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Zoning, TDRs and the Density of Development

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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 also to counter a trend toward so-called "large lot" development so that any given growth that does take place does so with 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 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 the widespread use of the car as a means of travel has made sprawl an inevitable market outcome.[1] Davis, Nelson, and Dueker (1994) report results of a survey finding that 60% of people who move to so-called "ex-urban" locations beyond traditional suburbs move there to have large lots and a rural lifestyle.

It is difficult to know, however, whether the spatial patterns of suburban and ex-urban development are solely the result of market forces or not. Most local governments use zoning to establish minimum acreage requirements for each dwelling unit; in ex-urban localities, these limits are often quite high. Developers might build a subdivision with average lot sizes greater than the minimum, but they cannot, by law, go below it. An important question, then, is whether zoning limits are the primary cause of low-density, sprawling development, or whether market forces tend to dictate this outcome. If zoning limits account for low-density development in at least some cases, how would development patterns be different if there had been no such rules?

In this paper we address these issues by analyzing the factors that explain subdivision density in a rapidly growing county on the fringes of the Washington, DC metropolitan area, Calvert County, Maryland. We first develop a simple model of a developer's choice over the number of building lots to put in a subdivision of a given size. Economic variables that influence density are identified, including factors that affect the value and cost of additional development. Regulatory constraints and rules on

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[1] Many studies have emphasized the role played by declining transportation costs (Brueckner, 2000); Glaeser and Kahn's (2001) 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.

building are included in the model. A transferable development rights (TDRs) program that allows developers to exceed base zoning limits in some areas by purchasing TDRs is also incorporated as an added cost of building more lots. We then econometrically estimate a density function using a unique dataset of subdivisions built in Calvert County over a 34-year period. Calvert County has had an active TDR program since 1981, and this program allows for more variability in density than one might find in other communities. This variability allows us to empirically assess the relative importance of market factors and regulatory constraints on density. In the cases where regulatory constraints have been binding, we are able to use our model to predict what housing patterns would have been without those constraints.

The extensive theoretical literature examining population density in urban areas helps to provide some insight in identifying the underlying economic factors that influence subdivision density. Traditional urban models find that density declines, usually exponentially, with distance from the urban center. Higher land prices near the center result in smaller lot sizes there relative to more distant locations (Mills, 1972; Muth, 1968). A fairly sizeable empirical literature on population and employment densities has arisen over time, drawing from this theoretical base (see McDonald, 1989). This literature looks mainly at gross density across a range of land uses rather than net density, or intensity of use, for individual land use categories.[2] The extant literature also primarily examines how density changes as distance to the central business district increases, i.e., the density gradient. Some studies look at a single urban area, others across different areas.

There is also a large literature on the determinants and impacts of zoning in urban areas. Debate over the motivation for zoning has led to studies of its impact on property values, as well as studies that attempt to explain zoning differences across communities and over time. Fischel (1978) argued that because exclusionary zoning positively influences property values, owners of developed properties effect zoning changes in communities in order to raise their own property values at the expense of owners of undeveloped land. Others have argued that there is a more benign motive for zoning – that by separating land uses, zoning mitigates the negative externalities associated with certain land uses and increases overall welfare. Still others have used fiscal arguments – i.e., that communities use zoning to influence the size of the local tax base and the demand for local government services (Hamilton, 1975). Examples of studies that have empirically assessed whether zoning differences, or surrounding land uses, influence property values include Stull (1975), Grether and Mieszkowski (1984), Mark and Goldberg (1986), and McMillen and McDonald (1991). Results are mixed, with some studies finding that separating land uses increases property values and others finding no consistent evidence of this. Studies that look at the determinants of zoning include Rolleston (1987), Pogodzinski and Sass (1994), and McDonald and McMillen (2004). These studies use data across jurisdictions and analyze how characteristics of the

[2] Many studies of density emphasize that gross employment or population density is a function of both intensity of use, sometimes called "net density" and zoning allocation – e.g., how many acres of land are devoted to residential use out of the total acreage in the jurisdiction (see, for example, Frew, Jud, and Wingler, 1990). McDonald (1989) points out that although the theory explains intensity of use and mostly ignores patterns of land use, most empirical work, probably because of data limitations, focuses mostly on measures of gross density such as population or employment per acre.

jurisdiction determine the zoning that results there. In general, the studies find that there is support for the property value, fiscal, and externality arguments for zoning.

In this study, we assume that it is possible that zoning affects property values, but we treat zoning as pre-determined from the perspective of the developer of an individual subdivision, which is the unit of observation in our empirical analysis. We have data in a single county over a 34-year period. Zoning changes that have taken place over that period have been based, for the most part, on external factors uncorrelated with the factors that explain developers' choices over subdivision density. We discuss this issue in greater detail below. We assume that density limits set by zoning constrain developers' decisions and allow for the possibility that zoning affects the value of houses in a development.

In other literature, a few studies have looked at residential housing density using more disaggregated data, including data at the subdivision level. Peiser (1989) uses subdivision data from three different communities over time to estimate average lot size as a function of median house value, age of the subdivision, distance from the city center, and other accessibility measures. Peiser's hypothesis is that jurisdictions that allow discontinuous development – interspersed developed and undeveloped parcels as the city expands – will have efficient development patterns and higher density. Over time, as property values increase, infill development occurs in areas developed earlier, resulting in higher overall density. If there are limits to this kind of activity or requirements for only continuous or sequential development, overall density will be lower. Peiser finds empirical support for his hypothesis.

Thorsnes (2000) also uses subdivision data. He focuses on the question of whether larger subdivisions, by being better able to internalize neighborhood externalities, lead to higher property values than smaller subdivisions, all else equal. Using prices of undeveloped lots, he finds some evidence of this. Song and Knaap (2004), using Census block data from neighborhoods in the Portland, Oregon, metropolitan region, examine how density and other measures of urban form have changed over time. Portland has had very aggressive policies for controlling development and sprawl, including minimum density requirements in some areas, subsidized expansion of a light rail system, and establishment of a now famous Urban Growth Boundary. The authors find that Portland appears to be having some success with its "war on sprawl" with single-family dwelling densities increasing over time.

Two theoretical studies that model a developer's density decision are Edelson (1975) and Cannady and Colwell (1990). Edelson examines how community tax rates and public services affect the willingness to pay for lots of different sizes in a subdivision and how these may affect the developer's optimal choice of lot size. His model is most applicable to subdivisions across jurisdictions rather than within a jurisdiction where public services and tax rates are more uniform. Cannady and Colwell (1990) solve for a developer's profit-maximizing choice of the lot size, frontage, and depth of a lot assuming that all three variables have a positive effect on both the value of the lot and on its development costs. They specify functional forms for both value and cost functions, and then do comparative static exercises with respect to key parameters in both functions. Although this model is not directly comparable to our study because we look at average characteristics and lot sizes within a subdivision, not individual parcel characteristics, the results do suggest which factors are likely to influence development costs and values.

Some empirical evidence suggests that subdivisions are being built at lower density than allowed by zoning, supporting the market forces argument for sprawl. Fulton et al. (2001) find this to be the case in Ventura County, California, for example. However, no study, to our knowledge, examines the factors that explain the net density of residential development in order to separate out the competing influences of zoning and market forces. Moreover, most studies do not have the extensive data that we have at the subdivision level of observation. Using subdivisions is ideal since this is the predominant way that residential development takes place in suburban and ex-urban locations. Also, by limiting our analysis to one county we are able to hold constant many factors that also might influence land and housing markets.[3]

The next section lays out the model of the developer decision on how many lots to build, including constraints due to zoning and the ability to purchase TDRs. The application to Calvert County is then developed, with explanation and description of the data used for the analysis. The fourth section presents the results of the empirical analysis. The last section offers conclusions and directions for future research.

II. The Developer Decision

In this section of the paper, we model a profit-maximizing developer's decision over the number of building lots to put on a given parcel of land, i.e., the density of a residential subdivision. We assume that the developer has already made the decision about where to build, and is deciding about the density of development at that site. One can certainly argue that the density decision is made jointly with the decision about where to build, but there are compelling reasons why the two can be separated. Developers may only have access to certain parcels, depending on which landowners are willing to sell. Many developers in high growth suburban areas, such as the one that we are considering in our empirical analysis, will build a subdivision on virtually any greenfield that becomes available to them. Thus they will purchase land for development where and when they can.[4] For each parcel, they will be making an individual decision about how to subdivide. We model that decision as depending on variables that affect the revenues and costs of development, zoning regulations about what density is allowed, and whether and how many transferable development rights can be purchased.[5] TDRs allow the developer to build at higher density than the baseline zoning permits. The developer

[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. Our results, however, would be most applicable to similar types of urban fringe locations and not more urban centers or other areas.
[4] See Jaklitch (2004). During the decade of the 1990s, Calvert County had the highest population growth rate of any county in the state of Maryland, 45%; the state average was 10.8% (McConnell, Kopits, and Walls, 2003).
[5] It is useful to distinguish here between the developer and the builder. We are modeling the developer's decision to subdivide the parcel into buildable lots. Developers may then sell lots to builders or build the houses themselves.

takes the zoning rules in place and the ability to purchase TDRs in any given location as given for any parcel.[6]

More formally, we assume the developer will decide how many building lots to create in subdivision i to maximize profits at that site, given regulatory constraints. The number of lots in the subdivision, l_i, will affect revenues, V_i, but will also influence development costs, C_i. In addition, revenues will depend on the total acreage of the land parcel, or subdivision plat area, L_i, since a larger parcel with a given number of lots will have greater value. Revenues from the plat will also depend critically on the amenity characteristics of the site, A_i. These include natural amenities of the site itself, n_i, such as the number of trees and topography, land uses of the properties immediately surrounding the site, u_i, and the zoning at the site, z_i. The surrounding land uses can have a complex effect on the value of development. There may be increased value from being adjacent to like uses, or there could be positive spillover effects from different uses. For example, the more preserved open space or parkland surrounding a subdivision site, the higher the residential value at that site. However, the increased value from the surrounding preserved areas might be greater for low density development than for high density development. Hence, it is difficult a priori to predict the effect of surrounding land uses on the choice over the number of lots. Zoning, which pertains to the general region in which the property is located, can also affect the site's amenities if, for example, separation of land uses raises the value of a site for residential purposes (Fischel, 1967). Finally, revenues will depend on location and accessibility variables, d_i, since greater access to employment centers should increase property values.

The developer's costs will be determined by the number of lots, l_i, the size of the plat area, L_i, and the costs of providing infrastructure at the site, I_i, which will depend on the zoning at the site, z_i, and the soil and topography characteristics of the land, s_i.[7] Cannady and Colwell (1990) show that even the shape of the parcel to be subdivided can affect the development costs.

In almost all communities today, the developer faces a limit on the number of lots he can put in any subdivision because of zoning rules. These rules usually establish the minimum average lot size, $\overline{Z}$.[8] Zoning rules have a long history and were initially designed to separate land uses in order to prevent negative spillovers among these uses. Separation of uses expanded over the years to include not only separation of commercial and industrial activities from residential uses but also separation of different types of residential uses. Thus, most communities have a variety of zoning categories with different limits on lot sizes, or equivalently, the number of housing units per acre.

TDRs provide a relatively new tool for allowing flexibility in zoning in some designated regions. If a community wants to encourage more protection in some areas,

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[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 which follows later in the paper.
[7] For example, areas zoned for residential development may require sewers, whereas areas zoned rural are more likely to use septic systems.
[8] Residential zoning limits are sometimes specified in terms of an absolute minimum lot size, i.e. no lot can be smaller than 1 acre. More often it is a minimum lot size averaged across the entire subdivision parcel. In the application analyzed below, Calvert County uses average minimum lot size zoning.

landowners in those areas may be permitted to sell their development rights and put their land in a permanent preservation easement status. The development rights can then be used in areas that can accept additional density above the allowed baseline zoning. In our model, developers can purchase development rights, t_i, at a price determined in the market for TDRs, P_{TDR}, and use them to increase density in an area *r*.[9] Areas designated as unavailable for TDR use are denoted *m* in our model.

The developer's decision is therefore:

$$\max_{l_i} \pi_i = V_i(l_i, L_i, A_i(n_i, u_i, z_i), d_i) - C_i(l_i, L_i, I_i(z_i, s_i),) - p_{TDR}t_i \qquad (1)$$

subject to the following constraints:

(i) in regions *m,* where TDRs cannot be used:

$$\frac{L_i}{l_i} \geq \bar{Z}_m \text{ , and } t_i = 0, \; i \in m$$

where $\bar{Z}_m$ is the minimum average lot size allowed in region *m*.

(ii) in regions *r*, where TDRs can be used:

$$\frac{L_i}{l_i} \geq \bar{Z}_{TDR_r} \; , \quad \bar{Z}_{TDR_r} < \bar{Z}_r \; , \; i \in r$$

and

$$t_i = l_i - \frac{L_i}{\bar{Z}_r} \; , \; i \in r$$

where $\bar{Z}_r$ is the minimum average lot size allowed under baseline zoning in region *r*, and

where $\bar{Z}_{TDR_r}$ is the minimum average lot size allowed with the use of TDRs in region *r*.

The developer decision about the number of lots on a given parcel, or the density of the development, can be shown more clearly in Figures 1 and 2.[10] Figure 1 illustrates the basic developer problem in region *r*, where TDRs cannot be used to increase density. The developer maximizes profits by choosing the number of lots where the marginal revenue from an additional lot at the subdivision site, *MV,* is equal to the marginal cost of developing an additional lot *MC*. If there is a zoning rule that sets a minimum lot size, then the developer may or may not be constrained. For example, if the zoning rule for the subdivision in region *m* is $\bar{l}$ in Figure 1, then the developer with a marginal revenue curve of MV_1 will not be constrained by zoning, and will build l_1 lots at density l_1/L. If,

[9] Here we assume that only one TDR is needed to create one additional lot.
[10] These graphs follow from the Field and Conrad (1975) model of efficiency and equity in TDR markets.

however, the marginal revenue from building at the site is MV_2, then the developer would be constrained by zoning, and would have to choose the allowable limit, $\bar{l}$, rather than the profit-maximizing choice, l_2. The subdivision would then be less dense – i.e., have larger average lot sizes – than the private market would have chosen.

Figure 2 shows the way in which the availability of TDRs affects density decisions in areas where TDRs can be purchased, areas designated *r*. MV_1 is left off the graph because, as in the non-TDR areas shown in Figure 1, if MV_1 is the marginal revenue from additional lots and MC_1 is the cost per lot, then profit-maximizing density is chosen and l_1 lots are built. The availability of TDRs does not affect the developer's decision. If the marginal revenue is MV_2, however, the developer is constrained and the TDR option may change the profit-maximizing outcome. TDRs can now be purchased at price P_{TDR}, so the profit-maximizing number of lots is where $MV_2 = MC_2$, or l_2'. In this case, t_2 lots are created through TDRs. A final constraint is that in most TDR programs, the number of TDRs that can be used to increase density is fixed at some maximum level. In Figure 2, this limit is shown as $\bar{l}_{TDR}$. If the marginal revenue of additional lots is as high as MV_3, the developer would again be constrained even with the availability of TDRs. The profit-maximizing number of lots in the subdivision would be l_3, but the developer is only allowed to build up to $\bar{l}_{TDR}$.

In summary, Figures 1 and 2 illustrate that there is a range of possible density levels across subdivisions. Density may be determined by market forces or it may be determined by the local zoning rules, by whether TDRs are available, or by the number of TDRs allowed. We explore all of these possibilities in the empirical analysis below.

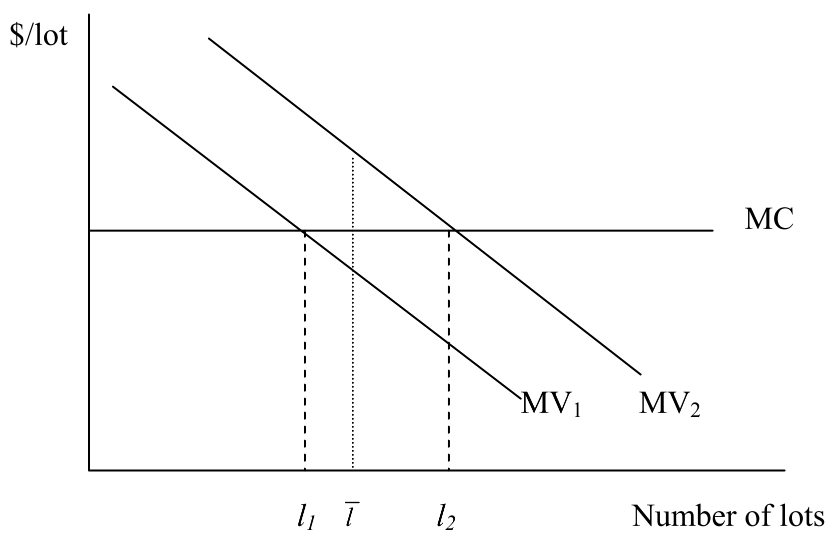

Figure 1. Developer's Density Decision: No TDRs Allowed (region *m*)

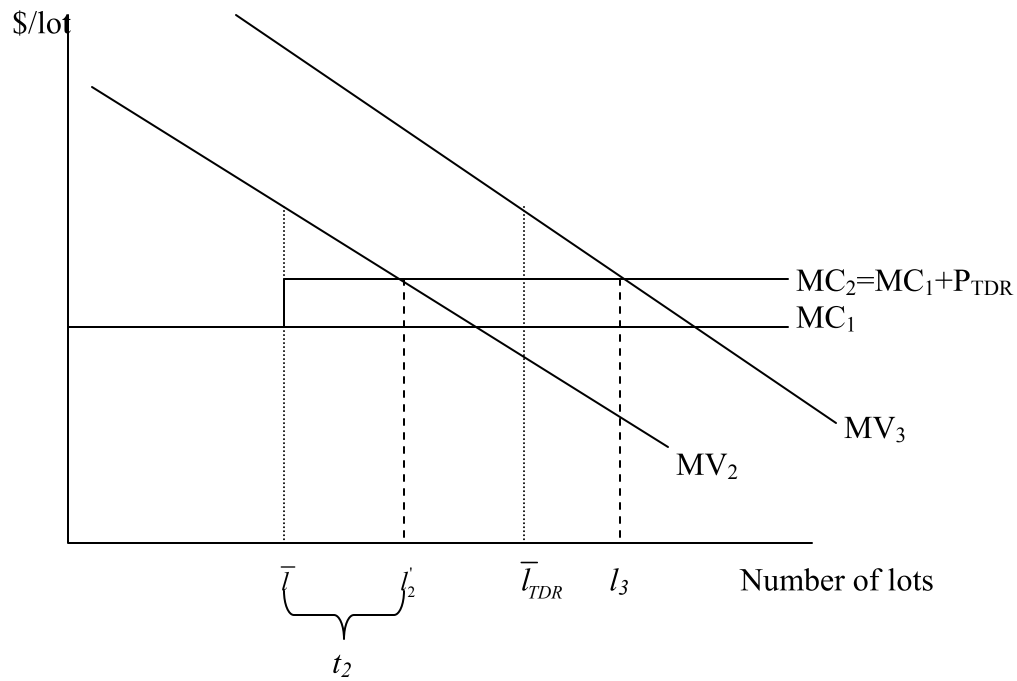

Figure 2. Developer's Density Decision: Purchase of TDRs allowed (region *r*)

III. Land Uses, Zoning, and Subdivision Development in Calvert County, Maryland

Calvert County is a 215-square mile peninsula in southern Maryland bordered by the Chesapeake Bay and the Patuxent River. The northern-most town in the county, Dunkirk, is approximately 25 miles south of Annapolis, Maryland, and 30 miles southeast of Washington, DC. It is a historically rural, agriculture-based county, but it has seen rapid population growth over the past twenty to thirty years because of its proximity to major centers of employment.

In an effort to manage growth and preserve farmland and forested areas, the county has undertaken several zoning changes over the years and most importantly, has introduced and refined a unique TDR program. Since the program began in 1979, the sale of TDRs has preserved over 13,000 acres of farmland.[11] The purchase of these TDRs has allowed developers to add density above that permitted by existing zoning rules; in total, 2,130 new housing units have been built with TDRs. Slightly less than 30% of the new subdivisions built over the 1980-2001 period used TDRs. The TDR program rules, along with the zoning changes over time, have led to variability in housing density in the county and allow us to look at the factors that explain density.

[11] Approximately 13,000 additional acres have been preserved through county and state Purchase of Development Rights (PDR) programs. In an earlier study, we analyzed detailed results from the Calvert TDR program (McConnell, Kopits, and Walls, 2003).

Zoning and TDR History. Table 1 shows the zoning rules over time in Calvert County. In 1967, the county adopted its first Comprehensive Plan in which all rural land was zoned to a maximum density of 1 dwelling unit per 3 acres. In 1974, the county updated the Plan to reflect a "slow growth" goal and changed the maximum density to 1 dwelling unit per 5 acres. Despite the 5-acre minimum lot requirement, there continued to be substantial population growth and conversion of land from agricultural uses to housing developments. In 1978, the county adopted a TDR program in an attempt to protect many of the prime farmland areas of the County from development.[12] The first TDR was sold in 1981.

The program targeted some regions to be so-called "receiving areas." These areas could accept higher density through the use of TDRs and included areas zoned as Town Centers, residential (R-1 and R-2 areas) and some rural areas. Other rural areas were identified as best preserved in farming uses and became known as Designated Agricultural Areas (DAAs). Parcels in DAAs could only be used as "sending areas" for TDRs, i.e., TDRs could be sold off land in these areas but developers could not use TDRs in these areas to increase density. In 1992, additional farmlands (called Farm Community Districts or FCDs) were designated as sending areas only, and effectively became part of the DAA areas.[13]

In 1999, all regions were downzoned in order to reduce overall development in the county. The baseline zoning in virtually all areas was reduced by about 50%. Density permitted with TDRs, however, was virtually the same as before the downzoning, thus the pre-1999 maximum density levels in all areas can still be attained, but only with the purchase of more TDRs. The effects of this change can be seen in the last two rows of Table 1.

Figure 3 helps to illustrate the spatial aspects of the different zoning classifications in the county. The farming regions that the county is aiming to protect, and which may only become TDR sending areas, are shaded with green dots and dashed blue lines. The green dotted areas are the DAAs and the dashed blue lined areas represent the FCD regions outside the DAAs added after 1992. The white indicates areas zoned as Rural Communities (RC), which can be either sending or receiving areas for TDRs. The yellow and orange areas are, respectively, Town Centers and residential areas; commercial and industrial zones are shown in purple. Though not zoning per se, land that is preserved through state, federal, or private conservation programs or that is county or state parkland, is shown on the map in brown.

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[12] There have been other growth controls implemented over the years as well. For example, in 1988, the county adopted an adequate public facilities ordinance which 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 1 dwelling unit per 20 acres in those areas. See Calvert County Planning Commission (1997) for more detail.

[13] All of the sending area-only regions are now generally referred to as Farm Community Districts (FCDs) or Resource Preservation Districts (RPDs). Since the original DAAs are a subset of the FCD/RPD region, for simplicity, in this paper we will continue to refer to the sending area-only regions as DAAs and the regions that were added on in 1992 as "FCD regions added to DAA." All other rurally zoned land in Calvert, known as Rural Communities (RC), can become either a sending or receiving area for TDRs.

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

	Rural			
	DAA*	***Rural Communities (RCD)***	***Residential***	***Town Centers*****
Year				
1967 -1974	3.3 units/10 acres	3.3 units/10 acres	10 units/10 acres***	---
1975 - 1980	2 units/10 acres	2 units/10 acres	10 units/10 acres***	---
1981 - 1998				
w/o TDRs	2 units/10 acres	2 units/10 acres	10 units/10 acres***	40 units/10 acres
with TDRs	2 units/10 acres	5 units/10 acres ****	40 units/10 acres***	140 units/10 acres
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 ****	40 units/10 acres	140 units/10 acres

* After 1992, this includes some additional farming regions that lie outside the original DAA areas. From 1981-1992, these additional areas could achieve the same density with TDRs as in the Rural Communities (RCD). After 1992, they were treated the same as DAAs. See footnote 12.
** The Town Center zoning classification came into effect in 1983.
*** Prior to 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.
**** Density in Rural Communities that are within 1 mile of a Town Center can go as high as 1 unit/acre with the use of TDRs.

Subdivisions in Calvert County. Data on each new subdivision and every farm enrolled in either the county TDR program or a state preservation program was gathered from the Calvert County Planning Department records and then digitized into GIS format using ArcInfo software. Overlaying this are data on the individual parcels from Maryland Property View, as well as topographical and soil quality information. For each subdivision we know total acreage, average individual lot size, the amount and configuration of open space within the subdivision, soil type and slope of both the lots and the open space areas, the location of the subdivision within the county, the baseline zoning designation, and the surrounding land uses at time of subdivision approval. These other land uses include the type of residential development, commercial and industrial uses, parks, wetlands, major bodies of water, and undeveloped farmland and forested lands – both those in protective status from the TDR program or other preservation programs and those unprotected.

Figure 3. Zoning Map, Calvert County, MD

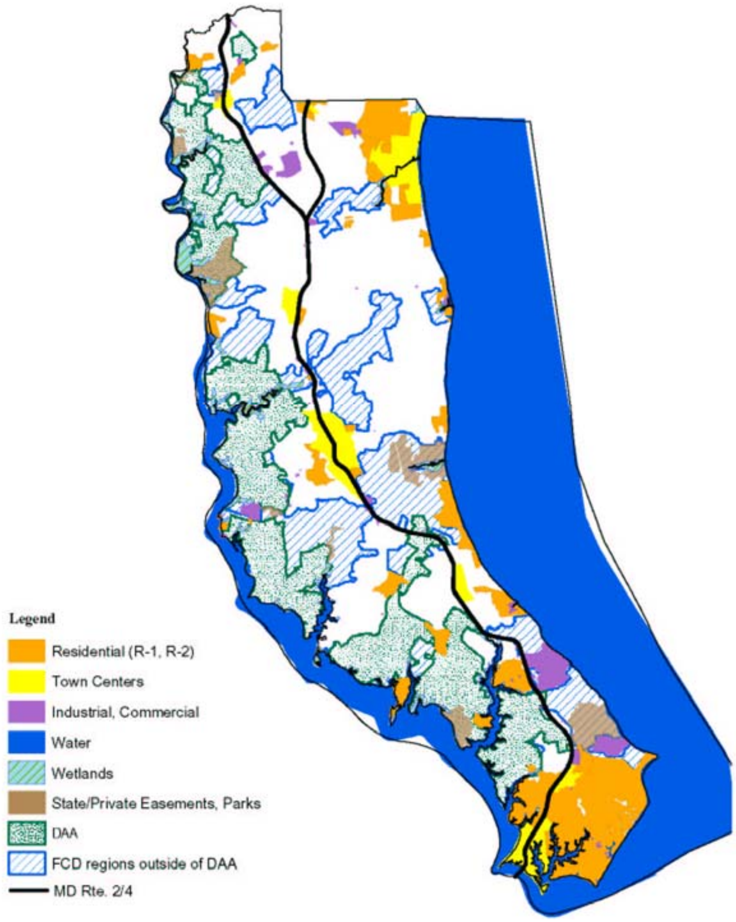

Figure 4 shows the subdivision acreage in new subdivisions from 1967 to 2001. The average amount of acreage developed each year appears to be roughly the same before 1981, when the TDR program began operating, as it is after. Annual new subdivision acreage averaged 820 acres over the 1967-1980 period and 880 acres over 1981-2001.[14] The number of new building lots recorded each year, however, increased by 35% over the two periods: an average of 318 new building lots were developed during the 1967-1980 period, compared with 429 during the 1981-2001 period. Thus, there was more density after 1981.

Figure 4 also shows the acreage in subdivisions using TDRs compared with non-TDR subdivisions. During 1992-1998, 43% of new subdivision acreage was developed using TDRs. The figures also highlight the increase in TDR usage since the 1999

[14] This fact should not be construed as suggesting that the TDR program was a failure; without knowing the counter-factual, it is difficult to say exactly how the amount of acreage in new residential development has been affected by the program. As we stated above, 13,000 acres of farmland have been preserved from development through the TDR program (and an equivalent amount through other county and state preservation programs).

downzoning. Over the 1999-2001 period, acreage in TDR subdivisions accounted for 84% of all new subdivision acreage.

Figure 5 shows the location of subdivisions built in the county over the 1967-2001 time period. The map shows that, as would be expected, most of the building appears to have taken place in the northern and north-central parts of the county, areas closer to the Washington, Baltimore, and Annapolis metropolitan regions. Moreover, the map shows that a great deal of building has taken place in rural areas: many subdivisions show up in the white areas on the map, Rural Communities, and even in the prime agricultural (DAA/FCD) zones, shown in blue lines and green dots on the map**.** There has been less new development in the areas designated for residential zoning, the yellow and orange areas. We come back to this point later in the discussion of the statistical results below.

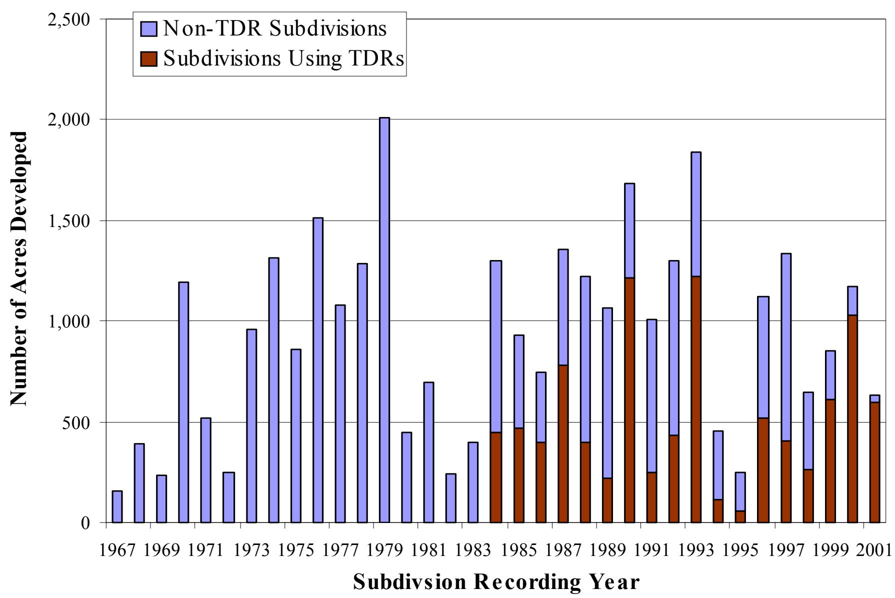

Figure 4. New Subdivision Acreage, by Year and TDR Use

Finally, the central focus of this paper is on choice over density. An important question discussed in the introduction is: to what extent are zoning regulations constraining the density of development? Is density primarily determined by the zoning regulations themselves, in which case most subdivisions would be at the limit of the number of houses that can be built? If density is constrained by zoning, TDRs offer an important opportunity to increase density in some areas, and preserve farmed or undeveloped land in others. If density is relatively unconstrained by current zoning laws, other factors are determining density levels. In this case, there is likely to be little demand for TDRs and they will not play much of a role in land use decisions.

Figure 5. Subdivisions Built in Calvert County, MD, 1967-2001

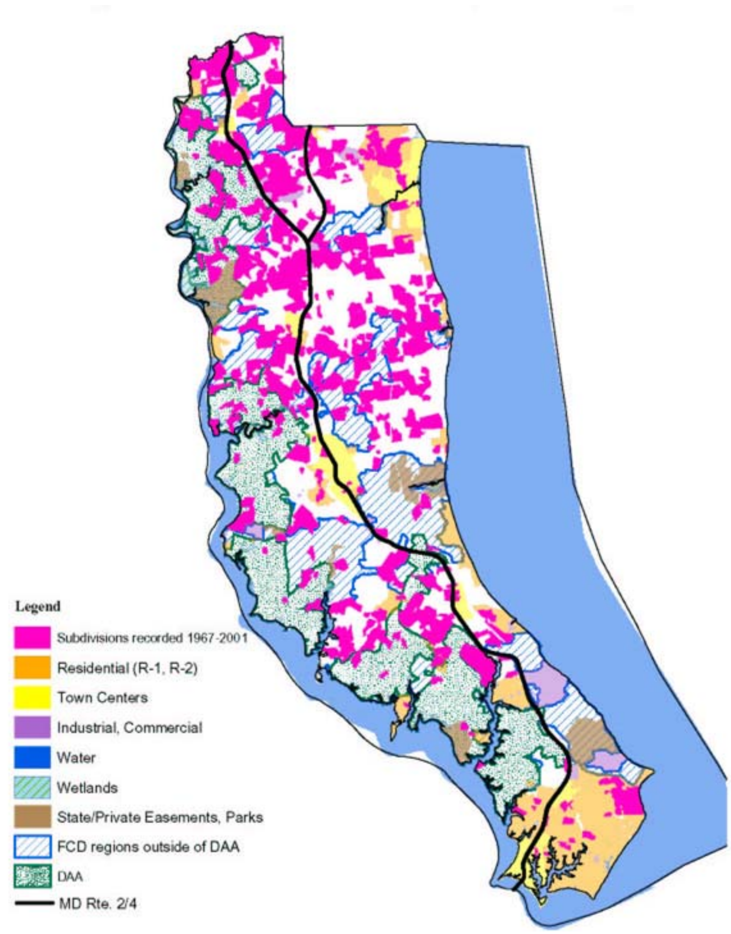

Table 2 summarizes the information about subdivision density in the Calvert County sample. The table shows that most of the subdivisions are not at the limit in terms of the numbers of lots that can be built.[15] In the residential areas – R-1, R-2, and Town Centers – where density limits are less strict (i.e., more housing units may be built per acre), only 2 of the subdivisions in our sample are at the maximum density.

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[15] Subdivisions are defined as constrained by the zoning or TDR program if they have the maximum number of lots allowed by either baseline zoning (if the subdivision is in a sending area-only region) or the TDR limit (if the subdivision is in a potential receiving area) at the time and location of the subdivision recording.

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

	Rural Areas	*Residential Areas/ Town Centers*	*Total*
Total number of subdivisions	334	64	398
Number constrained by zoning or TDR limit	28	2	30
Number unconstrained by zoning and/or TDR limit	306	62	368

IV. Empirical Models and Results

A. OLS Estimation

We use the subdivision sample for Calvert County to estimate a density equation, based on the model of the developer decision in section II above. The developer chooses the number of lots to put in a subdivision, given the total size of the plat area, the amenities and physical characteristics of the site, the characteristics of the neighboring areas, and the zoning and TDR rules in place. From equation (1), we can derive 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 optimal number of lots in subdivision *i* as:

$$\ln(l_i)^* = a + B_1 \ln L_i + B_2 n_i + B_3 u_i + B_4 d_i + B_5 s_i + B_6 z_i + B_7 p_{TDR} + e_i \qquad (2)$$

where L_i = subdivision size, in acres
n_i = vector of subdivision natural amenities
u_i = vector of neighboring land uses at the time subdivision is built
d_i = vector of accessibility variables
s_i = vector of soil and topography characteristics
z_i = zoning variables
p_{TDR} = average TDR price

It is important to note that we are treating the zoning variables 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; McMillen and McDonald, 1990; McDonald and McMillen, 2004) Our concern, from an econometric standpoint, is whether the zoning and TDR variables are correlated with the error term – i.e., that unobserved factors that explain a developer's decision over the number of lots to build in a given subdivision are correlated with the zoning established by the government. Because our data are at the subdivision level and we are modeling the individual developer's decision, we feel it is reasonable to treat zoning as predetermined. Moreover, in the case of Calvert County, there are several reasons to believe that the zoning and TDR rules are exogenous to the developers' decisions. 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.[16] Second, the changes in overall zoning rules that were made at various times were based either on county-wide population pressures, or on external factors, such as the soils and environmental characteristics of the areas designated for land preservation. For example, the down-zoning regulations that occurred in the county in 1975 and again in 1999 were both county-wide, and were a result of concern over population growth and the size of the transportation system. Finally, the TDR program, which was designed to protect the most productive farmlands and environmentally sensitive areas, identified areas for preservation and development based on external characteristics of the land such as soils, and slopes.

We estimate equation (2) for all of the 398 subdivisions in our sample, using OLS. In any spatial model such as this one, we must address the issue of unobserved spatial correlation in the error term.[17] Although spatial error correlation is likely to occur in hedonic pricing models, we feel it is less of a concern in the case of modeling density of larger land areas such as neighboring subdivisions. Nevertheless, we test for spatial autocorrelation by creating a weighting matrix in which we assign positive and equal weight to the subdivision 'neighbors'. We define 'neighbors' to be subdivisions that are directly adjacent to each other and consider both a row-normalized and non row-normalized weighting scheme. Using the Moran I test, we can not reject, at the 95% confidence level, the null hypothesis that no spatial correlation exists.[18]

Table 3 summarizes some of the key characteristics of the subdivisions in the sample. We have 398 subdivisions built over the 1967-2001 period with the average subdivision built in year 1986. The size of the subdivisions varies from 4 acres to almost 600 acres; average size is 71 acres. The average number of lots per subdivision is 27 but varies from 3 to 268. Some subdivisions are surrounded by between 40 and 50% preserved land, while others are adjacent to no open space; some are completely surrounded by other development, some by no other development.[19] The average subdivision is approximately 12 miles from the northern border of the county. In our regression, however, we use location dummy variables to capture differential effects of

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

[17] See Irwin (2002) for a general discussion of the issue.

[18] The Moran I test statistic is 1.608 and 1.278 for the row-normalized and non row-normalized weighting specifications, respectively. (Lagrange multiplier and robust lagrange multiplier tests for spatial error dependence and a spatial lag could not be rejected either.)

[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*. Hence, an adjoining farm is only considered to be *surrounding land in preservation* if the farm was preserved (i.e., sold TDRs or was placed under easement through some other program) by the year that the subdivision in question was recorded.

location on density. Location 1 is the northern-most area and includes 22% of all subdivisions in the sample. The location areas were chosen to roughly correspond to traffic lights and Town Center locations along the main commuting highway, Route 2/4. The average subdivision is located about 1.5 miles from Route 2/4.

Most of Calvert County relies on septic systems because the sewer system is not extensive. In our sample, only 2.3% of subdivisions have sewer available. Our soils and topography data allow us to calculate the percentage of land in each subdivision that lies in steep slopes (a grade of 15% or higher) and has "difficult" soils – i.e., areas that are part of a floodplain, or that have stony or clay-like soils, which are relatively unsuitable for residential development or are expensive to develop. We find that the average subdivision in our sample has steep slopes in 37% of its land area and difficult soils in 18% of its land area.

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

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Total number of lots	27.211	31.499	3.000	268.000
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	36.756	29.795	0	100
% Subdivision land in difficult soils	17.983	19.769	0	100
Within 1 mile of Patuxent River/Chesapeake Bay	0.221	0.416	0	1
Sewer service availability	0.023	0.149	0	1
% Surrounding land in preserved open space/farmland (privately held)	1.666	5.969	0	42.916
% Surrounding land in parkland	1.353	5.538	0	48.671
% Surrounding land in subdivisions	17.751	21.341	0	100
% Surrounding land in commercial/industrial zone	2.591	8.676	0	100
Location 1*	0.224	0.417	0	1
Location 2*	0.236	0.425	0	1
Location 3*	0.241	0.428	0	1
Location 4*	0.083	0.276	0	1
Location 5*	0.148	0.356	0	1
Location 6*	0.068	0.252	0	1
Distance to Route 2/4 (in miles)	1.503	1.148	0.005	4.840
TDR price (in 1999 dollars)**	1248.498	1105.587	0	2,582
Year of Subdivision Recording	1986.862	8.946	1967	2001

Notes: Total sample size is 398.
*Location 1, the omitted dummy in the regression model, is the northern-most area of the county; Location 2 is just south of Location 1, and so forth, with Location 6 the southern-most region.
**TDR price is averaged over those subdivisions that used TDRs, not all subdivisions.

As explained above, zoning rules have changed in rather complicated ways over time in the county, beginning with the first zoning of rural lands in 1967 and ending with the comprehensive downzoning that occurred in 1999. Table 4 below summarizes the variables that are used in the econometric model to capture these important changes. The baseline results of the model are for the 5-acre zoning that held for all rural areas from 1975 to 1981, when the first TDR was available for use in a subdivision. The dummy variables used in the econometric model and listed in Table 4 will capture zoning effects relative to this baseline.

Table 4. Variables Capturing Zoning and TDR Program Changes, 1967-2001

Variable	*Definition*	*Reflects*
Rural areas, pre1975	= 1 *if in rural area recorded before 1975* 0 *otherwise*	**1975 Downzoning**: Base density in all rural regions reduced from 1 lot/3 ac to 1 lot/5 ac
Rural areas outside DAA, 1981+	= 1 *if in rural areas outside of DAA and recorded since 1981* 0 *otherwise*	**1981 TDR Program Adoption**: Rural areas outside of Designated Agricultural Areas (DAA) allowed to build up to 1 lot/2 acres with TDRs
Residential, 1981+	= 1 *if in residential areas and recorded since 1981* 0 *otherwise*	**1981 TDR Program Adoption**: Residential areas allowed to build up to 4 lots/acre with TDRs
FCD regions added to DAA, 1992+	= 1 *if in FCD areas that lie outside the DAA and recorded since 1992* 0 *otherwise*	**1992 TDR Program Change**: Certain areas changed to DAA areas, where TDRs could no longer be used to increase density
TDR areas 1993+	= 1 *if in potential TDR receiving area*[20] *and recorded since 1993* 0 *otherwise*	**1993 Increased County Role in TDR Program**: County began purchasing and retiring TDRs and providing information to potential buyers and sellers
RCD within 1 mile of Town Center	= 1 *if in RCD areas that lie within 1 mile of a Town Center* 0 *otherwise*	**Additional TDR Density Bonus**: In RCD areas within 1 mile of the TC, TDRs could be used to increase density up to 1 unit/acre
Rural areas, 1999+	= 1 *if in rural areas and recorded since 1999* 0 *otherwise*	**1999 Downzoning**: Max base density in all rural regions reduced from 1 lot/5 acres to 1 lot/10 acres (no change in max density possible with TDRs)
Residential, 1999+	= 1 *if in residential areas and recorded since 1999* 0 *otherwise*	**1999 Downzoning**: Max base density in residential regions reduced from 1 lot/acre to 1 lot/2 acres (no change in max density allowed with TDRs)
Town Center, 1999+	= 1 *if in town centers and recorded since 1999* 0 *otherwise*	**1999 Downzoning**: Max base density in Town Centers reduced by half (no change in max density allowed with TDRs)

[20] Potential TDR receiving areas include residential zones, Town Centers, and the rural regions that lie outside the DAA/FCDs.

Regression results. The OLS regression results are shown in Table 5. Our central question is whether large average lot sizes in this ex-urban location are the result of restrictive zoning by the county government or whether market demand and supply factors dictate the patterns of development. The findings in Table 2 already provided some evidence that zoning is not solely responsible for existing density levels; less than 10% of subdivisions built in the county are built at a density that is at the limit of the allowable zoning. Table 5 speaks further to this point. Two sets of results are shown. Column 2 shows results of the full model with both zoning and TDR variables, as well as the subdivision characteristics, surrounding land characteristics, and accessibility variables. Column 1 uses only the zoning variables, along with the parcel size (*ln(acres)*) and the variable indicating the presence of grandfathered parcels. An F test of the hypothesis that all of the non-zoning/TDR variables are jointly insignificant is soundly rejected at the 99% level.[21] Both sets of results clearly show that the zoning variables are highly significant, however. Therefore, it appears that a combination of zoning and economic factors is responsible for the density patterns of subdivisions in Calvert County. In the remainder of this section, we use the results in Column 2 of the table and describe the effects of the individual variables.

Zoning and TDR Program Parameters. The variables that capture zoning restrictions across different zoning categories, including the limits established under the TDR program and the downzonings, are, for the most part, highly significant and have the signs that we would expect. These dummy variables are all relative to the baseline of 5-acre rural zoning that prevailed in the county from 1975 to 1981, prior to the TDR program. Relative to this baseline and holding subdivision size constant, the first two coefficients suggest that residential and Town Center zoning lead to more lots in a subdivision – i.e., higher density than the rural areas. On average, residential subdivisions have a little more than double the rural density and development in Town Centers is two and half times more dense than in the baseline rural areas.

As we mentioned above, the rural areas prior to 1975 had less restrictive zoning, 3-acre lots compared to 5-acre lots from 1975 on. This explains the positive and significant coefficient on the "Rural areas, pre1975" zoning variable. Finally, the "Grandfathered parcel" variable is a subdivision specific dummy variable equal to one if the subdivision is in a rural area and built in 1975 or after but had some grandfathered lots from less restrictive densities in place in earlier years. The results show that grandfathered parcels, all else equal, will have about 20% more lots per acre.

The next five variables in Table 5 are used to determine how well the TDR program worked to reduce density in some areas and increase it in others. The dummy variables "Rural areas outside DAA, 1981+" and "Residential, 1981+" indicate the TDR receiving areas for the rural and residentially zoned areas, respectively. We would expect more density in these areas after 1981 when they became eligible to be receiving areas and were able to use TDRs to increase density. As shown in Table 1, allowable density with the use of TDRs after 1981 increased by more than two times in the rural areas, and by four times in the residential areas. The results in Table 5 show that density levels did increase in the rural areas, but certainly not by the maximum allowable amount;

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[21]The F test statistic, with (21, 365) degrees of freedom, is 54.25.

Table 5. OLS Regression of Subdivision Density
(with robust standard errors)

Dependent Variable: ln(Lots)	coeff.	s.e.	coeff.	s.e.
Zoning variables				
Residential	1.260***	(0.157)	1.190***	(0.186)
Town Center	1.860***	(0.256)	1.510***	(0.304)
Rural areas, pre1975	0.474***	(0.099)	0.485***	(0.106)
Grandfathered parcel	0.215***	(0.053)	0.198***	(0.052)
TDR dummy variables				
Rural areas outside DAA, 1981+	0.257***	(0.071)	0.224***	(0.074)
Residential, 1981+	-0.148	(0.167)	-0.117	(0.197)
FCD areas added to DAA, 1992+	-0.144[2]	(0.101)	-0.151[2]	(0.110)
Rural (nonDAA) within 1 mile of Town Center	0.223***	(0.059)	0.121**	(0.060)
Downzoning dummy variables				
Rural areas, 1999+	0.004	(0.105)	-0.076	(0.102)
Residential, 1999+	-0.378*	(0.223)	-0.588***	(0.184)
Town Center, 1999+	-0.336	(0.643)	-0.630	(0.628)
Subdivision size and characteristics				
ln(Acres)	0.849***	(0.028)	0.937***	(0.118)
STEEP (% land in steep slopes)			-0.066*	(0.035)
ln(Acres) * STEEP			-0.004[2]	(0.003)
ln(Perimeter)			-0.182	(0.215)
ln(Perimeter) * STEEP			0.009*	(0.005)
% land in difficult soils			-0.001	(0.001)
within 1 mile of Patuxent River/Chesapeake Bay			0.052	(0.065)
Sewers			0.369[2]	(0.279)
Surrounding land uses				
% surrounding land in privately owned agricultural preservation status			-0.010***	(0.003)
% surrounding land in parks			-0.010*	(0.0055)
% surrounding land in another subdivision			0.0003	(0.0012)
% surrounding land in commercial/industrial zone			0.0002	(0.004)
Accessibility variables				
Location 2			-0.078	(0.069)
Location 3			-0.090	(0.072)
Location 4			-0.014	(0.100)
Location 5			-0.083	(0.078)
Location 6			-0.174[1]	(0.113)
ln(Distance to Route 2/4)			-0.059**	(0.024)
Access to town centers			0.901***	(0.324)
Time trend	-0.003	(0.006)	-0.004	(0.006)
Average Annual TDR Price ($1999)	0.00006	(.00004)	0.00003	(0.00004)
Constant term	-0.907***	(0.164)	0.405	(1.502)
R^2	.736		.761	
No. of Observations	398		398	

***Indicates statistically significant at the 99% level; ** at the 95% level; * at the 90% level; [1]85% level; and [2]at the 80% level.

approximately 22% more lots were built, on average. However, there is little effect on density in the residential areas – the coefficient is not statistically significant. Thus, the TDR program led to some increased density, but only in the rural receiving areas, and even in these areas, not by nearly as much as was allowed by law.

In 1992, some rural regions were taken out of TDR receiving area status. We expect the coefficient on the variable "FCD areas added to DAA, 1992+" to be negative, because developers building there after 1992 would no longer be allowed to use TDRs to increase density. It is of the expected sign, and indicates that density is about 15% lower in these areas after 1992.[22] Finally, subdivisions built in rural receiving areas and located within one mile of a Town Center were allowed to purchase additional TDRs.[23] These areas would be expected to have higher density, perhaps due to their close proximity to more densely populated areas. Indeed, the coefficient is positive and significant; density is approximately 12% higher, on average, than in the rest of the rural TDR receiving regions after 1981.

Downzoning. The next three variables examine the effect of the 1999 downzoning. In Table 1 and its accompanying text, we explained that baseline zoning in both the rural and residential areas was reduced by about 50% in 1999 but that subdivisions in most of these areas could go back to the previous zoning limits with the purchase of TDRs. This makes for an interesting test of the effects of the regulatory constraints relative to economic factors. To get to the density levels allowed prior to 1999, developers now had to incur an extra cost, the cost of purchasing TDRs (see Figure 2). The results suggest that developers found the extra expenditure worthwhile in the rural areas but not in the R1 and Town Center zones. We can see this from the fact that the coefficient on the "Rural areas, 1999+" variable is not significantly different from zero, thus average density of new subdivisions in these areas is not statistically different from average rural density before 1999. The coefficients on the "Residential, 1999+" and "Town Center, 1999+" variables are both negative and although the Town Center coefficient is insignificant, the coefficient on "Residential, 1999+" is significant at the 99% level. This suggests that developers responded to the 1999 downzoning by reducing the number of lots per acre in new subdivisions built in these areas and chose not to purchase TDRs to get back to pre-1999 levels. In fact, new subdivision density is about 60% lower.

These results highlight the advantages of the Calvert County data for analyzing density. The TDR program combined with the downzoning provide an interesting way to look at the effects on residential density of zoning limits vis-à-vis economic factors. In Calvert, it appears that the costs to developers of achieving higher density are not worth the benefits in the higher density residential areas but are worth the benefits in the relatively low density rural areas. We now turn to the economic factors likely to influence density.

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 nearly

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[22] Note that the coefficient is significant at only the 80% level.
[23] As mentioned in Table 1, density in these areas could go as high as 1 lot/acre with the use of TDRs.

1, indicating that increasing the amount of available acreage by a given percentage leads to approximately the same percentage increase in the number of lots built.[24]

The state of Maryland has developed a soil classification system based on the suitability of soils and topography for agriculture and residential development. We know the percentage of the subdivision acreage that falls into each of the soil and land types. From this, we construct a variable that shows the percentage of the total subdivision acreage that is steeply sloping. We find that the coefficient on this variable is negative as expected and significant at the 90% level. We also include a variable to account for the effect steep slopes may have on the relationship between the size of the parcel and the number of lots. The variable that interacts size and the percent steep slopes (*ln(acres)*% land in steep slopes*) 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 significant at only the 80% level.

The variable *ln(perimeter)* is a measure of the shape of the subdivision. It is calculated as the natural log of the length of the perimeter of the subdivision, holding subdivision acreage constant. For a given acreage, the longer the perimeter, the more irregular will be the shape of the parcel. It may be more difficult or costly to build a large number of lots on an irregularly-shaped tract of land compared with one that has a more regular shape, thus we expect this coefficient to be negative. The estimated coefficient is negative, but is not significant. We also interact this shape parameter with the steep variable, expecting that the shape of the subdivision footprint might also result in some interaction with the amount of steep slopes to affect the building potential at the site. Somewhat surprisingly, we find the coefficient to be small but positive on this interaction term, indicating that the more irregular the shape, the less the effect of steep slopes on the number of lots that can be built.[25]

In addition to the shape and topographical characteristics of the site, we control for the quality of the soils in the subdivision. We find the coefficient on our "difficult" soils variable to be negative as expected, but small in magnitude and not significantly different from zero. This finding that soils are not important in determining density could be because recent advances in wastewater management technologies may have reduced the importance of soil characteristics in housing site locations (LaGro, 1994).

We also include a dummy variable that measures whether the site is within 1 mile of the Patuxent River or the Chesapeake Bay. Subdivisions in these locations may be developed less densely, because consumers may demand larger lot sizes in such locations and because the state's "Critical Area" designations may limit density near the Bay and the river.[26] On the other hand, these are desirable locations so we might expect more building, and thus higher density, in these areas, all else equal. It is possible that these two effects offset because although the coefficient is positive, it is not significantly different from zero.

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[24] More precisely, however, when evaluated at the sample mean of STEEP, the elasticity of lots with respect to total plat area decreases slightly to 0.802 (0.072). The coefficient on the STEEP-plat interaction term is discussed below.

[25] In fact, when evaluated at the sample mean of the perimeter (and total plat area), the elasticity of STEEP becomes 0.0007 (0.0008).

[26] For more about Critical Areas, see Walls and McConnell (2004).

The final subdivision variable is a variable that indicates whether the subdivision is in an area that has access to the sewer system. Developments that can tie into the sewer system will not have to develop alternative sewage treatment or septic systems. We expect adjacency to sewer systems will increase the number of houses that can be built, and we do find the coefficient is positive and significant at the 80% level. Density is roughly one-third higher in these areas.

Surrounding land uses. The uses of the lands surrounding the subdivision site may affect how densely the subdivision itself is developed. Recall that the surrounding land uses are those in effect at the time the subdivision is built. In Table 5, we include four surrounding land variables: the percentage of land on the perimeter of the subdivision that is (i) permanently preserved in farmland or forestry (either through the TDR program or one of the state easement programs), (ii) parkland, (iii) another subdivision, or (iv) a commercial/industrial property.

One of the criticisms often voiced about the Calvert TDR program, particularly from farmland preservation advocates, is that TDR sending areas – farms and forests targeted for preservation – are not geographically separated from TDR receiving areas. There is a worry that preserved tracts will be non-contiguous and development will be intermingled with farming, and that this will limit the viability of agriculture (Daniels, 1997). Although we are not modeling the location decision and thus cannot fully address this issue here, our inclusion of the surrounding land variables in the model will indicate whether the free market tends to put more or less dense subdivisions next to preserved farms.

The results in Table 5 support the notion that subdivision density will be lower if the subdivision is located next to permanently preserved, privately owned land. The coefficient on land in preservation is negative and statistically significant. The coefficient on the preservation variable indicates that a 10 percentage point increase in the amount of preserved farmland on the boundary of the subdivision leads to a 10% decrease in the number of lots built in that subdivision. A difference in the percentage of surrounding land in parks has a similar effect on subdivision density.

The greater the percentage of a subdivision's boundary that is public parkland, the lower the density of the subdivision. Although surrounding parkland would seem valuable and more of it would thus lead to more lots built in a given subdivision, this seems not to be the case in our urban fringe location. This is consistent with recent hedonic studies of the value of open space which show that while parks are highly valuable in urban locations, they seem to add no value to houses in suburbia (see Anderson and West, 2003, for example, and the literature review in McConnell and Walls, 2005).

The percentage of a subdivision's boundary that is in either a commercial/industrial status or another subdivision does not appear to affect density. Neither coefficient is statistically significant.[27]

[27] We explored more specific ways that surrounding land uses might affect subdivision density, especially the density of the existing residential densities 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.

<u>Accessibility</u>. According to the conventional urban models, higher density development should take place in regions more accessible to major cities and closer to the highways leading to those cities. In the case of Calvert County, this means that we expect subdivisions in the northern and north-central regions of the county to be denser than those in the southern areas. To capture this effect, we create six location dummy variables for six regions of the county. The omitted region is the northern most area – from the northern border of the county down to the Town Center of Dunkirk. The remaining five locations are delineated by other towns located along the major commuting highway, Route 2/4. This is a reasonable approach since these towns have traffic lights and are often bottlenecks during commuting hours.[28] The signs of the coefficients on the location dummies are all negative, although only the region most distant from the top of the County (region 6) is close to being significant. That region is about 17% less dense than the northern region.

In addition to the subdivision's distance from major cities, we also expect subdivisions that are farther from major roads and commercial areas to be less dense. We find the subdivision's proximity to the major commuting road, Route 2/4, to be as expected: a subdivision that is 10% farther away from the major road is 0.6% less dense. We measure proximity to shopping and other commercial areas by the subdivision's location relative to the Town Centers in the County. To do this we create a simple gravity index that is increasing in the size of the eight major town centers and decreasing with distance from the subdivision location. 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. We find that the higher the value of the index, the greater is subdivision density and the coefficient is highly significant.

We include a time trend in the estimates, to pick up any general trend in density that may have occurred over this relatively long time scale of the analysis. We expect that the trend would have been toward less density over time, due to declining commuting costs and increasing demand for large lots through most of this period. The coefficient is negative but is not significant.

Finally, because the cost of purchasing TDRs should affect a developer's decision about how many lots to build in a subdivision, we include the annual average price of a TDR, in inflation-adjusted terms, as an explanatory variable. We find that it is not statistically significant in explaining differences in density. This may be because in the period after about 1993, the price was relatively constant, rising only slightly each year. (See McConnell, Kopits and Walls (2003) for more detail on TDR prices.)

[28] We also estimated versions of the model that had a continuous variable measuring distance to the northern border of the county. The distance variable had a negative and statistically significant coefficient but because of the location of the Town Centers at points along the north-south highway, we chose to use the dummy variable approach.

In summary, we find that zoning restrictions do have the expected effects on density of subdivisions. Reductions in allowable density, for example in 1975 and again in 1999, did result in lower density development. Furthermore, the TDR program appears to have the intended effect on density in different regions, although there is a clear preference on the part of developers to use TDRs to increase density in the rural areas and not the higher density areas the County would prefer to target for growth. We also find many of the economic variables – including physical site characteristics, accessibility measures, and surrounding land uses – have a significant influence on density. We would like to be able to say more about the how the zoning constraints are influencing density decisions that would otherwise be made on economic grounds. In order to do this, we now turn to an alternative way of estimating the model that will allow us to make some predictions about what density levels would have been in the absence of the zoning rules.

B. Estimation of Censored Model, and Forecasts of Development Patterns

An alternative and useful way to estimate the density function is to employ a censored regression framework. This specification is consistent with the model described in equation 1 and Figures 1 and 2 above, because some subdivisions are actually constrained by zoning limits and others are not. Each subdivision faces a different limit on the number of lots that may be built; this limit depends on the zoning rules and whether TDRs can be purchased where it is located, in the year that the subdivision is recorded. Some will be constrained and others will not be, and actual density will be a function of only the economic variables. 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 development patterns if the constrained subdivisions were not constrained.

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 would be allowed under baseline zoning or under maximum TDR purchases in TDR regions, however, then the choice over density is constrained and l_i is treated as right-censored. The model may be written as:

$$\ln(l_i)^* = a + B_1 \ln L_i + B_2 n_i + B_3 u_i + B_4 d_i + B_5 s_i + B_6 p_{TDR} + e_i$$

$$l_i = l_i^* \quad \text{if } l_i^* < \bar{l} \qquad\qquad (3)$$

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

where $\bar{l} = L_i/\bar{Z}_i$, $\bar{Z}_i$ is the zoned minimum average lot size for subdivision i,
and L_i = subdivision size, in acres
n_i = vector of subdivision natural amenities
u_i = vector of neighboring land uses at the time subdivision is built
d_i = vector of accessibility variables
s_i = vector of soil and topography characteristics
p_{TDR} = average TDR price

We estimate equation (3) as a censored regression, with observations censored if the density is up against a baseline zoning or TDR constraint. These constraints differ depending on the location and the rules in place at the time the subdivision is recorded. As can be seen in Table 3, 30 observations in the dataset, about 8% of the sample, are censored.

Most of the estimated coefficients on the economic variables in the censored model have the same sign and are of similar magnitude to the coefficients estimated above in the OLS model. The subdivision size, physical characteristics, and the surrounding land use variables appear to have a consistent effect on density in the two models. The presence of sewers has a larger, more significant effect on density in this model; holding all else equal, sewer service increases the number of lots by nearly 50%. Also, most of the accessibility variables are similar to the OLS results except increased proximity to Town Centers is found to have a larger impact on the number of lots in the censored regression. We include one additional variable as a subdivision characteristic, a dummy variable equal to one if the subdivision is located in a residential or Town Center area. This dummy should capture any amenities from separation of uses that residential zoning provides (Fischel, 1967; Rolleston, 1987) – e.g., benefits to residents from being separated from agricultural properties. The coefficient on this variable is positive and significant as expected. Both the time trend and the TDR price are statistically significant in the censored regression. The negative coefficient on the time trend suggests that density has been declining over time, all else equal. Unfortunately the sign on the TDR price coefficient is positive, contrary to intuition. However, the magnitude of the coefficient is so small – a $1000 increase in the average price of a TDR leads to a 0.09% increase in the number of lots built – as to make the variable economically insignificant.

Using the Censored Model to Predict

We can use the estimated model from Table 6 to predict what development densities would have been if the zoning rules had not been in place. As described above, only 8% or 30 of the 398 subdivisions are censored, or are at the limit of the zoning restrictions at the time and place at which they were built.

We first use the results from Table 6 to predict the number of lots using the values of the independent variables for each subdivision. We do this for all 398 subdivisions and find that the equation predicts quite well. The mean number of predicted lots is 25 with a standard deviation of 21. The actual mean number of lots is 27 with a standard deviation of 31.50. If we compare the predicted and actual number of lots just for the 368 subdivisions that are not censored, we find that the difference is about the same as for the whole sample.

What is of most interest is to use the equation to predict the number of lots or the density for the 30censored observations. The difference in the predicted and the actual lots for those 30 subdivisions is about 2.31, with more lots, or higher density, in the predicted equation as expected. The predicted number of lots is 23.51, with a standard deviation of 16.57, and the mean actual number is 21.2, with a standard deviation of 19.03. This suggests that there was not much excess demand for additional lots, above the zoning constraint.

Table 6. Censored Regression of Subdivision Density
(with robust standard errors)[29]

Dependent Variable: ln(Lots)	coeff.	s.e.
Subdivision size and characteristics		
ln(Acres)	0.922***	(0.134)
STEEP (% land in steep slopes)	-0.082**	(0.035)
ln(Acres) * STEEP	-0.004*	(0.003)
ln(Perimeter)	-0.238	(0.237)
ln(Perimeter) * STEEP	0.011**	(0.005)
% land in difficult soils	-0.001	(0.002)
within 1 mile of Patuxent River/Chesapeake Bay	0.044	(0.066)
Sewers	0.494*	(0.280)
Residential/Town Center dummy	0.750***	(0.091)
Surrounding land uses		
% surrounding land in privately owned agricultural preservation status	-0.008***	(0.003)
% surrounding land in parks	-0.011*	(0.006)
% surrounding land in another subdivision	0.0003	(0.0013)
% surrounding land in commercial/industrial zone	0.0008	(0.0038)
Accessibility variables		
Location 2	-0.083	(0.070)
Location 3	-0.083	(0.075)
Location 4	-0.036	(0.101)
Location 5	-0.020	(0.080)
Location 6	-0.171	(0.124)
ln(Distance to Route 2/4)	-0.079***	(0.026)
Access to town centers	1.410***	(0.241)
Time trend	-0.011**	(0.005)
Average Annual TDR Price ($1999)	0.00009***	(0.00004)
Constant term	1.534	(1.649)
No. of observations	398	
No. of right-censored observations	30	
Pseudo R^2	0.4978	

***Indicates statistically significant at the 99% level; ** at the 95% level; * at the 90% level

Considerable differences exist, however, across locations and time periods. Table 7 shows the results of the actual and predicted average lot sizes for the 28 constrained subdivisions in rural areas by zoning limits and year.[30] Before 1975, the average actual lot size for the constrained subdivisions in rural areas is at the regulatory limit of 3 acres.

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[29] We again test for spatial autocorrelation, this time using a Kelijian-Prucha (K-P) variation of the Moran I test for censored regression (Kelijian and Prucha, 1999). We can not reject, at the 95% confidence level, the null hypothesis that no spatial correlation exists. The test statistic is 1.456 and 1.394 for the row-normalized and non row-normalized weighting specifications, respectively.
[30] We omit the 2 subdivisions in residential areas since this sample size is so small.

The average predicted lot size is slightly smaller (meaning more dense development), at 2.65 acres. From 1975 to 1982, the average lot size of the constrained subdivisions in the rural areas was 5 acres, while the predicted lot size was approximately 3 acres in the rural areas outside the DAA areas and nearly 4 acres in the DAA areas. These predicted average lot sizes are 40% and 20% below the constrained average, thus the differences are substantial. Developers would have preferred to build to a higher density in these locations. Our results suggest that, over the sample period, 29% more lots would have been built in the 20 subdivisions that are most constrained by the zoning regulations. Of all the subdivisions built in areas facing a 3- or 5- acre minimum lot size requirement, this translates to approximately 10% more lots. It is important to point out, however, that subdivisions with 3- and 4-acre average lot sizes would still have to be considered very low-density developments.

Table 7. Actual and Predicted Lot Sizes by Time and Location for the 28 Censored Subdivisions in Rural Areas

Minimum average lot size	Zoning areas and years applicable	Number of Subdivisions	Average actual lot size (acres)	Average predicted lot size (std dev)
3 acres	All rural areas before 1975	5	2.99	2.647 (0.26)
5 acres	Rural areas outside the DAA, 1975-1982	8	4.86	2.91 (0.54)
	DAA areas, 1975 on	7	5.03	3.86 (0.67)
2 acres	Rural areas outside the DAA, 1983 on	8	2.02	2.62 (0.26)

With the introduction of TDRs, the maximum allowed density in the rural areas outside the DAAs (also known as Rural Communities (RCDs)) increased and minimum lot sizes fell from 5 acres to 2. Our predicted lot sizes from the censored model suggest that this new limit is approximately what the market demands. The predicted average lot size is 2.67 acres for these subdivisions compared to the actual average lot size of 2.02.[31] This is consistent with evidence above that the constraints on density arising from zoning

[31] In estimating the censored model, we assume that any subdivision that we observe being at the limit of the number of allowable lots is censored. However, it is possible that some of those subdivisions are at exactly the profit-maximizing level (see Figures 1 and 2 above). This may be the case for these 8 subdivisions built in the RCD 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.

regulations, at least in Calvert County, are in the more rural, out-lying areas, and that residential areas seem to have zoned density consistent with market outcomes.

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 density of development at the disaggregated, subdivision level, and studied the relative influence of zoning rules versus market forces. Some observers have argued that it is low density zoning that forces developers to build at lower densities than they would like and is a major cause of sprawl. On the other hand, economic factors can influence the density of development on a site – developers may be giving households the lot sizes and spatial structure they want. Variables that affect the revenues and costs of building a particular number of lots, such as subdivision size and shape, soil and topography characteristics, accessibility to urban centers and surrounding land uses may all be important. We find that both zoning rules and economic variables are important in determining density. A statistical test of the hypothesis that zoning rules alone explain density patterns across subdivisions within the county we study is strongly rejected in favor of a model in which both zoning and economic factors determine density. In fact, the economic factors appear to be particularly important in the case reviewed here. Only about 8% of subdivisions were at the zoning constraint on density.

Our results suggest that factors that affect both the value and cost of additional lots are important in the density decision. We find that the size of the land area to be developed 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. An increase in the percentage of surrounding land that is parkland or farmland under conservation easement (permanently preserved from development) decreases the number of lots developed on a given site, though the magnitude of the effect is very small. Accessibility to sewers, to the major highway in the region, and to town centers are all important determinants of density.

Our empirical analysis highlights the usefulness of TDRs to change the density of residential development. The county we study, Calvert County, Maryland, has had a long-running and very active TDR program. In fact, the TDR program helps give us more variability in density in our dataset. We found evidence that allowing TDRs in certain areas did increase the density of new subdivisions but did so mostly in rural areas. All else equal, the introduction of TDRs increased the number of lots in rural subdivisions by about 26% but had no statistically significant effect on subdivisions in residential areas. In addition, density decreased in areas that were switched from receiving to sending areas for TDRs – i.e., areas where the county hoped to limit development. Thus, the TDR program did work to redirect density. However, TDRs had a greater effect in the relatively lower-density rural receiving areas than in the residential and Town Center areas. The county is having only limited success in encouraging higher density development in established towns, one of the key components of so-called "smart growth." Zoning rules themselves appear to have little effect on density in these areas that permit relatively higher-density development without TDRs. Results from our censored regression model confirm that the main areas constrained by the zoning limits are not the residential and Town Center areas but rather the rural areas. Even in these rural zones, the percentage of subdivisions that are constrained is only about 10%, and although lot sizes in these areas would have been smaller without zoning, they would still have relatively low density (3 or 4-acre lots, compared to 5-acre).

These results suggest that it may be quite difficult to use policies such as TDRs or others to direct density to more urbanized areas, which is the goal of many anti-sprawl policies. If these areas have no demand for higher density, either because incoming households are satisfied with either existing or lower densities, or because existing residents don't want higher density, then policies to redirect growth toward them will have to be carefully considered. One important caveat is that while Calvert County is typical of many ex-urban, fast-growing rural areas around large metropolitan areas, the results may be somewhat different in the case of a more urban or older suburban area. Zoning rules may be binding and the market may desire higher density development than it is currently getting.

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