DISCUSSION PAPER

# Zoning, Transferable Development Rights, and the Density of Development

Virginia McConnell, Margaret Walls, and Elizabeth Kopits

RESOURCES
FOR THE FUTURE

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## Abstract

In this paper, we explore the effect of low-density zoning regulations and other factors on subdivision density. Using a unique dataset of new subdivisions built over a 34-year period in Calvert County, Maryland, we econometrically estimate a density function using both ordinary-least-squares (OLS) and censored regression. The variability in density permitted by the county's zoning and transferable development right (TDR) rules over the sample period allows us to assess the relative importance of market factors and regulatory constraints on density. We use the censored model to predict what density patterns would have been without zoning.

**Key Words:**  housing density, zoning, transferable development rights

**JEL Classification Numbers:** R14, R15, R52

**Contents**

# Zoning, Transferable Development Rights, and the Density of Development

Virginia McConnell, Margaret Walls, and Elizabeth Kopits[*]

## I. Introduction

Many communities on the urban fringe are implementing a range of policies to preserve farmland and open space, cluster residential development, and guide development to areas with existing infrastructure. These efforts are an attempt to control overall growth and to counter a trend toward so-called large-lot development so that the growth that does take place results in less consumption of land (Heimlich and Anderson 2001). Planners have argued that policies to manage density are the most important local policy focus for urban areas in the coming years (Danielson et al 1999).

Some researchers contend that large-lot development specifically and "sprawl" more generally are simply the natural result of household preferences and market forces (Gordon and Richardson 1997). Glaeser and Kahn (2003) argue that widespread use of the car as a means of transport has made scattered low-density development an inevitable market outcome.[1] Davis et al. (1994) report results of a survey finding that 60 percent of the people who move to so-called ex-urban locations beyond traditional suburbs move there to have large lots and a rural lifestyle.

Other authors have argued that local government zoning rules in the form of large minimum lot sizes may well contribute to current patterns of low-density development. Fischel (2000) suggests that growth controls in the form of large-lot zoning tend to result in suburban

[1] Many studies have emphasized the role played by declining transportation costs (Brueckner 2000); Glaeser and Kahn's (2003) particular point of emphasis is that the car has eliminated the scale economies that existed with older transportation technologies, such as ports and railroad hubs.

sprawl. Theoretical analyses have shown the conditions under which this might be true (Moss 1977, Pasha 1996), but very little empirical work provides any evidence on this issue.

Drawing on a unique dataset, we address two important questions in this paper: Do zoning regulations or primarily market forces create low-density, land-intensive development? And if zoning limits cause low-density development in at least some cases, how would development patterns be different if there had been no such rules?

We address these issues by analyzing the factors that explain subdivision density in rapidly growing Calvert County, Maryland, on the fringe of the Washington, DC, metropolitan area. Economic variables that influence density are identified, including factors that affect the value and cost of additional development. Regulatory constraints and rules on building are included in the model. Calvert's long-running transferable development rights (TDRs) program, which allows developers to increase density above base zoning limits in some areas by purchasing TDRs, is also incorporated. We econometrically estimate the density function in both an ordinary-least-squares (OLS) and a censored regression framework using detailed data on subdivisions built in Calvert County over a 34-year period. The variability in density permitted by the county's zoning and TDR rules over the sample period allows us to empirically assess the relative importance of market factors and regulatory constraints on density. We then use the censored model to predict, in the cases where regulatory constraints have been binding, what density patterns would have been without the zoning constraints.

Although much empirical literature examines population and employment densities, it tends to focus on how density changes as distance to the central business district of a metropolitan area increases and how zoning allocations (i.e., the proportion of land zoned residential, commercial, and industrial) affect overall density in a wide geographical area.[2] Among the few studies that analyze residential housing density at a smaller regional scale, Song and Knaap (2004) use census block data to examine how neighborhood density and other measures of urban form have changed in the Portland, Oregon, metropolitan region. They find that Portland's strict development policies appear to be having some success in increasing single-family dwelling densities over time. In an analysis of density patterns in three communities, Peiser (1989) finds that discontinuous or infill development results in higher overall density in a suburban region than would occur if only continuous or sequential development were permitted.

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[2] McDonald (1989) surveys this literature, which draws from the theoretical base of Muth (1969) and Mills (1972).

Thorsnes (2000) asks whether larger subdivisions, by being better able to internalize neighborhood externalities, lead to higher property values than smaller subdivisions, all else equal. Finally, Lichtenberg et al. (2005) examine the effects of land use and forest conservation regulations on open space in suburban Maryland. As part of the analysis, they observe how minimum lot size requirements affect the number of lots in a subdivision and average lot size. They find evidence that zoning constrains development.

Two theoretical studies model a developer's density decision: Edelson (1975) examines how community tax rates and public services affect the willingness to pay for lots of different sizes in a subdivision and how these factors may affect the developer's optimal choice of lot size; Cannaday and Colwell (1990) solve for a developer's profit-maximizing choice of lot characteristics, and their results suggest which factors are likely to influence development costs and values.

Some empirical evidence suggests that subdivisions are being built at a lower density than allowed by zoning, which indicates that, at least in some areas, factors other than zoning drive density decisions (Fulton et al. 2001). However, to our knowledge, no study examines the relative effects of zoning constraints and market forces on the net density of residential development. Moreover, most studies do not have extensive subdivision-level data. Subdivisions are the ideal unit of observation because most suburban and ex-urban residential development is of this type. In addition, by limiting our analysis to one county, we can hold constant many factors that also might influence land and housing markets.[3]

In Section II, we explain the developer's decision regarding how many lots to build, given regulatory constraints. In Section III, we provide background on Calvert County's zoning and TDR program rules. In Section IV, we describe the econometric model and data and then present the results of the empirical analysis. We summarize our results and conclusions in Section V.

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[3] Segmenting the housing market in the right way has been a long-standing issue with hedonic property value models. (See Straszheim 1974 for more on this point.) However, our results would be most applicable to similar types of urban fringe locations and not more urban centers or other areas.

## II. The Developer's Decision

We assume that the developer has already chosen a subdivision location and is deciding about development density on the parcel.[4] Although one can certainly argue that the density decision is made jointly with the decision about where to build, developers may have access to only certain parcels, depending on which landowners are willing to sell. Developers in high-growth suburban areas, such as the one considered in our empirical analysis, will build a subdivision on almost any greenfield that becomes available to them. Thus they purchase land for development where and when they can (Jaklitch 2004).[5]

For each parcel, the developer decides how many building lots to create to maximize profits at that site, given regulatory constraints. This decision depends on variables that affect the revenues and costs of development, zoning regulations about allowable density, and whether and how many transferable development rights can be purchased. The developer takes the zoning rules in place and the ability to purchase TDRs in any given location as given for any parcel.[6]

Revenues from development depend on the number of lots built in the subdivision, the total acreage of the subdivision, the natural amenities of the site itself (e.g., topography and views), land uses of the properties immediately surrounding the site, and the site's location and accessibility to employment and commercial centers. The surrounding land uses can have a complex effect on the value of development. Value may increase from being adjacent to like uses, and spillover effects from different uses could be positive or negative.

The costs of development depend on the number of lots, the total acreage of the subdivision, and the costs of providing infrastructure at the site, which depend on soil characteristics and topography. Cannaday and Colwell (1990) show that even the shape of the parcel to be subdivided can affect development costs.

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[4] It is useful to distinguish here between the developer and the builder. We model the developer's decision to subdivide the parcel into buildable lots. Developers may then sell lots to builders or build houses themselves.

[5] During the 1990s, the population growth rate in Calvert County was 45 percent, the highest of any Maryland county; the state average was 10.8 percent (McConnell et al. 2003 ).

[6] In some jurisdictions, developers or builders might be able to influence the zoning rules governing a property through petitions and zoning variances. Here we treat the zoning as exogenous, which is in keeping with the empirical analysis that follows later in the paper.

The developer's profit-maximizing choice of the number of lots to build in a subdivision is constrained by zoning regulations. These regulations establish a minimum average lot size that, given total subdivision acreage, constrains the number of lots a developer can build.[7]

TDRs provide a tool for allowing zoning flexibility in designated regions. If a community wants to encourage the protection of undeveloped land in some areas, landowners in these so-called TDR-sending areas may be permitted to sell their development rights and give their land a permanent preservation easement status. The development rights can be used by developers in so-called TDR-receiving areas to build more lots than allowed under baseline zoning restrictions.[8] Developers purchase the rights at a price determined in the market for TDRs.

The developer's profit-maximizing decision is illustrated in Figures 1 and 2.[9] Figure 1 illustrates the basic developer problem for a given tract of developable land in a region where TDRs cannot be used to increase density. Suppose the zoning rule (specified as a minimum average lot size) permits a maximum number of lots to be built on the parcel of $\bar{l}$. Then the developer with a marginal revenue curve of $MV_1$ is not constrained by zoning and builds $l_1$ lots, achieving an average density of $l_1/L$ (where $L$ is total subdivision acreage). If, however, the marginal revenue from building at the site is $MV_2$, then the developer is constrained by zoning and must choose the allowable limit, $\bar{l}$, rather than the profit-maximizing choice, $l_2$. In this case, the subdivision is less dense (i.e., has larger average lot sizes) than what the private market would have chosen. If $\bar{l}$ is reduced, then the zoning restriction is more likely to be binding.

Figure 2 illustrates the way in which TDR availability affects density decisions in areas where TDRs can be purchased. $MV_1$ is left off the graph because, as in Figure 1, if $MV_1$ is the marginal revenue from additional lots and $MC_1$ is the cost per lot, then the number of lots built is $l_1$ (maximizing profit). The availability of TDRs does not affect the developer's decision. If the marginal revenue is $MV_2$, then the developer is constrained by the baseline zoning limit, but TDRs can be purchased at price $P_{TDR}$. In this case, the profit-maximizing number of lots is where $MV_2 = MC_2$, or $l_2'$, and the developer creates $t_2$ lots through TDRs. A final constraint is that most

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[7] Residential zoning limits are sometimes specified in terms of an absolute minimum lot size (e.g., no lot can be smaller than 1 acre). More often, minimum lot size is averaged across the entire subdivision parcel. In the application analyzed in this paper, Calvert County uses average minimum lot size zoning.

[8] Here we assume that only one TDR is needed to create one additional lot.

[9] These graphs follow from the Field and Conrad (1975) model of efficiency and equity in TDR markets.

$/lot

MC

$MV_1$   $MV_2$

$l_1$  $\bar{l}$  $l_2$        Number of lots
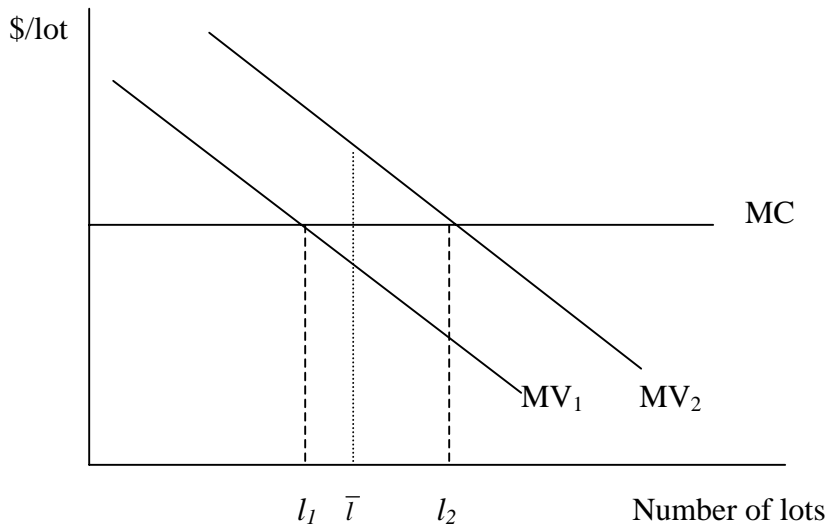
**Figure 1. Developer's Density Decision: No TDRs Allowed**

$/lot

$MC_2 = MC_1 + P_{TDR}$
$MC_1$

$MV_3$

$MV_2$

$\bar{l}$      $l_2'$     $\bar{l}_{TDR}$   $l_3$     Number of lots
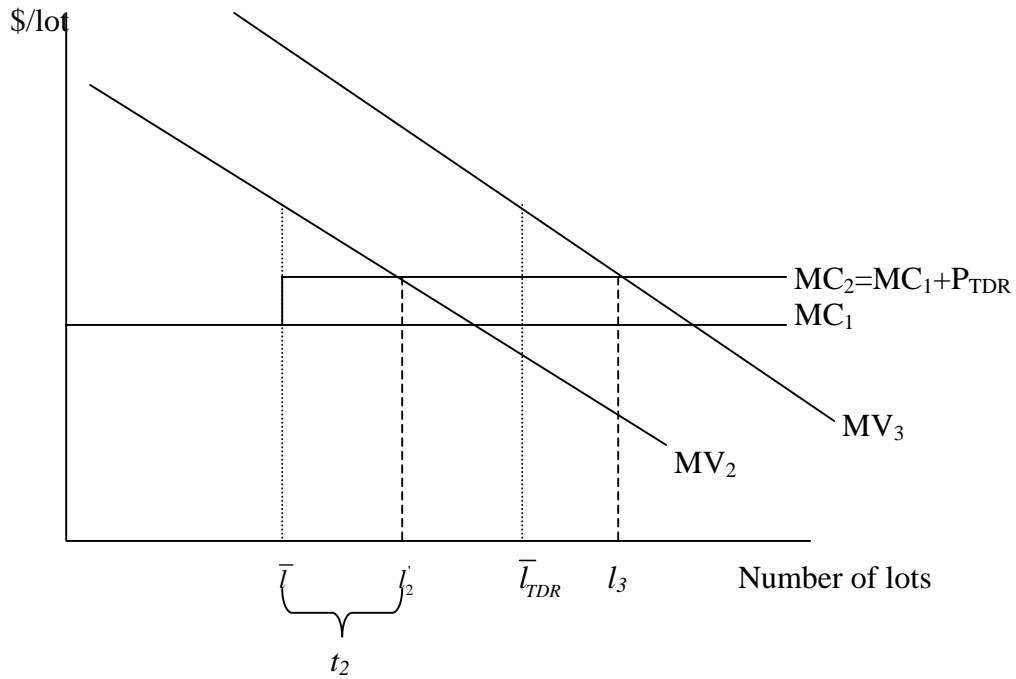
$t_2$

**Figure 2. Developer's Density Decision: Purchase of TDRs allowed**

TDR programs have a maximum density that is permitted with the use of TDRs. In Figure 2, this limit is shown as $\bar{l}_{TDR}$. If the marginal revenue of additional lots is as high as $MV_3$, then the developer is again constrained, even with the availability of TDRs. The profit-maximizing number of lots in the subdivision would be $l_3$, but the developer can build only up to $\bar{l}_{TDR}$ lots.

In summary, Figures 1 and 2 illustrate that a range of possible density levels exist across subdivisions. The number of lots may be determined by market forces or by local density restrictions, including baseline zoning rules and the number of TDRs allowed. We explore all of these possibilities in our empirical analysis.

## III. Land Uses, Zoning, and TDR History in Calvert County, Maryland

Calvert County is a 215-square-mile peninsula in southern Maryland, is southeast of Washington, DC, and bordered by the Chesapeake Bay and the Patuxent River. Its northernmost town, Dunkirk, is approximately 30 miles south of Annapolis, Maryland. The population of this historically rural, agriculture-based county has grown rapidly over the past 20–30 years because of its proximity to major centers of employment.[10]

Table 1 lists the residential density limits imposed by zoning regulations over time. In 1967, the county adopted its first *Comprehensive Plan,* in which all rural land was zoned to a maximum density of one dwelling unit per 3 acres. In 1975, the county updated the plan to reflect a "slow growth" goal and changed the maximum density to one dwelling unit per 5 acres. Despite the 5-acre minimum lot requirement, population growth and conversion of land from agricultural uses to housing developments continued to be substantial throughout the county. In 1978, the county adopted a TDR program in an attempt to protect many of the prime farmland areas of the county from development.[11] The first TDR was sold in 1981.

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[10] The population has more than doubled since 1980, to about 87,000 in 2005.

[11] Other growth controls were implemented over the years as well. For example, in 1988, the county adopted an adequate public facilities ordinance that halts building when it is determined that public facilities such as schools cannot handle additional growth. Critical areas near waterways were outlined in 1989 (as required by the state), and maximum residential density was reduced to one dwelling unit per 20 acres in those areas. (See Calvert County Planning Commission 2004 for more details.)

**Table 1. Maximum Density Allowed by Zoning Rules in Calvert County, Maryland**

| Year | *Rural* | | | |
|---|---|---|---|---|
| | *DAA[a]* | *RCs* | *Residential* | *Town Centers[b]* |
| 1967–1974 | 3.3 units/10 acres | 3.3 units/10 acres | 10 units/10 acres[c] | — |
| 1975–1980 | 2 units/10 acres | 2 units/10 acres | 10 units/10 acres[c] | — |
| 1981–1998 | | | | |
| w/o TDRs | 2 units/10 acres | 2 units/10 acres | 10 units/10 acres[c] | 40 units/10 acres |
| with TDRs | 2 units/10 acres | 5 units/10 acres[d] | 40 units/10 acres[c] | 140 units/10acres |
| 1999–present | | | | |
| w/o TDRs | 1 unit/10 acres | 1 unit/10 acres | 5 units/10 acres | 20 units/10 acres |
| with TDRs | 2 units/10 acres | 5 units/10 acres[d] | 40 units/10 acres | 140 units/10acres |

[a] After 1992, designated agricultural area (DAA) includes some additional farming regions that lie outside the original DAA. From 1981 to 1992, these additional areas could achieve the same density with TDRs as in the rural communities (RCs). After 1992, they were treated the same as the DAA. (See footnote 13.)

[b] The town center zoning classification came into effect in 1983.

[c] Before 1999, multifamily homes and townhouses were allowed in a small part of the residential zone (known as R-2). Density could go as high as 140 units/10 acres in these areas without the use of TDRs. After 1999, all residential areas (R-1 and R-2) had the same zoning and TDR rules.

[d] Density in RCs that are within 1 mile of a town center can go as high as 1 unit/acre with the use of TDRs.


       The program designated town centers and residential zones as TDR-receiving regions. Land in areas labeled as rural communities (RCs) could receive or send TDRs. The remaining rural land—identified as prime farmland—became known as the designated agricultural area (DAA). Parcels in the DAA could be used only as TDR-sending areas.[12] Figure 3 illustrates the spatial aspects of these different zoning classifications.[13]

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[12] In 1992, additional prime farmlands and environmentally sensitive lands were designated as TDR-sending areas only and effectively became part of DAA. All of the sending area-only regions were generally referred to as farm community districts (FCDs) or resource preservation districts (RPDs) after this time. Because the original DAA is a subset of the FCD/RPD region, for simplicity, in this paper we refer to the TDR-sending areas as DAA and the regions that were added on in 1992 as "regions added to DAA."

[13] A little more than 40 percent of the county lies in the RCs (rural regions outside the DAA), 40 percent is in the DAA, and about 16 percent lies in the residential and town center zones. The remainder is zoned for commercial or industrial use.

**Figure 3.  Zoning Map, Calvert County, Maryland**



**Legend**

| | |
|---|---|
| (dotted) | Designated Agricultural Area (DAA) |
| (diagonal hatch) | Regions added to DAA |
| (white) | Rural areas outside DAA (Rural Communities) |
| (black) | Town Centers |
| (dark gray) | Residential (R1/R2) |
| (medium gray) | Industrial, Commercial |
| (light gray) | Water |
| (hatched) | Wetlands |
| —— | MD Rte. 2/4 |
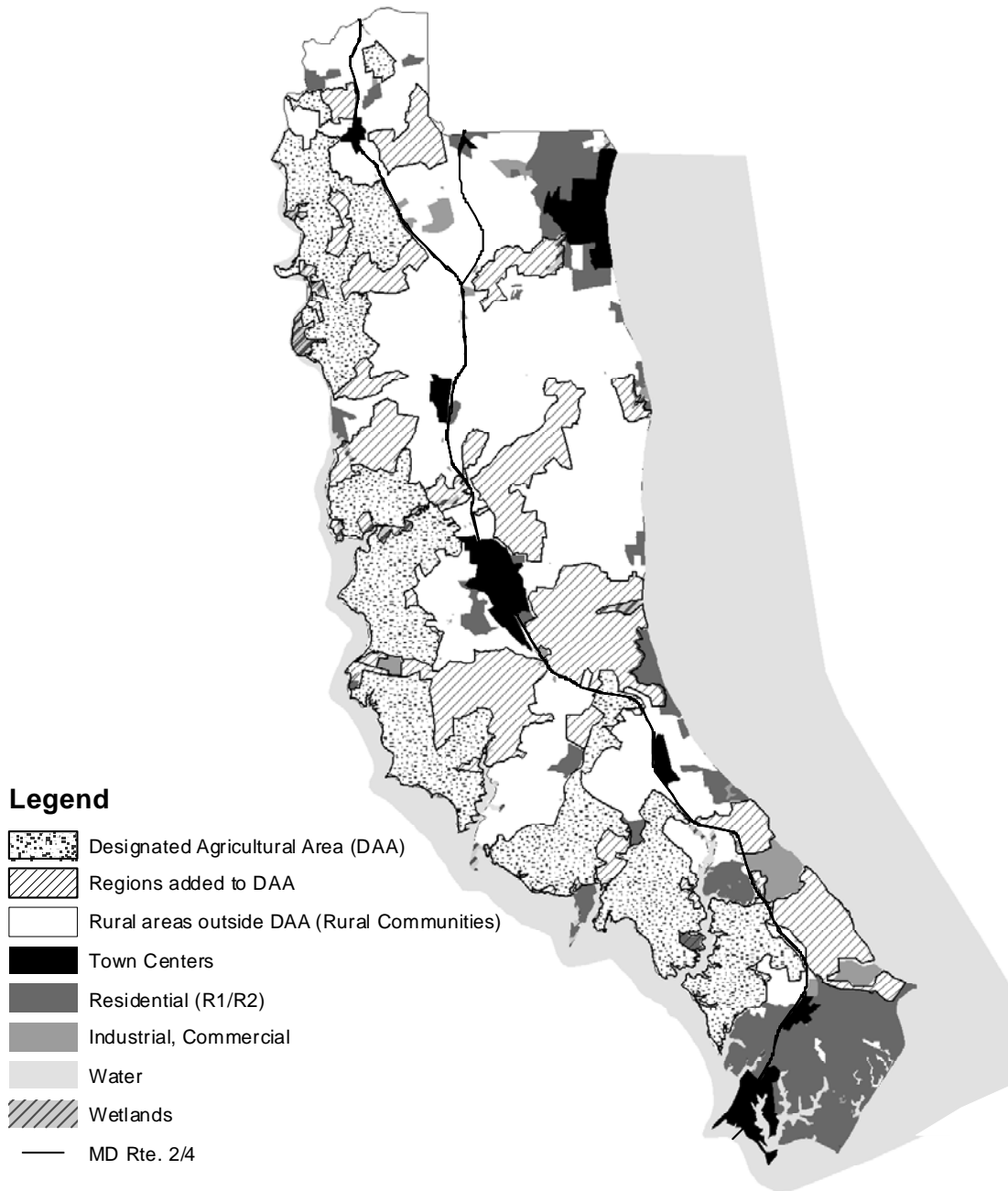
In 1999, as a result of rapid growth in the county and the county's reluctance to expand roadways, all regions were downzoned to reduce overall development. As shown in the last two rows of Table 1, the baseline zoning in all areas was reduced by 50 percent. Density permitted with TDRs, however, remained the same as before the downzoning. Thus the pre-1999 maximum density levels in all areas still could be attained, but only with more TDR purchases.

Since the TDR program began, TDR sales have preserved more than 13,000 acres of farmland in Calvert County.[14] Developers used TDRs in slightly less than 30 percent of the new subdivisions built between 1980 and 2001; in total, 2,130 additional housing units were created with TDRs. The TDR program rules, along with the zoning changes over time, have led to variability in housing density and allow us to look at the factors that explain density.

## IV. Empirical Models, Data, and Results

### A. Model Specification

Following the developer's decision described in Section II, we estimate an equation for the number of lots in a residential subdivision, given all exogenous factors affecting the marginal revenue and marginal cost of an additional lot. These factors include total size of the plat area, amenities and physical characteristics of the site, characteristics of neighboring areas, and zoning and TDR rules in place. For subdivisions located in TDR-receiving regions, the developer faces a TDR price as determined in the overall market for TDRs. Initially, we account for the density restrictions by including the maximum number of lots allowed in the subdivision (calculated on the basis of the subdivision's recording date and location in the county) as a covariate in the OLS estimation of the density equation.

We can write a reduced-form equation for the profit-maximizing number of lots as a function of all of the exogenous variables affecting profits. We specify the log of the number of lots in subdivision $i$ as

$$\ln(l_i)^* = a + B_1 \ln L_i + B_2 n_i + B_3 u_i + B_4 d_i + B_5 s_i + B_6 \overline{l_i} + B_7 P_{\text{TDR}} + e_i \qquad (1)$$

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[14] Approximately 13,000 additional acres have been preserved through other means, including five state programs: Maryland Agricultural Land Preservation Program (MALPF), Rural Legacy Program (RLP), Maryland Environmental Trust (MET), Program Open Space (POS), and Program GreenPrint.

where $L_i$ is the size of subdivision $i$ (in acres), $n_i$ is the vector of natural amenities in subdivision $i$, $u_i$ is the vector of neighboring land uses at the time subdivision $i$ is built, $d_i$ is the vector of accessibility variables for subdivision $i$, $s_i$ is the vector of soil and topography characteristics for subdivision $i$, $\bar{l}_i$ is the maximum number of lots allowed given subdivision $i$'s recording date and location, and $P_{\text{TDR}}$ is the price of a TDR as determined in the overall TDR market in the year the subdivision is recorded.

The statistical significance and magnitude of the estimated coefficient on $\bar{l}_i$ allow us to determine the extent to which zoning influences density relative to the market factors.

An alternative and useful way to estimate the density function is to use a censored regression framework. The censored model takes into account that the likelihood function includes the probability that an observation is uncensored (i.e., below the limit set by zoning) and, conditional on being uncensored, the likelihood that particular exogenous variables explain the variation in lots built. Accounting for the censored nature of the dependent variable not only gives us a more accurate way to model the error structure but also allows us to use the equation to predict what development would have been if the constrained subdivisions had not been constrained.

We use this second approach by adding two constraints to the model given by Equation 1:[15]

$$l_i = l_i^* \text{ if } l_i^* < \bar{l}_i$$

$$l_i = \bar{l}_i \text{ if } l_i^* \geq \bar{l}_i$$

where $\bar{l}_i$ is the maximum number of lots allowed on the parcel, as given by the baseline zoning or maximum TDR purchases allowed in that region in the year that the subdivision was recorded. If a developer is not constrained by the zoning regulations, then the dependent variable $l_i$ is equal to the optimal number of lots $l_i^*$. If the optimal number of lots is greater than $\bar{l}_i$, however, then

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[15] In addition, the variable $\bar{l}_i$ is dropped from the censored model because the censored regression technique accounts for the constraint imposed by this variable.

the choice over density is constrained. As listed in Table 2, of almost 400 observations in the dataset, 30 (about 8 percent of the sample) are censored.[16]

It is important to note that we treat the density restriction as exogenous in this model. It has been argued in the literature that local zoning, especially over a period of time as long as that considered here, is likely to be endogenous (Rolleston 1987, Wallace 1988, McMillen and McDonald 1990, McDonald and McMillen 2004). In Calvert County, several features lead us to believe that the zoning and TDR rules are exogenous to the individual developer's decision. First, the zoning rules and the ability to exceed those rules using TDRs are spelled out in the regulations, and exceptions and variances for any one property are not allowed.[17] Second, the changes in overall zoning rules in 1975 and 1999 affected all regions of the county uniformly and were a result of concern about population growth and the size of the transportation system. This leaves only the inception of the TDR program in 1981 as the other significant zoning change. Although adoption of the TDR program may have been market-led (i.e., in response to concern over declining farmland), the designation of particular regions as sending or receiving areas and the zoning limits set in those areas do not appear to be market-driven. Before 1981, development took place everywhere in the county, and at relatively similar densities across the

**Table 2. Number of Subdivisions in Calvert County at Maximum Density, by Zoning Category**

| *No. of subdivisions* | *Rural Areas* | *Residential Areas/ Town Centers* | *Total* |
|---|---|---|---|
| Total | 334 | 64 | 398 |
| Constrained by zoning and/or TDR limit | 28 | 2 | 30 |
| Unconstrained by zoning and/or TDR limit | 306 | 62 | 368 |

[16] Specifically, we right-censor all observations where $\bar{l} - 1 < l_i$ (because the $\bar{l}$ calculated from the parcel acreage and the average minimum lot size is rarely an integer). Because other lot requirements (e.g., minimum setbacks) could potentially prevent a developer from creating all the lots allowed by the average minimum lot size regulations, we also estimated the model when censoring all observations where the dependent variable is within two or three units of $l$ (i.e., when $\bar{l} - 2 < l_i$ and when $\bar{l} - 3 < l_i$). (Using these stricter censoring specifications, the number of censored observations increases to 38 and 46, respectively.) The results are qualitatively the same across these different censoring rules.

[17] Unlike many local governments, Calvert County generally does not allow case-by-case rezoning. The only exception to zoning rules is that parcels deeded before 1975 retain some grandfathered lots as compensation for the 3-acre to 5-acre lot downzoning that occurred in 1975. We account for this exception in our empirical analysis.

different rural areas.[18] The regions the county designated as TDR-sending areas had the most productive farming soils in the county. All others were TDR-receiving areas with baseline zoning unchanged but density increases allowed with TDRs.

Finally, our specific concern about possible endogeneity concerns whether the zoning limit variable in the OLS regression is correlated with the error term (i.e., whether unobserved factors that explain a developer's decision over the number of lots to build in a subdivision are correlated with the zoning established by the government for that subdivision). We use a Hausman (1978) test for endogeneity using the percentage of subdivision soils classified as prime farmland as an instrument for the lots allowed by zoning variable and are unable to reject that the zoning variable is exogenous. This finding is also consistent with our soils variable being a weak instrument. Nonetheless, the combination of the history in Calvert County, the way the TDR program was structured, and results of our Hausman test lead us to conclude that zoning is exogenous in this case.

## B. Data

We gathered data on each new subdivision from the Calvert County Planning Department records and digitized data into geographic information systems (GIS) format using ArcMap software. According to our data, 398 subdivisions were built over the 1967–2001 time period. Individual parcel characteristics and surrounding land use data were constructed from Maryland Property View and county records. Topographical and soil quality information was available in digitized GIS format from the state of Maryland. Table 3 lists summary statistics for all variables included in the econometric models.

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[18] For example, in our sample, average subdivision density before 1983 was 3.455 acres/lot in the DAA region and 3.589 acres/lot in the non-DAA rural areas.

The size of the subdivisions in our sample varies from 4 acres to almost 600 acres, with an average size of 71 acres. The number of lots in each subdivision ranges from 3 to 268; the average is 27. Some subdivisions are surrounded by 40–50 percent preserved farmland or parks, whereas others are adjacent to no open space. The average percentage of surrounding land that is

**Table 3. Summary Statistics of Total Subdivision Sample, *N* = 398**

| Variable | Mean | SD | Min. | Max. |
|---|---|---|---|---|
| Total no. of lots | 27.211 | 31.499 | 3.000 | 268.000 |
| No. of lots permitted by zoning/TDR restrictions | 51.781 | 92.333 | 2.496 | 1043.098 |
| Total plat area (acres) | 70.647 | 71.353 | 4.029 | 589.590 |
| Length of subdivision perimeter (feet) | 8211.555 | 4335.655 | 1947 | 33992 |
| Subdivision land in steep slopes ( percent) | 36.756 | 29.795 | 0 | 100 |
| Dummy for within 1 mile of Patuxent/Chesapeake Bay | 0.221 | 0.416 | 0 | 1 |
| Dummy for sewer service availability | 0.023 | 0.149 | 0 | 1 |
| Surrounding land in preserved open space or privately held farmland ( percent) | 1.666 | 5.969 | 0 | 42.916 |
| Surrounding land in parkland ( percent) | 1.353 | 5.538 | 0 | 48.671 |
| Surrounding land in subdivisions ( percent) | 17.751 | 21.341 | 0 | 100 |
| Surrounding land in commercial/industrial zone ( percent) | 2.591 | 8.676 | 0 | 100 |
| Dummy for located in residential or town center area | 0.161 | 0.368 | 0 | 1 |
| Dummy for location 1[a] | 0.224 | 0.417 | 0 | 1 |
| Dummy for location 2[a] | 0.236 | 0.425 | 0 | 1 |
| Dummy for location 3[a] | 0.241 | 0.428 | 0 | 1 |
| Dummy for location 4[a] | 0.083 | 0.276 | 0 | 1 |
| Dummy for location 5[a] | 0.148 | 0.356 | 0 | 1 |
| Dummy for location 6[a] | 0.068 | 0.252 | 0 | 1 |
| Distance to Route 2/4 (miles) | 1.503 | 1.148 | 0.005 | 4.840 |
| Access to town center index | 0.040 | 0.508 | 0.000 | 9.970 |
| TDR price (1999$)[b] | 1248.498 | 1105.587 | 0 | 2,582 |
| Year of subdivision recording | 1986.862 | 8.946 | 1967 | 2001 |

[a]Location 1, the omitted dummy in the regression model, is the northernmost area of the county; Location 2 is just south of Location 1, and so forth; Location 6 is the southernmost region.

part of another subdivision is 17 percent.[19] We use location dummy variables in our model to capture differential effects of location on density. Location 1 is the northernmost area and includes 22 percent of all subdivisions in the sample; the greater the location number, the farther south it is in the county. The locations were chosen to roughly correspond to traffic lights and town centers along the main commuting highway, Route 2/4. The average subdivision is located about 1.5 miles from Route 2/4. Proximity to shopping and other commercial areas is measured by a gravity index that is a weighted average of proximity to the major town centers in the county.[20]

Most of Calvert County relies on septic systems, thus only 2.3 percent of subdivisions have sewer available. Our soil and topography data allow us to calculate the percentage of land in each subdivision that lies in steep slopes (a grade of 15 percent or higher). The average subdivision in our sample has steep slopes in 37 percent of its land area.

## *C. Results*

We estimate Equation 1 for all of the 398 subdivisions in our sample with the use of both the OLS and censored regression frameworks. The results are listed in Table 4. Our focus in the OLS model is on the effect of zoning relative to the other factors in explaining density. We then use the censored model to determine which factors affect density and to predict what would have occurred in the absence of zoning.

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[19] The percentage of surrounding land in a given use is calculated as the share of the subdivision perimeter that lies in the specified land use at the time of subdivision recording.

[20] Specifically, the index is defined as $I_i = \sum_{k=1}^{c} (M_k / d_{ik}^2)$ , where $i$ denotes the subdivision, $c$ is the number of town centers, $M_k$ is the size of town center $k$, and $d_{ik}$ is the distance from subdivision $i$ to town center $k$.

In any spatial model such as this one, we must address the issue of unobserved spatial correlation in the error term.[21] We test for spatial autocorrelation by creating a weighting matrix in which we assign positive and equal weight to subdivisions that are directly adjacent to each other and consider both row-normalized and non-row-normalized weighting schemes. Using the

**Table 4. Regression of Subdivision Density (with Robust SE)**

|  | Coefficient | |
| --- | --- | --- |
|  | *OLS* | *Censored Regression* |
| *Dependent Variable: ln(Lots)* | *(SE)* | *(SE)* |
| **Ln(total lots permitted)** | $0.247^c$ (0.046) | |
| **Subdivision size and characteristics** | | |
| ln(Acres) | $0.624^c$ (0.133) | $0.952^c$ (0.142) |
| STEEP | $-0.068^b$ (0.034) | $-0.086^b$ (0.037) |
| ln(Acres) * STEEP | -0.004 (0.003) | $-0.005^a$ (0.003) |
| ln(Perimeter) | -0.137 (0.229) | -0.294 (0.260) |
| ln(Perimeter) * STEEP | $0.009^a$ (0.005) | $0.012^b$ (0.005) |
| Within 1 mile of Patuxent River/Chesapeake Bay | 0.021 (0.064) | 0.021 (0.065) |
| Sewers | 0.393 (0.257) | $0.472^a$ (0.284) |
| **Residential/town center dummy** | $0.260^a$ (0.133) | $0.784^c$ (0.088) |
| **Surrounding land use** | | |
| Privately owned preservation status ( percent) | $-0.006^b$ (0.003) | $-0.009^c$ (0.003) |
| Parks ( percent) | $-0.012^b$ (0.006) | $-0.011^a$ (0.007) |
| Another subdivision ( percent) | 0.0004 (0.001) | 0.001 (0.001) |
| Commercial/industrial zone ( percent) | 0.001 (0.004) | 0.001 (0.004) |
| **Accessibility variables** | | |
| Location 2 | -0.067 (0.065) | -0.066 (0.070) |
| Location 3 | -0.070 (0.072) | -0.079 (0.076) |
| Location 4 | -0.035 (0.095) | -0.028 (0.103) |
| Location 5 | -0.019 (0.076) | -0.002 (0.081) |
| Location 6 | -0.114 (0.126) | $-0.201^a$ (0.123) |
| ln(distance to Route 2/4) | $-0.045^a$ (0.026) | $-0.088^c$ (0.026) |
| Access to town centers | $0.114^c$ (0.024) | $0.141^c$ (0.024) |
| Time trend | $-0.008^b$ (0.003) | -0.002 (0.004) |
| Constant term | 0.908 (1.588) | 1.781 (1.802) |
| No. of observations | 398 | 368 |
| No. of right-censored observations | | 30 |
| $R^2$ | 0.7432 | |

Statistical significance: $^a$at the 90 percent level, $^b$at the 95 percent level, and $^c$at the 99 percent level.

*Note:* SE = standard error. STEEP = percent land in steep slopes.

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[21] See Irwin 2002 for a general discussion of the issue.

Moran *I*-test for OLS and a generalized Moran *I*-test for the censored model (Kelejian and Prucha 1999), we cannot reject, at the 95 percent confidence level, the null hypothesis that no spatial correlation exists.[22]

### 1. Zoning vs. Other Factors

Table 4 lists the OLS results for the log of density and provides additional evidence that zoning regulations have constrained subdivision density. The first row shows that the coefficient on the lots permitted variable is positive and highly significant. Holding all else equal, a 10 percent increase in the number of permissible lots through zoning would tend to increase the actual number of lots by about 2.5 percent. Zoning limits have therefore reduced development density to below what it would have been, providing some evidence of the "zoning causes sprawl" argument.

From Table 2, however, we know that the number of subdivisions built at the limit of the allowable density is relatively small—only about 10 percent. Data in Table 4 indicate that other factors are clearly also important in determining density. In fact, an *F*-test of the hypothesis that all of the all variables not related to zoning or TDR in the OLS results are jointly insignificant is soundly rejected at the 99 percent level.[23] We discuss these economic variables in the next section. The results are quite similar across the two model specifications listed in Table 4, so to simplify the exposition, we focus only on the censored model results.

### 2. Subdivision Size and Characteristics

A key subdivision characteristic is the size of the subdivision plat area in acres. The coefficient on ln(Acres) is significant and almost equal to 1 in the censored model; increasing the amount of available acreage by a given percentage leads to approximately the same percentage increase in the number of lots built.[24]

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[22] The Moran *I*-test statistics are 0.907 and 0.500 for the row-normalized and non-row-normalized weighting specifications, respectively, in the OLS case. (Lagrange multiplier and robust Lagrange multiplier tests for spatial error dependence and a spatial lag also could not be rejected for the OLS.) Under the censored model, the generalized Moran *I*-test statistics are 1.127 and 0.948, respectively.

[23]The *F*-test statistic, with (20, 376) degrees of freedom, is 16.02.

[24] More precisely, when evaluated at the sample mean of STEEP, the elasticity of lots with respect to total plat area decreases slightly to 0.774 (0.081) in the censored model. The coefficient on the STEEP–plat interaction term is discussed later. We also estimated the equation including a squared term in subdivision plat size. The coefficient is statistically insignificant and does not add much explanatory power to the model.

Among variables likely to affect the cost of developing an additional lot, the slope of the land exerts some influence over density, but the overall shape of the subdivision does not. The coefficient on the variable that measures the percentage of steeply sloping acreage in the subdivision is negative and significant, as expected. The variable that represents the interaction between subdivision size and the percentage of steep slopes also is negative, indicating that the positive effect of a larger acreage on the number of lots built is somewhat offset when the subdivision is more steeply sloped. Note, however, that the coefficient on this variable is only significant in the censored specification at the 90 percent level. The estimated coefficient on the perimeter variable—which, if acreage is held constant, captures how irregularly shaped the parcel is—is negative but insignificant. Somewhat surprisingly, we also find that the more irregular the shape, the lower the effect of steep slopes on the number of lots that can be built.[25]

The coefficient on the dummy variable that indicates whether the subdivision is located near the major bodies of water (the Patuxent River or the Chesapeake Bay) is statistically insignificant. The coefficient on the sewer availability dummy is highly significant. In the censored specification we find that, all else equal, sewer service increases the number of lots by nearly 50 percent. This result makes sense because septic systems require larger lots to accommodate the septic drain field.

The final subdivision variable studied is a dummy variable equal to 1 if the subdivision is located in a residential or town center area. This variable serves as a proxy for any advantages or unique characteristics of more urbanized areas and possibly any amenities from separation of uses that residential zoning provides (Fischel 1987, Rolleston 1987). The coefficient on this variable is positive and significant, as expected.

**Surrounding land uses.** The inclusion of the four surrounding land use variables allows us to assess whether the market tends to put more-dense or less-dense subdivisions next to preserved farms, parkland, commercial or industrial uses, and other residential subdivisions.[26] The results in Table 4 support the notion that subdivision density will be lower if the subdivision is located next to permanently preserved, privately owned land. In the censored model, 10-percentage-point increase in the amount of preserved farmland on the boundary of the

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[25] In fact, when evaluated at the sample mean of the perimeter and total plat area, the elasticities of STEEP become 0.0007 and 0.0008, respectively.

[26] These variables are measured as the percentage of land on the perimeter of the subdivision that is in a given use at the time the subdivision is recorded.

subdivision leads to about a 9 percent decrease in the number of lots built in that subdivision. The coefficient on the percentage of subdivisions that are adjacent to parkland is also negative, significant, and slightly larger in magnitude, suggesting that the additional value that adjacent preserved land provides to lower density development is higher if the open space is available for public use. Finally, the percentage of a subdivision's boundary shared with commercial or industrial land or another subdivision does not appear to affect density.[27]

**Accessibility.** In accordance with conventional urban models, we expect subdivisions in northern Calvert County that are more accessible to major cities to be denser than those in the southern part. The location dummy variables are delineated by towns located along the major commuting highway, Route 2/4, which often has bottlenecks during commuting hours.[28] The signs of the coefficients on the location dummies are all negative, although only the southernmost region (Location 6) is significant at the 90 percent level in the censored model, indicating that the subdivision density is approximately 20 percent lower than in the northernmost region.

The subdivision's proximity to the major commuting road, Route 2/4, also increases density slightly, as expected. Proximity to shopping and other commercial areas in the county (as measured by the gravity index[29]) increases subdivision density as well.

## 3. Time Trend

The negative coefficient on the linear time trend suggests that density has been declining over time, all else equal. However, the coefficient is insignificant in the censored model.

## 4. TDR Prices

Finally, because the cost of purchasing TDRs will affect only the number of lots built in subdivisions that are permitted to use TDRs—approximately 59 percent of the sample—we do not estimate the full model with the TDR price as a covariate. However, to look at the effects of

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[27] We explored more specific ways that surrounding land uses might affect subdivision density, especially the density of residential subdivisions existing at the time the subdivision was initiated. We found no consistent evidence that subdivision densities would be higher when surrounding densities were higher. Hence we display only the simplest results here.

[28] The omitted region is the northernmost area. We also estimated versions of the model that had a continuous variable measuring distance to the northern border of the county instead of the location dummies. The distance variable had a negative and statistically insignificant coefficient as well.

[29] This index is defined in footnote 20.

the TDR price, we estimate the OLS and censored model on the subsample of subdivisions built in TDR-receiving areas, including the annual average price of a TDR, in inflation-adjusted terms.[30] The estimated coefficient on this variable is negative but statistically insignificant in explaining differences in density in both models. This may be because in the period after about 1993, the price was relatively constant, rising only slightly each year.

In summary, we find that many of the economic variables—including physical site characteristics, accessibility measures, and surrounding land uses—significantly influence subdivision density. We can now use the results of the censored model to predict what density levels would have been in the absence of the zoning rules.

## D. Forecasts of Development Patterns

The censored regression framework provides a useful way to look at the extent to which the zoning and TDR limits constrain subdivision density. The different zoning categories, combined with the TDR program and downzonings that occurred over the sample period, also enable us to examine how the degree of constraint varies by region and over time.

Using the values of the independent variables for each subdivision, we first use the censored regression results listed in Table 4 to predict the number of lots. The equation predicts quite well over the whole sample. The mean predicted and actual numbers of lots are 25 (with a standard deviation [SD] = 21) and 27 (SD = 31.5), respectively. What is most interesting, however, is to use the equation to predict density for the 30 censored observations. The difference in the predicted and the actual lots for those 30 subdivisions is about 2.95, with more lots (higher density) in the predicted equation, as expected. The mean predicted number of lots is 24.15 (SD = 17.04), and the mean actual number is 21.2 (SD = 19.03). This rather small difference suggests that the demand for additional lots was not much higher than that allowed by zoning.

Considerable differences exist, however, across locations and time periods. Table 5 lists actual and predicted average lot sizes for the 28 constrained subdivisions in rural areas, by zoning limits and year.[31] Before 1975, the average actual lot size for the constrained subdivisions

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[30] If the demand for TDRs increases countywide, the price will rise, but the price facing each developer is set in the market. Hence we assume that the average annual price of a TDR remains exogenous to the individual developer's decision (McConnell et al. 2003).

[31] We omit the two subdivisions in residential areas because this sample size is so small.

**Table 5. Actual and Predicted Lot Sizes by Density Limit for Censored Subdivisions in Rural Areas**

| Minimum Avg. Lot Size Allowed | Zoning Areas, Years Applicable | No. of Subdivisions | Avg. Lot Size (acres) | |
|---|---|---|---|---|
| | | | Actual | Predicted (SD) |
| 3 acres | All rural areas, before 1975 | 5 | 2.99 | 2.64 (0.25) |
| 5 acres | Rural areas outside DAA, 1975–1982 | 8 | 4.86 | 2.80 (0.54) |
| | DAA areas, 1975 on | 7 | 5.03 | 3.64 (0.67) |
| 2 acres | Rural areas outside DAA, 1983 on | 8 | 2.02 | 2.63 (0.25) |

in rural areas is at the regulatory limit of 3 acres. The average predicted lot size is slightly smaller (indicating denser development), 2.64 acres. From 1975 to 1982, the average lot size of the constrained subdivisions in the rural areas was 5 acres, whereas the predicted lot size was a little less than 3 acres in the rural areas outside the DAA and closer to 4 acres in the DAA. These predicted average lot sizes are substantially different, at 40 percent and 25 percent below the constrained average, indicating that developers would have preferred to build to a higher density in these locations.

Our results suggest that, over the sample period, 46 percent more lots would have been built in the 20 subdivisions that were most constrained by zoning regulations. Of all the subdivisions facing a 3- or 5-acre minimum lot size requirement, this difference translates to approximately 1.2 percent and 22 percent more lots, respectively, and 11 percent more lots overall.[32] It is important to note, however, that even if subdivisions had been built with 3- and 4-acre average lot sizes, they still would be considered relatively low density developments.

With the introduction of TDRs, the maximum allowed density in the rural areas outside the DAA increased, and minimum lot size decreased from 5 acres to 2 acres. The predictions from the censored model suggest that this new limit is approximately what the market demands. The predicted average lot size is 2.63 acres for these subdivisions, compared with the actual

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[32] Note that the rural subdivisions that were awarded grandfathered lots in 1975 (see footnote 17) are uncensored observations and therefore are excluded from these calculations. The number of subdivisions actually subject to and constrained by the 5-acre restriction would have been greater had grandfathering not been allowed.

average lot size of 2.02 (see Table 5, last row).[33] This finding is consistent with the rest of the Table 5 results; at least in Calvert County, residential subdivision density appears to be most constrained by zoning regulations that require average lot sizes of 3 acres or more.

## V. Conclusions

Concern over urban sprawl is at least in part a concern over dispersed, low-density residential development patterns in suburban and ex-urban locations. In this paper, we examined the developer's decision about development density at the disaggregated subdivision level and studied the relative influence of zoning rules versus market forces. Some observers have argued that zoning forces developers to build at lower densities than they would like and is a major cause of low-density suburban growth patterns. However, economic factors also can influence development density on a site—developers may be giving households the lot sizes and spatial structure they want and are able to build, given site conditions. We found that both zoning rules and economic variables are important in determining density. Many of the economic variables affect density in the predicted ways, but some density limits also are binding. About 8 percent of subdivisions in the sample were developed to the maximum density allowed by regulation.

Our results showed that factors affecting both the value and cost of additional lots are important in the density decision. The size of the subdivision land area is important, as is the steepness of the terrain. Existing uses of land surrounding the subdivision also appear to affect the density of the subdivision. Availability of sewers, accessibility to the major highway in the region, and proximity to town centers are all-important determinants of density.

Our results indicate that zoning regulations contribute to low-density residential development in some areas. Although the number of constrained subdivisions is relatively small, those constrained by the lowest density limits (5-acre average minimum lot size) would have been nearly 50 percent denser absent any zoning regulations. However, we estimate that if zoning restrictions were relaxed, only a little more than 10 percent more lots would have been added overall in subdivisions that face relatively low density limits over the sample period. On

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[33] In estimating the censored model, we assume that any subdivision that includes the maximum number of allowable lots is censored. However, it is possible that some of those subdivisions are at exactly the profit-maximizing level (Figures 1 and 2). Such may be the case for these eight subdivisions built in the RC areas from 1983 on. Because of the integer problem—one cannot build a fraction of a lot—it is difficult to evaluate these differences precisely.

the one hand, relatively large lots would have predominated in these rural areas even if they hadn't been constrained by zoning. On the other hand, the increased density may represent a substantial reduction in land used for residential development.

We hasten to point out that although our data may be typical of many ex-urban, fast-growing rural jurisdictions around large metropolitan areas, the results could be somewhat different in the case of a more urban or an older suburban area. Comparisons of our study area with other areas will be an important part of future research.

## References

Brueckner, Jan K. 2000. Urban Sprawl: Diagnosis and Remedies. *International Regional Science Review* 23(2): 160–171.

Calvert County Planning Commission. 1997. *2004 Comprehensive Plan.* Calvert County, MD: Calvert County Planning Commission (December). <u>http://www.co.cal.md.us/residents/building/planning/documents/compplan/default.asp</u> Accessed Jan. 30, 2006.

Cannaday, Roger E., and Peter F. Colwell. 1990. Optimization of Subdivision Development. *Journal of Real Estate Finance and Economics* 3: 195–206.

Anderson, Soren T., and Sarah E. West. 2003. The Value of Open Space Proximity and Size: City Versus Suburbs. Working paper. St. Paul, MN: Macalester College. http://www.macalester.edu/~wests/index.htm.

Danielsen, Karen A., Robert E. Lang, and William Fulton. 1999. Retracting Suburbia: Smart Growth and the Future of Housing. *Housing Policy Debate* 10(3): 513–553.

Davis, Judy S., Arthur C. Nelson, and Kenneth J. Dueker. 1994. The New' Burbs: The Exurbs and Their Implications for Planning Policy. *Journal of the American Planning Association* 60(1): 45.

Edelson, Noel M. 1975. The Developer's Problem, or How to Divide a Piece of Land Most Profitably. *Journal of Urban Economics* 2: 349–365.

Field, B. C., and Jon M. Conrad. 1975. Economic Issues in Programs of Transferable Development Rights. *Land Economics* 1(4): 331–340.

Fischel, William. 2000. Zoning and Land Use Regulation. In *Encyclopedia of Law and Economics, Volume II: Civil Law and Economics,* edited by B. Boudewijn and G. De Geest. Cheltenham, U.K.: Edward Elgar, 403–423.

Fischel, William. 1978. A Property Rights Approach to Municipal Zoning. *Land Economics* 54: 64–81.

Fischel, William. 1987. *The Economics of Zoning Laws*. Baltimore, MD: The Johns Hopkins Press.

Fulton, William, et al. 2001. *Smart Growth in Action: Housing Capacity and Development in Ventura County*. Los Angeles, CA: Reason Foundation.

Glaeser, Edward L., and Matthew E. Kahn. 2003. *Sprawl and Urban Growth*. Cambridge, MA: Harvard Institute of Economic Research.

Gordon, Peter, and Harry Richardson. 1997. Are Compact Cities a Desirable Planning Goal? *Journal of the American Planning Association* 63(1): 95–105.

Hausman, J. 1978. Specification Tests in Econometrics. *Econometrica* 46(6): 1251–1271.

Heimlich, Ralph, and William Anderson. 2001. *Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land*. U.S. Department of Agriculture ERS Agricultural Report No. 803. Washington, DC: U.S. Department of Agriculture.

Irwin, Elena G. 2002. The Effects of Open Space on Residential Property Values. *Land Economics* 78(4): 465–480.

Jaklitch, Trent. 2004. Personal communication between T. Jaklitch, Kain Developers, Calvert County, MD, and the authors. September 14.

Kelejian, Harry, and I. Prucha. 1999. A Generalized Moments Estimator for the Auto-Regressive Parameter in a Spatial Model. *International Economics Review* 40: 509–533.

Levinson, Arik. 1997. Why Oppose TDRs? Transferable Development Rights Can Increase Overall Development. *Regional Science and Urban Economics* 27(3): 286–296.

Lichtenberg, E., C. Tra, and I. Hardie. 2005. Land Use Regulation and Provision of Open Space in Suburban Residential Subdivisions. Working Paper. College Park, MD: University of Maryland, Department of Agricultural and Resource Economics. June.

McConnell, Virginia, Elizabeth Kopits, and Margaret Walls. 2003. How Well Can Markets for Development Rights Work? Evaluating a Farmland Preservation Program. Discussion Paper 03-08. Washington, DC: Resources for the Future. http://www.rff.org/Documents/RFF-DP-03-08.pdf.

McDonald, John F. 1989. Econometric Studies of Urban Population Density: A Survey. *Journal of Urban Economics* 26: 361–385.

McDonald, John F., and Daniel P. McMillen. 2004. Determinants of Suburban Development Controls: A Fischel Expedition. *Urban Studies* 41(2): 341–361.

McMillen, Daniel, and John McDonald F. 1990. A Two-Limit Tobit Model of Suburban Land-Use Zoning. *Land Economics* 66(3): 272–282.

Mills, E.S. 1972. *Urban Economics.* Glenview, IL: Scott, Foresman & Company. Moss, W.G. 1977. Large Lot Zoning, Property Taxes, and Metropolitan Area. *Journal of Urban Economics* 4: 408–427.Muth, Richard. 1969. *Cities and Housing.* Chicago. IL: University of Chicago Press.

Pasha, H.A. 1996. Suburban Minimum Lot Zoning and Spatial Equilibrium. *Journal of Urban Economics* 40(1): 1–12.

Peiser, Richard B. 1989. Density and Urban Sprawl. *Land Economics* 65(3): 193–204.

Rolleston, Barbara. 1987. Determinants of Restrictive Suburban Zoning: An Empirical Analysis. *Journal of Urban Economics* 21(1): 1–21.

Song, Yan, and Gerrit-Jan Knaap. 2004. Measuring Urban Form: Is Portland Winning the War on Sprawl? *Journal of the American Planning Association* 70(2): 210–225.

Straszheim, Mahlon R. 1974. Hedonic Estimation of Housing Market Prices: A Further Comment. *Review of Economics and Statistics* 56(3): 404–06.

Thorsnes, Paul (2000). Internalizing Neighborhood Externalities: The Effect of Subdivision Size and Zoning on Residential Lot Prices. *Journal of Urban Economics* 48: 397–418. Wallace, N.E. 1988. The Market Effects of Zoning Undeveloped Land: Does Zoning Follow the Market? *Journal of Urban Economics* 23: 307–326.