Impacts of Land Use Regulation on the Provision of Open Space in Residential Subdivisions

Erik Lichtenberg, Constant Tra, and Ian Hardie

Department of Agricultural and Resource Economics
University of Maryland
College Park, MD 20742-5535

Contact author: Erik Lichtenberg, Department of Agricultural and Resource Economics, 2200 Symons Hall, University of Maryland, College Park Maryland 20742
Telephone: 301-405-1279
Fax: 301-314-9091
elichtenberg@arec.umd.edu

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Abstract

The effects of state and local regulations on minimum lot size, maximum density, and forested area on the physical utilization of space in suburban residential subdivisions are analyzed theoretically and empirically. Results suggest that the allocation of space within these subdivisions is not determined completely by existing regulations. Instead, developers appear to choose to limit the number of building lots in a subdivision in order to provide open space within subdivisions in response to buyers' willingness to pay a premium for the amenities open space provides. They do not appear to free ride on open space provided in nearby areas outside of the subdivision. Minimum lot size and forest conservation regulations are found to impose binding constraints on developers while maximum density regulation does not. Forest conservation regulations are found to meet their stated aim of increasing the amount of forested open space in these subdivisions beyond levels developers provide voluntarily.

Keywords: land development, land use regulation, residential open space, zoning, local public goods, neighborhood externalities, forest conservation

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Land use is regulated in jurisdictions undergoing development to ensure the continued provision of open space, to maintain woodlands, to protect streams and water quality, to abate traffic congestion, noise, and air quality degradation, and to provide similar public goods. The extent to which they are necessary for at least some of these purposes is not clear. As Thorsnes [14] and others have pointed out, even in the absence of land use regulations, developers may face incentives to provide many local public goods (e.g., neighborhood externalities such as open space, woodlands, parks, etc.) for which home buyers are willing to pay a premium. Empirical studies of residential developments provide evidence that private covenants can be used to ensure adequate provision of such neighborhood externalities (Speyrer [13], Hughes and Turnbull [8]. Thorsnes [14]) provides evidence suggesting that the ability to provide such neighborhood externalities motivates developers' choices of subdivision parcel sizes. Thorsnes [15] provides evidence indicating that suburban homebuyers' willingness to pay for such local public goods (specifically, forested land on or adjacent to building lots) is high enough to constitute a substantial incentive for developers to provide them.

This paper examines the effects of land use regulations on developers' provision of open space within a suburban subdivision. In contrast to the bulk of empirical studies of the impacts of zoning and other land use regulations, which examine how those regulations affect housing prices[1], we study how land use regulations influence the physical landscape within the subdivision. We concentrate on three major features of

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[1] See for example Pogodzinski and Sass [11], Holway and Burby [7], Fu and Somerville [2], Thorsnes [14]. An exception is Colwell and Scheu [1], who conduct a theoretical and empirical analysis of the impacts of regulation on the depth and frontage of residential building lots.

subdivisions: lot size, the number of lots (density), and open space. All are major determinants of the landscape of the subdivision and are thus sources of neighborhood externalities like open space, woodlands, and so on.

We consider three types of land use regulation. Two of them—minimum lot size and maximum density zoning—are in widespread use throughout the United States. The third is a set of forest conservation measures implementing the Maryland Forest Conservation Act of 1991 (FCA), which sets standards for identifying and retaining forests designated as sensitive (including flood plains, streams and their buffers, steep slopes, and critical habitats). The FCA requires developers to identify existing forest cover and submit a forest conservation plan specifying the total amount and location of forested area to be retained, delineating protective measures for stand edges and specimen trees, and proposing long term agreements (covenants, easements, etc.) to protect retained forested areas (Galvin et al. [3], Maryland Department of Natural Resources [10]).

Regulations like those implementing the FCA are of considerable importance in areas undergoing rapid urbanization. Land development is a primary reason for forest conversion in such areas. Even when developers retain trees, they may not do so in ways that best maintain amenities and other environmental services provided by forests. Developers may find it less costly to eliminate stream buffers, for example, rather than to let a riparian forest regenerate or to clear land of mature trees while building and replant young trees afterwards, depriving a newly developed area of environmental services provided by trees for several decades (see for example Richer [12]).

Empirical studies have found that home buyers place a positive value on preserving nearby open space generally and forests in particular, suggesting a positive willingness to pay for such local public goods. Thorsnes [15] found that building lots in Michigan (both undeveloped and with housing built on them) that had forests on or adjacent to them commanded large selling premia. The effect of forest on real estate price was highly localized, however: The selling prices of lots across the street from those adjoining forest preserves were not significantly different from those of lots farther away. Tyrvainen and Mettinen [16] estimate the effects of forest views and distance to the nearest forested area on the selling prices of homes in Finland. They found that a forest view increases housing prices and that housing prices decrease with distance from the nearest forest. Other studies have examined the effects of forested land in the general vicinity without consideration of proximity. Garrod and Willis [2] found that housing prices in Great Britain were increasing in the amount of broadleaf forest nearby but decreasing in the amount of coniferous forest nearby. Irwin [6] found that housing prices in the Washington/Baltimore corridor were decreasing in the amount of privately owned forest land nearby but increasing in the amount of permanently preserved open space, suggesting that home buyers value open space (including forests) but expect privately owned forest land to be developed. Geoghegan, Lynch, and Bucholtz [3] found that housing prices in the Washington/Baltimore corridor were increasing in the amount of nearby forest and farmland taken together. Wu, Adams, and Plantinga [17] found that housing prices in Portland were increasing in the amount of open space in the immediate vicinity (zip code) and in proximity to parks, lakes, and wetlands. Hardie and Nickerson [4], using the same Maryland data as those used in this paper, found that prices of developed land (exclusive of improvements) in new suburban residential subdivisions in the Baltimore/Washington area were decreasing in the amount of farmland nearby but were insensitive to the amounts of nearby park land. They also found that minimum lot size zoning requirements reduced prices of developed land.

A positive willingness to pay for open space and forested open space in particular gives developers an incentive to provide these amenities privately by incorporating them into their subdivision plans. We analyze this incentive both theoretically and empirically. We begin with a conceptual model of a developer's determination of lot size, density, open space, and other features in a subdivision of fixed size. We use the model to derive hypotheses about the impacts of land use regulation on developers' decisions regarding lot size, the number of lots, and the provision of forested and other open space. We then analyze those decisions empirically using data on 228 residential subdivisions in the Baltimore/Washington suburbs.

A Model of Subdivision Configuration Decisions

Consider the problem faced by a developer who has purchased a parcel of undeveloped land of size A with the intention of laying out a suburban residential subdivision composed of building lots, forested open space, and other public open space (e.g., fields, playgrounds, landscaping). For convenience, assume that the subdivision will be composed of n identical lots, each of which will subsequently be sold to a builder at $v(s,g(\phi,z,z^o),h(a,a^o))$, a price net of the value of housing improvements that depends on the size of each lot s, services provided by forested land g(.), and services provided by other public open space h(.). Services provided by forested land derive from a combination of the share of each lot that is forested ϕ, forested open space inside the subdivision z, and forested land in the vicinity of the subdivision z^o. Services provided by other public open space arise from a combination of open space inside the subdivision a and in the vicinity of the subdivision a^o. Assume that the value of a lot is increasing in s, g, h, and concave in all arguments. Services provided by forested and other public open space, g(.) and h(.), respectively, are similarly increasing and concave in all arguments. Let k(a) denote the cost of developing public open space within the subdivision, assumed to be increasing and convex in a. Let x denote the change in the amount of forested land due to development of the subdivision. A positive value ($x > 0$) denotes forest clearing, a negative value ($x < 0$) afforestation. The cost of clearing or planting is $c(x) > 0$, with $c'(|x|) > 0$. Finally, let $0 \leq \theta \leq 1$ be land required for infrastructure (e.g., roads) as a share of the size of each building lot.

The total area of the subdivision A is divided among building lots $ns(1+\theta)$, forested open space z, other public open space a, and unusable land w:

(1) $$A = ns(1+\theta) + z + a + w.$$

The subdivision may also be subject to land use regulation. First, the jurisdiction in which it is located may require that all lots be at least a minimum size σ:

(2) $$s \geq \sigma.$$

Second, the jurisdiction may also limit δ, the density of housing in the subdivision:

(3) $$n \leq \delta A.$$

Third, under Maryland's Forest Conservation Act each jurisdiction is required to implement regulations limiting forest clearing. We express this FCA requirement as

(4) $$ns\phi + z + \gamma w \geq \zeta A,$$

where γ denotes the share of unusable land that is forested and ζ denotes the share of the area of the total subdivision that must remain forested under FCA regulations. Forested acreage in the developed subdivision equals initial forested area $\zeta_0 A$ adjusted for clearing/afforestation x:

(5) $$\zeta_0 A - x = ns\phi + z + \gamma w.$$

In the absence of regulatory constraints like conditions (2)-(4), the developer will choose the number of lots n, lot size s, the forested share of each lot ϕ, forested open space z, and other public open space a to maximize the net value of the subdivision:

(6) $$nv(s,g(\phi,z,z^o),h(a,a^o)) - k(a) - c(x)$$

subject to the constraints on the total area of the subdivision (1) and forested acreage (5), both of which hold with equality. After substitution for forest clearing/afforestation x using equation (5), the necessary conditions characterizing the developer's choices can be written (letting subscripts denote derivatives and assuming an interior solution):

(7a) $$v - \lambda s(1+\theta) + \phi s c_x = 0$$

(7b) $$v_s - \lambda(1+\theta) + \phi c_x = 0$$

(7c) $$v_g g_\phi + s c_x \leq 0$$

(7d) $$n v_g g_z - \lambda + c_x \leq 0$$

(7e) $$n v_h h_a - k_a - \lambda \leq 0$$

plus the constraint (1). Conditions (7a) and (7b) hold with equality for any subdivision that is actually developed since development requires a strictly positive number of building lots (n) and lot size (s). Conditions (7c)-(7e) hold as weak inequalities since developers may choose not to provide forested area on each building lot (ϕ), forested open space (z), or other public open space (a).

Condition (7a) says that the net value of a building lot per acre, v/s, should equal $\lambda(1+\theta)$, the marginal value of land determined by the constraint on space in the subdivision (adjusted for infrastructure) less ϕc_x, the marginal clearing cost avoided (or marginal afforestation cost incurred) per acre due to forest on each lot. Condition (7b) says that the marginal value of lot size should equal the marginal value of land in the subdivision (adjusted for infrastructure) less marginal clearing cost avoided (or marginal afforestation cost incurred) due to forest on each lot. Condition (7c) says that if a portion of each building lot is forested ($\phi > 0$), the marginal value of forest on each building lot, expressed on a per-acre basis ($v_g g_\phi/s$) should equal the avoided marginal cost of clearing or marginal cost of afforestation c_x. Condition (7d) says that if forested open space is provided ($z > 0$), the increase in the value of all building lots in the subdivision due to an increase in forested open space should equal the marginal value of land in the subdivision less the avoided marginal cost of clearing or plus the marginal cost of afforestation c_x. Condition (7e) says that if other public open space is provided ($a > 0$), the increase in the value of all building lots in the subdivision due to an increase in other public open space should equal its marginal development cost plus the marginal value of land in the subdivision. As conditions (7d) and (7e) indicate, the developer has an incentive to provide both forested and other public open space as local public goods in order to increase the value of the lots on which housing will be constructed. Similarly, as condition (7c) indicates, the developer may have an incentive to leave a portion of each lot forested in order to enhance its value.

Land use regulations like minimum lot size zoning, maximum density zoning, and the FCA impose additional constraints on the developer. If all three forms of regulation are imposed, the conditions characterizing the developer's profit-maximizing choices become (letting μ, ν, and ψ denote the respective Lagrange multipliers corresponding to constraints (2), (3), and (4) and again substituting for forest clearing/afforestation using equation (5)):

(8a) $$v - \lambda s(1+\theta) + \phi s c_x - \nu + \psi s \phi = 0$$

(8b) $$v_s - \lambda(1+\theta) + \phi c_x + \psi\phi + \mu/n = 0$$

(8c) $$v_g g_\phi + s c_x + \psi n s \leq 0$$

(8d) $$n v_g g_z - \lambda + c_x + \psi \leq 0$$

(8e) $$n v_a h_a - k_a - \lambda \leq 0,$$

plus the constraints (1), (2), (3), and (5). The shadow prices of maximum density ν, minimum lot size μ, and FCA requirement ψ are equal to zero whenever the respective constraints are non-binding, with strict inequalities holding for corner solutions.

Condition (8a) says that the per acre net value of an additional lot (v/s) should equal the marginal value of land in the subdivision ($\lambda(1+\theta)$), less the marginal clearing cost avoided/plus the marginal afforestation cost incurred due to the forested share of each lot (ϕc_x), plus the marginal cost of increased density (ν/s), and less the value of the contribution of the forested portion of an additional lot in meeting FCA regulations ($\psi\phi$). Condition (8b) says that the marginal value of lot size (v_s) should equal the marginal value of land in the subdivision($\lambda(1+\theta)$), less the avoided marginal clearing cost/plus the marginal afforestation cost due to the forested share of each lot (ϕc_x), less the value of the contribution of the increase in forested portion of increased lot size in meeting FCA regulations ($\psi\phi$), and less the marginal value of lot size in meeting the minimum lot size constraint (μ/n). Condition (8c) says that if a portion of each building lot is forested ($\phi >$

0), the per-acre marginal value of forest on each building lot ($v_g g_\phi / s$) should equal the avoided marginal clearing cost or marginal afforestation cost incurred per acre (c_x) less its per-acre value in meeting the subdivision's FCA requirements (ψn). Condition (8d) says that if other public open space is provided ($a > 0$), the increase in the value of all building lots in the subdivision due to an increase in forested open space ($n v_g g_z$) should equal the marginal value of land in the subdivision (λ), less the avoided marginal cost of clearing or plus the marginal cost of afforestation (c_x), and less the marginal cost of meeting FCA requirements (the shadow price of the FCA constraint ψ). Like condition (7e), condition (8e) says that if other public open space is provided ($a > 0$), the increase in the value of all building lots in the subdivision due to an increase in other public open space should equal its marginal development cost plus the marginal value of land in the subdivision.

Conditions (8a-e) suggest that zoning restrictions on density and lot size should, if binding, affect developers' provision of both forested and other public open space as well as the number of lots and lot size, respectively. The direct effects of increasing maximum allowable density (holding minimum lot size constant) should be an increase in the number of lots and a corresponding decrease in total open space. If forest is retained on a share of each lot, however, an increase in the number of lots has the indirect effect of relaxing the constraint imposed by the FCA. As a result, forested open space (z) and/or the forested share of each lot (ϕ) will tend to decrease. In other words, greater density plus retained forest on building lots have the combined effect of counteracting to some extent any overprovision of forest due to the FCA. Similarly, the direct effects of greater minimum lot size (holding maximum allowable density constant) should be larger lots and a corresponding decrease in total open space. As with maximum allowable density, if forest is retained on a share of each lot, an increase in minimum lot size has the indirect effect of relaxing the constraint imposed by the FCA, so that forested open space and/or the forested share of each lot will tend to decrease.

Conditions (8a-e) also suggest that binding FCA requirements should influence lot size and density. Greater FCA requirements increase forested open space. If a share of each building lot is forested ($\phi > 0$), greater FCA requirements also increase both the number of lots and lot size. As a result, greater FCA requirements should lead to reductions in other public open space. At the same time, greater FCA requirements give developers an incentive to retain larger shares of each building lot in forest.

Conditions (7a-e) and (8a-e) both suggest that developers will tend to free ride on open space amenities provided in the vicinity of the subdivision if they believe that homebuyers value those amenities as substitutes for open space amenities provided within the subdivision ($\partial^2 g/\partial z \partial z^o$, $\partial^2 h/\partial a \partial a^o < 0$). If open space amenities nearby are not close substitutes for those within the subdivision, however, as the results obtained by Thorsnes [15] suggest, then open space amenities nearby will not influence developers' provision of those amenities within the subdivision.

Combining conditions (4) and (5) in the case where FCA restrictions constitute a binding constraint implies

(9) $$(\zeta_0 - \zeta)A = x.$$

If the initial level of forest exceeds the FCA requirement, developers will clear forest. If the initial level of forest is less than the FCA requirement, developers will afforest. Incorporating forest into building lots will be more expensive in subdivisions needing afforestation, suggesting that developers will find it preferable to use forested open space meeting FCA requirements in subdivisions with low initial forest area. Condition (9) similarly suggests that developers will find it preferable to retain forest in building lots in subdivisions with high initial forest area, since doing so will make it possible to provide more other public open space for any given level of clearing cost.

Finally, note that if minimum lot size zoning, maximum density zoning, and the FCA all impose binding constraints on the developer, these three regulations will determine the total area in building lots, ns, and in total open space, z+a. Even so, the regulations leave the developer free to choose the allocation of forested open space between forested land in building lots, ϕns, and forested open space, z, and thus the division of total open space between forested and other public open space.

Data and Estimation Method

We examine the effects of these land use regulations on lot size, the number of lots, and the provision of open space in suburban residential subdivisions empirically using data from five suburban counties in the Washington/Baltimore metropolitan area. Two (Montgomery and Prince Georges Counties) have densely populated urban areas that adjoin Washington, DC. Two others (Charles County southeast of Washington and Carroll County west of Baltimore) are less densely populated, with subdivisions either dispersed throughout the countryside or clustered around a county town center. The fifth, Howard County, is located between Washington and Baltimore; residents commute to both.

Subdivisions included in the study consist either entirely of single-family dwellings, including detached homes, townhouses, and combinations of the two. Subdivisions with commercial or industrial sites or with lots developed for apartment buildings were omitted. The study also was limited to subdivisions with five or more building lots for which plans were approved between 1991 and 1997. Small subdivisions of less than five lots were omitted to remove cases where land is subdivided primarily to provide residences for family members.

Data on each subdivision were collected from county planning agencies and from State-maintained GIS databases. Information from county planning agencies was used to identify the subset of subdivisions that fit the residential use criteria. County planning agency data were collected for a random sample of 50 percent of these identified subdivisions. These data were then matched to lot and parcel data in the Maryland Property View county databases developed and maintained by the Maryland State Department of Planning. The Property View databases were used to obtain information on tax assessments, sales, attributes of existing dwelling units, and GIS data on roads, streams, and land use in areas surrounding each subdivision. The five-county dataset consists of 261 subdivisions containing 13,100 building lots. Two those subdivisions contained multi-unit dwellings and were omitted from the analysis. Four others built around a single golf course were also omitted. Missing observations on a number of the subdivision characteristics listed below reduced the usable sample size to 228 subdivisions.

In addition to the total size (in acres) of each subdivision, the data contain measures of several attributes of the physical utilization of space in each subdivision: the number of building lots, the sizes of building lots, existing and retained total forested area, and area retained in open space. The planning data included information on geographic features such as areas of floodplain and wetlands and linear stream frontage as well as whether a public sewer system was available. The Property View data were used to calculate commuting distance to the nearest central business district (Washington, DC or Baltimore) and the area in farmland, residential land, land in parks and recreational facilities, and undeveloped forest and brush (combined) within a given distance from the centroid of each subdivision. Scores from state-administered school achievement tests were added to the data as measures of the quality of the public schools serving the subdivisions.

County planning data were used to identify which subdivisions were exempt from FCA requirements and to estimate required forest acreage for non-exempt subdivisions. Zoning codes for each subdivision were obtained from the Property View data base. County zoning documents were then used to convert these codes into quantitative measures of land use regulation, specifically, maximum allowable density and minimum lot size. In some cases, additional information was needed to determine maximum allowable density and minimum lot sizes. For example, some counties have a single zoning code that allows different maximum allowable densities and minimum lot sizes for townhouses and detached homes. Howard County zoning regulations explicitly allow a tradeoff between minimum lot size and open space within a subdivision under a single zoning code. Additionally, some subdivisions were regulated under transferable development rights (TDRs) or planned use development zoning (PUD), each of which had separate density and lot size requirements. These subdivisions were distinguished using dummy variable indicators.

We modeled three attributes of the allocation of space within these subdivisions—average lot size, the number of building lots, and total open space[2]—as linear functions of regulatory restrictions, geographical characteristics of the subdivision, land uses in the immediate vicinity of the subdivision, and other factors. Total open space was used instead of forested area because the data do not distinguish between forested portions of building lots and forested open space. Measures of regulatory restrictions included in the model were the maximum allowable number of lots (calculated as the product of the maximum allowable density and the net area of the subdivision, defined as the total area of the subdivision less the area of floodplains within the subdivision), minimum lot size, an indicator of whether the subdivision was exempt from the FCA, forested area required under the FCA for non-exempt subdivisions, an indicator of whether the subdivision was regulated under transferable development rights or planned use development rules, and interactions between this latter indicator and maximum allowable density and minimum lot size. An indicator of whether the subdivision was served by a public sewer system was also included. Public health regulations govern the amount of land needed for septic systems, so this variable can also be considered as an indicator of regulatory restrictions. Geographical characteristics of the subdivision included the total area of the subdivision, initial forested area, the area of wetlands and floodplain, and linear stream frontage. Density restrictions are applied to the net area of the subdivision, hence net area was used (in place of total area and floodplain area) in the equation modeling the number of lots.

[2] Some subdivisions contained outparcels reserved for future division into building lots. These outparcels were excluded from the subdivision and hence do not affect average lot size, open space, or the total area of the subdivision.

Land uses in the immediate vicinity of the subdivision included area in farmland, parks and recreation areas, and forest/brush land outside of the subdivision but within two miles of the subdivision centroid. These measures of nearby land use were estimated by calculating the amount of land in each category in a circle with a two-mile radius centered at the subdivision centroid, then subtracting the amount of land in each category within the subdivision. (Areas of each land use category within three and five miles of the subdivision centroid were also calculated. They gave the same results and are thus not reported.) Other factors included an indicator of the county in which the subdivision was located, the distance in road miles from the centroid of the subdivision to the closest central business district, and the score of the high school serving the subdivision on the Maryland School Performance Assessment Program (MSPAP) test, which is used to evaluate all schools in the state and is thus a useful measure of derived demand for school quality. Table 1 gives descriptive statistics of these variables.

One would expect explanatory factors omitted from the three regression equations to be correlated for each subdivision. The parameters of the model were thus estimated using seemingly unrelated regression (SUR). The estimated coefficients of the three equations are given in Table 2.

Estimation Results

Average lot size, the number of lots, and public open space in these subdivisions were each highly correlated with a few regulatory and geographic variables. The R^2 ranged from 0.56 to 0.79. Independent variables with coefficients significantly different from zero in the average lot size equation included the minimum zoned lot size, whether the subdivision was exempt from the FCA, whether public sewer service was available, and forested area prior to development. Independent variables with coefficients significantly different from zero in the number of lots equation included the maximum allowable number of lots, whether the subdivision was subject to transferable development rights or planned use development, the cross-product between the maximum allowable number of lots and TDR/PUD regulation, and whether public sewer service was available. Independent variables with coefficients significantly different from zero in the open space equation included acreage of forest required by the FCA, minimum zoned lot size, whether the public sewer service was available, total area of the subdivision, acreage of floodplain in the subdivision, and stream frontage in the subdivision. All of the significant coefficients had the expected signs.

To determine whether land use regulations imposed binding constraints on developers, we tested whether the coefficients of minimum zoned lot size, the maximum allowable number of lots, and forest acreage required by FCA were significantly different from one in the average lot size equation, number of lots equation, and open space equation, respectively. The Wald statistic for the test of the hypothesis that the coefficient of the maximum allowable number of lots was significantly different from one in the number of lots equation was 92.92, indicating that this hypothesis could be rejected at a 1 percent significance level. The respective Wald statistics for the hypotheses that the coefficients of minimum zoned lot size in the average lot size equation and forest acreage required by FCA in the open space equation each equaled one were 3.01 and 1.02, indicating that these hypotheses could not be rejected at a 5 percent significance level. These results suggest that minimum lot size zoning and FCA requirements do impose binding constraints on developers of suburban residential subdivisions in

Maryland: A one-acre increase in minimum lot size increases average lot size by one acre while a one-acre increase in the FCA requirement increases total open space in the subdivision by one acre. Density zoning does not impose a binding constraint, however: A one-unit increase in the maximum allowable number of lots results in only about 0.6 additional lots. In other words, it appears that developers do not to offer as many building lots as they are legally allowed.

Further evidence that minimum lot size zoning and the FCA impose binding constraints on developers while density zoning does not comes from the fact that FCA requirements affect lot size and minimum lot size zoning affects open space, while density zoning affects neither. The lots in subdivisions that are exempt from the FCA are, on average, 1 acre larger than lots in non-exempt subdivisions. The coefficient of zoned minimum lot size in the open space equation is significantly different from zero and quite large: Increasing the minimum lot size by an acre leads developers to reduce open space by almost 5 acres. The coefficients of the maximum allowable number of lots, the TDR/PUD indicator, and the cross-product of the maximum allowable number of lots and the TDR/PUD indicator—all of which do affect the number of lots—are not significantly different from zero in either the average lot size or the open space equation.

Subdivisions with public sewer service available have smaller lots, a greater number of lots, and more public open space, all as one would expect. Homes not served by public sewer systems are required to have lots large enough to accommodate septic fields and thus have tighter space constraints (and a higher marginal value of land within the subdivision). Average lot size is necessarily larger in these subdivisions, and the number of lots and total open space are necessarily smaller as a result.

The open space equation indicates that developers plan public open space around geographical features of the subdivision, as one would expect. The positive coefficient of stream frontage suggests that developers find it optimal to plan open space around streams. The positive coefficient of wetlands area suggests that developers tend to retain wetlands as open space rather than converting or incorporating them into building lots; this result may be due to regulatory limits on draining wetlands or to the cost of doing so.

It was argued earlier that developers provide more open space in subdivisions with a lower marginal value of space. The marginal value of space within a subdivision is decreasing in the area of the subdivision as a whole and in the area on which housing can be constructed, i.e. the net area of the subdivision. The coefficient of total subdivision acreage is positive, as expected. Larger floodplain acreage means smaller net acreage, as we have seen; the negative coefficient of floodplain acreage is thus expected as well.

The open space equation indicates in addition that developers choose to internalize the provision of public open space rather than attempting to free ride on open space available in the vicinity of the subdivision. The coefficients of parkland, farmland, and forest/brush land within two miles of the subdivision centroid are all individually not significantly different from zero. They were also collectively not significantly different from zero (the Wald statistic was 1.11). These results suggest that developers perceive no value added from land that is permanently (parkland) or possibly temporarily (farmland, forest/brush) providing open space nearby, but not in the subdivision. As noted above, estimating these models using nearby open space within 3 and 5 miles of the subdivision centroid gave qualitatively identical (and quantitatively almost identical) results.

The coefficient of zoned minimum lot size in the open space equation is significantly different from zero and suggests that increasing the minimum lot size by an acre induces developers to reduce open space by almost 5 acres. This result suggests that developers utilize forested portions of building lots as well as forested open space in order to meet FCA requirements. The theoretical model suggests that developers will increase the forested share of each building lot when the marginal value of space within the subdivision is higher. All else equal, the marginal value of space should be higher in subdivisions facing a larger minimum lot size, so that the sign of this coefficient is consistent with the predictions of the theoretical model.

The theoretical model also implies that developers will tend to retain forest in building lots in subdivisions with high initial forest area. Consistent with this prediction, the coefficient of initial forested area in the average lot size equation is positive and significantly different from zero. The coefficient of initial forested area in the open space equation is negative but not significantly different from zero, a result consistent with the hypothesis that developers choose to provide a given level of other public open space while satisfying binding constraints on total forested area imposed by the FCA.

As noted above, the coefficient of the TDR/PUD indicator in the number of lots equation was positive as expected, since these programs are used to relax density restrictions. The coefficient of the cross-product of the TDR/PUD indicator and the maximum allowable number of lots is negative, indicating that increases in maximum allowable density result in smaller increases in density in TDR/PUD subdivisions.

Finally, the coefficient of distance to the nearest central business district in the average lot size equation was positive (and significantly different from zero at an 8 percent significance level), which is consistent with the standard tradeoff between consumption of space and commuting cost.

Discussion

Taken together, the estimated coefficients are consistent with the hypothesis that developers provide open space voluntarily as a means of enhancing property values within suburban subdivisions. The fact that the coefficient of the maximum allowable number of lots in the number of lots equation is significantly less than one indicates that developers choose not to provide as many lots as regulators would allow. Instead, they provide only about 3 additional lots for every 5 allowed by regulation. The fact that the coefficient of the maximum allowable number of lots is not significantly different from zero in the average lot size equation suggests that developers limit the number of lots in order to provide open space rather than in order to increase lot size. Further evidence comes from the fact that the coefficient of forested area required under the FCA in the open space equation is not significantly different from one, which implies that developers do not cut back other public open space when faced with stricter FCA requirements. Instead, a one-acre increase in the forested acreage required by the FCA is met by increasing total open space by an acre, suggesting that developers cut back on area in building lots rather than other public open space to meet stricter FCA requirements. Finally, as the theoretical model indicates, open space is larger in subdivisions with a lower marginal value of space within the subdivision, which occurs when the subdivision as a whole and the area on which housing can be constructed are larger. The positive coefficient of total subdivision acreage and negative coefficient of floodplain acreage are consistent with such an explanation.

As noted above, the fact that the estimated coefficients of nearby farmland, parkland, and forest/brush are all not significantly different from zero is also consistent with the notion that developers internalize the provision of open space rather than attempting to free ride on open space provided by neighboring properties, as Thorsnes [14] has argued. One possible explanation is that the impacts of open space amenities on property values are highly localized, as Thorsnes [15] found in the case of forest preserves, so that open space outside of the subdivision adds little or no value to property within the subdivision.

The results are also consistent with the notion that the FCA has been effective in increasing forested acreage above and beyond levels that developers would provide in its absence. As noted above, the coefficient of forested acreage required under the FCA in the open space equation indicates that developers provide one acre of open space for each additional forested acre required under the FCA. At the margin, then, FCA requirements increase total open space without reducing non-forested public open space. Average lot size is significantly larger in subdivisions that are exempt from the FCA, suggesting that FCA requirements are met in part by reducing average lot size. The positive coefficient of initial forested area in the average lot size equation suggests that the FCA gives developers whose initial forested area exceeds the FCA requirement an opportunity to retain a larger share of forest on each building lot in order to economize on clearing costs. Overall, the results suggest that the FCA has been successful in meeting its stated purpose of increasing forested acreage in the state.

Conclusion

Rapidly urbanizing jurisdictions face substantial challenges in maintaining the provision of public goods such as limits on congestion, protection of air and water quality, and preservation of open space and other scenic amenities. Land use regulations are often justified as necessary for meeting those challenges. The extent to which regulation is needed to provide many such public goods is not clear, however. Both theoretical and empirical studies suggest that private developers provide public goods that are strictly local (such as open space, stream and forest preservation, and other scenic amenities) as a profitable means of enhancing property values.

This paper examines the effects of land use regulations on the provision of two related local public goods, open space and forest preservation. We present a conceptual model of a developer's decision regarding lot size, the number of lots, and the provision of forested and non-forested open space in suburban residential subdivisions when the developer is subject to regulations governing minimum lot size, maximum density, and forest conservation. The model suggests that when all three forms of land use regulation impose binding constraints, developers will tend to provide more than socially optimal levels of forested land. As a result, it is possible that land use regulations may distort the provision of local public goods, resulting in excessive provision of regulated neighborhood amenities and under provision of unregulated amenities that developers nonetheless have economic incentives to provide.

An empirical analysis of suburban single-family residential subdivisions in the Washington-Baltimore corridor suggests that the allocation of space within these subdivisions is not determined completely by zoning. Instead developers have some freedom to choose to provide open space amenities, presumably in order to increase land values. Minimum lot size zoning and forested area requirements under by Maryland's Forest Conservation Act did impose binding constraints on subdivision developers. Maximum density zoning did not: On average, developers created 3 building lots for every 5 allowed by zoning. The empirical results suggest that developers refrained from creating as many building lots as allowed in order to provide non-forested public open space. The availability of open space near but outside of each subdivision had no effect on the provision of open space within the subdivision, suggesting that developers act to internalize open space amenities rather than attempting to free ride on their neighbors. In sum, competition among developers seems to have been adequate to ensure adequate provision of public open space within subdivisions in Maryland during this time period.

Our results also indicate that regulation under Maryland's Forest Conservation Act did impose binding constraints, which developers met by expanding forested open space without reducing other public open space and by retaining forest on a larger share of each building lot. Thus, our analysis indicates that the Forest Conservation Act did meet its stated goal of increasing forested acreage in the state.

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Table 1. Descriptive Statistics of the Variables Used in the Empirical Model

Variable	Mean	Standard Deviation
Total site acreage	39.021	56.0429
Average lot size	1.14541	1.981549
Subdivision located in Carroll County	0.122807	0.328938
Subdivision located in Charles County	0.140351	0.348115
Subdivision located in Howard County	0.232456	0.423328
Subdivision located in Montgomery County	0.258772	0.438924
Acreage specified as open space in plan	11.98763	26.90833
Acres of floodplain in subdivision	3.784649	14.40865
Acres of wetland in subdivision	2.369298	5.60395
Linear feet of stream in subdivision	994.6184	2035.553
Subdivision exempt from FCA (yes = 1)	0.166667	0.373498
Public sewer supplied (yes = 1)	0.692983	0.462272
High school MSPAP score	101.6214	2.992942
Zoned minimum lot size	0.769627	1.061467
Zoned maximum density	2.425548	2.971265
TDR or PUD (yes =1)	0.100877	0.301829
Forested acres required by FCA	11.77259	18.35351
Commuting distance to nearest CBD	23.65658	17.65702
Density	2.255701	2.353802
Percentage of land within ½ mile in farmland	20.46032	20.77291
Percentage of land within ½ mile in forest, brush, or undeveloped	31.03956	18.74848
Percentage of land within ½ mile in parks, public spaces, etc.	2.078146	5.270785
Forested acreage prior to development	17.022304	30.31219
Number of observations	228	

Table 2. Estimated Parameters of the Empirical Models

Independent Variable	Dependent Variable		
	Average Lot Size	Number of Lots	Open Space
Constant	1.752886 (6.4997)	-100.525 (155.5)	-5.64984 (71.0300)
Subdivision exempt from FCA (yes = 1)	1.020588** (0.2556)	-7.26002 (6.1477)	-2.93322 (2.7933)
Forested acres required by FCA	0.0045292 (0.0130)	0.331506 (0.3118)	0.819434** (0.1416)
Zoned minimum lot size	0.801534** (0.1483)	-4.54789 (3.5671)	-4.88399** (1.6201)
Zoned maximum number of lots (Density times subdivision area)	0.000009396 (0.00180)	0.588068** (0.0434)	-0.02001 (0.0197)
TDR or PUD (yes =1)	-0.21897 (0.4743)	41.628417** (11.3971)	5.069363 (5.1837)
Cross product of zoned minimum lot size and TDR/PUD	-0.57032 (0.5406)	-5.85712 (12.9791)	8.768612 (5.9080)
Cross product of zoned maximum number of lots and TDR/PUD	-0.0001 (0.00195)	-0.28716** (0.0468)	0.014442 (0.0213)
Total site acreage	-0.00292 (0.00412)		0.211484** (0.0450)
Acres of floodplain in subdivision	-0.00099 (0.00846)		-0.36233** (0.0920)
Net acres in subdivision		0.151505 (0.0992)	
Acres of wetland in subdivision	-0.04543 (0.0223)	-0.65083 (0.5376)	0.551269* (0.2441)
Linear feet of stream in subdivision	-0.00008 (0.000069)	0.003892* (0.00165)	0.00188* (0.000756)
Forested acreage prior to development	0.015708* (0.00693)	-0.24665 (0.1634)	-0.14506 (0.0757)
Public sewer supplied (yes = 1)	-1.0197* (0.3833)	29.64897** (9.2070)	11.47964** (4.1889)
Percentage of land within 2 miles in farmland	0.017295 (0.0101)	0.227597 (0.2436)	0.096363 (0.1109)
Percentage of land within 2 miles in forest or brush	-0.01908 (0.0114)	0.493366 (0.2745)	0.072268 (0.1248)
Percentage of land within 2 miles in parks, public spaces, etc.	-0.004357 (0.0524)	-0.77493 (1.2605)	0.187061 (0.5722)
Commuting distance to nearest CBD	0.019137 (0.0108)	-0.4641 (0.2591)	-0.07283 (0.1182)
High school MSPAP score	-0.00568 (0.0667)	0.781263 (1.5967)	-0.06536 (0.7292)

Subdivision located in Carroll County	-1.00339 (0.5719)	4.321042 (13.7417)	-1.56629 (6.2502)
Subdivision located in Charles County	-0.19113 (0.6248)	20.74164 (14.9464)	2.193009 (6.8281)
Subdivision located in Howard County	-0.24564 (0.5000)	-4.20863 (11.9926)	1.133137 (5.4638)
Subdivision located in Montgomery County	-0.14636 (0.5070)	0.13349 (12.1561)	-1.3237 (5.5406)
R^2	0.5658	0.7973	0.7188

Standard errors reported in parentheses.
** denotes significantly different from zero at a 1% significance level.
* denotes significantly different from zero at a 5% significance level.