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Can transfer of development rights programs save farmland in metropolitan counties?

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Abstract

Transfer development rights (TDR) programs have been gaining popularity as a tool for farmland preservation, as they compensate landowners at minimal public cost. This study shows that despite their wide adoption, TDR programs do not save much farmland on the urban fringe. We use Department of Agriculture data and apply two quasi-experimental methods, synthetic control, and difference-in-difference, to evaluate the effect of TDR programs on farm retention for three fringe metropolitan counties in the state of Maryland. We also compare land use patterns before and after TDR implementation in these counties. The result shows limited effects of TDR programs on farm preservation, even in Montgomery County, one of the national models for TDR programs. TDR programs do contribute to low and medium density residential development. This cautions observation planners about their enthusiasm toward TDR programs and highlights the difficulty of preserving farmland on the fringe of metropolitan regions. We compare the features of the studied TDR programs, and highlight those that account for the programs' relative success/failure. Based on these analyses, we make recommendations to planners to help improve TDR effectiveness.

KEYWORDS

farmland preservation, land use patterns, transfer development rights, urban policy

1 | INTRODUCTION

Planners are committed to insuring urban environmental health and sustainability; one component has been preserving farms on the fringe of metropolitan regions (Alterman, 1997). In the context of a legal system of private property rights, farmland preservation hasn't been easy for urban planners. It either costs a significant amount of public funds to buy farms from private owners or causes legal and political backlashes if undertaken through downzoning without compensation. Transfer development right (TDR) programs have been credited for solving the dilemma. They preserve farms with few lawsuits and public funds, and thus have been replicated in many locations across the world, such as the United States, Spain, Australia, Italy, and Japan (Bryant & Conklin, 1975; Linkous, Laurian, & Neely, 2019; McConnell & Walls, 2009; Pruetz & Standridge, 2008).

Prior studies have examined the design and features of TDR programs (Johnston & Madison, 1997; Pruetz & Standridge, 2008), yet few have rigorously evaluated whether and to which extent TDR programs preserve farms. Most claims of success are based on counts of land acreages purchased with TDR sales. But TDR transactions may only decrease in density, not necessarily the preservation of farms. Prior case studies found that land acreages with TDR sales may turn into large lot residential development (Daniels, 1991; Nelson, 1992). Another problem with counting land acreages associated with TDR transactions is that while a TDR program may have preserved some acres of land, those acres may stay in farm anyway even without the program, simply due to the lack of demand for development. As Pfeffer and Lapping (1994) pointed out, TDR programs may have only preserved acres because of the abundant supply of land for development; once this supply is exhausted these programs may face political opposition. Thus, existing literature quantified TDR effectiveness with a problematic measurement, TDR sales, and their claims of success likely overestimate policy effectiveness and—farm retention.

This paper tackles this problem with a quasi-experimental approach. We employ synthetic control and difference-in-difference (DID) methods to compare the rate of farmland loss in counties with and without TDR programs. Different from the previous methods, our approaches construct a counterfactual scenario using counties without TDR programs but share similar attributes with TDR counties. This scenario demonstrates what the rate of farmland loss would be if there were no TDR programs. This reveals whether TDR programs can effectively fight against the economic pressure of converting farms into urban use. The effect of TDR programs is not judged by how many acreages of land are purchased by TDRs through these programs, but how many acres that otherwise would have been turned into urban use are preserved in farms.

Synthetic control and DID are standard methods for policy evaluations (Abadie, Diamond, & Hainmueller, 2010, 2015; Card & Krueger, 1994), and have been applied to examine land preservation programs. For example, using a DID approach, Lynch and Liu (2007) found that the Rural Legacy (RL) program in Maryland does little to conserve farmland relative to that of non-RL areas. The same authors also used a propensity score matching estimator to evaluate the effect of Purchase of Development Rights (PDR) programs for six Mid-Atlantic states. They found that PDR programs decrease a county's rate of farmland loss by 40%–55% and decrease farmland acres lost by 375–550 acres per year (Liu & Lynch, 2011). Note that although both studies covered the state of Maryland and applied quasi-experimental methods, PDR and RL are different programs from TDR policy.[1] Using the cases of three counties in Maryland, we find that TDR programs contribute to the expansion of low- and medium-density residential but do little to retain farmland. Using the DID approach, the TDR program in Calvert County has preserved 2.6% more of its 1959 farmland compared to the comparison counties without TDR programs. Montgomery County's TDR program is associated with an additional farmland preservation of 3.7%, again not statistically significant and St Mary's County

shows a 0.08% greater loss in the share of farmland, small but statistically significant (See Columns 3, 6, and 9, Table 2). However, none of the preservation effects, for Calvert County, St. Mary's, or Montgomery County, are statistically significant, which shows limited effect of TDR programs on farm conservation. We compare the features of these programs and highlight those that may contribute to the relative, but small success of the Montgomery and Calvert County programs. They (a) define sending and receiving areas clearly, (b) maintain an active market, (c) keep transaction cost low, and (d) have downzoned the sending areas. Related to the downzoning, these two programs do not allow much of the building to happen after the sales of development rights, especially in Calvert County, selling even one unit of development right would put the entire plot under easement. By cultivating these features, planners may have a better shot at improving TDR performance marginally.

This paper proceeds as follows. Section 2 introduces a generic TDR program, Maryland preservation context and TDR programs in the three Maryland counties. Section 3 reviews the literature. Section 4 introduces the data and methods. Section 5 presents the results and performs robustness tests. Section 6 discusses the results with an additional analysis on land use change in the three TDR counties and compares features of the three programs. Section 7 concludes.

2 | BACKGROUND

2.1 | TDR program

Under a generic TDR program, a landowner in the designated sending area can separate the development potential, called development rights, from a parcel, and sell them to another individual who can increase the density in another parcel in the receiving area. Having transferred the development rights, the landowner is restricted from developing his or her land at the original zoning density. With all allowable development rights sold, the parcel will be permanently protected from development by a conservation easement or restrictive covenant. The person to whom the rights are transferred—in most cases a real estate developer—uses them to develop another piece of property more intensively than allowed by baseline zoning.

The attractions of TDR programs are three-fold. First, landowners capture financial returns for the appreciation and development potential of their land, and therefore are less likely to oppose the preservation practices. Second, counties preserve farmland without paying for easements out of their budgets. Third, the program can be easily tailored to a county's specific market contexts and conditions. For example, Johnston and Madison (1997) and Pruetz and Standridge (2008) showed that TDR programs in different counties exhibit vastly different features; many of these features are determined by social, economic, and political conditions in the local jurisdictions. As a result, TDR programs have been gaining popularity all over the world. In the United States alone, Walls and McCormick (2007) estimated that by 2005, approximately 140 counties adopted a TDR program, and Rick Pruetz counted 254 by 2015 (Pruetz, 2016). Other counties and regions, such as Spain, Australia, Italy, Japan, Taiwan, and Hong Kong, have also adopted TDR programs (Bryant & Conklin, 1975; McConnell & Walls, 2009; Pruetz & Standridge, 2008; Shih, Chiang, Chang, Chiang, Chang, & Chang, 2017; Hou, Chan, & Li, 2018). With TDR programs blossoming around the world, it is important to empirically evaluate how effective they are in meeting one of their key goals—farmland conservation.

2.2 | Land preservation in the state of Maryland

The state of Maryland is among the pioneering states in land preservation. Maryland has a long history of land use laws, regulations, and state-level planning practices (Knaap & Frece, 2006). It enacted the

state planning law in the 1930s. In the 1960s, with the national environmental movement, Maryland implemented a series of land use laws to protect its forests, wetlands, and farmland. Several state programs were introduced in the 1970s–1990s, including the Maryland Environmental Trust in 1967, Program Open Space in 1969, the Maryland Agricultural Land Preservation Fund (MALPF) in 1977, and Rural Legacy in 1997 (McConnell, Walls, & Kelly, 2007). These programs use state funds to protect farmland and other environmentally sensitive lands from development.

The Maryland Environmental Trust buys out private natural lands and places easement to protect them from future development. Program Open Space provides financial and technical assistance to local subdivisions to protect open space. So far, more than 6,000 park and conservation area projects have been assisted through Program Open Space Local grants (http://dnr.maryland.gov/land/Pages/ProgramOpenSpace/home.aspx). MALPF is similar but focuses on agricultural land. MALPF purchases and places agricultural preservation easements that forever restrict development on prime farmland and woodland. As of 2016, MALPF has permanently preserved land in each of Maryland's 23 counties, at the magnitude of approximately 300,916 acres, representing a public investment of over $682 million. The Rural Legacy Program provides funding to protect valuable agricultural, forestry, and natural and cultural resources to local government and land trusts to purchase land, easements, and transferable development rights from willing sellers in designated "Rural Legacy Areas" (Cohen, 2002).

Aside from state-level practices, Maryland counties have also initiated their own land preservation programs. TDR programs are the most popular due to their low level of reliance on public funds. So far, 13 of 23 counties in Maryland have adopted TDR programs with the purposes to protect farmland, natural resources, and rural character; as of 2016, they have preserved more than 112,750 acres of land (Maryland TDR Committee, 2016; Shahab, Clinch, & O'Neill, 2018a). These TDR programs constitute one of the major ways of farmland preservation in Maryland, and for some counties, they are indeed the primary tools for preservation. For example, according to Montgomery County National Park and Planning Commission, by 2004, the TDR program has accounted for 73.8% of all farmland preservation in Montgomery (http://agresearch.umd.edu/sites/default/files/_docs/locations/wye/Virginia%20McConnell%27s%20Final%20Report%20HRHCAE%20Pub%202,007–03.pdf). In Calvert County, by 2013, it accounts for half (http://www.co.cal.md.us/DocumentCenter/View/6047).

2.3 | Maryland case studies

This paper focuses on three cases in Maryland: TDR programs in Calvert, Montgomery, and St. Mary's Counties. The locations of these counties are shown in Figure 1. They are chosen for five reasons. First, Maryland TDR programs are widely recognized as highly successful. According to the study conducted by Maryland TDR Committee (2016), TDR programs in Maryland had preserved over 112,750 agricultural, forest, and natural acreages, more than any other state. Montgomery County preserved 52,052 acres, Calvert County preserved 14,700 acres and St. Mary's County preserved 4,107 acres. Montgomery County and Calver County TDR programs are also among the seven most successful TDR programs in the United States (Pruetz & Standridge, 2008). We have taken a conservative approach by focusing on these successful programs: If we find these programs ineffective, it is likely that most TDR programs do little to preserve farmland. But if these programs are highly functional, the competence of less active programs remains a question.

Second, all three counties from the same state hold constant state land preservation programs. Third, the longevity of these three TDR programs makes sure their effect has been largely revealed. Calvert County initiated its TDR program in 1978, followed by Montgomery and St. Mary's Counties,

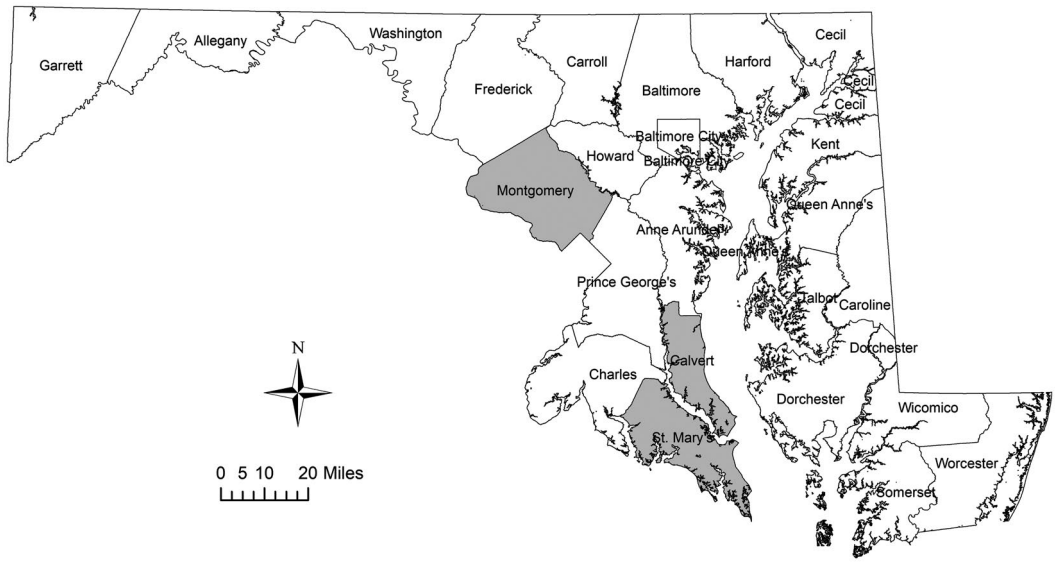

FIGURE 1 Three Maryland case study counties

in 1980 and 1990, respectively. Till the end of our study period (2012), these programs have been in place for 20–30 more years.

Fourth, all three programs explicitly stated farmland preservation as one of their goals; therefore, it is sensible to hold them accountable for how well they achieve this goal. TDR programs can serve multiple purposes, such as farmland conservation, density redistribution, and environment protection. For programs that primarily focus on other purposes, it may be unfair to evaluate them exclusively by their effects on farmland retention. This is not a concern for our three cases. Specifically, Calvert County emphasized farmland and forest conservation, Montgomery County cared more exclusively about farmland and farm economy, while St. Mary's County hoped to protect both farmland and open space (Walls & McConnell, 2007).

Last, despite their common essence as TDR programs, specific features of these three programs differ a great deal. This serves two purposes: It (a) extends the generalizability of our results across a wide range of TDR programs with various operational details, and (b) helps identify key features that contribute to relative success/failure of these programs. Following the analysis framework of Walls and McConnell (2007) and Linkous (2016), TDR program's design features may differ in following ways: (a) designation of sending and receiving areas, (b) TDR allocation rate, and (c) density bonus and TDR requirement in receiving areas. In these three cases, this study shows differences in each of these dimensions.

To be specific, the design of sending and receiving areas differs across the three counties. Montgomery County zoned 93,000 up-county acreages as sending areas with baseline zoning of one dwelling unit per 25 acres. The receiving area is limited to urban centers based on available or planned infrastructure to accommodate higher density. Calvert and St. Mary's Counties, on the contrary, have overlapping sending and receiving areas zoned at one dwelling unit per 20 acres and per 5 acres, respectively. Each plot can either increase or decrease density, depending on the autonomous outcome of TDR transactions. This breaks down the geographical continuity of protected areas and is likely to result in smaller farms. Also, as Linkous (2016) suggested, the single zone TDR programs have limited control over development pattern and may create sprawl instead of checking it. Additionally, Montgomery County downzoned massively in the sending area, followed the adoption of their TDR

policy, from one dwelling every 5 acres to every 25 acres. Calvert County also downzoned from one dwelling every 5 acres to every 10 acres in 1999, 20 years after the initial implementation of their TDR policy, and further downzoned to one dwelling every 20 acres in 2003. St. Mary's County never downzoned. The more aggressive the downzoning, the more effective the TDR program should be.

Another difference lies in the acreages associated with each unit of TDR. One TDR is attached with one acre of land in Calvert County, while five acres in Montgomery and St. Mary's County. This matters because one cannot buy or sell half a unit of TDR, and the program in Calvert County is thus more flexible. Moreover, in Calvert County, the sale of one unit of TDR puts the whole parcel under easement; in Montgomery County, a landowner can retain one TDR every 25 acre to build a dwelling while selling the rest; in St. Mary's County, a seller has the full option about how many TDRs to sell and to retain (and build). By this feature, the TDR program in St. Mary's County is likely to be the least effective in farm preservation, while that in Calvert County appears to be the most powerful.

Finally, while the receiving areas of Calvert and St. Mary's Counties are predetermined, those of Montgomery County have been added sequentially. At the same time, developers in Montgomery County are not guaranteed a density bonus at a location within the receiving area; density bonus is still discussed in a case-by-case fashion, which may undermine the effectiveness of the TDR program. This is not a feature shared by Calvert and St. Mary's Counties.

3 | LITERATURE

Planners have been looking for effective ways of farmland preservation for decades; they find no panacea. So far, zoning is the primary tool for regulating land uses (Woodbury, 1975), since preservation through downzoning faces legal and political challenges as it diminishes private property value (Johnston & Madison, 1997). As an alternative, preservation programs that uphold property value were designed and implemented, with TDR as an example.

TDR programs emerged in the 1960s as a tool to save landowners and county governments from paying for conservation. By transferring density from protection sites (the sending area) to growth centers (the receiving area), theoretically, TDR can support the development of compact communities while preserving rural land (Linkous & Chapin, 2014). Now, this tool has been used also to serve other purposes such as protecting environmentally sensitive resources, providing affordable housing (Linkous, 2016) or preserving historical sites (Stinson, 1996).

Many studies have examined the vastly different design features of TDR programs, to either explain them with the local contexts (Johnston & Madison, 1997) or use these features to explain TDR effectiveness (Pruetz & Standridge, 2008). For example, Johnston and Madison (1997) compared four TDR programs in the United States and explained their different features with different program aims, levels of push backs from residents and abundance of resources the local county can leverage to make TDR work. Pruetz and Standridge (2008) compared the design features of 20 U.S. TDR programs that have preserved most land and identified several features that contribute to TDR success. They concluded that demand for bonus development and customized receiving areas are essential to TDR success, strict sending area regulations, few alternatives to TDR to add density, and market incentives are extremely important, while certainty of use, strong public preservation support, simplicity, promotion, and facilitation, and a TDR bank are helpful but not necessarily critical. More recently, Shahab, Clinch, and O'Neill (2018a) evaluated the transaction costs of different TDR programs in the state of Maryland and attributed varied costs to different program designs. Linkous and Chapin (2014) and Linkous (2016) reviewed the change of TDR programs over time in the state of Florida and evaluated their effectiveness in managing growth.

However, most prior studies measured TDR success by the number of land acreages protected through the sales of TDRs. But this standard measurement for TDR success is problematic in three ways. First, land acreages associated with TDR sales, as mentioned above, are not completely exempted from development. Nelson (1992) and Daniels (1991) suggested that land with development rights sold may develop into hobby farms as well as large lot residential locations. Second, Schilling et al. (2014) used propensity score matching and found that farms preserved under TDR programs were no more profitable than farms unpreserved by TDRs. Third, as Pfeffer and Lapping (1994) pointed out, there are counties without TDR programs that have land remaining in farms merely because of a lack of demand for development. This paper extends our knowledge using the synthetic control method and differences in differences to further quantify the extent to which counties with TDR programs have retained more farmland than they would have without such programs. So far, limited proof has been provided about the scale of land remained in farms after the sales of TDRs.

4 | DATA AND METHODOLOGY

4.1 | Data

This paper compiles several data sets measured at the county level. Farmland data from 1959 to 2012, measured every 5 years, come from the Census of Agriculture conducted by the United States Department of Agriculture. The Census of Agriculture is a complete count of U.S. farms; it provides the only source of uniform, comprehensive, and impartial agricultural data for every county in the nation. Farmland value per acre are also collected from the Census of Agriculture. Population data are obtained from the Census Bureau, which counts the nation's population once every decade and projects annual growth rates according to the census results. Travel distance data are directly measured off map. We find the shortest driving path between the geometric centers of the two concerned counties/cities and measure the length of that path. This process is facilitated by a map tool "Distance from To" powered by Map Developers, available at https://www.mapdevelopers.com/distance_from_to.php.

Matching these data sets together, we construct a panel data set for a handful of U.S. counties, including the three Maryland TDR counties and a group of potential comparable counties for each of them, measured every 5 years. The procedure of finding the comparable counties is detailed below in section 4.3. In the discussion section, we employ the MdProperty View data as a complementary data set. MdProperty View, delivered by Maryland Planning Department, is a graphic representation of real property showing individual property boundaries and land use type. These data allow us to quantify the change of land use over time in the three Maryland counties.

4.2 | Synthetic control method

The construction of a counterfactual control group lies at the heart of policy evaluations. Without control groups, evaluations would take the forms of content analysis of policy documents, description of enforcement process, and comparison of the outcome before and after policy implementation. Meaningful as they are, these methods fail to account for time-varying shocks that can interfere with the outcome variable and produce biased results. A counterfactual control group, similar to treated units in all important dimensions while unaffected by the policy, can solve this issue. Because of the similarity across the treatment and control groups, both are likely to be affected by the same shocks. Thus, any difference in the outcome variable can be attributed to the policy, instead of the shocks.

In cases of small number of treated units, it is sometime challenging to find perfect control units; treated units may be unique in their characteristics. Under these circumstances, Abadie and Gardeazabal (2003) and Abadie, Diamond, and Hainmueller (2015) proved that using the weighted average of a group of untreated units to form a "synthetic" control unit may be superior, as it may mimic the treated unit much more closely than any single untreated unit. These authors developed a procedure of forming an optimal synthetic control unit, called the synthetic control method. It starts with a pool of untreated units that are broadly similar to the treated unit while unaffected by the policy. Then this method generates a weight for each untreated unit to minimize the disparity in essential characteristics between their weighted average and the treated unit before policy implementation. This makes sure that the particular combination is the best-possible counterfactual control group. According to the authors, the synthetic control method outperforms other methods of control unit construction, because it makes explicit (a) the relative contribution of each untreated unit (with weights) and (b) the similarities (or lack thereof) between the treated unit and the control group. Also, the synthetic control method removes the influence of researchers as much as possible, and therefore, is more objective. It is noteworthy that the traditional way of finding a single control unit is a special case of the synthetic control method, with a unity weight on one untreated unit and zero on others. The traditional way may or may not have minimized the difference between the treated and the control units, which is testable through the synthetic control method.

In terms of this study, since a handful of counties in the U.S. adopted TDR, we appear to be in no shortage of treated units. However, each TDR program is largely different in details; pooling them together would mask these differences and obtain results practically unhelpful. For example, if the result shows that TDR programs on average are effective in preserving farms, it may be driven by a few successful programs. Should we decide to launch new TDR programs to preserve more farms, we are left unsure of which specific program(s) to follow. Thus, in order to obtain more informative results, we decide to evaluate each program separately and that leaves us with a single treated unit. This brings us exactly to the situation described above and makes the synthetic control method an ideal approach.

4.3 | Implementation of the synthetic control method

We could use all U.S. counties without TDR programs (about 3,000 counties) as potential control counties, but many are apparently incomparable with the three Maryland cases in terms of location, development pressure, and the need for farm preservation. Also, as mentioned in Section 2, the state of Maryland implemented many preservation practices aside from the TDR programs, which may complicate the results if we compare Maryland cases with counties in other states. Thus, to avoid these problems, we use only the Maryland counties without TDR programs as potential control groups and identify the final control groups that share most similar trends of farmland loss with each of the three TDR counties before their adoption of TDR programs.

We then apply the synthetic control method to Maryland counties. This method makes sure that before the initiation of the TDR policy, the synthetic control counties track the TDR county most closely in farmland loss, and thus constitutes a plausible counterfactual scenario. The counterfactual control counties were chosen so that their rates of farmland loss, population change, farmland value, and distance to DC tracked that of Calvert and Montgomery counties for 20 years prior to implementation of their TDR policies and for 30 years prior to the 1990 TDR policy passage in St. Mary's county. The fact that farmland loss tracked in these prior decades suggests that there were no major cross-county differences in industry dynamics, land quality, farm size, or governance that might affect farmland loss prior to the passage of the TDR policy. In other words, our counter factual counties are similar except that do not have a TDR policy. The data-driven procedure also strips away the latitude of the

researchers to "cherry-pick" control counties, as the synthetic control county is essentially formed by the computer program. The only choice the researchers need to make is to pick a group of predictors for farmland loss, and the program will automatically minimize the difference in these predictors between the treated county and the synthetic control county. Following literatures on synthetic control (Abadie, Diamond, & Hainmueller, 2015) and urban economics (Brueckner, 1987; Brueckner & Fansler, 1983), we pick variables reflecting the development pressure as predictors. For development pressure variables, we use driving distance to the center of Washington, D.C. and population growth rates. These variables are chosen due to their strong predictability for farmland loss (Brueckner, 1987; Brueckner & Fansler, 1983). Thus, the control counties are chosen because of their similar farmland loss rates prior to passage of the TDR program, similar population growth rates, land value changes, and distance to D.C. Using Maryland counties only as our potential control groups help eliminate the complication of preservation program differences across states that could complicate our results.

Lagged outcome variables are commonly used in synthetic control studies as predictors of future outcome variables. In this study, our outcome variable is measured by (1) the percentage of 1959 county farmland retained in subsequent years and (2) the absolute acreages of land in farms. (2) is a stricter criterion, which requires the control county to have farmland of similar county size. In contrast, (1) normalizes the amount of farmland using the share of 1959 acreage over time, so that small counties can be compared to large counties if they share the same trend of farm loss. Although we ran our analysis for both dependent variables, we report only (1) the changing share of 1959 farmland over the decade, as the conclusions don't differ between the two variables. The same years are used for population and farmland value.

TDR programs in Calvert, Montgomery and St. Mary's Counties preserve farms, the development pressure may have spilled over to neighboring counties. Or, the TDR programs may create a critical mass of a farm economy and therefore encourage continuation of farming in neighboring counties. These issues may cause us to either overestimate or underestimate the effect of TDR. To solve this problem, in a robustness check, we use U.S. counties outside of the Washington-Baltimore CMSA as the potential pool of control counties to check for the sensitivity of the results.

4.4 | Difference-in-difference

The above procedure rests on the assumption that the control counties would have closely tracked farmland loss in the TDR counties if TDR programs have no effect. This assumption holds if their similarity prior to the initiation of the TDR programs extends to the later periods. However, since we are looking at 20–30 years post TDR adoption, similarity may have diverged during such a long time. To address this concern, we further adopt a difference-in-difference (DID) regression as follows to control for the potential divergence in growth pressure across the TDR and control counties.

$$Farm_{it} = \alpha_0 + \alpha_1 TDR_{it} + \alpha_2 lnPop_{it} + \alpha_3 lnLand\ Value_{it} + a_i + a_t + \varepsilon_{it}$$

where $Farm_{it}$ denotes the percentage of farms in 1959 that is retained in county i year t, and the absolute acreage of farmland in logarithm form in a robustness check, again the results from this second dependent variable is not reported but available on request. TDR_i is our key DID term, denoting whether county i has a TDR program as of year t. Pop_{it} denotes population for county i year t in logarithm form; this partially measures the growth pressure on farmland. Population data are either census data (for census year) or projected population data (for non-census year). $Land\ Value_{it}$ denotes the value of farmland per acre. a_i and a_t denote county and year fixed effects, and

ε_{it} is the error term. County fixed effects absorb all time-invariance county characteristics that affect farmland loss, such as the location of a county. These covariates control for post-TDR differences in development pressure between TDR and control counties, and thus mitigate the concern that their similarity may have faded in recent decades. Control counties enter this regression with their assigned weights from the synthetic control method. If TDR programs are effective, we expect $\alpha_1 > 0$.

We also carry out a series of robustness checks. We use counties in other MSAs as the potential control group to avoid the spillover effect of development pressure to neighboring counties, and we change the measurement for the outcome variable. Finally, we change the study period. Again, these results are not reported here, but do not affect our conclusions and are available on request.

5 | RESULT

5.1 | Main result

Four counties show up in the synthetic control group for Calvert County: Garrett County with a weight of 0.707, Anne Arundel County with a weight of 0.225, and Allegany and Dorchester Counties with weights of 0.063 and 0.007, respectively. Table 1 compares the conditions in Calvert County versus the synthetic control group, and shows numerical similarity in farmland retention prior to the implementation of the TDR program in 1978. This indicates a success in forming a counterpart. The synthetic control group loses a slightly greater share of farmland in the 1970s compared to Calvert County, but the difference is minimal. Calvert County has a much smaller population than its synthetics control counties, which may indicate weaker development pressure. Calvert County is located much closer to the center of Washington, D.C., which should add to its development pressure. The bottom row of Table 1 shows that the overall difference between Calvert County and the synthetic control group adds up to a root mean squared prediction error of 0.007, which will be compared to statistics of other county pairs. Figure 2 visualizes the effect of TDR program in Calvert. The synthetic control group tracks Calvert County quite closely in the percentage of 1959 farmland retained before the 1978 launch of the TDR program, but afterwards, Calvert County has lost a larger percentage its farmland Thus, we find no evidence that the TDR program in Calvert County preserves farmland. It's important to note that as mentioned above in Section 4.4, by comparing the trend of farmland loss after the implementation of TDR programs, we maintain the assumption that the development pressure remains similar between the control and test counties. While this assumption is tested to be true in the synthetic control analysis for the period before the TDR policy, it is not tested after TDR implementation. Since the post TDR period is quite long, nearly 20–30 years for the three TDR cases, the assumption can be problematic. Thus, we further conducted the DID regression which controls for population growth pressures, land value differences, and county and fixed year effects, which captures the state-level agricultural industry dynamics To the extent that there are other aspects of development pressure not captured by the above variables, we do maintain the (much loosened) assumption that those remaining aspects are similar across TDR and control counties. This assumption is strengthened by the results in columns (3) (6) and (9) in Table 2, which show the R^2 are all above 89%, meaning more than 89% variations in farmland loss is explained by our control variables.

Consistent with Figure 2, the DID regression shown in column (1) of Table 2 reports that after the implementation of the TDR program, compared to its synthetic control group, Calvert loses an additional 18.9% of its 1959 land in farms. The sample size is 50 as the time frame runs from 1960s to 2000s, with two points every decade for each of the five counties (Calvert and four counties in the synthetic group, weighted by their weights assigned in the synthetic control analysis). The 1959 and

TABLE 1 Comparison of pre-TDR conditions in treatment and synthetic control counties

	Calvert		Montgomery		St. Mary's	
Variable	**Calvert**	**Synthetic**	**Montgomery**	**Synthetic**	**St. Mary's**	**Synthetic**
Share of 1959 farmland retained in 1964	0.878	0.878	0.914	0.877	0.924	0.897
Share of 1959 farmland retained in 1969	0.729	0.729	0.683	0.730	/	/
Share of 1959 farmland retained in 1964	/	/	/	/	0.814	0.772
Share of 1959 farmland retained in 1978	0.604	0.617	0.678	0.678	/	/
Share of 1959 farmland retained in 1987	/	/	/	/	0.637	0.711
County population in 1959	12,100	47,238.53	1,64,401	1,64,378.8	29,111	53,755.51
County population in 1969	15,826	66,399.06	3,40,928	2,81,813	/	/
County population in 1974	/	/	/	/	51,700	68,790.9
County population in 1978	31,700	1,05,829	5,84,300	4,20,661.4	/	/
County population in 1987	/	/	/	/	69,083	73,861.75
Farmland value (per acre in $) in 1959	352.7	172.568	680.09	451.645	197.18	212.687
Farmland value in 1969	722	389.234	1704	876.738	/	/
Farmland value in 1974	/	/	/	/	904	825.675
Farmland value in 1978	1,904	1,325.81	3,629	2,019.502	/	/
Farmland value in 1987	/	/	/	/	2,085	1,822.923
Travel distance to urban core (miles)	40.56	139.267	20.32	92.364	80.56	88.452
Root mean squared prediction error	0.007		0.029		0.049	

2012 data points are excluded because the dependent variable for 1959 is one by definition, and population data have not been provided for 2012 by the Census Bureau. The coefficient becomes smaller and less significant with the addition of county and year fixed effects in column (2). And in column (3), with additional covariates to capture the difference in growth pressure over time, TDR program in Calvert shows an improvement in farm retention rate by 2.6%, though insignificantly so. Population growth, as expected, puts a pressure on farms; 100% increase in county population growth leads to a 0.167% lower farm retention rate. And farmland value, as expected, has a negative effect on farm preservation, though insignificantly so.

Results are similar for Montgomery County. The four synthetic control counties, Baltimore County, Prince George's County, Somerset County, and Allegany = County, are associated with weights of 0.33, 0.278, 0.202, and 0.19, respectively. The synthetic control group loses a greater percentage of farmland in the early 1960s (0.88 in the synthetic control county in 1964 versus 0.91 in Montgomery County, Table 1), but retains more in the later 1960s (0.73 in the comparison county with 0.68 in Montgomery County in 1969), and tracks Montgomery County quite closely in the rate of farm retention in 1978, as shown in Table 1. The synthetic control group also shares similar population with

TABLE 2 Effect of the TDR program in a DID analysis

	% 1959 farmland								
	Calvert			Montgomery			St. Mary's		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TDR	−0.189*** (0.049)	−0.097* (0.039)	0.026 (0.026)	−0.146*** (0.045)	−0.028 (0.042)	0.037 (0.040)	−0.190*** (0.025)	−0.093* (0.030)	−0.080* (0.026)
Pop			−0.167*** (0.022)			−0.206 (0.080)			−0.110 (0.058)
Land value			−0.015 (0.053)			−0.022 (0.073)			−0.117*** (0.023)
County fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Year fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
R^2/Within R^2	0.3358	0.9509	0.9761	0.1850	0.9299	0.9483	0.3196	0.8770	0.8912
Sample size	50	50	50	50	50	50	60	60	60

Note: Robust standard errors are in parenthesis.
*$p < 0.05$; ***$p < 0.005$.

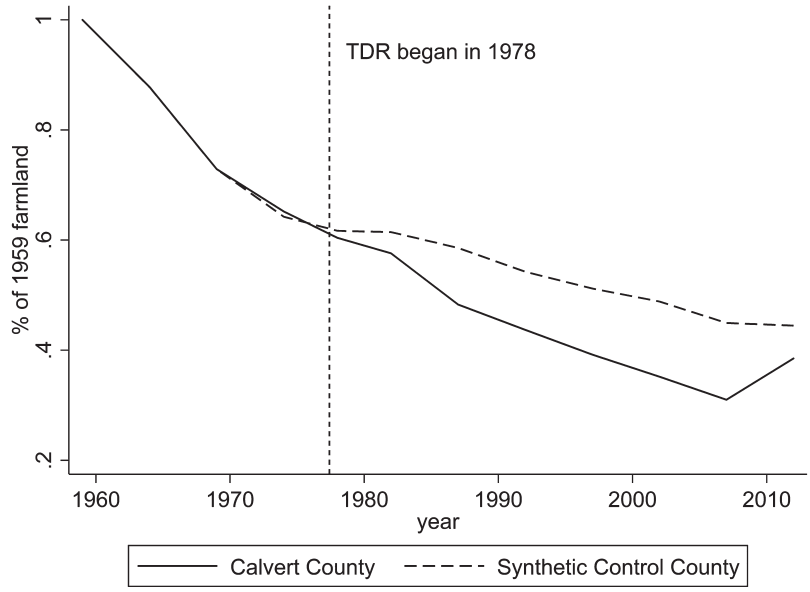

FIGURE 2 Farmland in Calvert County and its synthetic control group, as a percentage of 1959 farmland

Montgomery County in 1955, but Montgomery County experiences faster population growth afterwards in 1969 and 1978, suggesting Montgomery experienced greater development pressure to convert farmland to urban development. Consistently, Montgomery County also maintains higher farmland value throughout the years before TDR implementation in 1980. Finally, the synthetic control county is much farther away from the urban core than Montgomery County (20 miles for Montgomery County versus 92 miles for the comparison counties which may also lead to stronger development pressure in Montgomery County later on and cause an underestimate of the TDR effect. The overall root mean squared prediction error is 0.029, which indicates a slightly worse match between the synthetic "Montgomery" County and the true Montgomery County than the pairs for Calvert County (0.007). In general, Montgomery County should have experienced greater development pressure than the synthetic county, and the synthetic method therefore would have underestimated the effect of the TDR program. Figure 3 shows that while the synthetic control group closely tracks the rate of farm loss before 1978, it slightly outperforms Montgomery County after 1990. Considering that the synthetic control group likely experienced weaker development pressure, we are reluctant to conclude that the TDR program halts farmland preservation, but the result can be conservatively interpreted as a lack of evidence that TDR preserves farms.

Consistently, column (6) in Table 2 shows that Montgomery County preserves 3.7% more of its 1959 farmland compared to the synthetic control group, after the implementation of the TDR program in 1980; this effect is not statistically significant. Thus, again, this confirms the previous conclusion that TDR program in Montgomery County has not been successfully preserving farmland, despite its widely acknowledged reputation. Columns (4) and (5) confirm that this conclusion of lack of effectiveness is robust to different combination of control variables. Notice that since columns (5) and (6) control for the county fixed effects, and column (6) controls for population and farmland value, the fact that the synthetic control group is much farther away from the urban core, has fewer population and lower farmland value is no longer a concern.

The same qualitative conclusion holds for St. Mary's County. The synthetic control group for St. Mary's County is a weighted sum of five counties: Washington County with a weight of 0.456, Talbot

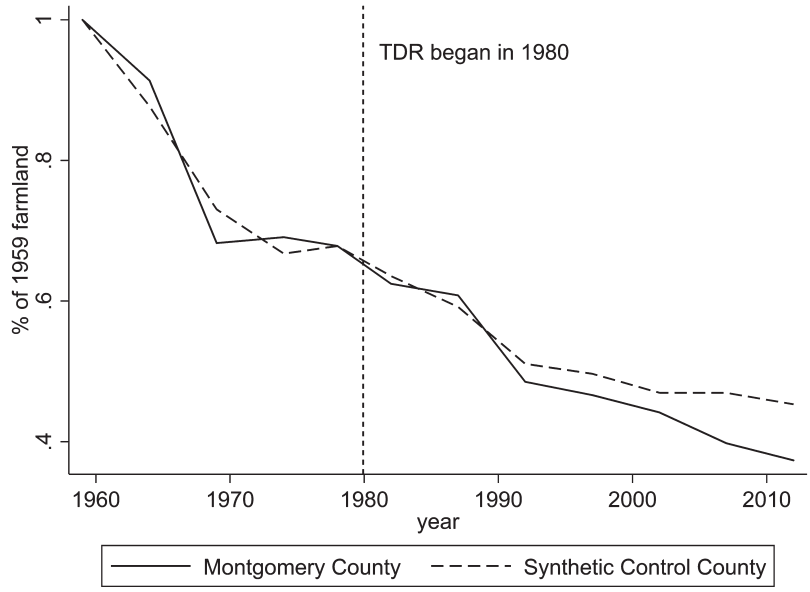

FIGURE 3 Farmland in Montgomery County and its synthetic control group, as a percentage of 1959 farmland

County with a weight of 0.343, Allegany County with a weight of 0.099, Garrett County with a weight of 0.089, and Dorchester County with a weight of 0.013. The third column in Table 1 shows the difference between St. Mary's County and the synthetic control group, while Figure 4 shows that St. Mary's County and the synthetic control group keeps relatively similar rate of farmland loss before the adoption of the TDR program in 1990, but then St. Mary's County lost more afterwards. The DID analysis in columns (7)–(9) in Table 2 confirms the results. Compared to the synthetic county, St. Mary's County loses an additional 8% of its 1959 farmland after the adoption of the TDR program, and this

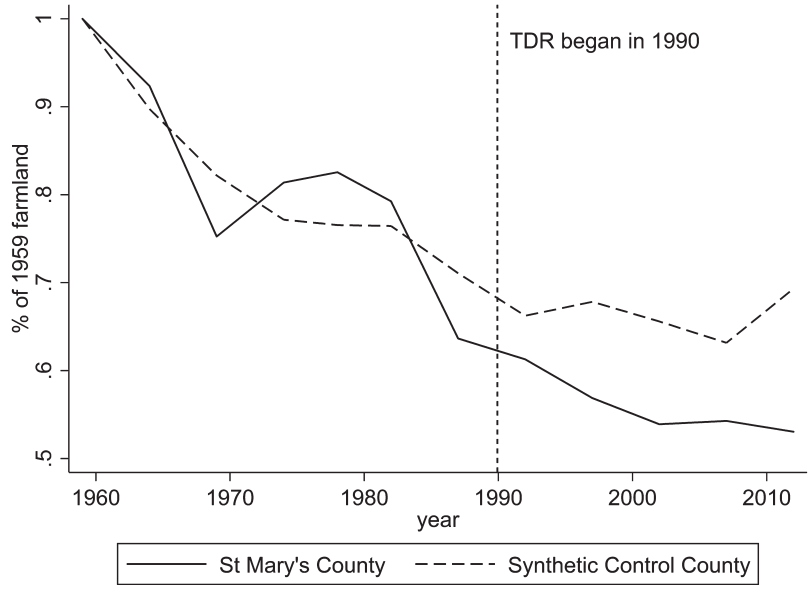

FIGURE 4 Farmland in St Mary's County and its synthetic control group, as a percentage of 1959 farmland

effect is statistically significant at the 5% level (column 9). No evidence of TDR program effectively retaining farmland is found with difference combinations of control variables.

5.2 | Robustness tests

We carry out a series of robustness checks. As mentioned above, we use counties outside of the Washington-Baltimore CMSA as the potential control group, change the measurement of the outcome variable, and change the study period. All robustness test results are available upon request.

5.2.1 | Counties outside of the Washington-Baltimore CMSA

As mentioned above, TDR programs in the three Maryland counties, if effective in farmland preservation, may have pushed development pressure onto neighboring counties. Or, the TDR programs may have created a critical mass of a farm economy and encouraged continuation of farming in neighboring counties. Thus, if neighboring counties are included in the final synthetic control group, we could have either overestimated or underestimated the effect of TDR programs. To deal with this concern, we use counties outside of the Washington-Baltimore CMSA as the potential control group and redo the analysis. The results again show no evidence that TDR programs successfully preserved farmland; in fact, compared to the synthetic control groups, the three TDR counties, Calvert, Montgomery and St. Mary's Counties have lost 10.3%, 14.9%, and 15% more of their 1959 farmland, respectively. Note that consistent with the main results, this also confirms that the TDR programs in Calvert County and Montgomery County are relatively more effective than that in St. Mary's County.

5.2.2 | Alternative measurement of the outcome variable

We change the outcome variable to the absolute acres of farmland in each year of the agricultural census; this is a stricter restriction than that in the main result, as it requires the synthetic control groups to have farmland of comparable size in addition to a similar rate of farmland loss with the TDR counties. Nevertheless, the results are qualitatively robust; none of the three TDR counties appear to have more effectively preserved farmland after TDR adoption compared to their synthetic control groups.

5.2.3 | Alternative study period

We change the start year to 1954 and 1964, and the results remain quite robust; we also change the end year to 2007 and 2002, and the results again are qualitatively the same.

6 | DISCUSSION

The above results all point to one counterintuitive conclusion that TDR programs, despite their popularity, do not preserve farmland in suburban metropolitan areas against development pressure. This becomes even more striking as TDR programs in both Montgomery and Calvert Counties are active with many transactions carried out within the past 30 years. Table 3 shows that low density residential grew in both 1973–2002 and 2002–2010 in all three counties, and more rapidly so in Calvert and St. Mary's Counties. Medium density residential also grew in 1973–2002; in Calvert it increased at an annual rate of 15.9%. In addition to low- and medium-density residential development, Calvert County also preserved urban open space in 2002–2010. High-density residential also surged in Calvert and

TABLE 3 Land use change rate in the three Maryland countries, 1973–2010

	Annual growth rate					
	Calvert		Montgomery		St. Mary's	
Land use type	**1973–2002**	**2002–2010**	**1973–2002**	**2002–2010**	**1973–2002**	**2002–2010**
Low-density residential	12.51%	6.62%	2.96%	1.92%	12.23%	1.08%
Medium-density residential	15.90%	−0.33%	2.48%	−0.29%	5.85%	−0.93%
High-density residential	0.11%	43.72%	1.6%	15.39%	1.38%	1.70%
Commercial	2.84%	−1.69%	−0.06%	0.39%	6.31%	−0.54%
Industrial	13%	−1.41%	43.84%	−0.88%	4.93%	3.38%
Institutional	6.80%	1.64%	2.49%	−0.35%	0.91%	1.45%
Open urban land	−0.18%	11%	1.01%	−3.16%	−0.25%	−1.55%
Agricultural	−0.80%	−3.72%	−1.40%	−1.42%	−0.57%	−1.82%
Forest	−0.71%	−1.23%	−0.27%	−0.72%	−0.5%	−1.3%

Note: Data are calculated from MdProperty View (http://planning.maryland.gov/OurProducts/PropertyMapProducts/PropertyMapProducts.shtml).

Montgomery Counties during 2002–2010; this demonstrates a desirable effect of TDR programs. They pushed development from the agricultural reserve onto urban receiving areas and promoted high-density smarter growth patterns in the receiving areas.

A question thus follows: If TDR transactions do not guarantee the protection of farms, what happened to those lands with their development rights severed? Using MdProperty View data from 1973 to 2010 in Montgomery Count in Table 4, we find that much has transformed to low- (1–3.5 dwelling units per acre) and medium-density housing (3.5–10 dwelling units per acre) consistent with previous studies (Cohen & Preuss, 2002). While more development has been concentrated in the receiving areas, the sending areas are not completely free from development pressure. While some lands have part of their TDRs sold, there may still be remaining TDRs that allow the owners to build one or two dwelling units. Since farm profitability on the urban fringe is challenging, and there is market demand for low-density residential with large land plots, many owners opted for residential development. The down sides of this are that it disrupted the farm economy and encouraged urban sprawl. The upside though is that this flexibility may have made the TDR programs politically feasible in the first place; keeping owners from fighting TDR programs more forcefully. In addition, the large land plot surrounding the residential units likely stay in open space, though not farms. The conservation of urban open space is still beneficial as open space improves environmental quality with cleaner air, attractive vistas, and less contaminated waterways.

Consistent with the statistical results, land in agriculture, including cropland, pastures, and orchard/horticulture dropped in all three counties in both 1973–2002 and 2002–2010 periods. Since the statistical and the land use analyses are based on completely different data sources, the consistency reinforces our confidence in the conclusion. Moreover, our results are in line with some previous planning literature. Daniels (1991) and Nelson (1992) both suggested that TDR is unlikely to preserve farms but may preserve some open space. Linkous and Chapin (2014) and Linkous (2016) also confirmed the ineffectiveness of TDR programs as a preservation tool and cautioned against measuring TDR success by counting the acreages preserved through TDR transactions.

TABLE 4 Land use change rate in the montgomery TDR sending and receiving areas, 1973–2010

	Annual growth rate			
	Sending area		Receiving area	
Land use type	**1973–2002**	**2002–2010**	**1973–2002**	**2002–2010**
Low-density residential	4.86%	8.40%	−1.50%	8.65%
Medium-density residential	22.25%	2.41%	3.73%	−3.08%
High-density residential	0%	6.55%	1.70%	14.80%
Commercial	1.32%	8.59%	0.001%	−5.49%
Industrial	3.06%	0%	23.33%	−5.91%
Institutional	11.24%	−8.15%	2.67%	−0.02%
Open urban land	1.44%	2.38%	2.67%	−9.22%
Agricultural	0.98%	−1.19%	−4.49%	−1.97%
Forest	−0.08%	−1.94%	−0.19%	−3.98%

Note: Data are calculated from MdProperty View (http://planning.maryland.gov/OurProducts/PropertyMapProducts/PropertyMapProducts.shtml).

Our interviews with staffs from the Department of Planning in Montgomery County also confirmed that the TDR program in Montgomery County may have preserved more open space and low density residential than farmland, and the staff members are aware of this issue. To combat the loss of farmland to low-density residential, the county has started a new Building Lot Termination Program (BLT) in 2008 to purchase the final buildable TDR on a 25-acre land. With the final unit of TDR severed, the 25-acre land is no longer buildable, and this may help keep farmland geographically continuous and make farm economy more feasible. Of course, the final unit of TDR is quite expensive, which makes BLT a challenging program for the county. As this program is new, our analysis cannot reveal its effect, but we expect it to reinforce the TDR program in Montgomery County and help with farm conservation.

Both our statistical results, land use records, and interviews with planners attest to the limited success of TDR programs. While this single study alone is insufficient for us to conclude for sure whether the limited success is due to the nature of TDR programs or the design of specific programs, our tentative conclusion leans toward the nature of TDR programs. This tentative conclusion is based on two factual observations. First, as described in section 2.3, the three TDR programs studied in this paper vary in their program design. However, none of them shows much of a success in preserving more farmland compared to control counties. Second, Pruetz and Standridge (2008) compared the design of 20 U.S. TDR programs that have preserved the most land and identified the following features as essential for TDR success: strict sending-area regulations, few alternatives to TDR to add density, and market incentives. The TDR program in Montgomery County has every single desirable design feature identified by Pruetz and Standridge (2008), and measured by our method and the U.S. Department of Agriculture data, these features do not effectively preserve farms against development pressure. For combating development pressures, we likely need more regulatory forces.

While acknowledging the general limitation of TDR programs, better design features may still marginally improve the program effectiveness. TDR programs in the three Maryland counties in general are ineffective in farm preservation, but the programs in Montgomery County and Calvert County outperform that in St. Mary's County. Thus, by looking into the specific features of these three programs may help us identify key features that improve program effectiveness. We search through the

differences across these three programs from our own analysis of program features in section 2.3 and from the literature such as Pruetz and Standridge (2008) and Shahab, Clinch, and O'Neill (2018a), Shahab Clinch and O'Neill (2018b, 2019). A couple of features are shared by the Montgomery County and Calvert County programs, but not the St. Mary's County program: (a) the sending and receiving areas are clearly defined rather than pooled together; (b) the market is relative active; (c) downzoning of the sending areas, and (d) the inflexibility of using the retaining development rights to build. The sale of even one unit of TDR puts the whole parcel under easement in the Calvert County TDR program, and in Montgomery County land owner can only build at the one dwelling per 25-acre zoning, while in St. Mary's County, landowners have the full discretion to sell any number of development rights and build with the rest. As shown in the land use analysis, acreages preserved through TDR transaction but not under easement likely develop into low- and medium-density residential; thus, this feature sets the program in Calvert County apart and adds to its power in farm conservation. In addition, Shahab, Clinch, and O'Neill (2018a) showed that TDR transaction in Calvert County has the lowest transaction cost among the three programs we study, followed by the Montgomery County program. The low transaction cost may have also added to the success of the Calvert County and Montgomery County TDR programs. Future planners wishing to conserve farmland at the fringe of metropolitan area need to be more realistic about how much TDR programs can help them achieve this goal. TDR programs are programs exploiting market incentives and can only be active with enough market demand. Thus, by nature, they are not built-in mechanisms to fight against market development pressure (Pfeffer & Lapping, 1994). As Linkous (2016) pointed out, planners give up some of their powers to control development patterns in exchange for the political support for the TDR program. For local jurisdictions already have TDR programs in place, planners may consider improving their programs with desirable features like the Montgomery and Calvert County programs.

It's also worthy of mentioning that the ineffectiveness of TDR programs identified in this paper is confined by the time frame of this study. Twenty to thirty years after TDR implementation, none of the studied TDR counties in Maryland preserved more farmland than control counties without TDR programs. However, this does not mean TDR programs don't support preservation in the long term. If zoning in TDR counties remains unchanged, more effects of TDR may reveal in the long run. Land with all TDRs sold is usually put under easement and permanently preserved. Thus, unlike some other market tools for farm preservation, such as providing tax incentive for keeping land in farms which only preserves farmland temporarily and is sensitive to the market price of land, the land under easement becomes insensitive to the growing market pressure. As a result, TDR programs may outperform other measures of farm preservation in the long run as the market pressure grows. It is possible that the same study after another thirty years would reveal a completely different result, with TDR counties retaining a large share of their current farmland while counties without TDR programs losing most of theirs. A follow-up study is needed to test this.

7 | CONCLUSION

We find no evidence that the TDR programs are successfully preserving farmland with cases of three Maryland counties. By applying two quasi-experimental methods to these counties and their counterparts from 1959 to 2012, we find that counties with TDR programs did not experience significantly slower farmland loss rates after the implementation of these programs.

We also conduct a land use analysis to confirm these findings. The land use data from 1973 to 2010 in each of the three Maryland counties show a consistent loss in agricultural land and a growth of low- and medium-density residential land. The data also show that the TDR program may have preserved

open space in Calvert County and thus is somewhat beneficial to environmental sustainability. The reason is that land where TDRs have been sold may not stay in farms; landowners have the option, except in Calvert County, to develop these lands into low-density residential with the remaining development rights. In the suburban areas of the Washington-Baltimore CMSA, farming is not particularly economically rewarding. Competition from agri-business, the economies of scale achieved by large farms, the rising costs of fertilizer and fuel and the low farming salaries coupled with the burdening cost of living in metropolitan areas all make profitability difficult (Imhoff, 2012). On the other hand, there is market demand for large lot residential development for people to work in DC while live in suburban areas to enjoy natural amenities. Many owners thereby opted for development. This study reveals that preservation of farms on the fringe of metropolitan areas is a challenging task. Nationwide, the small family farm is on the decline and TDR programs aimed at saving local farming are fighting against a national trend. This fight shows no sign of winning in sight. Planners therefore need to be realistic about what TDR programs can achieve in terms of farm preservation.

Though TDR programs show no sign of successfully preserving farms, the programs in Calvert County and Montgomery County appear to be somewhat more successful in retaining open spaces. Several features of these two programs stand out as potentially contributing to their competitive edge: They (a) define sending and receiving areas clearly, (b) maintain an active market, (c) keep transaction cost low, and (d) have downzoned the sending areas. And, in Calvert County, selling even one unit of development right would put the entire plot under easement. These may be features for planners to cultivate in future TDR programs.

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ENDNOTE

[1] PDR protects farmland through purchasing development rights directly with county budgets, which depends less on land owners initiating a sale and more on targeting and preserving valuable farmland, forests, and ecologically important resources. Similarly, RL designs special preservation areas to receive government or private trust funds to conserve farm, forest, and ecologically important resource lands in a contiguous fashion (Lynch and Liu, 2007), which are quite different from both TDR and PDR.

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