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A Note on the Value of Foregone Open Space in Sprawling Cities

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Abstract
Foregone benefits of the open space that is sacrificed through urban sprawl are hard to quantify. We obtain a simple benchmark measure by introducing a demand for trips beyond the urban boundary into the monocentric city model. The externality arises from the increase in travel costs that expansion of the city imposes on its prior inhabitants. An empirical application illustrates the moderate informational requirements. It indicates that open space externalities warrant rather mild restrictions on urban expansion.

JEL Classifications: Q26, R13, R52
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1 Introduction

Policies to curb urban sprawl may be justified by the external value of undeveloped land as open space. In their absence, developers do not internalize the value that people attach to the scenery, recreational opportunity or escape from frenetic urban life that open space may provide.[1] These benefits of undeveloped land are, however, difficult to quantify.

We obtain a simple measure by introducing a demand for trips to open space beyond the urban fringe into the conventional monocentric city model. City parks are an imperfect substitute for such 'true open space' as forests, wetlands or a scenic countryside.[2] Travel costs are the implicit price for a visit, so residents value the accessibility of true open space rather than its total land area.[3] This assumption is consistent with popular concern about urban sprawl in the US, where no more than two percent of all land is built-up or paved.[4] The external value of undeveloped land derives from the increase in travel costs that urban expansion imposes on prior inhabitants.

Our measure for open space benefits may usefully serve as a benchmark. As we illustrate for the city of Amsterdam, empirical application only requires information on basic urban parameters and an estimate of the average frequency of trips to true open space. Hedonic analysis of house prices, which is a common approach to the valuation of open space, imposes a considerably larger informational burden. Moreover, it entails a focus on comparably localized benefits.[5] Hence, this approach is less suitable for the assessment of anti-sprawl policy. Local demand for open space should be satisfied through the provision of local parks, while reduced access to true open space throughout an urban area warrants restrictions on expansion.

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[1] Brueckner (2000) reviews the economic arguments for anti-sprawl policy.

[2] Large chunks of parkland interior to the city, like Central Park in New York or Hampstead Heath in London, may offer a good substitute to recreation in greenbelt land. The availability of such substitutes will reduce the frequency of trips to open space beyond the urban fringe.

[3] This travel cost approach was first suggested by Hotelling (1947) for the valuation of National Parks. See Phaneuf and Smith (2006) for a survey of applications to recreation demand. It has rarely been applied to the valuation of open space in or near urban areas (McConnell and Walls, 2005).

[4] This figure refers to 1992, see Burchfield *et al*. (2006).

[5] For instance, open space amenities in Cheshire and Sheppard (2002) are confined to a surrounding squared kilometre. Walsh (2007) also considers the benefit of proximity to public open space, yet the average distance is only about one kilometre in his empirical application. In a particularly comprehensive analysis, Anderson and West (2006) find that property values rise with proximity to special parks, which on average have a size of thousand acres and a distance of two kilometres in their sample. However, Table 1 shows that the average length of trips to true open space is about 10 kilometres in our data.

2 Theory

We consider a circular city with radius *b*, surrounded by agricultural land. The amount of land available for residential purposes at distance $r \le b$ from the centre is $L(r)$. True open space is agricultural land at some critical distance $d \ge 0$ from the urban fringe, large enough for instance to make the city skyline disappear from the horizon.[6]

Residents derive utility *u* from the consumption of a composite consumption good *z*, from land *s* and from trips to true open space *n*:

$$u = u(z, s, n). \tag{1}$$

True open space is nonexcludable, so residents only incur travel costs. The price of a trip equals $t_n(b-r+d)$, where $b-r+d$ is the distance to the nearest place where true open space can be enjoyed and t_n denotes the per unit travel costs for recreational trips. All prices are expressed in units of the composite good.

Jobs are located in the city centre and each resident provides one unit of labour with a constant marginal product of *w*. This requires an exogenous number of commuting trips *m* and the commuting costs per unit of distance t_m is allowed to differ from t_n, possibly because of a difference in the valuation of travel time. For the city to maintain its monocentric structure, we must have that $t_m m > t_n n(r)$, so that locations at closer distance to the centre are more attractive. This inequality is likely met in practice as for most people $m \gg n(r)$.

In order to derive the efficient allocation of resources, we define social surplus as the total income generated in the city minus all costs incurred in order to assure a utility level *u* for its inhabitants. The minimum amount of the composite good that has to be consumed in order to reach utility level *u* when $n(r)$ trips to open space are made and $s(r)$ units of land are consumed is denoted $Z(n(r), s(r); u)$. Surplus may then be written as:

$$S = \int_0^b \left(\frac{w - t_m m r - t_n n(r)(b+d-r) - Z(n(r), s(r); u)}{s(r)} - p^A \right) L(r)\, dr, \tag{2}$$

[6] This condition effectively ensures that true open space is not provided within the urban fringe, yet the parameter *d* will not show up in our externality measure. See Lee and Fujita (1999) for a more general model of optimal greenbelt provision. In order to keep the analysis simple, we assume homogeneity in the open space benefits that different places beyond *d* provide. This may also be justified if a trip to true open space is mainly enjoyed as an escape from the frenetic urban scene. See for instance Colwell *et al*. (2002) or Wu and Plantinga (2003) for urban models with a site-specific amenity.

where p^A is the agricultural land rent. The problem of a benevolent planner is to find $n(r)$, $s(r)$ and a boundary b that optimize this expression. This yields the following first order conditions:

$$-\frac{\partial Z(n(r),s(r);u)}{\partial n}=t_n(b+d-r), \tag{3}$$

$$-\frac{\partial Z(n(r),s(r);u)}{\partial s}=\frac{w-t_m mr-t_n n(r)(b+d-r)-Z(n(r),s(r);u)}{s(r)}, \tag{4}$$

and, making use of Leibniz's rule,

$$\frac{w-t_m mb-t_n n(b)d-Z(n(b),s(b);u)}{s(b)}=p^A+\frac{1}{L(b)}\int_0^b\frac{t_n n(r)L(r)}{s(r)}dr. \tag{5}$$

Condition (3) embodies the core of our valuation approach, stating that the willingness to pay for the marginal visit to true open space should equal travel costs. Condition (4) states that the marginal willingness to pay for residential land should equal the maximum a person can afford if she earns her marginal product and covers expenses for travel and consumption of the composite good from it. Hence, condition (5) implies that at the urban fringe, the willingness to pay for residential land should exceed the agricultural land rent by a levy τ that may be rewritten as:

$$\tau=\frac{t_n\hat{n}N}{L(b)}. \tag{6}$$

In this expression, $\hat{n}$ denotes the average frequency of trips to true open space and N is the total number of residents in the city. The numerator equals the total additional travel cost to true open space that is imposed by expanding the urban fringe by one unit of distance and the denominator scales this amount to the additional residential land that becomes available.[7]

Consider an open city in which migration ensures an exogenous utility level u. The social optimum in this city may be decentralized by trading labour, residential land and the composite good on competitive markets, while levying a tax on the conversion of agricultural to residential land that equals τ. Developers will then find it profitable to build the city outwards until condition (5) is met. Furthermore, in a spatial equilibrium, residents will choose the trip frequency and lot size that maximize their bid for residential land, thus ensuring that conditions (3) and (4) hold. Cities that neglect to implement the development tax

[7] Note that the externality involved in outward trips to true open space is absent for inward commuting trips, because the location of the city centre is exogenous.

are too large and not sufficiently dense, since residential land is worth less if trips to true open space are more costly.

The taste for trips to true open space is likely to vary across residents and those with the highest taste will locate closest to the urban fringe. We show in the Appendix that expression (6) is robust to the presence of such heterogeneity in preferences.

3 Application

We define trips to true open space in a Dutch leisure activity survey either as ‘outdoor recreation’ that takes place outside the municipality of residence, or as activities conducted in types of open space that are usually not found within city boundaries – see Table 1 for an overview and some basic descriptives. Trips with a length of over 50 kilometres have been discarded as these are unlikely to be affected by city size.[8]

Table 2 offers rudimentary support for our modelling approach. It shows average monetary travel costs and the frequency of trips for three classes of a density-based measure of urbanity. Inhabitants of less urbanized places where true open space is readily accessible visit it more frequently. This effect may partly be due to residential sorting with regard to the taste for such visits, but in that case it still confirms that at least a considerable share of the population values access to true open space in our definition. As noted, heterogeneity in preferences does not invalidate our measure for the external effect.

Table 3 puts numbers into expression (6) for the city of Amsterdam, while assuming that $L(r) = \omega r$, where ω denotes the share of land in residential use.[9] The implied optimal development tax of about 10 Euros per square metre is modest compared to estimates of the actual shadow tax on residential land use at the fringe of this city. For instance, Vermeulen (2011) reports a gap of 254 Euros per square metre between the value of residential land and its opportunity and development cost.[10]

[8] About 10% of all trips exceed this threshold in either definition.
[9] Our computation assumes that a segment of the circle is available for residential use, both in the existing city and for urban expansion.
[10] The implied regulatory tax rate of almost 30% ranks Amsterdam amongst the more restrictive cities in the US, as measured by Glaeser *et al*. (2005) – only San Francisco and San Jose impose regulatory tax rates that are significantly higher.

4 Conclusion

We have derived a simple tax rule for internalization of the loss of open space benefits that urban expansion induces. This rule is crude in that it assumes specific urban form and ignores the non-use value of open space and unique locational attributes like outstanding beauty, environmental quality or historical value. Yet, as the informational burden is minimal, it may serve a useful benchmark. Our application suggests that open space preservation warrants rather moderate policies to curb urban sprawl.

Appendix: extension with heterogeneous tastes for true open space

We consider two resident types with different preferences and different reservation utilities u_1 and u_2. Conditional demands for the composite commodity are then given by $Z_1\left(n_1(r), s_1(r); u_1\right)$ and $Z_2\left(n_2(r), s_2(r); u_2\right)$. The two types are assumed to face similar travel costs. Suppose that resident type 1 is less concerned about trips to true open space and therefore inhabits the inner part of the city. Surplus may be written as:

$$\begin{aligned} S = &\int_0^{b_1}\left(\frac{w - t_m mr - t_n n_1(r)(b_2 + d - r) - Z_1\left(n_1(r), s_1(r); u_1\right)}{s_1(r)} - p^A\right)L(r)\,dr \\ &+ \int_{b_1}^{b_2}\left(\frac{w - t_m mr - t_n n_2(r)(b_2 + d - r) - Z_2\left(n_2(r), s_2(r); u_2\right)}{s_2(r)} - p^A\right)L(r)\,dr, \end{aligned} \tag{A1}$$

where b_1 is the boundary between the areas where each resident type lives and b_2 is the urban fringe. The optimal choice of $s_1(r)$, $s_2(r)$, $n_1(r)$ and $n_2(r)$ follows from similar first-order conditions as in the main text. Furthermore, at the optimal choice of b_1, both resident types have the same willingness to pay for land.[11] The key result of interest obtains by taking the first-order condition with respect to b_2. This yields the condition:

$$\frac{w - t_m m b_2 - t_n n_2(b_2) d - Z_2\left(n_2(b_2), s_2(b_2); u_2\right)}{s_2(b_2)} = p^A + \frac{t_n \hat{n} N}{L(b_2)}, \tag{A2}$$

where the average frequency of trips to true open space is now computed as

[11] Our assumption that the resident type with the lowest taste for trips to true open space inhabits the central part of the city ensures that the second-order condition is met as well.

$$\hat{n} = \frac{1}{N}\left(\int_0^{b_1} n_1(r)\frac{L(r)}{s_1(r)}dr + \int_{b_1}^{b_2} n_2(r)\frac{L(r)}{s_2(r)}dr \right). \quad \text{(A3)}$$

Hence, the willingness to pay for land of resident type 2 should exceed the agricultural land rent by the same levy as in expression (6) and our empirical approach to estimating τ is robust.

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TABLES

Table 1: Defining trips to true open space

	Outdoor recreation outside municipality of residence	Trips to surroundings classified as true open space
Surroundings (%)		
Forest	20.0	31.8
Sea / water / wetlands	13.0	21.3
Countryside	14.4	27.0
Park outside built-up area	6.2	10.8
Dunes / sands / heath	6.5	9.1
Other	40.0	-
Location (%)		
Own municipality	-	37.0
Elsewhere	100.0	63.0
Descriptives		
Weekly frequency	0.69	0.70
Total duration (hours)	2.9	2.7
Distance to location (km)	11.3	8.9
Monetary travel cost (€)	1.13	0.74

Note: Based on Continu VrijeTijdsOnderzoek (CVTO) 2006-2007. The sample consists of 16,392 respondents who report their leisure activities for one week. Total duration of the activity includes travel time. Distance to location of the activity refers to the point of departure in the case of 'mobile activities' like hiking and cycling. Monetary travel costs incurred for the recreational activity have been imputed in the CVTO on the basis of distance and modal choice.

Table 2: Urbanity and trips to true open space

Degree of urbanity	Outdoor recreation outside municipality of residence		Trips to surroundings classified as true open space	
	cost (€)	*frequency*	*cost (€)*	*frequency*
High	1.19	0.68	0.84	0.59
Medium	1.11	0.66	0.77	0.68
Low	1.06	0.72	0.60	0.88

Note: The definition of the degree of urbanity from Statistics Netherlands is based on local address counts: high is more than 1500 addresses and low is less than 1000 addresses per square kilometre.

Table 3: Optimal development tax

Variable	Value	
Annual frequency of trips	35	28
Travel cost (€/km)	0.2	
Total population	1 million	
Total area of city (ha)	45 thousand	
Share in residential use	0.18	
Length of residential boundary (km)	13.5	
Discount rate	0.05	
Optimal development tax	10.3	8.3

Note: Trip frequencies for both alternative definitions have been estimated for residents of the urban agglomeration of Amsterdam. An average monetary travel cost of 0.08 €/km is based on CVTO 2006-2007. The total travel costs are based on a speed of 80 km/h and a value of time of 10 €/h. The total population, area and share of land in residential use for Amsterdam are obtained from Statistics Netherlands.

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