Open Space and Urban Sprawl: The Case of the Maryland Forest Conservation Act

by

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WP 08-07

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Abstract

Rapid urbanization enhances the desirability of policies for preserving open space but those policies may expand the urban boundary and create leapfrog development. We investigate this potential conflict between open space preservation and urban sprawl conceptually and empirically using data from the Baltimore-Washington suburbs. The estimated econometric model indicates that both zoning and forest planting requirements contribute to sprawl by increasing the amount of land needed to accommodate the current number of households. The impacts of these regulations on sprawl are modest, however, increasing urbanized area by less than one percent in response to a one percent increase in any of these three forms of regulation. Thus, while there does seem to be some conflict between open space preservation and prevention of urban sprawl, that conflict does not appear to be acute.

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Introduction

Preserving open space is an important component of land use policy in rapidly urbanizing areas. Both current and incoming residents place a significant value on nearby open space, as evidenced by the fact that the presence of nearby open space—especially open space that has been permanently preserved in some form—increases residential property values (Cheshire and Sheppard 1995, Geoghegan et al. 1997, Tyrvainen and Mettinen 2000, Geoghegan 2002, Thorsnes 2002, Irwin 2002, Geoghegan et al. 2003, Wu et al. 2004, Hardie et al. 2007). Preservation of open space is a common justification for land use regulations like zoning. It also motivates programs such as easement purchases or transferable development rights whose explicit purpose is permanent preservation of open space (Bockstael and Irwin 2000).

But open space preservation can exacerbate problems of urban sprawl both by extending the urban boundary out farther into rural areas and by promoting leapfrog development. Zoning and other forms of land use regulation can induce developers to reduce the number of housing lots within subdivisions, in which case more extensive land development is needed to accommodate any given increase in population. Theoretical analyses show that, by reducing density, minimum lot size zoning pushes the equilibrium urban boundary outward (Moss 1977, Pasha 1996). An econometric study of Calvert County, Maryland provides evidence supporting this prediction, finding that zoning reduces density (McConnell, Walls, and Kopits 2006). Other econometric evidence from Maryland shows that proximity to permanently preserved open space increases the likelihood that a parcel of land will be developed, suggesting that open space preservation can foster non-contiguous, “leapfrog” development (Irwin and Bockstael 2004) Simulation studies based on data from Portland, Oregon similarly show that open space preservation can create leapfrog development (Wu and Plantinga 2003).

This paper investigates how minimum lot size zoning and forest planting requirements under the Maryland Forest Conservation Act affect the design of suburban residential subdivisions; in particular, the average size of lots, the number of lots, and the amount of land used for roads and other infrastructure. We present a conceptual model of how these two regulations influence the way that a developer chooses to subdivide land into building lots, forested and non-forested open space, and infrastructure such as roads and sidewalks. We use that conceptual model to specify an econometric model using data from subdivisions developed in the Baltimore-Washington suburbs during the mid-1990s. We then use the econometric results to draw inferences about the impacts of these regulations on the amount of land needed to accommodate population growth in the Baltimore-Washington corridor and hence on urban sprawl.

The Maryland Forest Conservation Act

From the 1960s on, Maryland lost a great deal of forested land due to the rapid pace of urban expansion. In response, the state enacted the Forest Conservation Act (FCA). Sensitive areas such as flood plains, stream banks, steep slopes, and critical wildlife habitat were of special concern to legislators because even when developers choose to retain trees, they may choose to eliminate stream buffers, for example, rather than to let a riparian forest regenerate; clear land of mature trees while building and replant young trees afterwards; or otherwise provide forest in ways that provide less than desired levels of amenities.

The FCA applies to any project involving grading on 40,000 or more square feet (slightly less than an acre). Under the FCA, developers must have an approved forest conservation plan as part of the overall development permit approval process. That forest conservation plan must specify the total amount and location of forested area retained, protective measures for stand edges and specimen trees, and measures that will protect retained forested areas permanently (e.g., covenants or easements incorporated into land deeds). The FCA also specifies minimum amounts of forested area to be provided, set according to the area and land use category of the site, existing forest cover, and proposed cleared area. County planning agencies administer the FCA as part of the overall development permit approval process but have little, if any flexibility in how the requirements of the Act are met: Levels of reforestation or afforestation and exemption from the Act are determined by pre-established formulas specified in the Act (Galvin, Wilson, and Honeczy 2000, Hardie, Lichtenberg and Nickerson 2007, Lichtenberg, Tra, and Hardie 2007).

A Model of Land Allocation within a Residential Subdivision

Our conceptual framework extends Hardie, Lichtenberg, and Nickerson's (2007) model of the choices made by a subdivision developer. A land developer subdivides a parcel of fixed size L into n identical lots of size s; forested and non-forested open space, z and a, respectively; and land devoted to roads, sidewalks, and other forms of infrastructure. Forested open space provides amenities $f(z, \phi s, z^o)$, where ϕ denotes the share of forested area incorporated into building lots and z^o denotes forested open space nearby but outside of the subdivision. Non-forested open space provide amenities

$h(a,a^o)$, where a^o denotes non-forested open space nearby but outside of the subdivision. Identical buyers have a willingness to pay per unit of developed land (bid rent):

$$(1) \qquad R(s, f(z, \phi s, z^o), h(a, a^o), y, T, g, u, i) = \frac{y - T - x(s, f(z, \phi s, z^o), h(a, a^o), g, u, i)}{s}.$$

Here y denotes household income, T commuting cost, x a composite of all other purchased commodities, g other public good amenities (e.g., school quality), u the equilibrium level of utility in the metropolitan area, and i the amount of land devoted to roads, sidewalks, and other infrastructure.

The land developer's goal is to maximize the rent generated by the subdivision:

$$(2) \qquad V \equiv R(\cdot)ns - c(z) - k(a) - m(i) - Q(L),$$

where $c(z)$ is the increasing and convex cost of afforestation; $k(a)$ is the increasing and convex cost of developing other open space; $m(i)$ is the increasing and convex cost of infrastructure development; and $Q(L)$ is the acquisition cost of the parcel, that is, the price of raw land prior to subdivision.

Development is subject to several constraints. First, development is constrained by the total area of the subdivision:

$$(3) \qquad ns + z + a + i = L.$$

Second, zoning imposes a restriction on minimum lot size:

$$(4) \qquad s \geq \sigma.$$ [1]

Third, the FCA requires that the developer provide a minimum amount of forested area, which can consist of forested open space z or forested area incorporated into building lots ϕns:

[1] In some cases zoning may limit maximum density rather than minimum lot size, in which case the relevant zoning restriction can be written as $n \leq \nu$, where ν denotes the maximum number of building lots allowed on the parcel.

(5) $$z + \phi ns \geq \zeta \ .$$

Because developers in the Maryland suburbs typically purchase entire parcels for subdivision, we assume that the constraint on total land availability (3) is always binding. If both regulatory constraints are binding as well, the developer's problem can be concentrated into the choice of forested space, non-forested open space and infrastructure *(z,a,i)*. The necessary conditions characterizing these choices are:

(6) $$\frac{\partial R}{\partial f}\frac{\partial f}{\partial z}(L-z-a-i) - \frac{\partial f}{\partial \phi}\frac{\sigma(L-\zeta-a-i)}{(L-z-a-i)} - R - c' \leq 0$$

(7) $$\frac{\partial R}{\partial h}\frac{\partial h}{\partial a}(L-z-a-i) + \frac{\partial R}{\partial f}\frac{\partial f}{\partial \phi}\frac{\sigma(\zeta-z)}{(L-z-a-i)} - R - k' \leq 0 \ .$$

(8) $$\frac{\partial R}{\partial i}(L-z-a-i) + \frac{\partial R}{\partial f}\frac{\partial f}{\partial \phi}\frac{\sigma(\zeta-z)}{(L-z-a-i)} - R - m' \leq 0 \ .$$

When land is allocated to all three, the choice of forested open space equates the increased value of building lots due to forested open space $\frac{\partial R}{\partial f}\frac{\partial f}{\partial z}(L-z-a-i)$ with the opportunity cost of land R plus the marginal cost of developing forested open space c' adjusted for any change in the value of building lots due to substitution of forested open space for permanent forested land portions of building lots $\frac{\partial R}{\partial f}\frac{\partial f}{\partial \phi}\frac{\sigma(L-\zeta-a-i)}{(L-z-a-i)}$. The choice of non-forested open space similarly equates the increased value of building lots due to non-forested open space $\frac{\partial R}{\partial h}\frac{\partial h}{\partial a}(L-z-a-i)$ with the marginal cost of developing that open space k' plus the opportunity cost of land R adjusted for any change in the value of building lots due to the substitution of non-forested open space for permanent forested portions of building lots $\frac{\partial R}{\partial f}\frac{\partial f}{\partial \phi}\frac{\sigma(\zeta-z)}{(L-z-a-i)}$. The choice of infrastructure area also equates the increased value of building lots due to nfrastructure $\frac{\partial R}{\partial i}(L - z - a - i)$ with the marginal cost of developing that infrastructure m' plus the opportunity cost of land diverted R adjusted for any change in the value of building lots due to the substitution of infrastructure land for permanent forested portions of building lots $\frac{\partial R}{\partial f}\frac{\partial f}{\partial \phi}\frac{\sigma(\zeta - z)}{(L - z - a - i)}$.

Hardie, Lichtenberg and Nickerson (2007) used this basic framework to study the effects of minimum lot size zoning and FCA forest planting requirements on developed land values. Using data from a random sample of suburban single-family residential subdivisions in the Washington-Baltimore corridor, they found that the average value of land in these subdivisions was decreasing in zoned minimum lot size and increasing in the FCA forestation requirement, as predicted by analysis of the theoretical model when forested portions of building lots and infrastructure requirements are ignored ($\phi = \gamma = 0$). A subsequent study by Lichtenberg, Tra, and Hardie (2007) using these same data found that minimum lot size zoning decreased total open space and that a one-acre increase in the FCA forest planting requirement increased total open space by an amount less than one, confirming a prediction (derived from the theoretical model under an assumption of Cobb-Douglas utility) that FCA forest planting requirements crowd out other forms of open space. Both the average value of land and total open space within a subdivision were unaffected by the amounts of open space nearby but outside that subdivision, indicating that the benefits of open space are largely internalized within subdivisions. A third study using these same data by Lichtenberg and Hardie (2007) found that minimum lot size zoning increased the average size of building lots and reduced the number of building lots in each subdivision, especially in subdivisions with public sewer access, confirming earlier findings of that zoning reduces density (Moss 1977, Pasha 1996, McConnell, Walls, and Kopits 2006). In contrast, FCA planting requirements increased the average size of building lots but left the number of lots unchanged.

Data

We investigate the effects of these regulations on average lot size, number of lots and infrastructure area empirically using these same data, which are described in detail in Hardie, Lichtenberg, and Nickerson (2007) and Lichtenberg, Tra, and Hardie (2007). The data set comprises a random sample totaling half of the single-family residential subdivisions approved for development between 1991 and 1997 in five Maryland counties (Charles, Carroll, Howard, Montgomery, and Prince Georges) in the Baltimore-Washington corridor. Two of these counties (Montgomery and Prince Georges Counties) have densely populated urban areas adjacent to 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 county town centers. The fifth, Howard County, is located between Washington and Baltimore; residents commute to both.

The subdivisions included in the study have five or more lots for single-family dwellings. Some of these subdivisions consist entirely of detached homes, others entirely of townhouses, and still others of combinations of the two. None of them have commercial or industrial sites or lots developed for apartment buildings. We omitted small subdivisions with less than five lots to avoid cases where land is subdivided primarily to provide residences for family members.

The data include information on the size of each developed lot in the subdivision; forest planting requirements under Maryland's Forest Conservation Act; minimum lot size and maximum density zoning requirements; the availability of public water and sewer services; total subdivision size; geographical attributes of the subdivision such as areas of floodplain and wetlands and linear stream frontage; commuting distances from Washington and Baltimore; the amounts of land surrounding the subdivision in farms, residential use, parks and recreational facilities, and undeveloped forest and brush.

County planning agency files were the source of information on geographic features of each subdivision (e.g., areas of floodplain and wetlands and linear stream frontage), subdivision size, the physical utilization of space within the subdivision (including the number and sizes of building lots and total area designated as open space), forest conservation plans (including FCA forest planting requirements), and the availability of public sewer service. The amount of land in roads, sidewalks, and other forms of infrastructure in each subdivision was calculated as a residual by subtracting land in building lots, open space, wetland and floodplain from the total area of the subdivision.

Maryland Property View GIS databases were the sources of information used to calculate commuting (road) distance from each subdivision to the nearest central business district (Washington, DC or Baltimore) and the surrounding area within a given distance of the centroid of each subdivision in farmland, parks and recreational facilities, and undeveloped forest and brush. The latter were calculated under the assumption that the subdivision occupied a circle with an area equal that of the subdivision around its centroid. The Property View data were then used to calculate the amounts of land in farms, parks/recreation areas, and forest/brush in a ring of a half mile radius surrounding the circle representing the subdivision.

County zoning documents were used to determine minimum lot sizes and maximum allowable densities corresponding to zoning codes obtained from the Property View data. In cases where zoning codes did not specify maximum allowable density (about 12% of the sample), density restrictions were calculated as the reciprocal of minimum lot size. Zoned maximum allowable density was then multiplied by the net (buildable) area of the subdivision (total subdivision area less the area in floodplain and wetlands) to obtain the maximum allowable number of lots in each subdivision. Subdivisions regulated under transferable development rights (Montgomery County) or planned use development zoning (Prince Georges and Charles Counties) were excluded from the analysis, resulting in a usable sample of 228 subdivisions. Descriptive statistics are shown in Table 1.

Specification and Estimation of the Econometric Model

Our econometric model has three dependent variables for each subdivision: the average size of building lots; the number of building lots; and land in roads, sidewalks, and other forms of infrastructure. Following the conceptual framework, we assume that all three are functions of zoning and regulation under the FCA. Also included in each regression equation were control variables such as the size of the subdivision, geographic features of the subdivision that may limit the way space can be used, land uses outside but nearby the subdivision, and the location of the subdivision.

All three dependent variables were treated as functions of FCA forest planting requirements. A dummy variable indicating subdivisions exempt from the FCA was also included in all three equations. Because minimum lot size and the maximum allowable number of lots were so closely related in many cases (the maximum allowable number of lots was calculated using the reciprocal of minimum lot size for about 12% of the sample), we tested statistically whether minimum lot size and/or the maximum allowable number of lots was the pertinent form of zoning regulation. As one would expect, minimum lot size was a statistically significant determinant of average lot size while the maximum allowable number of lots was not, so the maximum allowable number of lots was excluded from the average lot size equation. Similarly, the maximum allowable number of lots was a statistically significant determinant of the actual number of lots while the minimum lot size was not, so minimum lot size was excluded from the number of lots equation. Both forms of zoning regulation were used in the infrastructure land equation because preliminary regressions indicated that both might have statistically significant effects.

Control variables such as floodplain and wetlands acreage and linear stream frontage were included in all three regression equations to measure geographical features that might limit the ways developers are able to use land within the subdivision. Measures of open space in the vicinity of the subdivision were also included as control variables. Some previous hedonic studies have found housing prices to be increasing in various forms of nearby open space, raising the possibility that developers might choose to substitute permanently preserved open space in close proximity to the subdivision in place of open space within a subdivision. All three regression equations also included distance from the subdivision to the nearest urban center (Washington or Baltimore and dummies for the county in which the subdivision was located, the latter to control for unobserved attributes of these very different jurisdictions.

The availability of public sewer service may influence the effects of zoning and FCA forest planting requirements because the amount of land required for septic systems to meet health regulations may supersede minimum lot size zoning (and, in doing so, change the opportunity cost of land which affects the attractiveness of open space and infrastructure). Likelihood ratio tests indicated statistically significant differences between subdivisions with and without public sewer, so we estimated separate models for each.[2]

A number of studies have shown that zoning designations may be altered over time in response to economic pressures (Wallace 1988, McMillan and McDonald 1991, Munneke 2005). Features of the zoning regulations in the counties we consider give further grounds for this potential endogeneity. Howard County zoning regulations include an explicit formula trading off lot size for open space; other counties set different open space requirements for townhouses and for detached homes. Hausman tests indicated no correlation between unobserved factors influencing zoned minimum lot size and average lot size or zoned maximum allowable density and the number of lots so we estimated the econometric model treating zoning as exogenous in these two equations. A Hausman test did indicate correlation between minimum lot size and land in infrastructure in subdivisions with public sewer access but not in subdivisions without

[2] The likelihood ratio test statistics were 54.19 for the average lot size equation, 95.08 for the number of lots equation, and 136.65 for the infrastructure area equation; all had 16 degrees of freedom and corresponding p-values of 10^{-5} or lower.

public sewer access.[3] We thus treated minimum lot size zoning in the infrastructure area as endogenous in subdivisions with access to public sewer service and exogenous in subdivisions without public sewer access.

We estimated the models for subdivisions with and without public sewer access as separate systems of three equations taking into account correlation between unobserved factors affecting average lot size, the number of lots, and infrastructure area in the same subdivision. The model for subdivisions with public sewer access was estimated using three stage least squares; the variables used as instruments for zoned minimum lot size in the infrastructure equation in this model were the total subdivision area; the county in which the subdivision was located; and the road distances between the subdivision and Baltimore, Washington, the Chesapeake Bay Bridge, the nearest town center, the nearest large shopping mall, the nearest military installation, and the nearest sports stadium. The model for subdivisions without public sewer access was estimated using a seemingly unrelated regressions model.

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[3] The Hausman tests were conducted using reduced form first-stage regressions of minimum lot size and lot numbers on subdivision area, county dummies, and road miles from the subdivision to Washington, Baltimore, the Chesapeake Bay Bridge, the nearest town center, the nearest large shopping mall, the nearest sports facility, and the nearest military installation in addition to all of the variables included in the open space tobit model. The first-stage regression for average lot size had an R^2 of 0.35 for the subsample with public sewer access, and 0.46 for the subsample without public sewer access. The Hausman test t-statistics for minimum lot size in subdivisions with public sewer access were 1.89 in the average lot size equation, 1.69 in the number of lots equation, and 2.50 in the infrastructure area equation. The Hausman test t-statistics for minimum lot size in subdivisions without public sewer access were 0.90 in the average lot size equation, 0.67 in the number of lots equation, and 0.48 in the infrastructure area equation. The first-stage regression for maximum number of lots had an R^2 of 0.43 for the subsample with public sewer access, and 0.44 for the subsample without public sewer access. The Hausman test t-statistics for maximum number of lots in subdivisions with public sewer access were 0.98 in the average lot size equation, 1.28 in the number of lots equation, and 1.73 in the infrastructure area equation. The Hausman test t-statistics for maximum number of lots in subdivisions without public sewer access were 0.21 in the average lot size equation, 0.05 in the number of lots equation, and 0.29 in the infrastructure area equation.

Estimation Results

The econometric models for both classes of subdivisions fit the data quite well. The estimated coefficients confirm that both zoning and FCA forest planting requirements influence average lot size in these subdivisions. As is standard, average lot size is increasing and density is decreasing in distance from the closest central business district.

Impacts of Minimum Lot Size Zoning

The coefficients of zoned minimum lot size are statistically significantly greater than zero in the average lot size equation in subdivisions with and without public sewer access. Interestingly, they are not significantly different from one in either kind of subdivision (the respective t-ratios for subdivisions with and without public sewer access are 1.76 and -1.49) implying that a one-acre increase in zoned minimum lot size is associated with a one-acre increase in average lot size. This result suggests that in the absence of minimum lot size zoning developers would subdivide land into smaller lots. The actual coefficient of zoned minimum lot size is greater than one in subdivisions with access to public sewer service, suggesting that zoning is highly restrictive in these closer-in areas. It is less than one in subdivisions without access to public sewer service, possibly because septic system requirements are binding determinants of the sizes of some lots in these more remote areas.

The coefficient of minimum lot size is negative but not significantly different from zero in the infrastructure area equation in both types of subdivisions, making it likely that minimum lot size zoning has no effect on the amount of land allocated to roads, sidewalks, and other forms of infrastructure.

Impacts of Density (Maximum Allowable Number of Lots) Zoning

The coefficient of the maximum allowable number of lots in the number of lots equation is significantly greater than zero in subdivisions with access to public sewer service. It is significantly less than one, suggesting that developers' choices are limited by other restrictions such as minimum lot size zoning, forest planting requirements, and/or limitations imposed by the presence of floodplains, streams, or other geographical features. The coefficient of the maximum allowable number of lots is positive but not significantly different from zero and quite small in magnitude in subdivisions without public sewer access.

The coefficient of the maximum allowable number of lots is positive in both infrastructure area equations but significantly different from zero only in subdivisions without public sewer access. The coefficient of the maximum allowable number of lots for subdivisions without public sewer access indicates that each building lot uses close to a half-acre of land in infrastructure. In subdivisions with public sewer access the coefficient of the maximum allowable number of lots is close to zero in magnitude as well as statistically insignificant.

Impacts of FCA Forest Planting Requirements

The coefficient of the FCA forest planting requirement is significantly different from zero in all three equations in subdivisions with access to public sewer service but significantly different from zero in subdivisions without public sewer access only in the equation for infrastructure area. It is positive in both average lot size equations, suggesting that developers respond to FCA forest planting requirements in part by setting aside portions of building lots as permanent forested acreage. It is quite small in magnitude in both average lot size equations (0.01-0.02), suggesting that permanently preserved forest makes up a very limited share of building lots. It is positive in both number of lots equations, suggesting that FCA requirements increase the attractiveness of clustering. The effect of FCA planting requirements is especially pronounced in subdivisions with public sewer access; it is negligible (its coefficient is quite small in magnitude) in subdivisions without public sewer access.

The coefficient of the FCA planting requirement in the infrastructure equation is significantly less than zero in both kinds of subdivisions, suggesting that developers respond to forest planting requirements by economizing on infrastructure land. It is not significantly different from one in absolute value in subdivisions with public sewer access, suggesting a one-for-one tradeoff between forest planting and infrastructure. It is significantly less than one in absolute value in subdivisions without public sewer access, suggesting that developers have greater flexibility to allocate land in these farther-out subdivisions.

Impacts of Regulation on Sprawl

An estimate of the effect of these regulations on sprawl can be obtained by differentiating the land availability constraint (3) with respect to each form of regulation to obtain the additional amount of land needed to accommodate any given level of population growth. Following this procedure for an arbitrary regulation $\gamma = (\sigma,\zeta,\nu)$ (where ν represents the zoned maximum allowable number of lots) yields:

(9) $$\frac{dL}{d\gamma} = n\frac{\partial s}{\partial \gamma} + s\frac{\partial n}{\partial \gamma} + \frac{\partial (z+a)}{\partial \gamma} + \frac{\partial i}{\partial \gamma}.$$

The coefficients of the models estimated here give $\partial s/\partial\gamma$, $\partial n/\partial\gamma$, and $\partial i/\partial\gamma$.[4] Lichtenberg, Tra, and Hardie (in press) find $\partial(z+a)/\partial\zeta$ equal to 0.39 in subdivisions with public sewer access and 0.85 in subdivisions without public sewer access; $\partial(z+a)/\partial\sigma$ equal to -7.98 in subdivisions with public sewer access and -6.44 in subdivisions without public sewer access; and $\partial(z+a)/\partial v$ equal to zero in both kinds of subdivisions.

Using these parameter estimates in equation (9), we find that a one-acre increase in minimum lot size increases the amount of land needed to accommodate the current number of households by about 34 acres in subdivisions with public sewer access and about 3.5 acres in subdivisions without public sewer access. The proportional effect of a one-acre increase in minimum lot size on the amount of land needed to accommodate existing population levels in subdivisions with public sewer access is quite large, about 170%. It should be noted, though, that a one-acre increase effectively quadruples minimum lot size in these subdivisions. In contrast, a one-acre increase in minimum lot size in subdivisions without public sewer access, which increases the amount of land needed to accommodate the existing population by about 5%, represents an increase in minimum lot size of only about one-third.

Following the same procedure, we find that a one-lot reduction in the maximum allowable number of lots increases the amount of land needed to accommodate the current number of households by about 0.28 acres in subdivisions with public sewer access and about 0.74 acres in subdivisions without public sewer access, or roughly 1% in both kinds of subdivisions. On a proportional basis the amount of land needed to accommodate the existing population is actually somewhat more sensitive to density

[4] In the 12% of subdivisions where minimum lot size determines the maximum allowable number of lots, $\partial n/\partial\sigma$ can be calculated as $(\partial n/\partial v)(-B/\sigma^2)$ where B denotes the net area (total area less floodplain and wetland) of the subdivision.

(maximum allowable number of lots) zoning than lot size zoning: A 10% decrease in the maximum number of lots increases the amount of land needed to accommodate current households by 7% in subdivisions with public sewer access of average size and 3% in subdivisions without public sewer access of average size, compared to 5% and 1%, respectively, for a 10% increase in minimum lot size.

Overall, these results are in line with the claim that zoning promotes urban sprawl by reducing density and thus pushing the urban boundary out farther into rural areas. They support the results of theoretical models such as Pasha's (1996) that predict that minimum lot size zoning has a large effect on land use in close-in suburban areas. They also confirm existing empirical evidence, notably the results of McConnell, Walls, and Kopits' (2006) Calvert County study.

Applying equation (9) to forest conservation regulation, we find that a one-acre increase in the FCA planting requirement increases the amount of land needed to accommodate the current number of households by about 0.62 acres in subdivisions with public sewer access and about 0.72 acres in subdivisions without public sewer access, indicating that forest conservation regulation can exacerbate sprawl in much the same manner as zoning. At subsample averages, a 10% increase in the forest planting requirement increases the amount of land needed to accommodate the existing population by 2% in both types of subdivisions. Thus, on a percentage basis the amount of land needed to accommodate the existing population is actually somewhat more sensitive to FCA planting requirements than to either lot size or density zoning in more remote subdivisions without public sewer access but less sensitive to FCA planting requirements than zoning in closer-in subdivisions with public sewer access.

Concluding Remarks

Rapid urbanization threatens the availability of and access to open space and thus often triggers the enactment of policies designed to preserve open space. Both theoretical studies and prior econometric studies suggest that some of those policies may result in more extensive development by reducing housing density so that more land is needed to accommodate population growth. In other words, open space preservation policies may contribute to urban sprawl.

We present a conceptual framework of the choices facing a developer subdividing a parcel of fixed size and use it to specify an econometric model of average lot size, the number of lots per subdivision, and land allocated to roads, sidewalks, and other forms of infrastructure. Lot size, lot numbers and infrastructure are functions of minimum lot size and maximum density zoning, forest planting requirements under the Maryland Forest Conservation Act, and control variables influencing the use of space such as subdivision size, geographic features of the subdivision, subdivision location, and land use in areas surrounding the subdivision. We fit the parameters of the econometric model using data from suburban subdivisions in five counties in the Baltimore-Washington suburbs.

The estimated coefficients indicate that minimum lot size zoning increases average lot size; that maximum density zoning reduces the number of lots and, in subdivisions without public sewer access, infrastructure area; and that forest planting requirements increase both average lot size and the number of lots in subdivisions with public sewer access and reduce infrastructure area in all subdivisions. The effects of all of these changes on the amount of land needed to accommodate the current number of households are modest, however, increasing urbanized area by less than one percent in response to a one percent increase in any of these three forms of regulation. Thus, while there does seem to be some conflict between open space preservation, most notably forest preservation, and prevention of urban sprawl, that conflict does not appear to be acute.

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Table 1. Descriptive Statistics of the Data Used in the Econometric Analysis

Variable	Subdivisions with Public Sewer Access		Subdivisions without Public Sewer Access	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Average subdivision lot size (acres)	0.408854	0.4446604	3.008105	2.8734212
Number of lots in subdivision	38.60366	55.1894249	19.79104	17.699116
Acres in roads, sidewalks, and other infrastructure	1.000853	11.6976716	3.529806	22.8129784
Subdivision exempt from FCA (yes = 1)	0.195122	0.3975083	0.119403	0.3267094
Forested acres required by FCA	6.111159	10.3775542	22.66403	25.7391033
Zoned minimum lot size (acres)	0.313773	0.3106216	1.922164	1.3616676
Zoned maximum number of lots	53.31677	76.9839086	30.55684	36.6930959
Total site acreage	19.74052	26.6988004	73.90503	77.7979909
Acres of floodplain in subdivision	1.548781	4.7727947	7.431343	24.4997106
Acres of wetland in subdivision	1.15122	2.8868963	4.430303	7.9599182
Linear feet of stream in subdivision	577.2744	1226.83	1664.04	2911.32
Percentage of land within ½ mile in farmland	10.30601	13.3123776	38.88156	20.6566289
Percentage of land within ½ mile in parks, public spaces, etc.	2.887145	6.0749432	0.118967	0.4369511
Percentage of land within ½ mile in forest, brush, or undeveloped	28.30204	17.8050248	37.98824	20.8223467
Commuting distance to nearest CBD (road miles)	17.65915	12.5054776	38.0806	21.4802463
Subdivision located in Carroll County	0.036585	0.1883165	0.343284	0.4783887
Subdivision located in Charles County	0.079268	0.2709845	0.298508	0.4610569
Subdivision located in Howard County	0.256098	0.4378132	0.074627	0.2647716
Subdivision located in Montgomery County	0.27439	0.4475731	0.19403	0.3984366
Number of observations	164		67	

Table 2. Estimated Parameters of the Econometric Models

Variable	Subdivisions with Public Sewer Access			Subdivisions without Public Sewer Access		
	Average Lot Size	Number of Lots	Infrastructure Area	Average Lot Size	Number of Lots	Infrastructure Area
Intercept	0.089174 (0.053414)	26.26339** (8.681614)	1.025033 (2.243123)	-2.68601 (2.180776)	12.42288 (7.676382)	-4.65301 (14.36369)
Subdivision exempt from FCA (yes = 1)	-0.02311 (0.042139)	-14.4145* (6.719066)	1.846359 (1.698451)	4.045513** (0.990613)	-7.28269* (3.551771)	1.080632 (6.563622)
Forested acres required by FCA	0.011120** (0.00395)	1.644565* (0.641174)	-0.86866** (0.210340)	0.020901 (0.026156)	0.010218 (0.093372)	-0.57019** (0.173008)
Zoned minimum lot size (acres)	1.112685** (0.064012)		-1.50248 (6.601744)	0.571127* (0.287637)		-0.98321 (1.658766)
Zoned maximum number of lots		0.644008** (0.051181)	0.012375 (0.012922)		0.063588 (0.035602)	0.548384** (0.079066)
Total site acreage	0.000643 (0.001123)	-0.86123** (0.230232)	0.523324** (0.058222)	-0.00280 (0.011331)	0.212982** (0.041747)	0.054831 (0.079066)
Acres of floodplain in subdivision	-0.01257 (0.012796)	0.387461 (2.037017)	-2.54900** (0.527693)	-0.00329 (0.018696)	-0.18824** (0.067136)	-0.11705 (0.126096)
Acres of wetland in subdivision	0.021129 (0.011453)	2.618769 (1.846651)	0.79159 (0.474234)	-0.04365 (0.050682)	0.393486* (0.165034)	-1.15154** (0.326113)
Linear feet of stream in subdivision	-0.00009** (0.000026)	0.004676 (0.004264)	-0.00009 (0.001080)	-0.00005 (0.000154)	-0.00030 (0.000539)	0.000595 (0.001010)
Percentage of land within ½ mile in farmland	0.003774* (0.001498)	0.340285 (0.2324927)	-0.17480* (0.070747)	0.016431 (0.024308)	-0.03068 (0.085781)	0.128826 (0.160387)

Variable	Subdivisions with Public Sewer Access			Subdivisions without Public Sewer Access		
	Average Lot Size	**Number of Lots**	**Infrastructure Area**	**Average Lot Size**	**Number of Lots**	**Infrastructure Area**
Percentage of land within ½ mile in parks, public spaces, etc.	0.000984 (0.002788)	-0.10381 (0.445018)	-0.11363 (0.112410)	0.984888 (0.830238)	4.460358 (2.860747)	-4.01507 (5.457124)
Percentage of land within ½ mile in forest, brush, or undeveloped	-0.00128 (0.001101)	-0.16796 (0.174557)	0.008070 (0.045670)	0.056389 (0.032327)	-0.16394 (0.113724)	-0.00165 (0.213811)
Commuting distance to nearest CBD (road miles)	0.000835 (0.002124)	-0.90139** (0.339038)	-0.08036 (0.087660)	0.029797 (0.026758)	-0.00835 (0.094805)	-0.18740 (0.176548)
Subdivision located in Carroll County	-0.25461* (0.100735)	-7.93666 (15.80899)	14.96395** (4.495132)	0.77132 (1.253787)	-0.11496 (4.400196)	-5.05684 (8.250769)
Subdivision located in Charles County	-0.14500 (0.100508)	51.75285** (16.00471)	0.903504 (4.371287)	-0.68703 (1.667686)	-2.57904 (5.939579)	15.68503 (11.03199)
Subdivision located in Howard County	-0.07918 (0.042499)	-6.39652 (6.709121)	-0.41429 (1.822279)	0.547196 (1.665141)	-3.23307 (5.732736)	43.46674** (10.99886)
Subdivision located in Montgomery County	-0.12904** (0.046493)	0.463540 (7.237701)	-0.34092 (2.144516)	0.124721 (1.306898)	-5.78415 (4.6668080)	6.883352 (8.656985)
Number of Observations	162			66		
System R^2	0.7702			0.8239		

Note: Standard errors reported in parentheses. Model for subdivisions with public sewer access estimated using three stage least squares. Model for subdivisions without public sewer access estimated using seemingly unrelated regressions. ** denotes significantly different from zero at a 1% significance level, * denotes significantly different from zero at a 5% significance level.