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Making Markets for Development Rights Work

What Determines Demand?

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Abstract

Many economists see current land use patterns as inefficient due to various market failures, and planners argue that current patterns do not follow sound planning practice. One policy of interest to both groups is transferable development rights (TDR). TDRs allow the development rights from land that is preserved in an undeveloped state to be transferred to other areas where development can be made denser. This paper addresses one of the greatest difficulties that TDR programs face—insufficient demand. We develop a simple theoretical model and estimate a TDR demand function using data from Calvert County, Maryland, one of the only regions where data on individual sales are available. We find that baseline zoning is a critical determinant of TDR demand—demand is high in low-density rural areas but not in the relatively high-density residential areas. We also identify subdivision characteristics that are significant in explaining TDR use.

Key Words: housing density, zoning, transferable development rights

JEL Classification Numbers: R14, R15, R52

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Elizabeth Kopits, Virginia McConnell, and Margaret Walls*

1. Introduction

There is widespread interest both in preserving undeveloped land as either farmland or open space and in reducing the problems associated with rapid suburban and exurban growth. Many economists see current land use patterns as inefficient due to various market failures, and planners argue that current patterns do not follow sound planning practice (Brueckner 2000; Levine 2006). One policy for promoting better land use that has been of interest to both groups is the establishment of transferable development rights (TDR) markets. These markets have the potential to preserve farmland or open space and to make developed areas more compact. Because they use private markets to achieve these goals, TDRs may result in more efficient land allocation without requiring the expenditure of public funds.

In practice, however, most TDR programs have not worked as well as advocates had hoped. Keeping these created markets active requires adequate incentives for landowners to sell their development rights and a strong demand for higher density development than is permitted under baseline zoning rules. This paper addresses one of the greatest difficulties faced by many programs: insufficient demand for development rights. We develop a simple model of the demand for TDRs and estimate the TDR demand function for a region with a long-standing TDR program.

TDRs are a market-based, local planning tool used to protect open land from development. They sever ownership of the right to develop property from ownership of the property itself, creating a market in the development rights. Typically, TDR programs work by first down-zoning properties in so-called sending areas—that is, restricting development in those areas—and then allowing landowners to sell their development rights as a means of

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compensation. Those rights can be used to increase the density of development in other regions, called TDR receiving areas.

Approximately 142 TDR programs are in existence in the United States, with goals ranging from farmland preservation and protection of environmentally sensitive areas in suburban and exurban locations to building height limits and historical preservation in urban areas (Pruetz 2003). Many of these programs, however, are inactive. TDR programs have preserved an estimated 90,000 acres of land (American Farmland Trust [AFT] 2001), for example, but nearly half of those acres are from the much-discussed program in Montgomery County, Maryland. Only eight programs, according to AFT, have preserved more than 1,000 acres each.

TDR markets can be inactive because landowners do not want to participate by selling TDRs, but more often it is the demand side of the market that is the problem. Since TDRs allow developers to build more houses on a given number of acres, each house built will have a smaller lot than under baseline zoning. Developers have to believe that they will be able to sell such houses and cover the additional costs incurred from purchasing TDRs. There are a number of possible explanations for the lack of demand in the market for these rights. In some areas, lack of available infrastructure or environmental constraints limits the potential for higher density development. In others, baseline zoning is set at such a level that developers feel homebuyers are satisfied with the existing density. Or, even if there is demand for higher density development, existing residents may try to block or delay new, relatively dense development in their neighborhoods.

It is important to understand how TDR markets work and to explore ways to make them more effective at achieving their higher density goals. In a theoretical model, Mills (1980) shows that TDRs produce efficiency gains in land markets and distribute the gains from development more equally among landowners than do direct land use controls. Thorsnes and Simon (1999) derive similar results in a graphical analysis and also argue that TDRs are likely to have much lower administrative costs than alternatives such as a purchase of development rights (PDR) program, a combined development tax/PDR program, and strict zoning. Mills (1989) emphasizes a further point: that TDRs are likely to mitigate the rent-seeking behavior that is commonplace with zoning. Carpenter and Heffley (1981; 1982) focus on the spatial equilibrium outcomes from a TDR market. Their simulation results show that the extent of any efficiency benefit depends on how the TDR program is set up, the elasticity of the supply of residential space, and several other factors. In contrast, Johnston and Madison (1997), in a view that seems to be shared by many in the planning community, see the major role of TDRs as compensating landowners for down-

zoning and as a way of preserving specific geographic areas of land. Finally, the incentives provided by TDRs and how they are best used in combination with broader land use policies are emphasized by Fulton et al. (2004).

What is missing from the literature is empirical analysis of TDR markets. In a recent paper, McConnell et al. (2006b) analyze the factors that explain overall residential density in Calvert County, Maryland, a rapidly growing county on the fringes of the Washington, DC, metropolitan area. The main purpose of that paper was to examine whether zoning limits are the primary cause of low-density development or whether market forces tend to dictate this outcome. Calvert County's TDR program was incorporated into the empirical analysis as an added cost of building more lots, and we found evidence that allowing the use of TDRs in certain areas did increase the number of lots in new subdivisions. In this paper, we delve further into the details of the demand for TDRs in the Calvert County program, examining why TDRs are used in some locations and not in others and the factors that affect TDR use. Although Calvert has one the longest running, active TDR programs in the country—the sale of TDRs has built more than 2,100 houses and permanently preserved more than 13,000 acres of farmland—only about a third of the subdivisions built during the 1982–2001 period were built using TDRs.

In this paper, we attempt to examine which subdivisions use TDRs, how many they use, and the factors that determine demand. The next section provides a simple theoretical model of a developer's decision over TDR use. Background on land uses in Calvert County, the TDR program, and underlying zoning in the county is explained in section three. Section four describes the data used in the econometric model and provides the econometric results. Section five concludes.

2. The Developer Decision: Choice over the Use of TDRs

We construct a simple model of the developer's decision about whether to buy TDRs to achieve greater density at a development site. We restrict the analysis to the decision in receiving areas only. That is, we assume that the development site is in a region where the developer is permitted to purchase TDRs (up to some limit) to create a larger number of lots than the baseline zoning will allow. The question for developers is, given that TDRs can be used, should they use them, and, if so, how many?

We assume that the developer already has made the decision about where to build and is deciding about whether to use TDRs to increase density at that site. While it is true that the developer could make the decision about the use of TDRs jointly with the decision about where

to build, there is evidence, at least in the jurisdiction we are examining, that these decisions are separate. Many developers in high-growth suburban areas will build a subdivision on virtually any greenfield site that becomes available to them. Thus, they will purchase land for development where and when they can (Jaklitch 2004). For each parcel, the developer makes an individual decision about whether to use TDRs.

The decision to use TDRs is derived from the profit maximizing decision that developers make about how densely to build on any parcel.¹ We assume developers build the number of lots on a given site (i.e., choose density) to maximize profits. The decision to use TDRs depends on whether profits can be enhanced by the additional density that TDRs allow. In addition, the developer faces the zoning and TDR purchase limits at any given location.² Revenues, R_i , depend on the number of lots in subdivision i , l_i , and 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 also depend critically on the amenity characteristics of the site. These include natural amenities of the site itself, n_i , such as the number of trees and topography, and land uses of the properties immediately surrounding the site, u_i . The surrounding land uses can have a complex effect on the value of development. There may be increased value from being adjacent to similar 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. Or, higher density surrounding residential uses might make higher density of the new subdivisions more likely. The opposite may result, however, if higher density of surrounding developed areas means there are more residents to object to new, 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. Finally, revenues depend on location and accessibility variables, a_i , since greater access to employment and shopping areas should increase property values.

¹ 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.

² 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 costs also are affected by the number of lots, l_i , and the size of the plat area, L_i . Soil and topography characteristics, d_i , also are important determinants of cost.³ Cannaday 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, \bar{Z} .⁴ 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. The ability to purchase TDRs allows the developer to achieve a greater density (or smaller lot size) than zoning rules would allow. In our model, developers can purchase development rights at a price determined in the market for TDRs, p_{TDR} , to build t_i additional lots.⁵ In TDR programs, however, the ability to use TDRs for greater density is not unlimited. There is a minimum average lot size even with the purchase of TDRs; hence, there is a limit on the number of TDRs that may be used in subdivision i , which we identify here as \bar{t}_i .

The developer's decision in subdivision i is to choose the number of lots, l_i , to maximize profits:

$$\max_{l_i} \pi_i = R_i(l_i, L_i, n_i, u_i, a_i) - C_i(l_i, L_i, d_i) - p_{TDR} t_i \quad (1)$$

subject to the following constraints:

$$t_i = l_i - \bar{l}_i \text{ if } l_i \geq \bar{l}_i, \mathbf{0} \text{ otherwise} \quad (2)$$

$$l_i \leq l_i^{\max} \quad (3)$$

³ For example, areas zoned for residential development may require sewers, whereas areas zoned rural are more likely to use septic systems.

⁴ Residential zoning limits are sometimes specified in terms of an absolute minimum lot size; that is, no lot can be smaller than one acre. More often, it is a minimum lot size averaged across the entire subdivision. In the application analyzed below, Calvert County uses average minimum lot size zoning.

⁵ Here we assume that only one TDR is needed to create one additional lot.

where $\bar{l}_i = L_i/\bar{Z}$ = maximum baseline density, or the number of lots that can be built on parcel i without purchasing TDRs, and

\bar{Z} is the minimum average lot size allowed without purchasing TDRs.

$l_i^{\max} = \bar{l}_i + \bar{t}_i$ = maximum number of lots that can be built on parcel i with the purchase of TDRs.

The first constraint, equation (2), shows that TDRs can be used to build additional lots beyond the baseline, but the number of TDRs must be nonnegative. The second constraint, equation (3), shows that the total number of lots built on parcel i cannot exceed the maximum number allowed under TDR purchase rules.

For convenience, let y_i represent the vector of factors that affect revenues on parcel i , (L_i, n_i, u_i, a_i) , and s_i represent the vector of factors that affect costs (L_i, d_i) . The maximization problem becomes:

$$\begin{aligned} \max_{l_i} \mathfrak{S}_i &= R(l_i, y_i) - C(l_i, s_i) - p_{TDR} t_i + \lambda(l_i^{\max} - l_i) \\ &= R(l_i, y_i) - C(l_i, s_i) - p_{TDR} (l_i - \bar{l}_i) + \lambda(l_i^{\max} - l_i) \end{aligned} \quad (4)$$

The first-order condition for (4) is an expression where the marginal revenue from an additional lot equals marginal cost plus the TDR price plus the shadow value on the zoning constraint. Using subscripts on R and C for first partial derivatives, when $l_i^{\max} > l_i^* \Rightarrow \lambda = 0$, then

$$\text{for } l_i^* \leq \bar{l}_i, R_{l_i}(l_i^*, y_i) - C_{l_i}(l_i^*, s_i) = 0, \text{ and}$$

$$t_i = 0, \quad (4a)$$

$$\text{for } \bar{l}_i < l_i^* \leq l_i^{\max}, R_{l_i}(l_i^*, y_i) - C_{l_i}(l_i^*, s_i) - p_{TDR} = 0 \text{ or}$$

$$R_{l_i}(\bar{l}_i + t_i, y_i) - C_{l_i}(\bar{l}_i + t_i, s_i) - p_{TDR} = 0, \text{ and}$$

$$t_i = f(y_i, s_i, p_{TDR}, \bar{l}_i). \quad (4b)$$

$$\text{If } \lambda > 0, \text{ then } l_i^* = l_i^{\max} \text{ and } R_{l_i}(l_i, y_i) - C_{l_i}(l_i, s_i) - p_{TDR} - \lambda = 0 \text{ and}$$

$$t_i = \bar{t}_i. \quad (4c)$$

If the profit maximizing number of lots, l_i^* , is less than or equal to the allowed number under the baseline zoning (4a), then the developer will have no demand for TDRs. If $\bar{l}_i < l_i^* < l_i^{\max}$ (4b), then the developer's demand for TDRs, t_i , will be a function of the arguments of the revenue and cost functions from equation (1), the price of TDRs, and the baseline zoning, \bar{l}_i . The developer cannot buy more than the allowed limit of TDRs, however, so if $l_i^* = l_i^{\max}$, then $t_i = \bar{l}_i$ (4c).

Any changes in the factors that affect revenues or costs from development change the optimal density, l^* . Also, different zoning rules mean different levels of profit and new constraints. Any of these can affect whether the subdivision falls under case (4a), (4b), or (4c) above. Using our detailed subdivision level data from Calvert County, Maryland, we estimate the TDR demand equation in section four and derive results for how differences in the underlying parameters affect TDR demand.

3. The Calvert County TDR Program: Background and Residential Development Outcomes

Calvert County is located in southern Maryland on the western shore of the Chesapeake Bay. The county is a 215-square mile peninsula formed by the bay and the Patuxent River estuary. The county seat, Prince Frederick, lies in the middle of the county and is approximately 40 miles southeast of Washington, DC, 60 miles south of Baltimore, and 37 miles south of Annapolis, Maryland. Although a historically rural, agriculture-based county, Calvert has seen rapid population growth over the past 20 to 30 years because of its proximity to major centers of employment. In the decade of the 1990s, it was the fastest growing county in Maryland, with a population increase of more than 45 percent, well above the state average increase of 10.8 percent. However, average population density remains low.

Over the years, the county government has exhibited increasing concern over the significant loss of farmland and open space resulting from these trends. In 1967, Calvert adopted its first Comprehensive Plan, in which all rural land was zoned to a maximum density of one dwelling unit per three acres. In 1974, the county updated the plan to reflect a "slow growth" goal and changed the maximum density to one dwelling unit per five acres. Despite the five-acre

minimum lot requirement, significant amounts of farmland were lost to development throughout the 1970s. So around 1980, the county attempted to curb the trend by adopting a TDR program.⁶

Table 1 shows the density permitted in the county since the TDR program began, both with and without TDRs. Most of the county's prime farmland and forested areas lie within the Designated Agricultural Area (DAA), though there is still a great deal of farming in the rural regions outside the DAA, which are designated as Rural Communities (RCs). As can be seen in the table, prior to 1999, TDRs could not be used to increase the density of development in the DAA; thus, these areas only could be TDR sending areas.⁷ Residential and Town Center zones are targeted TDR receiving areas, as are RCs. Figure 1 illustrates the spatial aspects of these different zoning classifications.⁸

Table 1 and Figure 1 highlight some interesting features of the Calvert County TDR program. Compared with other programs in the United States, Calvert's is one of the most unconstrained. Land in either of the rural zones can be preserved, and these areas cover many different parts of the county. Moreover, no part of the county has extremely restrictive baseline zoning. Development can occur at a maximum density of one dwelling unit per five acres of land in all rural areas. By comparison, many other TDR programs down-zone sending areas to one house per 25, 40, or even 50 acres (Pruetz 2003). Calvert's is the one of the few programs where the receiving areas are not only in high-density zones; TDRs may be used in Residential and Town Center areas, as well as in the relatively low-density zoned RCs. Landowners in the RCs may choose to either: (a) sell TDRs, thereby permanently preserving their land from development; (b) develop their land without using TDRs up to a maximum of one unit per five acres; or (c) purchase TDRs and develop to a greater density.

⁶ The county has implemented other complementary land preservation programs. In 1988, it 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. Land also has been put into protective status through numerous state easement purchase and easement donation programs. This information is summarized in Calvert County Planning Commission (1997).

⁷ In 1992, additional prime farmlands and environmentally sensitive lands were designated as sending areas only and effectively became part of the DAA. After this time, all of the sending area-only regions were referred to as Farm Community Districts (FCD) or Resource Preservation Districts (RPD). Since the original DAA is a subset of the FCD/RPD region, for simplicity we will continue to refer to the sending area-only region as the DAA and to the region that was added in 1992 as the "region added to DAA."

⁸ A little more than 40 percent of the county lies in the RCs, another 40 percent is in the DAA, and about 16 percent lies in the Residential and Town Center zones; the remainder is zoned for commercial/industrial use.

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

<i>Zoning classification</i>	1981–1998		1999 to present	
	<i>Baseline zoning</i>	<i>Density allowed with TDRs</i>	<i>Baseline zoning</i>	<i>Density allowed with TDRs</i>
Rural				
DAA	2 units/10 acres	2 units/10 acres	1 unit/10 acres	2 units/10 acres
Rural Communities	2 units/10 acres	5 units/10 acres	1 unit/10 acres	5 units/10 acres*
Residential	10 units/10 acres**	40 units/10 acres	5 units/10 acres	40 units/10 acres
Town Centers***	40 units/10 acres	140 units/10 acres	20 units/10 acres	140 units/10 acres

TDR = Transferable Development Rights; DAA = Designated Agricultural Area

* Density in Rural Communities that are within 1 mile of a Town Center can go as high as one unit/acre with the use of TDRs.

** Prior to 1999, multi-family 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.

*** The Town Center zoning classification came into effect in 1983.

The county did reduce the allowable baseline density everywhere in the county in 1999. As shown in Table 1, the baseline density was reduced by 50 percent in all zoning categories. However, TDRs could be purchased to get back to the same maximum density levels allowed prior to 1999. Hence, after 1999, all regions of the county, including the DAA, were eligible receiving areas for TDRs.

Another program change that occurred over the sample period is the “Purchase and Retire” (PAR) program the county initiated in 1993. This program allows the county to buy TDRs in order to retire them. The county also has provided better information to potential TDR buyers and sellers since 1993. The Planning Office publishes a newsletter that provides information on prices, as well as the names and telephone numbers of surveyors and engineers in the county who may know of potential buyers. These actions seem to have had some stabilizing effect on TDR prices (see McConnell et al. 2006a). The additional information provided to market participants also lowered transaction costs to developers, thereby potentially increasing the private market demand for TDRs.

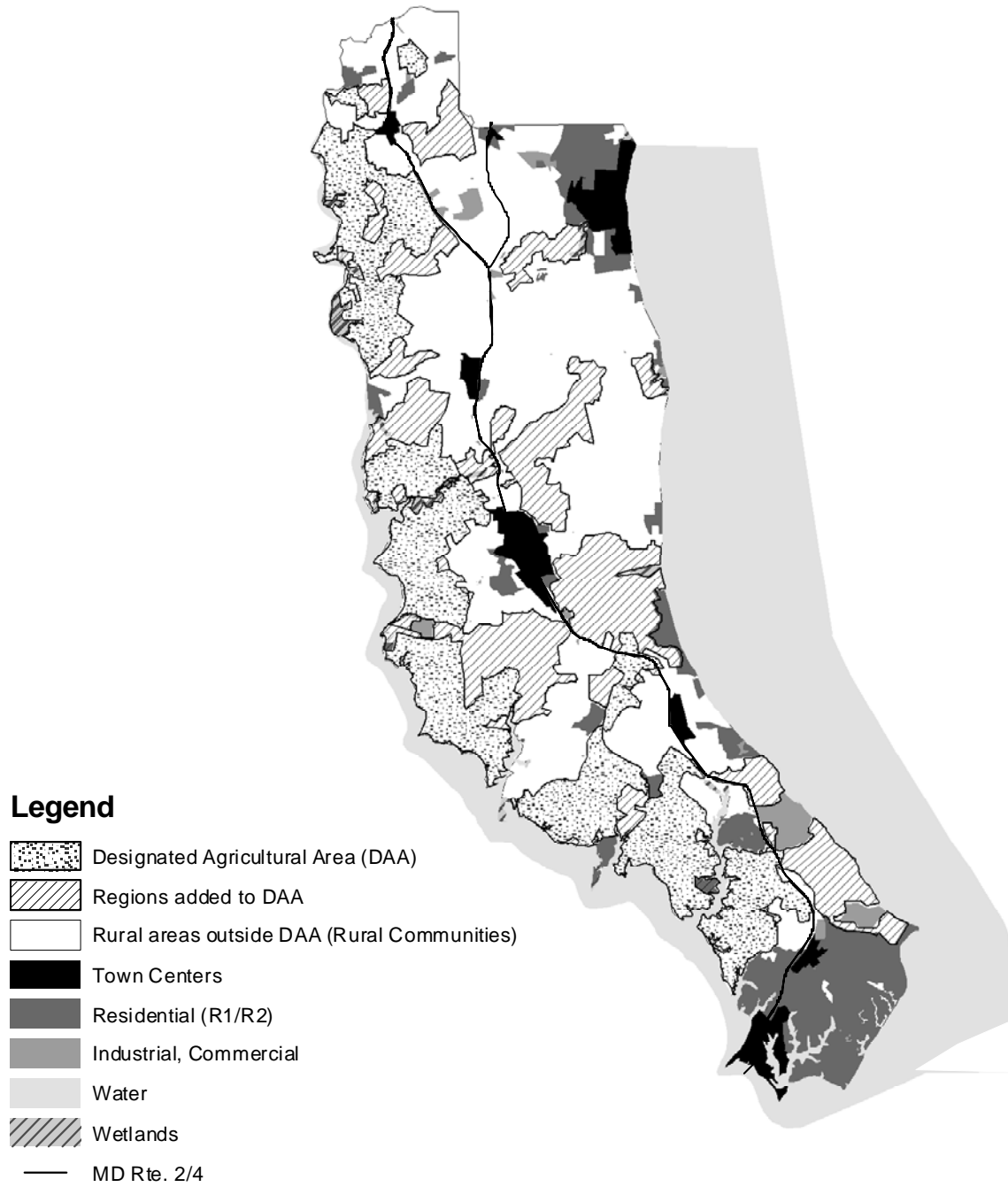


Figure 1. Zoning Map of Calvert County, Maryland

Descriptive statistics offer some indication that overall subdivision density is increasing. The average amount of acreage developed each year remained roughly constant before and after the TDR program was enacted. Annual new subdivision acreage averaged 820 acres before the program began (during 1967–1980) and 880 acres over the 1981–2001 period.⁹ The number of new lots recorded each year, however, increased by 35 percent 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.

Table 2 shows the percentages of new subdivisions developed using TDRs by zoning classification and time period. Countywide, just under 40 percent of new subdivisions recorded in the sample period used TDRs. Nearly 50 percent of subdivisions built in RCs used TDRs, however, compared with only 9 percent of subdivisions in the Residential and Town Center zones. These findings suggest that developers may have been satisfied with the baseline zoning in the residential zones but not in the RCs. The table also shows the increase in TDR usage since the 1999 down-zoning. Over 1999–2001, TDRs were used in 64 percent of new subdivisions in the RCs, and they were used to a similar degree in the DAA, where developers were allowed to purchase TDRs to achieve the pre-1999 permitted density.

Table 2. Percentage of New Subdivisions Using TDRs in Calvert County, Maryland, by Recording Year and Zoning

Zoning	Subdivision recording year			1982–2001
	1982–1992	1993–1998	1999–2001	
Residential/Town Centers	0%	5.9%	42.9%	8.9%
Rural				
DAA	0%	0%	64.3%	44.8%
Rural Communities	27.7%*	58.5%	63.6%	48.1%
Countywide	31.5%	43.1%	60.5%	39.9%

DAA = Designated Agricultural Area

*This includes the handful of subdivisions that used TDRs in the regions that were added to the DAAs in 1992.

⁹ This fact should not be construed as suggesting that the TDR program was a failure; without knowing the counterfactual, 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).

4. Estimation and Results

4.1. Specification

We estimate the developer's demand for TDRs derived in section two as a two-limit tobit model. In any spatial model, we must address the issue of unobserved spatial correlation in the error term.¹⁰ Results of a generalized Moran I test for limited dependent variables (Kelejian and Prucha 1999) clearly reject the null hypothesis that no spatial correlation exists.¹¹ Therefore, we account for any spatial correlation caused by misspecification of the regression function (e.g., omitted variables) by imposing structure on the error term of the tobit model. Rewriting (4a) – (4c) as a spatial tobit, the reduced-form equation for the optimal number of lots built with TDRs can be specified as:

$$t_i^* = f(y_i, s_i, p_{TDR}, \bar{l}_i) + u_i, \quad (5)$$

$$u_i = \rho W_i u + \varepsilon_i$$

$$t_i = 0 \quad \text{if } t_i^* \leq 0$$

$$t_i = t_i^* \quad \text{if } 0 < t_i^* < \bar{t}_i$$

$$t_i = \bar{t}_i \quad \text{if } t_i^* \geq \bar{t}_i$$

where t_i^* is the latent variable,

t_i is the observed number of TDR lots in subdivision i , and

W_i is the i^{th} row of the weighting matrix, W .¹²

As before, y_i is the vector of variables that affect revenues from development and s_i is the vector of variables that affect costs.

The corresponding log-likelihood function is given by:

¹⁰ See Irwin (2002) for a general discussion of the issue.

¹¹ 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 a row-normalized and non row-normalized weighting scheme. The Moran I test statistics were found to be 5.563 and 7.985 for the row-normalized and non-row-normalized specifications.

¹² $W = \{w_{ij}\}$ where $w_{ij} = 1$ if i and j are adjacent subdivisions and $w_{ij} = 0$ otherwise ($w_{ij} = 0$ for all i).

$$\ln \mathfrak{L} = \sum_{i \in M} \log \Phi \left(\frac{-\hat{x}_i \beta}{\sigma} \right) - \frac{1}{2} \sum_{i \in C} \left\{ \left(\frac{\hat{t}_i - \hat{x}_i \beta}{\sigma} \right)^2 + \log 2\pi\sigma^2 \right\} + \sum_{i \in R} \log \left\{ 1 - \Phi \left(\frac{\hat{t}_i - \hat{x}_i \beta}{\sigma} \right) \right\}, \quad (6)$$

$$\hat{t} = (I - \rho W)t$$

$$\hat{X} = (I - \rho W)X$$

$$\hat{t} = (I - \rho W)\bar{t}$$

where X represents the arguments of $f(\cdot)$ in (5), $\Phi(\cdot)$ is the standard cumulative normal, and σ is the standard deviation of ε_i . Observations $i \in M$ are those subdivisions not using any TDRs and are left-censored at zero. Observations $i \in C$ are uncensored, corresponding to those subdivisions where TDRs were used but the developer did not purchase the maximum number allowed. Finally, subdivisions in which the developer built the maximum number of TDR lots allowed are right-censored at the TDR limit, \bar{t}_i . Since the maximum density allowed with TDRs depends on the zoning category and year of subdivision recording, the maximum number of lots that can be built with TDRs varies by subdivision, meaning the upper limit in our tobit regression varies across observations $i \in R$. (Note that if $\rho = 0$, then (6) is the log-likelihood function for a standard 2-limit tobit model with left-censoring at zero.) We estimate the spatial tobit using the Maximum Likelihood application of the GAUSS computer package.

4.2. Data

Our sample includes all subdivisions in Calvert County that were allowed to use TDRs from 1983 (the year the first TDR was sold to a developer) to 2001.¹³ Table 3 summarizes some of the key characteristics of the sample of subdivisions that use TDRs and those that do not. In total, 228 subdivisions were built in TDR receiving areas over the 1983–2001 period, with the average subdivision built in 1992. The size of the subdivisions varies from 4 acres to almost 600 acres, and the average size of those using TDRs is roughly double that of those which did not use TDRs. The average number of TDR lots in subdivisions using TDRs is 19 but varies from 1 to 76. The second row of Table 3 shows that the number of lots allowed (i.e., the average number of lots that could be built under the baseline zoning regulations) is roughly the same in both TDR

¹³ This means that subdivisions in the DAA that were recorded prior to 1999 are not included in the sample since TDRs were only permitted in these regions after the down-zoning.

Table 3. Summary Statistics of Subdivision Sample, N = 228

Variable	Subdivisions using TDRs, N=91		Subdivisions not using TDRs, N=137	
	Mean	Std. Dev.	Mean	Std. Dev.
Number of lots built with TDRs	19.466	16.364	0.000	.
Number of lots allowed without TDRs	18.584	20.163	19.423	33.024
Total plat area (acres)	97.003	88.509	47.666	46.853
Length of subdivision perimeter (feet)	9828.813	4483.373	6606.606	3470.757
% Subdivision land in steep slopes	38.406	29.029	35.561	29.604
% Subdivision land in difficult soils	16.046	13.130	16.880	19.664
Within 1 mile of Patuxent River/Chesapeake Bay	0.143	0.352	0.241	0.429
Sewer service availability	0.011	0.105	0.044	0.205
% Surrounding land in parks or private preserved open space/farmland	1.548	4.462	3.515	9.074
% Surrounding land in open space area of another subdivision	5.940	9.893	3.619	8.367
% Surrounding land in high-density residential use	0.919	3.124	7.605	16.457
% Surrounding land in low-density residential use	33.214	20.698	29.299	21.117
% Surrounding land in commercial/industrial zone	2.502	6.716	3.858	11.720
Distance to North end of county (meters)	16995.150	9678.308	23238.860	13101.850
Distance to Route 2/4 (miles)	1.189	1.077	1.533	1.282
Access to Town Centers (index variable)	77707	741254	972508	8581315
Annual TDR price (1999 dollars)*	2188.87	441.782	2065.99	480.317
Year of subdivision recording	1993.440	5.546	1991.241	5.289
Residential/Town Center	0.044	0.206	0.299	0.460
Grandfathered parcels	0.132	0.340	0.679	0.469

TDR = Transferable Developments Rights

*The annual TDR price is calculated as the mean price paid per TDR in a given year, averaged over all subdivisions that used TDRs in that year.

and non-TDR subdivisions. The same number of lots on twice the land area again shows that the TDR subdivisions tend to be those with larger lot sizes, as indicated in Table 2 above.

The figures in Table 3 show that the average percentage of surrounding land in preserved acreage is small, less than 4 percent, but ranges from zero to 50 percent.¹⁴ Similarly, there is considerable variation in the amount of adjacent residential development; some subdivisions are completely surrounded by other development, some by no other development. The average amount of surrounding land in high-density residential use varies considerably across the two types of subdivisions; those using TDRs have on average less than 1 percent of their perimeter adjoining high-density residential development (defined as having lots smaller than one acre), whereas more than 7 percent of land surrounding non-TDR subdivisions is in high-density residential use. The average subdivision is approximately 13 miles (20,700 meters) from the northern border of the county and is about 1.4 miles from Route 2/4, the key north–south commuting highway.

Most of Calvert County relies on septic systems because the sewer system is not extensive. In our sample, fewer than 2 percent of TDR subdivisions have sewers available, and fewer than 4 percent of the non-TDR subdivisions are on sewers. Using data from the state of Maryland’s soil classification system, we are able to calculate the percentage of the subdivision acreage that falls into each of the soil and land types. From this, we construct variables that show the percentage of the total subdivision acreage that is steeply sloping (at a grade of 15 percent or higher) and the percentage in other “difficult” soils—areas that are part of a floodplain or that have stony or clay-like soils—that are relatively unsuitable for residential development or are expensive to develop. We find that the average subdivision in our sample has steep slopes in a little more than 35 percent of its land area and difficult soils in 16 percent of its land area.

The annual TDR price (in inflation adjusted 1999 dollars) averaged a little more than \$2,000 per TDR over the sample period, rising at an average annual rate of 6.3 percent from 1983 to 2001, but most of the increase occurred in the first decade of the program. Between 1983 and 1993, the average real price more than doubled, rising from \$1,211 (in 1999 dollars) to

¹⁴ 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 or parks 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.

\$2,578. Between 1993 and 2001, on the other hand, real prices remained relatively constant. In Calvert County, a developer needs five TDRs to build one additional lot; thus, over the sample period, the average cost of each TDR lot to the developer was more than \$10,000. The prices shown in Table 3 reflect the average TDR price faced by developers at the time the subdivisions were built.¹⁵ Developers who used TDRs faced slightly higher TDR prices than those who did not use TDRs.

4.3. Tobit Regression Results

The regression results are displayed in Table 4. The first column provides the tobit coefficients that show the effect of a change in the independent variables on the latent variable, t_i^* . These can be used to obtain information about the effect of changes in an explanatory variable on the observed dependent variable, t_i , for uncensored observations (McDonald and Moffit 1980). These effects are displayed in column (3) of the table. Specifically, they show the change in the expected number of TDR lots built in a subdivision given a change in the independent variable for the subdivisions that did buy some TDRs (but did not go to the maximum TDR limit).¹⁶

In addition, one can calculate the marginal effect of a change in each factor on the probabilities of crossing either the upper or lower censoring threshold. Column (2) shows the effect of a unit change in each independent variable on the probability that a subdivision will have at least one TDR lot calculated just for the subdivisions that didn't use any TDRs (i.e., the

¹⁵ See McConnell, Kopits and Walls (2003) for more detail on TDR prices in Calvert County and arguments for why the market there is competitive, with land owners and developers taking the equilibrium price as given.

¹⁶ Assuming $f(y_i, s_i, p_{TDR}, \bar{l}_i) = \beta'X_i$, where X_i is a vector of all the explanatory variables for subdivision i , and $\hat{X} = (I - \rho W)X$ as in (6), then the marginal effect of the k -th independent variable, X_k on the expected observed dependent variable, given that it is uncensored, is given by

$$\frac{\partial E(t_i | 0 < t_i^* < \bar{t}_i)}{\partial X_{ik}} = \beta_k \left[1 - \frac{\phi_{2i}(\bar{t}_i - \beta' \hat{X}_i) / \sigma + \phi_{1i}(\beta' \hat{X}_i) / \sigma}{\Phi_{2i} - \Phi_{1i}} \frac{(\phi_{2i} - \phi_{1i})^2}{(\Phi_{2i} - \Phi_{1i})^2} \right] \text{ where } \beta_k \text{ is the tobit coefficient estimate}$$

on the k -th variable and $\Phi_{2i} = \Phi \left[(\bar{t}_i - \beta' \hat{X}_i) / \sigma \right]$ and $\Phi_{1i} = \Phi \left[(-\beta' \hat{X}_i) / \sigma \right]$, with corresponding definitions for ϕ_{1i} and ϕ_{2i}

(see Maddala (1983)). The computed partial derivative is averaged over all the uncensored observations to obtain the marginal effects displayed in the 3rd column of Table 4.

left-censored observations). Similarly, column (4) gives the marginal effect of a change in an independent variable on the probability of buying less than the maximum number of TDRs allowed, calculated for the subdivisions that were observed to be at the TDR limit (i.e., the right-censored observations).¹⁷

Table 4. Spatial Tobit Regression of TDR Demand

<i>Dependent Variable:</i> Number of lots built with TDRs	(1) Coeff. (std. err.)	(2) Marginal effect on $P(t_i > 0)$	(3) Marginal effect on $E(t_i 0 < t_i^* < \bar{t}_i)$	(4) Marginal effect on $P(t_i < \bar{t}_i)$
Zoning/TDR dummy variables				
Lots allowed under baseline*Rural	-2.069 (0.580)***	0.026	-0.735	0.036
Lots allowed under base*(Residential /Town Center)	-0.315 (0.135)**	-0.004	-0.112	0.006
Residential/Town Center	-16.205 (7.329)**	-0.201	-5.758	0.284
Grandfathered parcels	-21.187 (3.085)***	-0.262	-7.528	0.371
Subdivision size and characteristics				
Acres	0.791 (0.149)***	0.010	0.281	-0.014
STEEP (% land in steep slopes)	-0.389 (0.133)***	-0.005	-0.138	0.007
Acres * STEEP	-0.005 (0.002)***	-0.00006	-0.002	0.00008
Perimeter	-0.004 (0.002)**	-0.00005	-0.001	0.00007
Perimeter * STEEP	0.00008 (0.00003)***	0.000001	0.000036	-0.000002
% land in difficult soils	-0.172 (0.085)**	-0.002	-0.061	0.003
within 1 mile of Patuxent River/ Chesapeake Bay	-4.348 (4.451)	-0.054	-1.545	0.076
Sewers	32.997 (11.292)***	0.408	11.724	-0.578

¹⁷ The marginal effect on the probability that the developer buys at least some TDRs is given by $\partial P(t_i > 0) / \partial X_{ik} = \beta_k \phi_i / \sigma$. Averaging over all the non-TDR (left-censored) observations yields the estimates displayed in column 2 of Table 4. Similarly, the marginal effect on the probability that the developer does not purchase the maximum number of TDR lots allowed is given by $\partial P(t_i < \bar{t}_i) / \partial X_{ik} = -\beta_k \phi_{2i} / \sigma$; the mean value (for the right-censored observations) is shown in the 4th column.

Table 4 (continued)

Surrounding land uses				
% surrounding land in parks or privately owned agricultural preservation status	-0.493 (0.211)**	-0.006	-0.175	0.009
% surrounding land in open space of another subdivision	-0.069 (0.130)	-0.001	-0.024	0.001
% surrounding land in high-density residential use	-0.390 (0.209)*	-0.005	-0.139	0.007
% surrounding land in low-density residential use	-0.131 (0.069)*	-0.002	-0.047	0.002
% surrounding land in commercial/industrial zone	-0.365 (0.161)**	-0.005	-0.130	0.006
Accessibility variables				
Distance to North end of county	-0.001 (0.000)***	-0.00001	-0.00021	0.00001
Distance to Route 2/4	-1.953 (1.526)	-0.024	-0.694	0.034
Access to town centers	0.361 (0.495)	0.0040	0.128	-0.0056
Time Trend (4-segment spline)				
1983–1987:	5.778 (3.399)*	0.071	2.053	-0.101
1988–1992:	3.559 (2.216)	0.044	1.265	-0.062
1993–1998:	1.055 (0.891)	0.013	0.375	-0.018
1999–2001:	-1.225 (2.798)	-0.015	-0.435	0.021
Annual TDR Price (\$1999)	-0.017 (0.013)	-0.0002	-0.006	0.0003
Constant Term	31.690 (14.144)**			
sigma	12.717			
rho	0.3986			
No. of observations	228	137	80	11
No. of observations: 228, Left-censored: 137, Uncensored: 80, Right-censored: 11				

TDR = Transferable Developments Rights

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

Zoning/TDR variables. The variables that capture the baseline density limit (i.e., the number of lots that can be built without TDRs, \bar{l}_i) across different zoning categories are negative and highly significant, as expected.¹⁸ Holding subdivision size constant, the first coefficient suggests that an increase in \bar{l}_i leads to fewer TDR lots. On average, TDR subdivisions in rural areas (RCs and in the DAA after 1999) will build 0.7 fewer TDR lots for each additional lot that is allowed without the purchase of TDRs. In addition, a 10 unit increase in \bar{l}_i causes a 0.26 decline in the probability that a rural subdivision will use any TDRs and a 0.36 increase in the probability that a subdivision does not go to the maximum TDR limit.

Increases in the baseline zoning allowance have a much smaller impact on TDR demand in the Residential and Town Center zones. On average, one less TDR lot is built for each 10-unit increase in \bar{l}_i in those subdivisions already using some TDRs. This is in addition to the general negative effect that the Residential/Town Center designation has on TDR demand. On average, TDR subdivisions in Residential/Town Centers buy approximately six fewer TDR lots than those in the rural areas (third row). Also, a Residential or Town Center designation causes a 0.20 decline in the probability that a non-TDR subdivision would purchase any TDRs and a 0.28 increase in the probability that a subdivision does not go to the maximum TDR limit. This supports evidence from Table 2 that subdivisions going into the more densely zoned Residential or Town Center areas are less likely to buy TDRs than subdivisions going into the RCs.

We can also use the results to examine the effects of the 1999 county-wide down-zoning. As shown in Table 1, the 1999 down-zoning reduced the baseline density by 50 percent in all zoning categories. However, TDRs could be purchased to get back to the same maximum density levels allowed prior to 1999. The results suggest that developers found the extra expenditure more worthwhile in the rural areas than in the Residential and Town Center zones. For example, in a 100-acre rural subdivision that uses TDRs, the 1999 down-zoning reduced the baseline zoning, \bar{l}_i , from 20 to 10 houses. The estimated coefficient in column (3), row 1 indicates that this would have lead to seven additional TDR lots. The same subdivision in a Residential/Town

¹⁸ It is important to note that we treat the baseline zoning variables as exogenous in this model. It has been argued in the literature that local zoning is likely to be endogenous (Rolleston, 1987; McMillen and McDonald, 1990, 1991; McDonald and McMillen, 2004). 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, the only downzoning that occurred over the sample period was countywide and was a result of concern over population growth and the size of the transportation system.

Center zone would have experienced a 50 unit drop in number of lots permitted without purchasing TDRs, leading to only five more TDR lots (see column (3), row 3).

We also have included a dummy variable to control for the presence of grandfathered lots, since grandfathering essentially allows for a few additional lots without requiring TDRs. Unlike many local governments, Calvert County generally does not allow rezonings or exemptions to baseline 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. The “grandfathered parcel” variable is a subdivision specific dummy variable equal to one if the subdivision had some grandfathered lots from less restrictive densities in place in earlier years. We find, as expected, that for the subdivisions that purchase TDRs, the presence of grandfathered lots reduces the number of TDR lots by seven, all else equal. Adding grandfathered lots also reduces the probability that any TDR lots will be purchased by 0.26 and increases the probability that a subdivision will not reach the TDR limit by 0.37.

Subdivision size and characteristics. Among the key subdivision characteristics included here is the total size, shape, and topography of the subdivision. Total subdivision acreage and the percentage of land that is in steep slopes (*STEEP*) enter the equation both separately and interactively. The length of the perimeter of the subdivision (*Perimeter*) is included as a measure of the shape of the subdivision. 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. We also interact this shape parameter with the steep variable, expecting the shape of the subdivision footprint to affect the relationship between the amount of steep slopes and the building potential of the site.

As seen in Table 4, we find that TDR use increases with total subdivision acreage, as expected. The negative coefficient on the variable that interacts size and the percent steep slopes (*Acre*STEEP*) indicates that the positive effect of a larger acreage on the number of TDR lots is somewhat offset when the subdivision is more steeply sloped. Evaluated at the mean value of *STEEP*, the results suggest that a 10-acre increase in subdivision size leads to approximately three more TDR lots in subdivisions using TDRs.

The coefficient on *STEEP* when it is entered independently is also negative and significant at the 1 percent level. The estimated coefficient on *perimeter* is negative but, somewhat surprisingly, we find the coefficient on the *perimeter-STEEP* interaction term to be

small but positive, indicating that the more irregular the shape, the less the effect of steep slopes on the number of lots that can be built. When evaluated at the sample mean of STEEP, we find that a 10,000 foot increase in the subdivision perimeter leads to approximately one less TDR lot.

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; a 10-percentage-point increase in *difficult soils* reduces the number of TDRs lots by 0.6 in TDR subdivisions.

We also include a dummy variable that measures whether the site is within one mile of the Patuxent River or the Chesapeake Bay. TDR use may be lower in these locations because consumers may demand larger lot sizes on waterfront properties and because the state’s “Critical Area” designations may limit density near the bay and river.¹⁹ On the other hand, these are desirable locations, so we might expect more building and, thus, higher TDR use, in these areas, all else equal. It is possible that these two effects offset one another because although the coefficient is positive it is not significantly different from zero.

We find sewer availability to be a strong determinant of TDR demand. Sewer systems increase the number of houses that can be built since septic systems require larger lots to accommodate the septic drain field. In subdivisions that are already using TDRs, the presence of sewers leads to on average 12 more TDR lots per subdivision. Sewer availability also increases the probability that a non-TDR subdivision will purchase TDRs by 0.41 and decreases the probability that a subdivision will remain below the max TDR density by 0.58.

Finally, we note that with the exception of sewer availability, changes in the other subdivision characteristics generally are not found to have large impacts on either the probability of buying at least one TDR or the probability of being under the maximum TDR limit (columns (2) and (4) of Table 4). For example, even a 10-acre increase in the total subdivision size would only increase the probability of buying TDRs by 0.07 (evaluated at the mean of STEEP for the non-TDR subdivisions). Similarly, a 10-percentage-point increase in the amount of land in steep slopes or difficult soils would lead to a 0.006 or 0.02 change in the probability of buying TDRs, respectively (evaluated at the mean subdivision size and perimeter of non-TDR subdivisions).

¹⁹ For more about Critical Areas, see Walls and McConnell (2004).

Surrounding land uses. Due to our detailed data on existing uses of the land surrounding each subdivision, we are able to examine specific ways that surrounding land uses might affect TDR use, especially the density of existing residential developments. As discussed in the previous section, our five surrounding land use variables indicate the uses in effect at the time the subdivision was initiated. In Table 4, we find that the greater the percentage of land on the perimeter of the subdivision that is in parks or permanently preserved in farmland or forest (either through the TDR program or one of the state easement programs) decreases the probability that a developer will choose to buy TDRs or the number of TDRs purchased. A 10-percentage-point increase in the amount of surrounding preserved land leads to two fewer TDRs lots in subdivisions that use TDRs. This could reflect that there is some additional value afforded by adjacent preserved land that increases the marginal profit to developers from building subdivisions that are lower density with higher-end housing. Lower-density subdivisions might also be more profitable in such areas if land uses occurring on the surrounding preserved land exert any negative externalities, such as noise or odor from farming practices, on new residential development. This is consistent with the finding that an increase in the percentage of a subdivision's boundary that is in another subdivision's open space area (which would not be in agricultural use) has no significant impact on TDR demand.

We also find consistent evidence that TDR use falls when surrounding residential densities are higher. Relative to no surrounding development, a 10-percentage-point increase in the amount of the perimeter that is adjacent to low-density residential development (specified as greater than one-acre average lot size) leads to 0.5 fewer lots being built with TDRs. An equal change in the perimeter adjacent to higher density development (with average lot size of one acre or less) has a significantly larger effect on TDR demand; the expected number of TDR lots would decline by 1.4 in subdivisions already using TDRs.²⁰ There are two possible arguments for why this may be true. One is that existing residents may be able to exert some influence over the density of new developments in their neighborhoods. More surrounding neighbors means more likelihood of higher density being fought by existing residents. Alternatively, if developers are allowed to use TDRs in receiving areas by right (as is claimed to be the case in Calvert County), then these negative coefficients on the surrounding residential use variables could reflect an increase in amount of open land the developer chooses to reserve in the subdivision (either

²⁰ The magnitude of this effect becomes even larger if the cutoff between high- vs. low-density is increased to one-half acre lots.

through an increase in open space areas or through larger lot sizes) in order to buffer the new residents from being directly adjacent to high-density, existing development. We also note that the percentage of a subdivision's boundary that is in a commercial/industrial zone appears to affect TDR demand to the same degree as does adjacent high-density residential development.

Accessibility variables. In accordance with conventional urban models, we expect subdivisions in the northern regions of Calvert County that are more accessible to major cities to be denser than those in the southern areas. We find an increase in the distance from the subdivision to the northernmost point of the county to significantly reduce TDR demand as expected; moving 1,000 meters (0.62 miles) farther south leads to 0.2 fewer TDR lots in those subdivisions already purchasing TDRs. The corresponding results in columns (2) and (4) in Table 4 suggest that such a change would have little effect on the probability of buying TDRs at all.

In addition to distance from major cities, we also find the subdivision's proximity to the major commuting road, Route 2/4, to be negative as expected but statistically insignificant. Proximity to shopping and other commercial areas in the county, as measured by the gravity index,²¹ also is found to have no significant effect on the demand for additional density in Calvert County.

Time trend. In addition to controlling for the baseline zoning limits, we include a (four-segment linear spline) time trend to capture any overall changes in TDR demand over the sample period. The coefficients on the time trend terms indicate that TDR use increased over time, although at a decreasing rate. In the first five years of the program, TDR use increased by two lots per TDR subdivision each year and the probability of purchasing any TDRs increased by 0.07 annually, holding all else equal. This result may reflect an increase in familiarity or understanding of the TDR program rules on the part of the developers or a countywide increase in the demand for smaller lots on the part of homebuyers. After 1988, the overall trend in TDR use slowed, and there was no discernable annual change in TDR demand following either the adoption of the county's PAR program in 1993 or the countywide down-zoning in 1999.

21 The "Access to Town Centers" 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 .

TDR Price. The final explanatory variable included in the model is the annual average price of a TDR in inflation-adjusted terms. As expected, the results show that an increase in TDR price reduces the number of TDRs purchased, but the coefficient is only significant at the 80 percent level; in subdivisions using TDRs, a \$100 increase in the TDR price (which corresponds to an increase of \$500 per TDR lot) would lead to 0.6 fewer TDR lots.

5. Conclusion

The data from Calvert County's 23 years of experience with TDRs provides a unique opportunity to evaluate the performance and efficiency of a real-world TDR market. The Calvert County program is one of the first programs to allow markets to price development rights and to allocate land between development and preservation. It is also one of the few active TDR markets in the country and is unusual in the degree of flexibility it allows landowners and developers in making density decisions in sending and receiving areas. This stands in contrast to many other TDR programs that have had little market activity and low or fluctuating prices. This makes the Calvert County TDR program an ideal laboratory to examine what influences the demand for additional density of development in a suburban region of a large urban area. It also allows us to determine what contributes to market activity in a TDR market.

Estimating a spatial tobit model of the number of TDR lots a developer chooses to put in a given subdivision, we are able to identify many of the factors that influence the demand for TDRs. We find that both the baseline zoning rules and economic variables are important in determining TDR use. All else equal, developers use far fewer TDRs in subdivisions located in the more densely zoned Residential or Town Center areas than in the rural receiving areas. In addition, increases in the baseline zoning limits reduce TDR demand in the rural areas to a greater extent than in the Residential or Town Center regions. It appears that the baseline zoning limits in the Residential and Town Center zones are roughly set at desired density levels. In at least some of the RCs, however, the baseline zoning requires lower density development than would be attained through pure free market outcomes (i.e., in the absence of all zoning). The relationship of baseline zoning to desired density is therefore critical in creating demand for TDRs. If planners want to use policies such as TDRs to direct additional density primarily toward existing urbanized, higher density areas, they will need to think carefully about the baseline zoning that exists in those areas to understand whether such outcomes can be achieved with TDRs.

Sewer availability seems the most important determinant of TDR demand. Other factors do influence the expected number of TDRs purchased in those subdivisions already using them,

but it takes large differences in the characteristics to cause a subdivision that previously was not using any to start buying TDRs. We find that TDR use rose over time in the county during the early years of the program, and the price does have a marginally significant influence on developer purchases of TDRs.

The land uses surrounding a new subdivision were found to have an effect on the use of TDRs and therefore the density of the development. Having a larger fraction of the subdivision perimeter adjacent to permanently preserved land resulted in fewer lots built with TDRs, other things the same. An awareness of permanently preserved land surrounding the site may enhance its value for a more rural, lower density development, perhaps with higher-end housing. Another interesting result is that, all else equal, an increase in the amount of surrounding higher density subdivisions reduces TDR use. This could reflect that homebuyers in relatively rural, exurban areas like Calvert County prefer not to be adjacent to other residential development. Alternatively, existing residents may perceive higher density development as imposing more costs on the community and therefore may seek to influence the use of TDRs to create higher density.

Planners have been very critical of the Calvert County program because it allows TDRs to be used throughout much of the rural area, which allows TDRs to be used in low-density development and potentially contributes to scattered development. Without a counterfactual, it is difficult to know to what extent this is true. In any case, it is clear that with the active TDR program, more land has been permanently preserved, and the development that does occur is denser than it would have been otherwise. Other areas considering the use of TDRs have a number of different lessons to draw from this experience.

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