Communities, Competition, Spillovers, and Open Space

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ABSTRACT. *We explore the impact of the spatial distribution of developers on the private provision of open space. Our analysis yields three main findings. First, we demonstrate that the mixed public good nature of open space (relative to private lot consumption) can lead a single land rent-maximizing developer to over-supply open space relative to the utility-maximizing level. Second, by explicitly incorporating the spatial distribution of open-space spillovers, we show how competition can lead not only to inefficient levels of open space, but also to inefficiencies in its spatial distribution. Finally, we evaluate the impact of market-based open-space instruments.* (JEL H41, R14)

I. INTRODUCTION

Open space protection is a focus of local governments across the United States. Communities are motivated to protect open space for its amenity and recreation value, but also as a tool to control urban growth. In the 2003 election alone, there were at least 134 ballot initiatives regarding open space preservation in the United States. Of those, 100, or approximately 75% were passed by voters generating over $1.8 billion for land conservation (Land Trust Alliance 2004). With this ongoing policy focus on land protection, it is important to understand how competition between developers affects the provision of open space. This paper is particularly motivated by the continued spread of edge communities that are not necessarily tied to a municipality. By one estimate, over 60% of the growth in metropolitan populations is accruing to suburban border communities as compared to just 11% to the inner rings (Berube and Forman 2002). The character of these new communities is largely determined by the optimizing behavior of a small number of profit-maximizing developers. To better understand this process, we evaluate the impact of competition between developers on the provision of protected open space in a spatially differentiated general equilibrium framework.

Open space is an interesting public good for a variety of reasons that we explore in this paper. First, the primary input to open-space production is land. Land is also the key input to the private good in question, namely residential lots. That is, through the provision of open space, we are automatically increasing the scarcity of land for residential development. Further, we know from various hedonic studies that proximity to undeveloped land can have a marked impact on housing prices.[1] Hence, open space protection is linked to the residential land provision decisions of developers through two channels: (1) the amenity value of open space increases the value of proximate houses, and (2) additional land protection leads to a reduction in the supply of land for residential housing.

The second key characteristic of open space as a public good is that the spatial distribution of open space may be as

Land Economics • May 2008 • 84 (2): 169–187
ISSN 0023-7639; E-ISSN 1543-8325
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The authors are, post-doctoral research associate, Center for Environmental Economics and Sustainability, Arizona State University and assistant professor, Department of Economics, University of Colorado. The assistance of Thomas Rutherford is gratefully acknowledged. The authors would also like to thank John Boyce, Herb Emery, the participants at the University of Colorado Workshop in Environmental and Resource Economics, and two anonymous reviewers for helpful comments. This work was supported in part by the G8 Legacy Chair in Wildlife Ecology, University of Calgary.

[1] Recent examples of include: Riddel (2001), Bolitzer and Netusil (2000), and Schultz and King (2001).

important as the level of provision. This spatial link implies that even when a large quantity of land is allocated to open space, it is possible that only a few residents will benefit due to sub-optimal distributional patterns. For instance, from the perspective of a household located near the urban core, the amenity benefits of large quantities of open space at the urban fringe may be much lower than those provided by small parks in the immediate vicinity.

To explore these issues, a general equilibrium model incorporating homogeneous residents and profit-maximizing, spatially explicit developers is constructed. Our analysis within this framework starts by considering the implications of different competition regimes on open-space allocation, development land values and residential welfare. We then consider the efficacy of market-based and command-and-control policy instruments for addressing inefficiencies in open-space provision. The results of this analysis demonstrate that both the level and spatial distribution of open space provision are sensitive to the structure of competition between developers—with low to moderate levels of competition generally leading to more socially preferable outcomes. We also find that, due to the spatial inefficiencies that arise from the inability of competing developers to internalize the spillover of open space benefits outside of their development region, command-and-control regulatory approaches may be more effective than simple market mechanisms in moving the provision of open space under competitive regimes toward the social optimum.

II. LITERATURE REVIEW

Our basic problem is to model how developers in close proximity compete in a scalable public good with spillover benefits to neighboring developments. Our approach draws on several strands of literature. Key concepts include the link between urban spatial structure and amenities, the capitalization of public goods in the presence of spillovers, and the role of a profit-maximizing developer in the allocation of public goods.

First, consider the relationship between urban spatial structure and open-space amenities. Begin with an area of land that is slated for residential development. The question this paper asks is "are more or fewer developers advantageous in terms of the public welfare from the provision of open space?" The closest extant research to our analysis is that of Marshall (2004). Her work focuses on the socially optimal allocation of open space with interacting jurisdictions as opposed to developers. Her main focus is on the role of foresight in the jurisdictions' allocation decisions. She finds that open-space allocations increase as jurisdictions have greater foresight into the ability of residents to move. Further, a high-income community may "free-ride" on the provision of open space from a lower-income community if the high-income community is located at the center of the region. This differential open-space allocation is driven by foresight, combined with either income or land area heterogeneity. In general, her results suggest that myopic decisionmakers provide uniform open-space allocation unless there are edge effects at the boundary of the developed area. Our approach differs from hers in that rather than a social planner in each of the jurisdictions, we consider the role of profit maximization and competition between developers under varying competitive regimes.

Our analysis also builds on the work of Brueckner (1983a) in which he explicitly models the tradeoff between land in residential building footprint and in yard space within the context of a monocentric city model. We extend this work by incorporating the spillovers of communal undeveloped land from one development to another and evaluating the impact of differing competition structures. Wu and Plantinga (2003) also consider the impact of environmental amenities on spatial structure. Their work focuses on how municipalities may develop given an exogenous environmental amenity such as a hill or stream. Our work differs from theirs in that we consider an endogenous environmental amenity.

Additionally, we focus on the interaction between benefit spillovers and the structure of competition. Our results demonstrate that each competitive regime implies a different pattern of amenity capitalization and hence differences in both the distribution and quantity of open space provision. In particular, larger developments capture more of the spillovers associated with open space provision at a given location. We model these spillovers as a continuous analog of the work of Cremer, Marchand, and Pestieau (1997). In their work, they consider how two neighboring municipalities decide to allocate a single non-scalable public good such as a recreation center or stadium. They consider a Nash equilibrium in the public good provision and find that although the efficient level of the public good is not typically provided in the noncooperative equilibrium, there does exist a cooperative system such that both municipalities share the cost and construct a single public good—the efficient outcome of their model. Our model constructs reaction functions for each developer in open space and suggests a similar result to that of Cremer, Marchand, and Pestieau (1997). Specifically, we find that when spillovers from open-space provision cannot be captured, in general, competition will lead to an under provision. Our analysis differs from that of Cremer, Marchand, and Pestieau in that both the level and spatial distribution of the public good provision are important to households.

A key issue is the link between open-space protection and housing prices. To highlight these capitalization effects, in our model we fix the boundaries of the development region. As suggested by Brasington (2002), if the jurisdictional boundary may fluctuate, internalization of the public goods in housing price may not occur since more land can be allocated driving down the price to the marginal cost of land. Thus, communities located at the center of a metropolitan area may have greater capitalization than edge cities. Further, if the boundaries are allowed to fluctuate, any jurisdiction may capture all of the amenity rents that a potential buyer may have for the amenity. This result is formalized in Heal (2001).

The role of the developer in our model is that of a land-rent maximizer. There is a large body of work on the role of property value maximization in the provision of efficient public good levels. Early examples from this literature include Sonstelie and Portney 1978, 1984, Bruekner 1983b, and Epple and Zelenitz 1984. These papers outline the assumptions that equate property-value maximization with the efficient provision of public goods. In contrast to this literature, we find that under a variety of competition assumptions, including a single monopolistic developer, property-value maximization does not equate to the efficient provision of public goods. This is a result of the link between public and private good provision through the input, land. The developer wishes to restrict the supply of the private good which automatically causes an over-provision of the public good. Thus, by explicitly incorporating the input to public good production, the result of the previous work is overturned.

III. THE MODEL

The model posits two sets of decision-makers, developers and residents. There exists a set of N identical households, J spatially delineated developable regions of area A_j, and a set of K developers each controlling one or more of the developable regions. Households choose a location in one of the development regions, and conditional on location choice, quantities of land (residential lot size) and the numeraire good (which includes housing, but not the residential lot and whose price is normalized to one). We abstract from the notion of housing in order to reduce the developer's decision on vertical development and concentrate only on the horizontal aspect of development. Developers control a set of regions that compose developments and this set of developments, each controlled by a different developer, makes up the total development area.

Formally, the household's problem is to choose a location, j, and consumption levels of land and numeraire to solve

$$\max U_j = U(x, D, Q_j) \quad s.t. \quad Y = x + P_j D, \quad [1]$$

where x is numeraire consumption, P_j is the price of land in region j, D is lot size, Q_j is a measure of environmental quality in region j, and Y is the shared-income level.

Environmental quality is the spatially weighted sum of the amount of open space, O_j, in region j as well as all other neighboring regions. The level of the open space amenity in region j is given by

$$Q_j = \sum_{j' \in J} \phi_{j',j} O_{j'}, \quad [2]$$

where $\phi_{j',j}$ is a weighting matrix that defines how the contribution of open space to environmental quality decays as a function of distance from region j. We assume that the only areas that supply environmental quality are those within the total development area. That is, nothing outside of the total development area enters the utility function of the model's agents. There are two motivations for this approach to modeling the benefits from open space. First, from the perspective of use values, greater distances to open space sites will be associated with increased travel costs. Thus, the weighting matrix can be viewed as a reduced form representation of travel costs in the preference function. Second, households also care about their ambient environment. From this perspective, the weighting matrix can be viewed as capturing the diminishing role that specific open space parcels play in a household's perceived ambient environment as the distance from the household to the parcel increases.

Each developer controls a set of regions which form a development and chooses a quantity of open space in each region that she controls—subject to the constraint that the total available land in each region is fixed. Thus, $A_j = L_j + O_j$, where L_j is the supply of residential land in region j. Developer profit from a given region is given by

$$\Pi_j = P_j L_j. \quad [3]$$

Or, embedding the land constraint into the profit function:

$$\Pi_j = P_j (A_j - O_j). \quad [4]$$

Taking the derivative with respect to open space yields the first order condition:

$$\frac{\partial P_j}{\partial Q_j} \frac{\partial Q_j}{\partial O_j} (A_j - O_j) = P_j. \quad [5]$$

Incorporating the fact that an individual developer may control more than a single region, and letting J_k represent the set of regions controlled by developer k, the first order condition for open space provision in each of locations that she controls becomes

$$\sum_{j' \in J_k} \left(\frac{\partial P_{j'}}{\partial Q_{j'}} \frac{\partial Q_{j'}}{\partial O_j} (A_{j'} - O_{j'}) \right) = P_j. \quad [6]$$

Hence, each developer must equate her marginal benefit of open space provision—ignoring spillovers into areas controlled by other developers—with the marginal cost of setting land aside as open space. If benefits from open-space provision are not completely captured by the developer, they "spill" into neighboring developments and inefficiencies arise. We assume that developers compete in a Cournot fashion in terms of land allocation between open space and housing supply. Further, we assume that developers are not atomistic in the sense that they may exert market power in the housing market through restrictions in the supply of residential land. Thus, as we discuss below, this market power is a second channel through which inefficiencies may arise.

Prices in each region, P_j, are determined in equilibrium, which is characterized by the following conditions:

1. Equal Utility

$$U(x_j, D_j, Q_j) = U(x_k, D_k, Q_k) \quad \forall j, k; \quad [7]$$

2. Market clearing

$$D_j(P_j, Q_j, Y)^* n_j = A_j - Q_j, \quad \forall j; \qquad [8]$$

3. All residents must have a place to live

$$\sum_{j \in J} n_j = N, \qquad [9]$$

where n_j represents the number of residents choosing to live in region j. Hence, prices in each region are not only a function of the open space within the region, but of all open-space allocations within the total development area.

In order to close the model, we must consider both the mobility of residents and to whom developer profits are distributed. For simplicity of analysis, in particular welfare calculations, we close the model to population. That is, we fix the population at a specific level, N.[2] Second, we recycle developer profits equally to all residents. This allows us to simply consider resident welfare and not to have to separately incorporate developer profits into our welfare calculations. The equilibrium outcome that arises from competition between rival developers in open space is characterized as a Nash equilibrium in which each developer maximizes profits contingent on the allocation of the other developers.

For a second set of analyses, we incorporate a market-based policy mechanism. We introduce a subsidy, s, on open-space provision in order to change developer behavior at the margin. We finance this subsidy via an income tax, τ. The role of the income tax is simply to finance the subsidy and is not used to change the behavior of households. Although it may seem advisable to use a property tax to finance an open-space provision, this approach introduces unwanted dimensions to the analysis making it difficult to identify the impact of the subsidy on development decisions. Specifically, using a recycled property tax to generate the revenue needed to finance the policy is not neutral with respect to the provision of open space. Since profits are recycled equally to all households, the income tax is equally recycled to all households; a property tax would not have this same property since some households would bear more of the burden. This is because the imposition of the property tax increases the price of land for housing relative to the price of land for open space and thus leads to the provision of additional open space.[3] We also note that this assumption is consistent with a number of state policies that are designed to support open-space provision by localities. Thus, the resident and government budget constraints, respectively, for these analyses are given by

$$P_j D_j + x_j = \left(Y + \sum_j \Pi_j / N \right)(1 - \tau) \qquad [10]$$

$$\tau\left(Y + \sum_j \Pi_j / N \right) = \sum_j subsidy^* O_j. \qquad [11]$$

The complexity of the model's spatial Nash equilibrium precludes analytical solutions.[4] We therefore adopt a numerical strategy for analyzing the implications of the model. Much of the literature in the area of urban spatial structure adopts a Cobb-Douglas formulation for utility. As examples, Wu and Plantinga (2003) and Marshall (2004) both use a utility function of the form:

$$U(x, D, Q) = x^{\alpha}(DQ)^{(1-\alpha)}. \qquad [12]$$

Within this literature there is either a very limited role for a developer or developers are non-existent. Once we move to a model

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[2] Qualitatively, analysis using an open city model as well as an intermediate migration scenario provide similar results.

[3] This effect is akin to the link between land taxes, as opposed to property taxes, and sprawl identified by Bruekner and Kim (2003).

[4] Cremer, Marchand, and Pestieau (1997) are able to derive analytical results in a two location model with a non-scalable public good and no explicit consideration of space.

in which developers have market power this utility function becomes much less desirable. In particular, consider a single developer. Since each resident spends $(1 - \alpha)$ of her income on the composite land good and the developer provides this composite good, the developer simply extracts $Y(1 - \alpha)$ from every household. In effect, any open-space allocation is optimal for a single developer. To address this issue, we assume that household utility takes a nested constant elasticity of substitution (NCES) form. Because lot size and open space amenities are more substitutable for each other than they are for the numeraire good, we place lot size and environmental quality in one nest with the numeraire in a separate nest. Thus, the utility of households living in location j is of the form:

$$U(x_j, D_j, Q_j) = \left(\alpha x_j^\rho + (1-\alpha)\left(\beta D_j^\gamma + (1-\beta)Q_j^\rho\right)^{\rho/\gamma}\right)^{1/\rho} \quad [13]$$

and they are subject to the budget constraint:

$$x_j + P_j D_j = \left(Y + \sum_j \Pi_j / N\right)(1-\tau). \quad [14]$$

Drawing on the hedonic literature, we assume that environmental quality declines with distance to open space. There is further evidence that this is a non-linear and convex relationship (Acharya and Bennett 2001). Thus, the environmental quality function assumes the form:

$$Q_j = \left[\sum_{j' \neq j} \frac{\phi_0}{\sqrt{dist_{j',j}}} O_{j'}\right] + O_j, \quad [15]$$

where $\phi_0 \in [0,1]$ is a constant that reflects the degree of spillovers between regions. When $\phi_0 = 0$ there are no spillovers and as ϕ_0 increases, there is a greater influence of neighboring open-space provision on environmental quality.

Typically with an NCES utility, it is possible to derive demands for each of the goods using a two-stage budgeting process. But given the public goods nature of environmental quality this is not possible. Thus, to numerically solve the model, we use the fact that in equilibrium the marginal rates of substitution between housing demand, D_j, and the numeraire, x_j, must equal the price ratio, P_j. Note that:

$$\frac{\partial U}{\partial x} = \alpha \rho x^{\rho - 1} \quad [16]$$

$$\frac{\partial U}{\partial D} = (1-\alpha)\frac{\rho}{\gamma}(\beta D^\gamma + (1-\beta)Q^\gamma)^{\frac{\rho}{\gamma}-1}(\beta\gamma D^{\gamma-1}). \quad [17]$$

And, hence the marginal rate of substitution between housing land consumption and numeraire is given by

$$MRS = \frac{(1-\alpha)\left(\beta D_j^\gamma + (1-\beta)Q_j^\gamma\right)^{\frac{\rho}{\gamma}-1}\beta D_j^{\gamma-1}}{\alpha x_j^{\rho-1}}. \quad [18]$$

Rewriting in the calibrated share form[5] and setting the MRS equal to the price ratio and simplifying, we obtain

$$\frac{P_j D_j}{x_j} = (1-\alpha)\frac{\beta}{\alpha}\left(\frac{D_j}{D_0}\right)^\gamma \left(\frac{x_j}{x_0}\right)^{-\rho} \left[\beta\left(\frac{D_j}{D_0}\right)^\gamma + (1-\beta)\left(\frac{Q_j}{Q_0}\right)^\gamma\right]^{\left(\frac{\rho}{\gamma}-1\right)}, \quad [19]$$

where, the subscript 0 denotes a benchmark allocation.

Our numerical analysis requires choosing values for the model's parameters. As is typical when working in a CES framework, we calibrate the numerical model to a

[5] The calibrated share form of the NCES utility function provides a good framework for considering a calibration to a benchmark allocation. It allows us to directly input the calibration into the utility specification and facilitates easy evaluation of changes to the benchmark. Specifically, if an individual purchases the benchmark consumption bundle and receives the benchmark level of environmental quality, she receives a utility of 1. For further information on the calibrated share form see: http://www.gamsworld.org/mpsge/debreu/ces.pdf.

benchmark consumption bundle.[6] We assume that all residents and developable plots look exactly the same and average over locations to compute the reference open space amenity level. Calibrating to a benchmark allows us to look at the model around a "real world" allocation and not in a parameter space far from reality. In this benchmark, residents spend 70% of their income on consumption of the numeraire good, leaving 30% for housing lot consumption.[7] Further, in the benchmark, residents live on approximately quarter-acre lots and approximately one-sixth, or 16.7% of the land in all regions is allocated to open space. Table 1, taken from Harnick (2000), reports the percentage of land in an open space use for a number of major cities. Our chosen calibration of 16.7% falls in the middle of these reported open space percentages.[8]

The literature offers little guidance on how to choose the elasticity parameters. We adopt an upper level elasticity of 1.2 and an elasticity of substitution between lot size and environmental quality of 0.8. This parameterization for the elasticities allows us to maintain our prior assumptions regarding substitutability while still remaining close to the elasticity assumptions embedded in the Cobb-Douglas specification typically used in the literature.

TABLE 1

Open Space Percentages within City Boundaries for Selected Cities

City	Open Space as % of City Area
New York	25.7
San Francisco	19.8
Washington, D.C.	19.1
Minneapolis	16.2
Boston	15.7
Philadelphia	12.4
Oakland	10.3
Los Angeles	9.9
Baltimore	9.8
Long Beach	8.9
Chicago	8.0
Miami	5.8

Source: Harnik(2000).

The total development area is defined as follows. We assume that there are 100 one-acre regions of developable land arranged in a 10×10 grid and parameterize to a population of 346.[9] We normalize household income to 1. This corresponds to a baseline utility of 1 in the calibrated share form of the NCES utility function. Finally, in the calibration we benchmark the environmental quality under the assumption that an equal amount of open space is provided in each region. We do this to abstract away from the spatial aspect in the benchmark calibration. In our particular calibration, we assume that each region allocates one-sixth of the land to open space.[10]

IV. NUMERICAL METHOD

The modeling framework that we adopt incorporates multiple optimizing decision-makers. Computing the Nash equilibrium in the model is facilitated by the fact that once the level of open space is determined for each location, all other variables are uniquely determined by the interaction of household demands and market-clearing

[6] To facilitate computing the benchmark, we assume that all individuals consume identical bundles. This assumption ignores both the endogeneity of land market outcomes and the actual spatial process through which open space amenities accrue. Thus, while this approach is useful for illustrating the implications of the parameter assumptions, the benchmark is not an equilibrium in our model.

[7] It is important to note that this 30% share is for the virtual expenditure on residential land *and* rationed environmental quality, relative to virtual income. In the baseline specification, this virtual expenditure share is associated with an actual expenditure share of 25% on residential housing lot. Sensitivity analysis on this parameter revealed no qualitative differences in our results.

[8] We have considered alternative specifications that incorporate both higher and lower baseline open space percentages. Qualitatively our results do not change. As we increase (decrease) the benchmark calibration of open space the calculated social optimum increases (decreases) as well. Similarly, if we increase the calibrated lot size, the optimal equilibrium lot size increases but our basic results remain unchanged (note: this increase in baseline lot size is associated with a decrease in population).

[9] This population corresponds with the benchmark allocation of land into residential and open space uses.

[10] These assumptions result in a value of Q_0, equal to 0.523.

conditions. The numerical algorithm for computing market equilibrium uses a diagonalization method which sequentially solves for the optimal open-space provision decision for a given developer, taking all other developer's open-space decisions as given. The process is iterated until an equilibrium is reached.

In order to illustrate the solution algorithm, consider two development regions and two corresponding developers. First, arbitrarily set the level of open space provision chosen by the second developer. The algorithm then identifies the profit-maximizing level of open space provision for the first developer, taking the second developer's open space provision as fixed. Next, the optimal level of open space for developer two is identified, taking developer one's open space provision as fixed at this recently identified optimum. In effect, we are computing points along the reaction functions for the two developers. The algorithm iterates this process until it converges to a fixed point that corresponds to the intersection of the two reaction functions. When we solve the 100-region model the set of developers, K, is smaller and each developer chooses open space levels in multiple locations. Nonetheless, the basic solution algorithm is the same. Each developer chooses a distribution of open space over her entire region, taking all other developers' open space decisions as given. Hence, we are simply computing the intersection of a set of reaction surfaces.

Finally, to compute the allocations associated with the social planner's problem, we ignore developers and simply identify the matrix of open space levels that maximizes the shared utility level of the residents subject to the market clearing conditions defined by equations [7]–[9].

V. WELFARE CALCULATIONS AND BASELINE RESULTS

Complications arise within this model for welfare calculations because individuals residing at different locations consume different bundles of environmental quality, lot size, and the numeraire. Each of these different locations is therefore associated with a different point along the equilibrium iso-utility surface. As a result, there are 100 different values of compensating variation associated with each simulation—one for each of the regions in the model. As a summary welfare measure, we report the population-weighted average compensating variation, CV, across all 100 of the model's regions.

The use of a general equilibrium framework complicates welfare analysis and imposes the need for additional assumptions. One common approach is to treat agents as atomistic individuals for the purpose of welfare calculations. That is, allow each individual in turn to adjust their various consumption levels—ignoring any inconsistencies or price/quantity changes implied by these adjustments. Given the inherent link between levels of residential land consumption and the provision of open space, this approach is inappropriate for our model vis-á-vis residential land consumption. In response to this dual nature of residential land and open space, we instead fix the open-space level in each region and then allow individuals to adjust on all other dimensions, namely region choice, lot size, and numeraire consumption while imposing market clearing land prices. Individuals can readjust in every dimension but the land market must still clear in each region. In order to compute our measure of welfare change, we fix the shared utility level at the social optimum and then minimize the amount of additional total income needed to achieve this utility level at each location given the fixed distribution of open space and imposing the market clearing condition. The choice of the social optimum as a baseline is just one choice but seems to make sense in this situation. Finally, we normalize in each case by income so that our CV numbers are in income percentages.

As a baseline for our welfare comparisons, we solve the social planner's problem and calculate baseline outcomes under two general model specifications. First, we consider the case where there are no open-space spillovers. This is accomplished by setting ϕ_0 in equation [15] to 0. This

TABLE 2
SOCIAL PLANNERS PROBLEM

	No Spillovers	Spillovers
Percentage of open space	14.500	14.469
Total land rents	118.086	118.061
Average lot size	0.2500	0.2500
Utility level	1.2863	1.2864

specification allows us to focus solely on issues of market power in residential land supply and abstract from the connection between increased levels of competition and reductions in the ability of individual developers to capture rents associated with open-space spillovers. In the second set of model specifications, we incorporate spillovers, setting ϕ_0 equal to 0.1.[11]

Summary statistics for the socially optimal levels and distribution of open space under each of these specifications appear in Table 2. The distribution of open space, represented as the percentage of open space in each region, is presented in Figure 1.[12] Under the calibrated model, both the spillover and no spillover social optima are associated with an aggregate provision of open space of approximately 14.5%. There is a small decline in the average amount of open space when we move from the no spillovers case to that with spillovers. This arises from the fact that by providing a greater amount of open space at the center that then "spills" to all regions the social planner can provide less open space on average and still obtain a higher level of average environmental quality relative to the no spillovers case. With spillovers, because the development region is isolated, regions near the edge will provide less open space than at then center. As we move to the center of the development region, distances to all other regions decrease on average—yielding larger benefits from open-space provision. Thus, with spillovers, the social planner concentrates open space in the center of the development region, as is shown in Figure 1.

Under the social planner, the open-space allocation internalizes all spillovers and maximizes the value of protected open space. While not formally presented here, it is also interesting to note that as the spillover coefficient, ϕ_0, is perturbed not only does the aggregate quantity of open space change but also the spatial distribution open space. A decrease in spillovers increases the total amount of open space and reduces the rate at which open-space provision declines as one moves from the center of the development region to its edges.

VI. COMPETITION WITHOUT SPILLOVERS

In order to analyze the role of competition, we begin by isolating the market power effect of open-space provision and abstract from the role of benefits spillovers across developments. We evaluate market power in two ways. First, we consider the role of market power in a land market with two developers. We start with a model of a single developer and assymetrically reduce the market power by adding a developer of greater and greater size until we are at a situation with two developers controlling symmetric sets of land. Second, we consider symmetric configurations with increasing numbers of developers. That is, we begin with a single developer controlling the entire 100 acres, then subdivide into two symmetric side-by-side, 50-acre developments, and then four 25-acre developments positioned symmetrically at the corners. Symmetry of the developers, in the sense of land size as well as position in the development allows us to focus on the role of relative size in the market and abstract away from issues associated with asymmetric spatial configurations. We could have used "strips" of development, but this would have allowed developers near the center to act completely differently from those on either side of the development area. We want to isolate the effect of size in

[11] We have considered alternate specification for ϕ_0 and qualitatively the results do not change.

[12] We only show the distribution of open space for cases of the model with spillovers as the no spillover cases yield perfectly uniform distributions of open space.

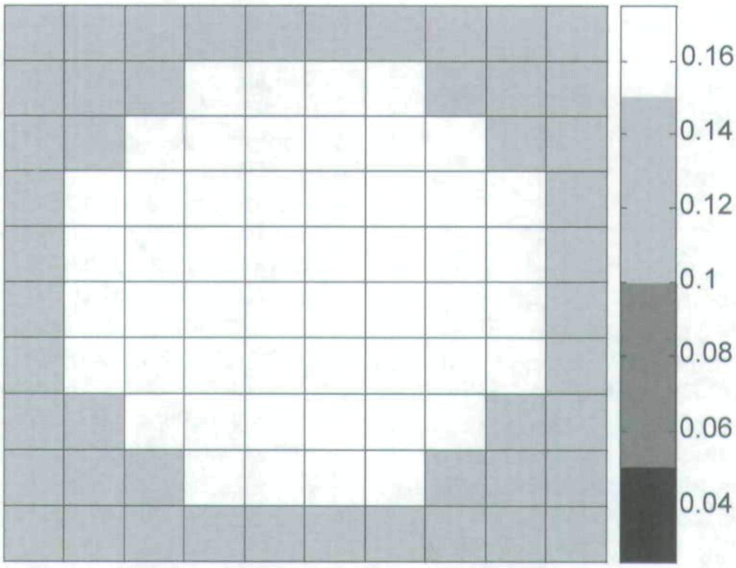


FIGURE 1
Socially Optimal distribution of Open Space with Spillovers

the market, rather than relative position. Finally, we consider a scenario under which each acre is owned by a different developer. Although this case is not symmetric, it is an approximation of perfect competition.

Working with the two developer cases, we progress from a single developer, to a small developer beside a large developer, a 90–10 split, and then progress up to a 50–50 split. The results of this analysis appear in Table 3. First note that moving from a single developer to a model that includes the presence of a small competing developer (90%–10% split) has a large effect on the provision of open space. This small decrease in market power in the land market leads to a large increase in welfare relative to the social optimum, reducing the welfare loss relative to the social optimum by nearly 66%. Thus, even low levels of competition serve to alleviate the under provision of residential land that occurs in the single developer case.

The single developer case highlights the importance of the fact that the public good and the private good that are linked through the input, land. The single developer acts as a monopolist to restrict the supply of the private good. As a result, she significantly over supplies open space in order to restrict the supply of residential land and drive up prices, thus, increasing profits. As we decrease the market power in steps of 10%, we see roughly a halving of the welfare loss at each step.

As a second approach, we consider symmetric configurations of developers, still with no spillovers. The results from this analysis appear in Table 4. Again, we find that decreasing market power moves the equilibrium outcome toward the socially optimal allocation of open space. As with the case of two asymmetric developers, the largest increase in welfare comes through the first step in the analysis, that of the movement from a single developer to two developers. Under this change, we see a weakening of the over provision of open space on the order of 86%. As we approach a truly competitive equilibrium, we see that competition drives the allocation to the socially optimal level. Since, in the absence of spillovers, developers can perfectly capture the benefits to open space provision, competition drives down the under supply of the residential land. Thus, perfect com-

TABLE 3

Two Developers, No Spillovers

	Optimum	Monopolist	10–90		20–80		30–70		40–60		50–50
Percentage of open space	14.500	29.726	14.67	23.35	15.06	20.40	15.49	18.65	16.00	17.50	16.636
CV	0.0	3.06	1.05		0.44		0.20		0.10		0.07
Rents	118.086	120.16	12.35	107.35	24.16	95.09	35.89	83.06	47.61	71.17	118.731
Average lot size	0.2500	0.2055	0.239	0.225	0.241	0.234	0.245	0.239	0.2447	.2419	0.2438
Welfare rank	1	7	6		5		4		3		2

petition in the land market is socially beneficial if all of the benefits can be captured by the developer.

It is also interesting to note that in all of the no-spillover cases there is an over provision of open space. Because each developer completely internalizes the value of open space that she provides, under perfect competition developers will provide efficient levels of open space. However, under imperfect competition, market pricing power leads developers to undersupply residential land, and because of the dual nature of residential land and open space there is an associated over supply of open space. Hence, even when the developer captures all of the benefits, without complete competition the social optimum is not achieved.

VII. COMPETITION WITH SPILLOVERS

We now consider the role of competition in the presence of spillovers between regions. In the no-spillovers case, open space is provided uniformly. Once open space benefits fall outside the region of provision, a second type of inefficiency arises. Not only can the open space level be provided sub-optimally, but the spatial distribution of open space may also be sub-optimal.

As in the no-spillovers case, we begin by considering two developers with differential land allocations. The results for this analysis are presented in Table 5 and Figure 2. With a single very small competing developer, spillovers induce free-riding by the small developer on the open space provided by the larger developer. In fact, the small developer converts all of her land to residential use, setting no land aside as open space. As market power decreases free-riding decreases, developments become more symmetric, and welfare increases. In terms of aggregate open space levels, increased competition leads to an under-provision of open space because of the inability of the developers to capture all of the allocation benefits. Finally, decreases in market power beyond a 70–30 split have virtually no effect on welfare. The reduction in market power in the land supply is perfectly offset by the change in the ability to capture environmental quality benefits. As in the no-spillovers case, the initial step from a single developer to a very small development and a very large development produces most of the gain in welfare from increased competition.

Next, consider the role of symmetric competition in the presence of spillovers. The results for this analysis appear in

TABLE 4

Symmetric Developments, No Spillovers

	Optimum	One Developer	Two Developers	Four Developers	100 Developers
Percentage of open space	14.500	29.726	16.636	15.285	14.525
CV	0.0	3.06	0.07	0.007	0.00007
Rents	118.086	120.162	118.731	118.344	118.095
Average lot size	0.2500	0.2055	0.2438	0.2477	0.2499
Welfare rank	1	5	4	3	2

TABLE 5
TWO DEVELOPERS, SPILLOVERS

	Optimum	Monopolist	10–90		20–80		30–70		40–60		50–50
Percentage of open space	14.469	29.714	0.00	20.00	5.39	17.13	8.69	14.48	10.67	13.46	12.136
CV	0.0	2.29	0.47		0.26		0.23		0.23		0.23
Rents	118.061	120.134	12.91	105.86	24.13	93.62	35.47	81.83	46.93/	70.13	116.984
Average lot size	0.2500	0.2055	0.265	0.237	0.266	0.246	0.263/	0.251	0.260	0.254	0.2569
Welfare rank	1	7	6		5		2		2		2

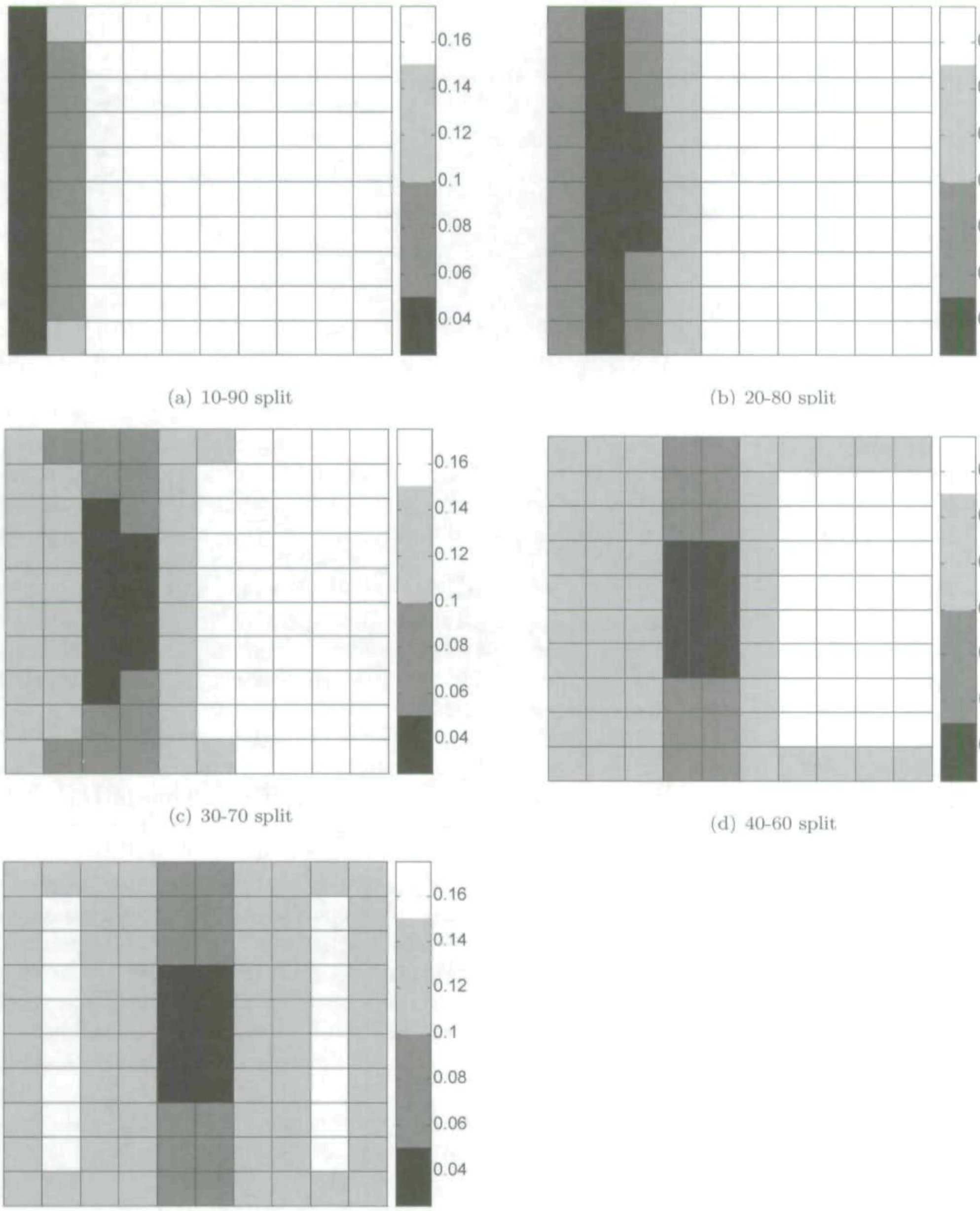
Table 6 and Figure 3. In the analysis without spillovers, as we moved to greater competition, provision of open space moves toward the social optimum. With spillovers between regions, the movement to greater competition pushes open-space provision down for two reasons. First, market power is reduced, thus relaxing the ability of individual developers to affect price by restricting the supply of residential land. Second, as the size of individual developments shrinks, fewer spillovers are captured—reducing incentives for open space provision. Movement from a single development to two adjoining developments causes a movement from drastic over provision to a slight under provision of open space. In contrast to the no spillovers case, once we move to 100 independent developments, inefficiencies from under-provision, driven by the inability of individual developers to capture the benefits of open-space provision, rival the inefficiencies from over-supply under a single developer who restricts the residential land supply to drive up prices. With spillovers, competition reduces the ability of the developers to capture rents from open space-provision. Thus, there is an inherent tradeoff with increased competition between reducing the residential land restriction and the ability of the developer to capture rents from provision. Increasing competition initially has a welfare-improving effect, but as we increase the competition further, the inability to capture rents dominates the residential land supply restriction and welfare declines.

An additional result relates to the distribution of open space when spillovers are present. With a single development, while in aggregate too much open space is provided, the spatial distribution of open space provision resembles that of the socially optimal distribution – with the highest concentrations of open space appearing at the center of the development region. As we break up the land area among multiple competing developers, the open space distributions resemble less and less the socially optimal distribution. In fact, in the 100 developer case, there is actually more open space provided near the edges of the development region than at the center because these locations experience fewer spillovers from neighboring competitors than do locations near the center.[13]

VIII. MARKET-BASED INSTRUMENT VS. COMMAND-AND-CONTROL

The previous analysis demonstrates how market power and openspace spillovers can lead to distortions in both the level and spatial distribution of open space. Our final set of experiments compares the effectiveness of a spatially independent, market-

[13] The result that open space provision near the edges is larger in the 100 developers case is a result of our assumption that the world ends at the edge of the development area, and hence open space benefits spilling in is not present. If we were to instead assume that this development area was one of an infinitely many repeating symmetric development areas, as in Marshall (2004), open space provision by each of the 100 developers would be the same, the edge effects would vanish. Conversely, had we assumed some fixed proportion of open space is provided near the edge, such as may be the case with a transition to agricultural land at the edge, we would have edge effects that may increase or decrease the open space provision near the edge depending on the fixed percentage provided. With a large amount of open space there would be a decrease toward the edge and with a small amount, and in our case zero, there would be an increase in the provision.



(a) 10-90 split

(b) 20-80 split

(c) 30-70 split

(d) 40-60 split

(e) 50-50 split

FIGURE 2
Open Space Proportion under Two Developers with Different Land Allocation and Spillovers
Note: The Smaller Developer Is Always on the Bottom of Each Scale.

TABLE 6
SYMMETRIC DEVELOPMENTS, SPILLOVERS

	Optimum	One Developer	Two Developers	Four Developers	100 Developers
Percentage of open space	14.469	29.714	12.136	9.722	5.781
CV	0.0	2.28	0.24	0.74	2.86
Rents	118.061	120.134	116.984	115.591	111.887
Average lot size	0.2500	0.2055	0.2569	0.2640	.02755
Welfare rank	1	5	2	3	4

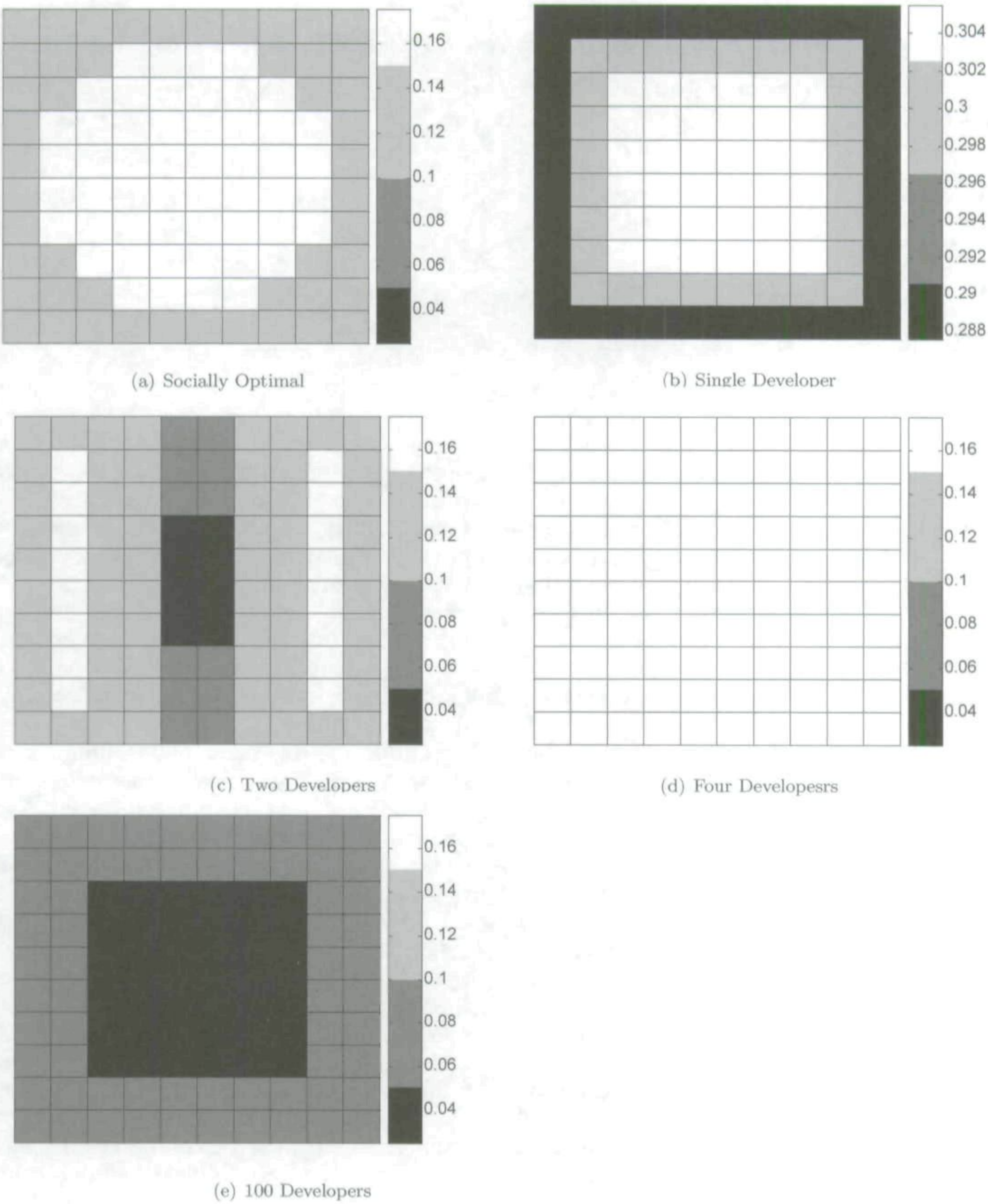
based instrument to that of a spatially independent, command-and-control instrument for moving open-space provision toward the social optimum. The market-based instrument that we will consider is a per unit subsidy on open-space provision financed through an income tax. The use of the income tax allows us to consider uniform taxation of households. Under the income tax-subsidy instrument, we first identify the subsidy that maximizes the shared utility and then, in equilibrium, an income tax rate is set to exactly the level of revenue needed to finance the resulting subsidies. Thus, we choose the optimal tax rate conditional on the competitive structure. Because spillovers lead to inefficiencies in the spatial distribution of open space, we will never be able to restore social optimality using a simple market mechanism except in the case of a single developer. For the command-and-control instrument, we identify a uniform lower bound on open-space provision that maximizes the shared utility. Because the single development case over supplies open space, we use an upper bound in this case rather than a lower bound.

The results from this analysis are presented in Table 7 and Figure 4.[14] We begin by considering the market-based instrument. First note that in the single-developer model, because the unregulated equilibrium leads to an over provision of open space, the optimal tax and subsidy are both negative. As the first column of Table 7 shows, in the case of a single developer, a subsidy of −0.3442 units of income per acre returns the system to the socially optimal level of open space, land rents, income, and shared utility. This result is fairly intuitive. Because all households are endowed with the same income, the income tax is identical to a non-distortionary head tax. In equilibrium, each subsidy level is associated with a specific aggregate open-space level. In the single-developer case, the single developer internalizes all spillovers and the developer chooses the optimal distribution of open space conditional on the level of open space. Hence, we can drive a single developer to social optimality in every respect.

Comparison of the market-based regulatory outcomes to the unregulated outcomes provides some insights. The simple market mechanism is effective in changing aggregate levels of open-space provision, but has little impact on the spatial distribution of open-space provision. Comparing the compensating variation under the market instrument to that for the unregulated simulations shows that most of the divergence from the social optimum can be ameliorated by simply adjusting the aggregate levels of open-space provision. Thus, it appears that the welfare loss from inefficient spatial distribution of open space is small relative to the loss from providing inefficient aggregate levels of open space.

Under the command-and-control system, since the lower bound (upper bound in the single-development case) on open space is above (below) the unregulated provision, all developers provide the bound in all regions. With the command-and-control regulation, the regulation compensates for the spatial inefficiency by providing an excess of open space. The uniform allocation of open space in excess of the socially optimal level

[14] Because the command-and-control regulation fixes the level of open space at a uniform level in all locations, its impact is independent of the competitive regime.



(a) Socially Optimal

(b) Single Developer

(c) Two Developers

(d) Four Developesrs

(e) 100 Developers

FIGURE 3

Open Space Proportion under Competition with Increased Number of Developers and Spillovers

Note: The Scale on the Single Developer Has Changed Compared to All Others Since It Is Significantly Different than Any of the Other Scales.

TABLE 7
COMPARISON OF LEVELS OF OPTIMAL TAX WITH DIFFERENT LEVELS OF COMPETITION AND COMMAND-AND-CONTROL

	Single Developer	Two Developers	Four Developers	100 Developers	Command-and-Control
Percentage of open space	14.469	14.597	14.613	14.578	14.980
Shared utility	1.2863	1.2855	1.2854	1.2855	1.2861
CV	0.000	0.010	0.011	0.043	0.009
Rents	118.061	112.421	117.962	118.022	118.213
Average lot size	0.2500	0.2497	0.2496	0.2497	0.2486
Optimal tax (%)	−1.09	0.56	1.48	3.03	NA
Subsidy/tax	−0.3442	0.1775	0.4728	0.9860	NA
Welfare rank	1	3	4	5	2

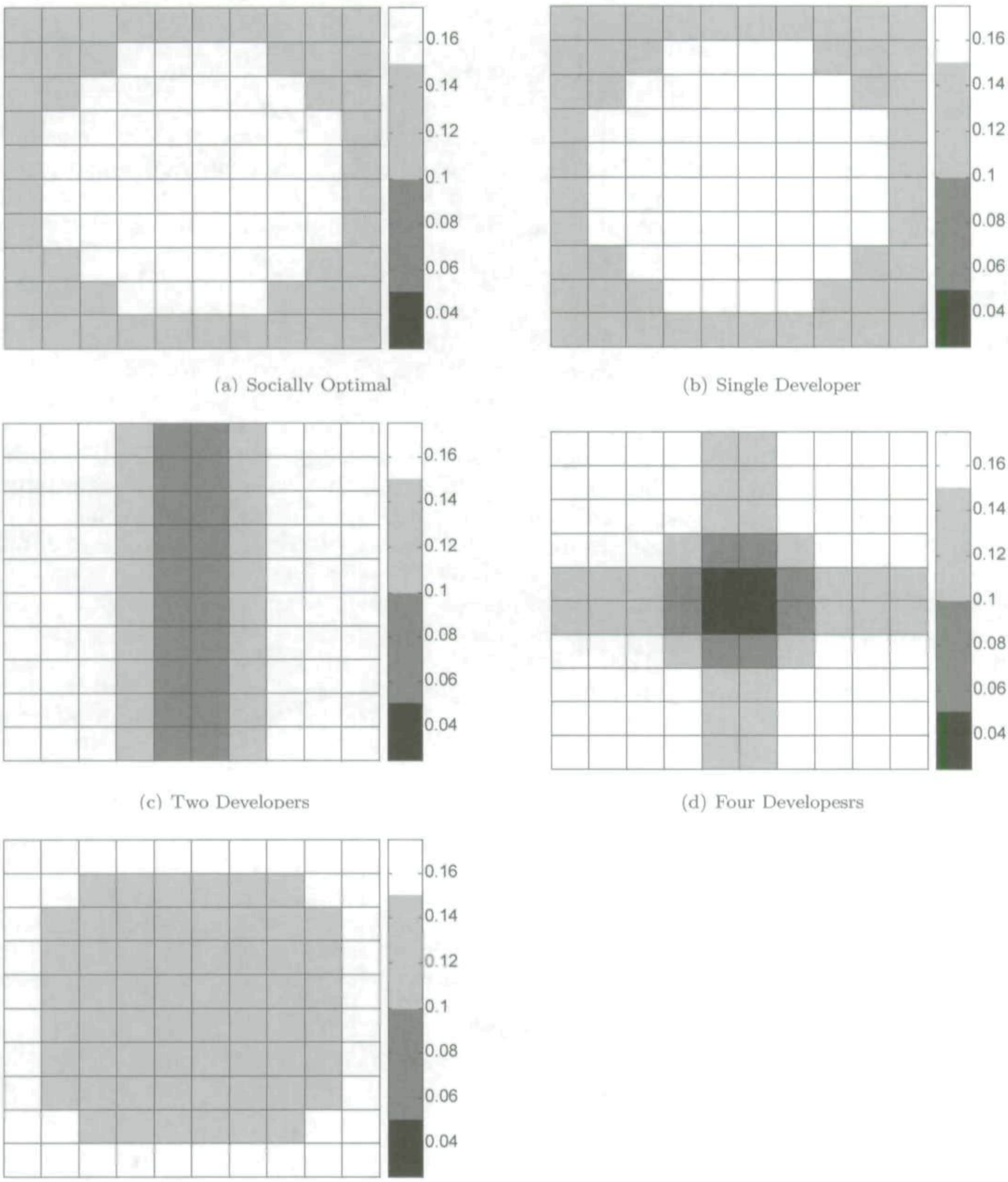
increases welfare by decreasing the role of distribution. Because the uniform spatial distribution imposed by the command-and-control regime is closer to the optimal than is the spatial distribution under the competitive regimes with the market mechanism, the command-and-control regulation dominates the market-based system in all but the single-developer case.

IX. CONCLUSION AND DISCUSSION

The economics of open space amenities and their provision is important to both the academic and policy communities. In this paper, we have highlighted two aspects of open space as a public good that complicate economic analysis of open-space provision and make it difficult to design simple policies for achieving first best outcomes. Further, we demonstrate how these special features of open space overturn results regarding the optimal provision of public goods by rent-maximizing landowners.

Our results demonstrate that due to the dual nature of open space and residential land, when developers exercise market power, their rent-seeking behavior will have implications for the level of open space they provide. This dual nature leads to inefficient levels of open-space provision, even when a single developer captures all of the rents associated with open space-provision. While increased competition reduces the distortions associated with market power, these reductions are associated with each developer controlling smaller areas of land. These reductions highlight the second special characteristic, namely the fact that open-space amenities diffuse over space from the point of provision. As the size of individual developments decrease, the proportion of open-space amenities associated with the protection of land within a given development that spill out of the development increase. Thus, because these benefits cannot be captured by the rents paid for land within the development, a second distortion arises.

Within the confines of our numerical model, we evaluate the welfare implications of differing levels of competition vis-á-vis open-space provision. In all cases where spillover effects exist, the model suggests that welfare is maximized at moderate levels of competition, essentially splitting the difference between off-setting market-power and capturing open-space spillovers. We then consider the effectiveness of two simple market mechanisms, a uniform command-and-control open-space requirement and uniform open-space tax/subsidy. Our analysis suggests that when developers are large enough to capture all of the open space spillovers (i.e., the single-developer case) that the market mechanism can successfully reverse any rent-seeking behavior associated with market power, while not leading to any distortions in the spatial distribution of open-space provision—thus returning the system to the social optimum. As the number of developers and un-captured spillovers increases, the spatial distribution of open-space provision moves so far away



(a) Socially Optimal

(b) Single Developer

(c) Two Developers

(d) Four Developesrs

(e) 100 Developers

FIGURE 4
Open Space Proportion under Optimal Tax Instrument and Spillovers

from the social optimum that the uniform open-space levels associated with a command-and-control strategy are actually closer to the optimum than are the second best tax/subsidy outcomes.

In our highly stylized model, it was not possible to have enough competition to significantly reduce market power and still have developments large enough that the majority of benefits from open-space provision remain in the developers region. However, in the real world this may be possible. For example, in large metropolitan areas it may be possible to have development carried out by a large number of competing developments, each of which is on a scale large enough that the majority of the benefits from open-space provision remain inside their development. In this situation, there may be no need for policy intervention. An example of this type of outcome is the Rock Creek Ranch subdivision in Superior, Colorado. This 3,500 home subdivision on approximately 700 acres, built in the 1990s comprises a significant portion of the town of Superior. Even though it was privately built, it incorporates enough significant open space, 170 acres of open space and parks as well as 6.7 miles of trails, for the town of Superior to be willing to take over managing its incorporated open space—including Purple Park which is prominent enough to draw visitors from outside the town.

Conversely, there are likely many cases in the real world where these two conditions don't hold and policy intervention may be welfare improving. At one extreme is the case where development is driven by large numbers of small developers. In these situations, because each developer controls such small lots, one would expect to see both an under-provision of open space and an inefficient spatial allocation of open space. Our analysis suggests that in these environments, market-based policy interventions designed to change the behavior of individual developers may not be effective. Instead, regulators should either consider command-and-control interventions aimed at directly establishing an efficient allocation of open space or implement policies designed to increase the average development size.

At the other extreme, are locations where developers are large enough to capture all open space spillovers, but their numbers are small enough that they exert market power and over-supply open space. While it is not clear that there are many real-world examples of this type of market structure, it seems completely plausible that a very similar outcome could arise as voters act collectively to restrict supply and drive up their own property values. To accomplish such an outcome, voters could utilize either direct purchases of land or restrictive zoning—types of interventions that, as we note in our introduction, continue to garner marked voter support.

References

Acharya, G., and L. L. Bennett. 2001. "Valuing Open Space and Land-Use Patterns in Urban Watersheds." *Journal of Real Estate Finance and Economics* 22 (2–3): 221–37.

Berube, A., and B. Forman. 2002. "Living on the Edge: Decentralization Within Cities in the 1990s." The Brookings Institution: The Living Cities Census Series. Washington, D.C.: The Brookings Institution.

Bolitzer, B., and N. Netusil. 2000. "The Impact of Open Spaces on Property Values in Portland, Oregon." *Journal of Environmental Management* 59: 185–93.

Brasington, D. M. 2002. "Edge versus Center: Finding Common Ground in the Capitalization Debate." *Journal of Urban Economics* 52: 524–41.

Brueckner, J. 1983a. "The Economics of Urban Yard Space: An "Implicit-Market" Model for Housing Attributes." *Journal of Urban Economics* 13 (2): 216–34.

———. 1983b. "Property Value Maximization and Public Sector Efficiency." *Journal of Urban Economics* 14 (1): 1–15.

Bruekner, J. K., and H. A. Kim. 2003. "Urban Sprawl and the Property Tax." *International Tax and Public Finance* 10 (1): 5–23.

Cremer, H., M. Marchand, and P. Pestieau. 1997. "Investment in Local Public Services: Nash Equilibrium and Social Optimum." *Journal of Public Economics* 65 (1): 23–35.

Epple, D., and A. Zelenitz. 1984. "Profit Maximizing Communities and the Theory of Local Public Expenditure: Comment." *Journal of Urban Economics* 16: 149–57.

Harnik, P. 2000. *Inside City Parks*. Washington, D.C.: Urban Land Institute.

Heal, G. 2001. "Bundling Public and Private Goods." Working paper. Columbia Business School, Columbia University, New York.

Land Trust Alliance. 2004. "Land Vote 2003: America Invests in Parks and Open Space." Washington, D.C.: Land Trust Alliance.

Marshall, E. 2004. "Open Space Amenities, Interacting Agents, and Equilibrium Landscape Structure." *Land Economics* 80 (May): 272–93.

Riddel, M. 2001. "A Dynamic Approach to Estimating Hedonic Prices for Environmental Goods: An Application to Open Space Purchases." *Land Economics* 77 (Nov.): 494–512.

Schultz, S., and D. King. 2001. "The Use of Census Data for Hedonic Price Estimates of Open-Space Amenities and Land Use." *Journal of Real Estate Finance and Economics* 22: 239–52.

Sonstelie, J., and P. Portney. 1978. "Profit Maximizing Communities and the Theory of Local Public Expenditure." *Journal of Urban Economics* 5: 263–77.

———. 1984. "Profit Maximizing Communities and the Theory of Local Public Expenditure: Reply." *Journal of Urban Economics* 20: 250–55.

Wu, J., and A. J. Plantinga. 2003. "The Influence of Public Open Space on Urban Spatial Structure." *Journal of Environmental Economics and Management* 46 (2): 288–309.

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