

Urban Planning and the Location of Environmental Amenities¹

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Abstract. In this paper, we use a simple urban economic model to study how choosing park locations within a city might contribute towards urban planning goals. For multiple possible park placements, we solve for the associated equilibrium urban structure, including the equilibrium rent gradient, city boundary, total number of park visits, the overall utility level, and total vehicle miles traveled. We then examine how these change with alternative park placement sites. We find that, as a prescription for reducing urban sprawl, park provision has mixed results. When placed close to the central business district, the park can result in an increase in inner city housing density; such placement could help ameliorate problems of commuter traffic congestion related to urban sprawl. Parks placed further out toward the periphery, although consistent with improved accessibility and utility maximization, have the opposite effect— pulling residents away from the central business district and thereby likely worsening the congestion problem related to commuter traffic.

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1. Introduction

Over the past three decades, a combination of forces, including increased population, increased income, and falling commuting costs, has been drastically changing the face of the American landscape (Mieszkowski and Mills, 1993). The net population migration into cities has reversed, and people are instead moving back out into the country and suburbs and consuming larger amounts of land. According to census and HUD data, the population density of urbanized areas has decreased by more than 50% in the last fifty years, from 8.4 people per acre to 4 people per acre (Heimlich and Anderson, 2001). According to data from the USDA's National Resources Inventory, land in the categories of "urban and built-up area" increased from 51.9 million acres in 1982 to 76.5 million acres in 1997, and much of this increase was due to low-density, large-lot development beyond the urban fringe (Heimlich and Anderson, 2001). Johnson (1999) calls this the "rural rebound," arguing that the population is not returning to a rural, farm-centered way of life, but is instead using technology to reduce the effective distance between rural and urban areas. Given continuing increases in transportation and communication technology, the effects of this force on the landscape are expected to grow even stronger in years to come.

Whether the spatial expansion of cities, a phenomenon known by some as "urban sprawl," should warrant the intervention of policy makers, and what forms possible interventions might take, is intensely debated in political arenas. One side might argue that Adam Smith's invisible hand smooths over the landscape in such a way that everyone is where they want to be, and the whole is as well off as it can be. Survey research repeatedly finds a preference among American families for less densely populated rural settings with easy access to a larger city (Heimlich and Anderson, 2001). In a recent essay, Brueckner (2000) argues that urban spatial expansion is not inherently socially undesirable. In the presence of rising incomes, falling

commuting costs, and increasing populations, one would expect society to choose a certain amount of urban expansion.

The fundamental economic criticism of “urban sprawl,” on the other hand, is that there are market failures in the system that distort the amount (and, perhaps, the pattern) in which development occurs, driving the market pattern of development away from what would be considered the socially optimal development pattern. Three sources of such failure are commonly identified: the failure to account for the social costs of congestion in commuting, the failure to take account of the benefit of open space, and the failure to make new development responsible for the infrastructure costs it generates (Brueckner, 2000). These market failures can lead to cities that are larger and less densely settled than they should be.

One line of urban economic research has looked at the problem of the congestion externality generated as commuters jockey for space on crowded freeways or rail systems, and at what the implications of this externality are for policies aiming to encourage a more efficient residential settlement pattern (Oron *et al.* (1973); Fukushima and Shigeno, 1995; Wheaton, 1998; Daniel and Bekka, 2000). Wheaton (1998) argues that the internalization of traffic congestion externalities would result in an optimal city whose residential density close to the CBD is orders of magnitude larger than that achieved under a market equilibrium. Policy prescriptions that increase the density of inner cities can therefore be expected to ameliorate the problems associated with traffic congestion.

Another line of research in the environmental economics literature has focused on how to account for the benefits of open space. A growing body of literature suggests that people value the amenities they receive from open space. The largest body of literature in this field uses hedonic models to show that proximity to environmental amenities and open space such as golf

courses, public parks, and wetlands increases residential property values (e.g., Ready *et al.*, 1997; Doss and Taff, 1996; Palmquist, 1992). These results, together with an escalating number of grass-roots, open-space preservation initiatives, indicate that people are willing to pay more to be closer to these amenities because they receive some benefit from them.

Apart from the issue of whether intervention to stem excessive urban expansion is justified is the question of which policies should be implemented. In his essay, Brueckner (2000) goes on to suggest corrective measures. A congestion tax is the most theoretically appealing means to correct the congestion externality, but political and operational obstacles make implementation unlikely (Wheaton, 1998). A tax on development would be an effective way to incorporate the cost of lost open space in development decisions. Again, obstacles to implementation of such a tax are both political and operational (i.e., the correct level of the tax depends on an accurate estimate of the value that people place on open space). In contrast, the anti-sprawl prescription of requiring development to bear the full costs of infrastructure development has led to operational planning practices that are in widespread use, including in particular the delineation of growth boundaries and/or municipal service areas.

While Brueckner focuses on the value of open space outside city limits, the literature suggests that city residents also value parks and other open space within city boundaries. This has implications for land-use planners. First, it would seem that if open space provides benefits, then residents will be made better off if planners ensure that open space exists in their communities. This is the philosophy behind land-use policies such as land acquisition and transferrable development rights, which use a combination of environmental and amenity arguments to restrict the use and development of land in a region. There is a large body of literature on the optimal provision of local public goods (such as open space) in the regional and

urban economics literature, as well as on the use of specific policy tools in its provision. This literature encompasses the urban planning literature, and often relies on theoretical, rather than empirical, modeling— such as extensions of classic Alonso-Muth-Mills urban models and Tiebout's (1956) residential decision model— to explore the implications of different policy tools on an urban center or a system of urban centers.

Land use planners may be interested in another dimension of the open space issue that is not as well studied in the literature— the relationship between welfare, urban settlement patterns, and location of open space. Little research has focused specifically on the question of where public goods are located and what the implications of public goods location might be for urban planning efforts. In one of the first such efforts, JunJie Wu (2001) confirms the promise of this field of analytics in demonstrating that, because amenities in urban areas increase the desirability of proximate areas, they create an incentive for clustering; amenities could, therefore, be strategically positioned to manipulate development patterns and perhaps reduce sprawl.

Our research continues this line of exploration with a conceptual model that looks at the urban structure implications of a circular park—or greenbelt—located within the city boundaries. In particular, we are interested in exploring the effects of the greenbelt on urban structure, whether those effects differ with its distance from the city's center, and what the effect of location will be on other environmental concerns related to urban structure. We investigate the potential of local public good provision (specifically, a greenbelt) to address the symptoms of the market failures identified in the literature. Is it possible that, when open space is provided within city boundaries, the incentive to build on open space at the city's edge is reduced? Can the placement of a greenbelt help to reduce the expansionist pressures that the congestion externality market failure places on city size?

We build a simple urban model in which residents enjoy visits to the greenbelt yet where the cost of their visits enter their budget constraint. For multiple possible park placements, we solve for the associated equilibrium urban structure, including the equilibrium rent gradient, city boundary, total number of greenbelt visits, the overall utility level, and total vehicle miles traveled. We then examine how these change with alternative reserve placement sites.

2. The Model

This model is based on Solow's (1973) version of a monocentric urban model, in which it is assumed that all individuals commute to a central business district (CBD) to work. We consider the case of a closed city, where urban population is fixed. Every household receives a fixed wage, and must pay commuting costs that increase with distance to the urban center. Total income differs from wage due to the way in which we model land ownership.

There are two extremes in the treatment of land ownership in these models (Kanemoto, 1980). One is to assume that one or more absentee landlords own all the land and collect all the rents. If one of the items of interest is how residents' utility responds to the establishment of a greenbelt, this is a complicating assumption because when rents leave the city, one must account for the effect of the open space on the welfare of the absentee landlord. An alternative is the case of public ownership; we assume the existence of a city government that rents all the land for the city at the agricultural rental rate, rents it out to the city residents, then redistributes the proceeds evenly among the population. This assumption keeps rents, and all welfare effects associated with moving the greenbelt, within the city.

Total income therefore comprises both wage income (y) and the social dividend (SD) received. Employment transportation costs are paid out of this amount; for our purposes, the

income that remains is referred to as disposable income, and is spent on the goods that provide utility. Because each resident receives an equal wage and an equal dividend, the farther the individual lives from the city, the smaller their disposable income. Our model builds on Solow's model by introducing into the utility function an additional, spatially explicit, good. This good represents an amenity good, which we call a greenbelt, that residents must travel to consume. The only cost associated with amenity consumption is the travel cost, which varies according to residential location.

We start with a utility function built around a linear expenditure systems, where utility is a function of a consumption good (c), housing (h), and visits to a greenbelt (w):

$$U(c,h,w) = \alpha \ln c + \beta \ln h + \gamma \ln [w+1] \quad (1)$$

Every household spends income ($y + SD$) on the consumption good, housing (h), commuting to the central city (the distance from the residence to the central business district (x)), and travel to the greenbelt, which is located at distance \hat{x} . With the price of the consumption good normalized to 1, the budget constraint is written:

$$y + SD - j t x = c + r(x) h + [m + t(|x - \hat{x}|)] w, \quad (2)$$

where t is a per-unit travel cost. Commuters must take j trips per year to the central city to work, but choose the number of visits to the reserve. Visits to the greenbelt have both a fixed cost component (m) and a travel cost component. In this model, $y, j, t, m, \alpha, \beta,$ and γ are all exogenous.

Plugging the optimal quantities of $c, h,$ and w into the utility function yields the indirect utility function:

$$\begin{aligned}
V(1, m, j, t, y) = & \alpha \text{Log}\left[\frac{(y - jtx + m + SD + |x - \hat{x}|t)a}{\alpha + \beta + \theta\gamma}\right] + \beta \text{Log}\left[\frac{(y - jtx + m + SD + |x - \hat{x}|t)\beta}{r(x)(\alpha + \beta + q\gamma)}\right] \\
& + q\gamma \text{Log}\left[\frac{(y - jtx + m + SD + |x - \hat{x}|t)\gamma}{(m + |x - \hat{x}|t)(\alpha + \beta + q\gamma)}\right]
\end{aligned} \tag{3}$$

The indirect utility function gives the maximum achievable utility for a set of commodity prices and income. In this model, two of the commodity prices (rent and transportation cost to the greenbelt) are endogenous; for a given landscape (fixed \hat{x}), they vary with x , and for a given x they vary with \hat{x} .

In order to solve for an equilibrium solution, it is assumed that individuals distribute themselves on the landscape in such a way that they equalize their utility; this precludes the possibility that individuals could make themselves better off by moving closer to, or farther from, the central business district (CBD).

The rent function is found by setting the indirect utility equal to this constant utility level (\bar{v}) and solving for $r(x)$:

$$r(x) = \frac{1}{\alpha} \left[e^{-\frac{\bar{v}}{\beta}} \beta \left(\frac{(y + SD - jtx + m + |x - \hat{x}|t)}{\alpha + \beta + q\gamma} \right)^{\frac{\alpha + \beta}{\beta}} \left(\frac{q\gamma (y + SD - jtx + m + |x - \hat{x}|t)}{(m + |x - \hat{x}|t)(\alpha + \beta + q\gamma)} \right)^{\frac{q\gamma}{\beta}} \right] \tag{4}$$

The two remaining unknowns are the utility level (\bar{v}) and the distance to the boundary of the city (x^*). As in Solow, we solve for these variables using additional equations. The first equation sets the rent level at the extensive margin $r(x^*)$ equal to the agricultural rent generated

by the land at the city's periphery (r_A):

$$r(x^*) = r_A. \quad (5)$$

A second equation equates supply and demand for housing. Demand at a particular distance x is equal to $h(x)n(x)dx$, where $n(x)$ represents the number of residents at distance x . Supply of land area at that distance is $2\pi x dx$. Equating supply and demand for housing at each location yields a representation of how many households can "fit" at each x , given their demand for housing:

$$n(x) = \frac{2\pi x}{h(x)}. \quad (6)$$

The final assumption is that all the households in the city must reside within the city limits, so that at the city's equilibrium size, x^* , the number of residents at each location adds up to the total population, N :

$$(6) \quad N = \int_0^{x^*} n(x)dx = \int_0^{x^*} \frac{2\pi x}{h(x)} dx.$$

We used a simulation model to solve the model with the greenbelt placed at various distances from the central business district. Our objective was to explore the extent to which placement of the greenbelt could be used to influence city size, residential rent levels and density, vehicle miles traveled, and resident utility. The concept of optimum that we use with respect to park placement refers to the location that results in the maximum achievable utility provided that all residents are treated equally. The parameter values we chose for generating simulation results are presented in Table 1.

3. Results

3.1 Urban Structure

In the classic urban models, the rent gradient is found to decrease monotonically with distance to the CBD. Because inhabitants of the outer city rings are spending more money on commuting, they have less disposable income to spend on consumer goods. The price of the composite good is invariant with distance to the CBD, so that leaves only the rent (or price of housing) available to equilibrate in order to equalize utility among all city residents. If outer-ring inhabitants are to receive the same utility as inner-ring inhabitants, they must be able to consume a greater amount of housing at a reduced price, yielding a declining rent gradient.

Introduction of the greenbelt complicates the rent gradient by providing a location-specific source of benefits to residents at a specified distance from the CBD. The equilibrium distribution of inhabitants will therefore reflect a tradeoff between the benefits derived from living close to the CBD, which are reflected in a higher disposable income, and the benefits derived from living close to the park, which are reflected in a lower effective cost of greenbelt visits due to travel cost differences. In order for an equilibrium solution to occur, one would expect the benefits derived from living close to the park to be capitalized into the rents that must be paid for residential proximity; this hypothesis underlies hedonic studies of property value and the extent to which they are affected by adjacent amenities. Thus, people who live closer to amenities earn benefits from the decreased effective cost of amenity visits, but in order for utility to equalize across the city, these benefits must be offset by increased residential rental rates.

As expected, the results of our model illustrate this amenity effect. Park location within the city is characterized by a local peak in rental rates. Figure 1 illustrates the rental gradient associated with a park located at three different locations within the city. As expected, a centrally

located amenity tends to reinforce the high central area rents, with declining rents through the rest of the city. As the greenbelt moves farther out, however, rents at the central business decline as inhabitants are pulled away from the CBD and are attracted by proximity to the park.

In a linear expenditure system, each household's total expenditure on housing is fixed. Therefore, if rents near the central business drop, it means that per household housing consumption must increase. The rent differences illustrated above therefore also suggest a difference in the pattern of residential density; as people near the CBD consume a larger amount of housing, i.e. settle less densely, people near to and on the far side of the park (away from the CBD) settle more densely. The magnitude of this effect on the density distribution of residents depends on the magnitude of the preference parameter for greenbelt visits, γ . At the value of the parameter that we used, $\gamma=.03$, equilibrium lot sizes adjacent to the CBD increase from 4.8 acres to 6.6 acres as the park placement changes from 1 to 18.

In addition to looking at the effect on density distribution, we were interested in exploring whether the changing rent structure would cause the urban area to expand or contract in response to park placement at different points. Our results suggest that for most park locations, provision of the park decreases the extent of the urban area relative to its equilibrium extent without a park at all. When a park is centrally located, small variations in its location have almost no effect on the extent of the urban area. As the park approaches the periphery of the urban area, the urban area expands, exceeding the size of the parkless urban area only when the park itself passes beyond the periphery (Figure 2).

In this paper, we consider only the effects of a park placed within the urban area, rather than beyond its perimeter. Our model indicates that parks placed beyond the urban boundary can have unusual effects on overall urban structure, in some cases creating satellite residential rings

around the CBD that are separated from the bulk of the urban residential area by a swath of agriculture. Examples of leapfrog development such as this are in fact commonly observed. Although we recognize that certain types of amenity could indeed have that effect on urban structure, further analysis of such cases in the context of open space or recreation area provision would require a more detailed analysis of the relationships among residential preferences, recreational opportunities, open space, and agricultural areas.

Our final consideration in looking at the urban impact of park placement is its effect on total vehicle miles driven. To the extent that individual utility increases with access to both the CBD and the park, one might expect to observe a certain amount of congruence between decreasing vehicle miles and increasing utility. However the relationship is complicated by the fact that a park increasingly accessible to one group of city residents becomes less accessible to another, and the question becomes one of finding a balance. The overall effect, as shown in figure 3, is that total vehicle miles driven initially decrease as the park is placed more centrally within the urban area, making it more accessible to the majority of the city residents. However, as the park is pushed further out, total vehicle miles driven increases again. Peripheral residents continue to enjoy increased accessibility, and to increase their trips to a peripheral park, but central-city residents must travel increasing distances to reach it. Similarly, as the cost of a trip to the park drops for peripheral residents, these residents will substitute trips to parks for housing consumption. This increase in travel comes at a cost of increasing total vehicle miles.

Although increases in total vehicle miles driven are often cited as sprawl statistics, perhaps even more relevant to the problem of urban air quality is the effect of park location on total number of automobile trips. Because a major component of air pollution comes from cold starting the car, total amount of automobile-related air pollution may be more closely related to

number of trips (and length of time on the road) than to length of trips in miles (Heimlich and Anderson, 2001). Our analysis found a significantly different relationship between park location and total trips, as compared to the relationship between park location and total vehicle miles (Figure 4). In particular a less accessible park (i.e. one located at either the CBD or the extreme urban periphery) may result in an increase in total vehicle miles traveled, but those miles represent fewer trips overall and therefore may be associated with relatively less automobile-related air pollution.

3.2 Measurement of Welfare

Different park locations on the landscape can be expected to have welfare effects through the impact of park location on both the cost of travel for greenbelt visits and the cost of housing, which we have seen varies with park location. The explicit expression derived for landscape-level indirect utility (eq. 3) enables us to compare achievable welfare levels across the possible park locations. Because, by assumption, everyone on the landscape is characterized by the same utility level, when that level is observed to increase with a change in the park's location, we can make the statement that providing the park at a different location makes every individual on the equilibrium landscape better off.

In order to explore the welfare effects of the greenbelt placement on this landscape, we considered for each scenario the maximum achievable landscape utility associated with that park position. Results of our model are illustrated in figure 5. This figure illustrates that indirect utility initially increases as the park is located farther from the CBD, but eventually peaks and

declines. Utility is maximized when the greenbelt (located 18.25 miles from the CBD²) is 7.95 miles inside the city boundary. At this location, roughly 50% of the city's population resides inside the greenbelt (103,902) and 50% reside outside the greenbelt (96,109).³

The mechanics of how utility changes with park location can best be understood by considering a resident who lives at the city's edge ($x = x^*$). Because all residents on the landscape must have the same utility level, we can evaluate the overall effect of park placement by looking at the effect of park placement on this outermost resident. By definition, this resident will be paying R_a in residential rent; this amount is fixed regardless of park placement. Park placement can change two variables of interest to this resident— x^* , which determines how far the outermost resident must commute to work, and $|x^* - \hat{x}|$, which determines that individual's cost of visits to the park. The outermost resident's utility will decrease with increases in both x^* and $|x^* - \hat{x}|$. To the extent, therefore, that park location decreases $|x^* - \hat{x}|$ without at the same time increasing x^* , the outermost resident, whose utility level reflects overall landscape utility level, will be better off. When park location is pushed out far enough that x^* begins to increase, however, utility may begin to decline, depending on how high increased commuting costs are relative to the benefits of decreased cost of access to the park.

To understand why landscape utility can continue to increase as a park is pushed further out, despite the increasing burden of travel on the central-city resident, recall that these central

²Utility is actually at its maximum level on the interval $\hat{x} = [18.00, 18.35]$; for convenience, we chose $\hat{x} = 25$ to represent that interval.

³Equilibrium solutions were numerically attained in this model, and are not exact solutions. The total population on this landscape, 200,011, was as close to the required population, 200,000, as we could get given our solution search procedure.

residents are simultaneously benefitting from the increased housing consumption that comes with lower central city rents. The peripheral resident, whose rental and housing consumption are fixed, again represents a benchmark for evaluation of landscape utility; the peripheral residents enjoy the advantages of increased access to the park as long as x^* , together with their commuting costs, do not increase.

Expressing the changes in landscape-level indirect utility as some type of money metric, or dollar-value equivalent associated with the change in utility, may provide a more familiar context for determining the value of changing a park location. This task involves converting utils (the units of the indirect utility function) to dollars. The money metrics most often presented in economic analysis of individual welfare are consumer's surplus, equivalent variation, and compensating variation (Johansson, 1987). The relationship between these individual measures of welfare change and the change in landscape-level utility that our model captures is not immediately clear. The endogeneity of prices complicates the analysis, since each individual's welfare change from a shift in park location (and what they would be willing to pay to secure it) will depend on the response of everyone else in the landscape in determining a new equilibrium.

The traditional measure of compensating variation (CV), for instance, is described as the lump sum payment that an individual would be willing to make that would just exhaust the welfare gain to be derived from an amenity improvement (Freeman, 1993). In our model, amenity improvement comes in the form of park location change; with a park location change from \hat{x}_0 to \hat{x}_1 , for instance, every individual on the landscape experiences a utility change from V_0 to V_1 . It is not possible to separate the welfare change of one individual from that of the other individuals, and similarly it would not be possible to ask one individual what they would be willing to give up without explaining what others are giving up, and therefore what the new

equilibrium price levels will be, as well.

It is possible to apply the concept of the compensating variation measure at a landscape scale, asking the question “how much income would each individual be willing to give up to ensure that the park is provided at \hat{x}_1 rather than at \hat{x}_0 , given that everyone else in the city will give up the same amount and an equilibrium city structure will be reached accordingly?” We applied this aggregate-level analysis to our landscape, asking how much income each individual could give up (assuming that everyone else on the landscape gave up the same amount) to ensure that the park was provided at a variety of park locations from $\hat{x} = [1,25]$ rather than not at all. Such an analysis on our landscape yields the results shown in figure 5. The CV measure closely tracks the change in utility, and provides a monetary estimate of the utility change.

4. Conclusions

There is considerable evidence that urban residents value the presence of open space and green areas in their communities. Because open space is a public good, however, it often falls upon governments, rather than residents, to arrange for the provision of open space. Urban planners may have multiple objectives when arranging for the provision of open space in urban areas, however, including the internalization of externalities caused by dispersed development patterns and the minimization of vehicle dependence and its accompanying air quality issues.

This study illustrates that the effect of the provision of urban amenities such as greenbelts and open space on welfare and urban structure has a spatial dimension, and that optimal pattern, as well as optimal amount, must be considered in decisions regarding amenity provision. From an economic perspective, this spatial dimension may take the form of proximity effects on utility (Wu, 2001), or, in the case of our model, of differential accessibility and the variable travel cost

associated with use of a site-specific amenity. Questions about greenbelt location and accessibility must be considered in an overall context in which effects on direct utility, city size, density of residential development, and total vehicle miles traveled are each considered. Because the optimal locations associated with different objectives are not necessarily coincident, tradeoffs among objectives are required in ultimately settling on an amenity location.

As a prescription for reducing urban sprawl, park provision has mixed results. When placed close to the CBD, the park can result in an increase in inner city housing density; such placement could help ameliorate problems of commuter traffic congestion related to urban sprawl. Parks placed further out toward the periphery, although consistent with improved accessibility and utility maximization, have the opposite effect— pulling residents away from the CBD and thereby likely worsening the congestion problem related to commuter traffic.

The provision of the park raises the additional issue of the impact of trips to the park itself. The accessibility of the utility-maximizing greenbelt location has a downside; the more accessible the park, the more trips will be made overall, and the more automobile-related air quality problems the community may experience. This analysis disregards the automobile trips and mileage associated with consumption of the composite good, and therefore overestimates the mileage impact of substituting park trips for consumption goods. Our model parameters also ensure that demand for trips results in a very large total number of trips to the greenbelt. However, the suggestion that park location and accessibility will impact number of trips and miles covered should remain relevant, though at perhaps a smaller scale, in analyses with different preference structures and differing parameters.

This study shows that, while urban parks may be valuable in their own rights as recreational amenities and hosts to wildlife, they also might be strategically placed to achieve

other environmental goals such as open space preservation and the reduction of air pollution. In future work, it would also be useful to consider how the urban landscape would change if there were several parks established in a city or if a single park consumed more land area. How would increasing the quality of an urban park be received, if it meant conceding residential land? Would it be possible to create an urban growth boundary with a wide park that would work through incentives to locate within the boundary rather than through prohibitions on residential infrastructure? Small modifications of the current model could be made to address these questions, and would further illustrate the promise of using environmental amenity siting as an urban planning tool.

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