,3)$; (c) open space at $(0,6)$; (d) open space at $(0,12)$; (e) open space at $(0,1)$ and $(0,-1)$; (f) open space at $(0,3)$ and $(0,-1)$.

3.2.2 Ambient Amenities Absent

Panels (a)-(d) of Figure 4 illustrate how the proximity of open spaces to the CBD influence the urban spatial structure for the closed city model without ambient amenities. Panels (a)-(b) show a public open space progressively further from the CBD until commuting costs are so high that no development occurs around the open space. The open space does not need to be far from the CBD before no development occurs around the open space because the strong attraction of the ambient amenities is absent. In panels (c)-(d), there are two open spaces. While one open space is held fixed at $(0, -1)$, the other open space is placed progressively further from the CBD.

The land rent gradient is flat in all these simulations because there are no ambient amenity benefits. For panels (a)-(b), the further the open space is from the CBD the flatter is the land rent gradient of the city. For panels (c)-(d), the open spaces are initially close enough to each other, but not too close, that the land rents are diffused. However, as the open space is placed further from the CBD, the influence of the displaced open space loses all significance, and the land rent gradient actually steepens. For all these simulations, the attractiveness of the CBD far exceeds the attractiveness of the locations around the open space.

Table 2 lists the equilibrium features of the urban spatial structure of the cities in Figure 4. The equilibrium utility falls the further that open space is from the CBD. The developed area falls the more that a small region of the landscape is very attractive to households. In panel (b), since there are two distinct locations of spatial attraction, the developed area is quite large. In panel (d), there is actually only one location of attraction since the open space far away from the CBD is completely unattractive to the households. As a consequence, the developed area in panel (d) is less than the developed area in panel (c).

Similar to the other simulations where ambient amenities are absent the total land rents are lower in cities with open space than for a city with no open space. The developed area falls because there is attraction to the open spaces, but the bid price for housing rises very little since income is siphoned away to recreation. The net result is a decline in the total land rents.

Table 3 lists equilibrium features of the recreation done at the public open spaces in Figure 3. The further the public open space gets from the CBD the more that the net benefits of recreation fall. Since the CBD is the most attractive feature of the city, there are no shifts in recreation demand since the developed area of the city remains around the CBD The fall in the net benefits of recreation is largely because the travel costs of recreation rise the further the open space is from the CBD.

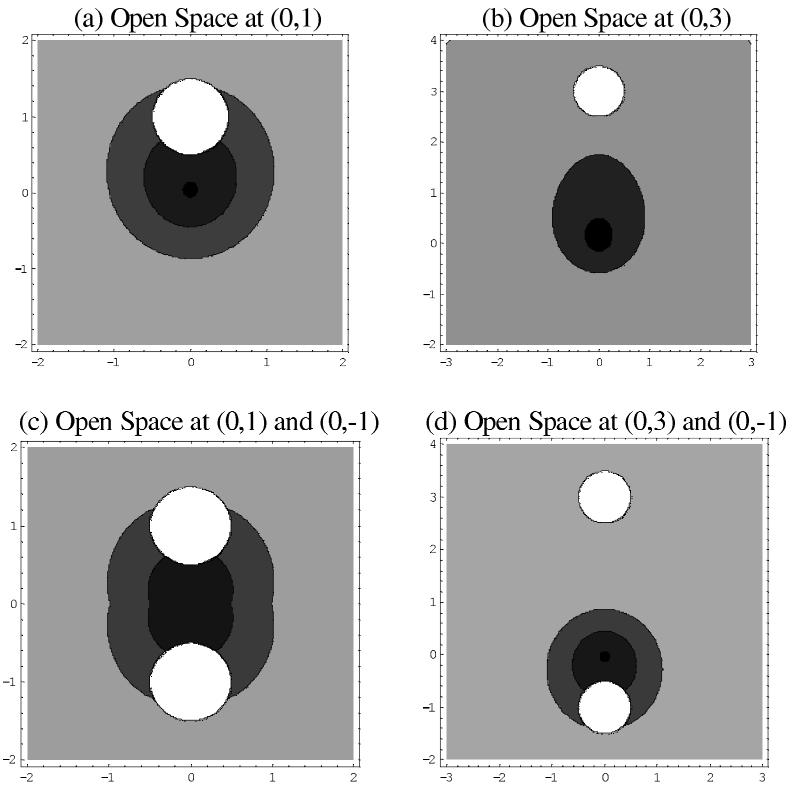

Figure 4: Open space at different proximities to the central business district (CBD) for a closed city model without ambient amenities. (a) open space at (0,1) ; (b) open space at (0,3); (c) open space at (0,1) and (0,-1); (d) open space at (0,3) and (0,-1).

4 Conclusion

This paper illustrates how different locations of open space influence recreation and urban spatial structure. There has been no prior work examining exclusively the recreation implications of different placements of open space. First, the importance of the proximity of open spaces to each other was investigated. The extent that the developed area is drawn away from the CBD and double dosages of ambient amenities were shown to be influential determinants of the equilibrium utility and the net benefits of recreation. Second, the importance of the proximity of the open spaces to the CBD was investigated. The extent to which the open spaces create a small region of attractive locations near the CBD was shown to have the most dramatic effects on developed area, equilibrium utility and the net benefits of recreation.

Future work will include simulations of the open city model. Also, the presence of different income groups is likely to offer an useful perspective on how different socioeconomic characteristics of the city influence the urban spatial structure and recreation characteristics of a city.

References

Colwell, P., C. Dehring, et al. (2002). "Recreation Demand and Residential Location." Journal of Urban Economics 51: 418-428.
Correll, M., J. Lillydahl, et al. (1978). "Effects of greenbelts on residential property values-some finding on the political-economy of open space." Land Economics 54(2): 207-217.
Doss, C. R. and S. J. Taff (1996). "The Influence of Wetland Type and Wetland Proximity on Residential Property Values." Journal of Agricultural and Resource Economics 21: 120-129.
Fujita, M., et al. (1989). "Testing the Efficiency of Urban Spatial Growth: A Case of Tokyo." Journal of Urban Economics 25(March): 156-92.
Hotelling, H. (1947). An Economic Study of the Monetary Evaluation of Recreation in the National Parks, U.S. Department of the Interior, National Park Service and Recreational Planning.
Johnston, R. J., S. K. Swallow, et al. (2002). "Spatial factors and stated preference values for public goods: Considerations for rural land use." Land Economics 78(4): 481-500. Kim, C. W., T. T.
Phipps, et al. (2003). "Measuring the benefits of air quality improvement: a spatial hedonic approach." Journal of Environmental Economics and Management 45: 24-39.
Lansford, N. H. and L. L. Jones (July 1995). "Marginal Price of Lake Recreation and Aesthetics: An Hedonic Approach." Journal of Agricultural and Applied Economics 27: 212-23. Lee, C. M. and M.
Fujita (1997). "Efficient Configuration of a greenbelt: theoretical modelling

of greenbelt amenity." Environment and Planning A 29: 1999-2017.
Leggett, C. G. and N. E. Bockstael (March 2000). "Evidence of Water Quality on Residential Land Prices." Journal of Environmental Economics and Management 39(2): 121-44.
Mahan, B. L., S. Polasky, et al. (2000). "Valuing Urban Wetland: A Property Price Approach." Land Economics 76: 100-113.
Marshall, E. (2004). "Open-Space Amenities, Interacting Agents, and Equilibrium Landscape Structure." Land Economics 80(2): 272-293.
Polinsky, M. A. and S. Shavell (1976). "Amenities and Property Values in a Model of an Urban Area." Journal of Public Economics: 119-129.
Randall, A. (1994). "A Difficulty with the Travel Cost Method." Land Economics 70(1): 88-96.
Roe, B., E. Irwin, et al. (2004). "The Effects of Farmland, Farmland Preservation, and Other Neighborhood Amenities on Housing Values and Residential Growth." Land Economics 80(1): 55-75.
Tiebout, C. (1956). "A Pure Theory of Local Public Expenditures." Journal of Political Economy 64: 416-24.
Tyrvainen, L. and A. Miettinen (March 2000). "Property Prices and Urban Forest Amenities." Journal of Environmental Economics and Management 39(2): 205-23.
Weicher, J. C. and R. H. Zerbst (February 1973). ""The Externalities of Neighborhood Parks: An Empirical Investigation."" Land Economics 49: 99-105.
Wile, J. (1978). "Open spaces, Revenue sharing, and urban structure." Journal of Urban Economics 5(1): 88-100.
Wu, J., R. M. Adams, et al. (2004). "Amenities in an Urban Equilibrium Model: Residential Development in Portland Oregon." Land Economics 80(1): 19-32.
Wu, J. and A. J. Plantinga (2003). "The Influence of Public Open Space on Urban Spatial Structure." Journal of Environmental Economics and Management 46(1): 288-309.
Yang, C. H. (1990). "The optimal provision of a central park in a city." Journal of Regional Science 30(1): 15-36.
Yang, C. H. and Fujita (1983). "Urban spatial structure with open space." Environment and Planning A 15: 67-84.

Table 1
The values of parameters used in the simulations

Parameter	Value	Interpretation
γ	0.5	The elasticity of utility with respect to amenities
α	0.4	Households spend four-tenths of their income after commuting costs on housing
β	0.05	Households spend one-twentieth of their income after commuting costs on housing
y	40000	Gross household income
t	1000	Annual commuting cost per mile (round-trip)
r_{ag}	3000	Agricultural land rent per acre
θ	2	Intra-city travel cost per mile (round-trip)
ψ	1.5	Intra-city travel cost parameter
oc	10	On-site cost per trip to an amenity
a_d	0.16	Ambient amenity function parameter
rd	0.5	Radius of circular amenity
ϕ	2.69	Ambient amenity function parameter
λ	0.1	Ambient amenity function parameter
η	2	Ambient amenity function parameter
δ	1.4	The ratio of housing value to non-land construction costs
c_0	1000	Fixed cost prior to construction

Table 2
Equilibrium features of closed city models with open space
Circular open space with radius of 0.5

	Utility	Developed Acres (acres)	Average housing density (sq. ft per acre)	Total land rents (million dollars)
No open space (Fig. 1 and Fig. 3)	3669.58	2192	759.49	7.27
Proximity of open spaces to each other				
Ambient amenities present (Fig. 1)				
At $(0,1)$ and $(0,-1)$	5093.8	1638.79	896.43	7.32
At $(1,0)$ and $(0,-1)$	5127.04	1428.48	982.33	7.51
At $(\sqrt{2},-\sqrt{2})$ and $(0,-1)$	5115.24	1340.32	1021.8	7.58
Proximity of open space to the CBD				
Ambient amenities present (Fig. 2)				
At $(0,1)$	4851.39	1479.05	957.49	7.44
At $(0,3)$	4642.25	1468.92	930.77	7.03
At $(0,6)$	4337.29	1597.75	849.07	6.52
At $(0,12)$	4096.37	2091.42	758.35	6.91
At $(0,1)$ and $(0,-1)$	5093.81	1638.79	896.43	7.32
At $(0,3)$ and $(0,-1)$	4912.91	1586.82	905.55	7.24
Proximity of open spaces to each other				
Ambient amenities absent (Fig. 3)				
At $(0,1)$ and $(0,-1)$	4521.27	2017.91	776.28	6.96
At $(1,0)$ and $(0,-1)$	4513.62	2007.47	778.92	6.97
At $(\sqrt{2},-\sqrt{2})$ and $(0,-1)$	4506.61	2000.97	780.73	6.98
Proximity of open space to the CBD				
Ambient amenities present (Fig. 4)				
At $(0,1)$	4509.85	1986.56	788.29	6.97
At $(0,3)$	4441.73	2091.59	755.46	6.97
At $(0,1)$ and $(0,-1)$	4521.27	2017.91	776.28	6.96
At $(0,3)$ and $(0,-1)$	4509.85	2014.82	777.24	6.97

Table 3
Recreation features of closed city models with open space
Circular open space with radius of 0.5

	Total net benefits (million dollars)	Total trips (thousands)	Total travel costs (thousands)	Ratio of trips to travel costs
No open space (Fig. 1 and Fig. 3)	NA	NA	NA	NA
Proximity of open spaces to each other				
Ambient amenities present (Fig. 1)				
At $(0,1)$ and $(0,-1)$	16.91	382.11	78.58	4.86
At $(1,0)$ and $(0,-1)$	16.88	383.23	59.47	6.44
At $(\sqrt{2},-\sqrt{2})$ and $(0,-1)$	16.82	381.39	66.84	5.71
Proximity of open space to the CBD				
Ambient amenities present (Fig. 2)				
At $(0,1)$	16.78	377.44	107.14	3.52
At $(0,3)$	15.81	359.09	108.67	3.3
At $(0,6)$	13.83	280.67	712.27	0.39
At $(0,12)$	8.75	44.02	3,327.73	0.01
At $(0,1)$ and $(0,-1)$	16.91	382.11	78.58	4.86
At $(0,3)$ and $(0,-1)$	16.59	376.81	72.59	5.19
Proximity of open spaces to each other				
Ambient amenities absent (Fig. 3)				
At $(0,1)$ and $(0,-1)$	16.85	373.36	174.28	2.14
At $(1,0)$ and $(0,-1)$	16.77	367.34	232.74	1.58
At $(\sqrt{2},-\sqrt{2})$ and $(0,-1)$	16.68	358.66	319.34	1.12
Proximity of open space to the CBD				
Ambient amenities absent (Fig. 4)				
At $(0,1)$	16.65	354.5	362.71	0.97
At $(0,3)$	15.25	252.51	1,362.13	0.19
At $(0,1)$ and $(0,-1)$	16.85	373.36	174.28	2.14
At $(0,3)$ and $(0,-1)$	16.65	354.5	362.71	0.97