# A Relative Efficiency Analysis of Farmland Preservation Programs

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## Introduction

Agricultural land preservation concerns researchers and policy makers due to food security and amenity value issues. Most economists have dismissed food security arguments due to confidence in the market system to allocate land (Castle; Crosson; Gardner). However, the amenity values of farmland preservation for open space and for the pollution reduction potential in areas where suburban development is occurring has been given support (Castle; Fishel; Gardner; McConnell; Wolfram). States and counties use a variety of policy mechanisms including exclusive agricultural and/or low-density zoning, reduced property tax rates, and purchase of development rights (PDR) and transfer of development right (TDR) programs to slow farmland conversion (Duncan; Mulkey and Clouser; Rose). Contingent valuation ( Beasly, Workman, and Williams; Bergstrom, Dillman, and Stoll; Halstead) and public choice analysis of votes on establishing such programs (Kline and Wichelns) have been conducted However, economic analysis of the performance of these programs has been limited.

Agricultural land preservation programs in Maryland provide an opportunity for such analysis. In the last decade, more than 22 thousand acres of Maryland farmland per year have been converted to urban use. The Maryland Office of Planning's latest predictions project 400,000 more acres leaving agriculture (18 percent of the base) for development by the year 2010. Because zoning changes and preferential taxation was not stemming the conversion of farmland, PDR and TDR programs were established to place perpetual easements on parcels to restrict non-agricultural uses. PDR programs use tax money to purchase the difference between the fair market value and the agricultural value based on appraisals or on a point system. The TDR programs create a "market" where rural landowners sell rights to develop land to a developer who uses these rights to build at a higher density in a growth or "receiving" area. The Maryland Agricultural Land

Preservation Foundation (MALPF) started in 1978 (MALPF Annual Report). By 1995, MALPF had enrolled statewide more than 277,693 acres. Calvert County established both a TDR and a PDR program and Howard County set up a PDR program; Carroll County relies primarily on the State program but all three counties have some MALPF easements (Lynch and Horowitz). The number of acres preserved by the state and county programs is reported in Table 1.

**Table 1. Number of Acres Preserved by County and Program**

| | Calvert | Carroll | Howard |
|---|---|---|---|
| MALPF | 3,377 | 25,181 | 3,956 |
| County PDR | | | 13,470 |
| County TDR | 7,708 | | 404 |

This paper presents a Farrell efficiency analysis of the outcomes of these state and county agricultural land preservation programs. The programs share goals of preserving a large number of acres, contiguous parcels, the most threatened land or land most likely to be converted in the near future, and the most productive farms (larger farms, row crops, good soils). This paper considers these goals as multiple products. The detailed analysis of the different program outcomes allows evaluation of which type of program is most efficient in achieving particular goals and which is efficient in trading off among these goals. Data on the characteristics of the preserved tracts of land are used. The analysis concentrates on multiple outputs rather than inputs developing and using a specific form of efficiency analysis.

**Model**

This paper utilizes an adaptation of Farrell non-parametric methodology to determine the efficiency of the various programs. Farrell's methodology was developed to evaluate a firm's efficiency in maximizing production for a given level of inputs relative to other firms with similar technology. The model evaluates both a firm's technical efficiency (TE) and economic efficiency. Thus, the goal of maximizing profits subject to constraints depends on the ability both to use inputs well and to buy the right combination of inputs (Fare, Grosskopf and Lovell). Lovell reviews some of the applications where this approach has been used in evaluating the efficiency of public good production.

In this paper, program administrators maximize the goals of the programs to achieve the highest and best mix of preserved land characteristics given program constraints and existing land characteristics in the county. TE is the a measure of the achievement of the highest possible level of outcome characteristics given one acre and the local conditions. While the overall goal of the programs is to preserve the agricultural economy, more specific goals can be delineated and are described in the data section. These goals are the outputs of the preservation programs. Previous analyses of public goods have also interpreted goals as outputs. For example, McCarty and Yaisawarng used percentages of students who pass proficiency tests as outputs in evaluating efficiency of school districts. Burgess and Wilson used inpatient days, discharges, and surgery, outpatient visits, and ambulatory surgical procedures as outputs.

Lovell notes that efficiency analysis allows hypotheses testing about the efficiency of different programs in achieving certain goals. We hypothesize that some programs will maximize acres more efficiently, others will preserve the most productive farms, while others may be less efficient for all goals. The Farrell approach does not require assuming a specific functional form. In addition, no exogenous level of efficiency or absolute standard is necessary as the parcels can be compared with each other. Thus, programs are not evaluated as better if local conditions allow a higher level of achievement of these goals.

In the general model, $y_j$ and $x_j$ are vectors of output and input quantities for the jth preserved parcel, $\Theta_j$ is a nonnegative scalar and $v_j$ is a vector of variables. The linear programming model which produces as index of TE for the jth multiproduct firm is specified as (Paris):

(1)
$$\begin{aligned} & Max\ \Theta_j \\ s.t.\quad & (1+\Theta_j)y_j - Yv_j \leq 0 \\ & Xv_j \leq x_j \\ & \Theta_j \geq, v_j \geq 0 \end{aligned}$$

Here Y and X are matrices of outputs and inputs, respectively, for the n parcels. Given only one input, an acre of land, it is not necessary to explicitly model inputs so the second constraint can be eliminated similar to the analysis of only one output conducted solely in input space. With this situation, the first constraint can be rewritten as: $1/(1+\Theta_j)Yv_j \geq y_j$. Note that maximizing $\Theta_j$ is the same as minimizing $1/(1+\Theta_j)$. Using a unit vector $u$ and the rewritten constraint, equation (1) can then be rewritten as:

(2)
$$\begin{aligned} & Min\ uv_j \\ s.t.\quad & Yv_j \geq y_j \\ & v_j \geq 0 \end{aligned}$$

This problem is an inverted single product-multiple input problem where *max* is replaced with *min* and the constraint has the opposite inequality (Paris). Lovell discusses converting a problem from input to output space with similar transformations. For an efficient parcel, $uv_j$ equals one, and for an inefficient parcel, less than one. Thus, $uv_j$ is a measure of TE which can be interpreted as the program's ability to achieve the same mix of outcomes with less than one acre.

Overall efficiency (OE) is calculated with the model by adding another constraint to equation (2): $cv_j \leq c_j$ where $c$ is a vector of easement prices of the preserved parcels and $c_j$ is the scaler easement price of the jth parcel. OE can be interpreted as considering both the outputs and cost of a parcel and answers the question of whether the program administrator could have achieved a higher level of outcomes without spending more per acre.

**Data**

This analysis includes land preserved by state and county programs in Howard, Carroll and Calvert . Data was collected for each parcel: number of acres, year of enrollment, and price paid for the development rights. Prices were discounted with the Index of Prices Paid by Farmers(USDA). These data were merged with the Maryland Division of Tax and Assessment Database obtaining tax identification codes and geographic coordinates as well as data on parcel size, location, and waterfront access. Using a Geographic Information System, we added parcel characteristics from Maryland Office of Planning digitized maps such as percent of soil types, distances to cities and percent of pasture, row crops, forest or orchards.

Characteristics of the parcels are used to proxy the levels of achievement of the program goals or outputs. Several variables are used to proxy each of the three goals. 1) Maximizing the number of preserved acres: Number of acres preserved is the total number of acres in the preserved parcel. 2) Preserving productive farms: Percent of the parcel that is Prime I soil, Prime 2 soil, cropland, vegetables, and orchards are used to proxy productivity. Negative values of percent of land in pasture, brush or wetlands are also used. Because Maryland has its own soil classification system, we define Prime I soils based on the Maryland soils that have no slope or drainage problems and Prime II on soils with very limited slope or minor drainage problems (Maryland Department of Planning). 3) Preserving farms most threatened by development: Distance to Baltimore, distance to Washington D.C., and distance to nearest town are used to proxy threat of development. Shorter distances to urban centers will increase the threat of development so all of these variables are entered as negative numbers.

TE and OE were calculated for all parcels with each county as separate models. Efficiency estimates were then pooled and used as the dependent variables in two Tobit regressions with bounds of zero and one. Independent variables in the regressions were dummy variables for county, year of purchase of the easement, a dummy variable for parcels purchased with MALPF and TDR programs, and number of crop acres in the parcel. County dummies were included to test differences in efficiency due to land resources and/or programs among counties. As Howard is the most urban county, more threatened parcels should be available so that this dummy should be positive. It also calculates its easement value using a point system paying higher prices for the "right" characteristics which also implies a positive coefficient for the TE equation. However, the easements may have higher prices resulting in lower OE measures. Year of purchase is expected to be negatively related to efficiency under the assumption that administrators choose the most desirable parcels first. An alternative hypothesis is that programs purchase the least expensive development rights in the early years and later must pay higher prices which implies a negative sign for the coefficient in the OE equation. Number of crop acres in the parcel is expected to be positively related to efficiency because larger parcels are harder to duplicate with other parcels. In addition, larger parcels may have lower per acre prices which should result in a positive coefficient for OE. TDR would be expected to have a negative coefficient for TE as developers have no preferences for farmland characteristics but would simply choose the least expensive rights to purchase. On the other hand, one could expect a positive coefficient for TDR in the OE equation. MALPF has set minimum requirements on soil type and size for all the easements it purchases, and it is hypothesized to positively impact TE. It also engages in a bidding system which could result in lower prices for the easements and a positive impact on OE.

**Results**

Mean TE was 0.82 in Calvert, 0.76 in Carroll, and 0.90 in Howard. These means indicate that the level of TE was quite high. Distributions of TE are given in Table 2. More than 50% of the parcels had efficiency levels of 1.0 in both Calvert and Howard . Another 27.5% in Howard and 15.4% in Calvert had efficiency ratings between 0.8 and 1.0, and only 2.1% in Howard and 13% in Calvert were below 0.50. These county programs do quite well on maximizing outputs in the parcels that are preserved. Carroll only had 19.9% with 1.0, 29.9% between 0.80 and 1.0, and 12.2 % below 0.50. The lower level of TE in Carroll indicated that many parcels had inefficient mixes of output characteristics relative to the efficient ones. In addition, MALPF was the primary program here while the other two had county programs. As a state program, MALPF may not be as tailored to the specific conditions of the county. We also examined the relationship of the distribution of efficiency to the level of efficiency. The distribution for Howard is essentially monotonically increasing in efficiency. Those for the other two counties are not; the second highest percent for both Calvert and Carroll is .50-.69. Howard made fewer inefficient purchases as the inefficiency became larger.

Mean OE was 0.90 in Howard, 0.82 in Calvert, and 0.79 in Carroll. These means are the same as for TE in Howard and Calvert but slightly higher in Carroll. Howard had 45.0% with a level of 1.0, which is about 6% less than for TE; the next highest category was higher and the other categories were about the same. Percentages of OE was also monotonic increasing in efficiency levels. In Calvert, the percent of overall efficient parcels were about 5% higher than for technically efficient parcels with the next three lower levels being slightly smaller. Some of the parcels that had less of the desirable characteristics than the efficient parcels cost less than the efficient parcels so were overall efficient. This difference was even more dramatic in Carroll. Nearly 9% more parcels had an OE of 1.0 compared to TE, and 1.5% more had an OE between 0.9 and 1.0. The increasing OE at the two highest levels were redistributed from all the lower categories of TE except the lowest. In this rural county, many parcels with quite low TE had a lower cost than the parcels with higher TE.

**Table 2. Percent of Preserved Parcels With Different Levels of Technical and Overall Efficient**

| Efficiency Level | Howard County | | Carroll County | | Calvert County | |
|---|---|---|---|---|---|---|
| | TE | OE | TE | OE | TE | OE |
| 1.0 | 51.5 | 45.0 | 19.9 | 28.8 | 52.1 | 57.0 |
| .90 to .99 | 16.7 | 23.9 | 6.9 | 8.4 | 8.1 | 4.8 |
| .80 to .89 | 10.8 | 10.9 | 22.9 | 18.3 | 7.3 | 6.5 |
| .70 to .79 | 10.9 | 10.1 | 16.0 | 14.5 | 5.7 | 4.9 |
| .50 to .69 | 8.0 | 8.0 | 22.1 | 19.1 | 13.8 | 13.8 |
| .25 to .49 | 2.1 | 2.1 | 10.0 | 9.2 | 9.0 | 8.2 |
| 0 to .24 | 0 | 0 | 2.2 | 2.2 | 4.0 | 4.0 |

These differences among counties were further investigated with regression analysis that is presented in Table 3. These regressions had the same set of significant variables–county dummies and acres in parcels. Carroll was the deleted dummy so the other two dummies indicate a significantly higher efficiency than this county. Unlike the discussion of the percentage distributions above, these coefficients were larger in the OE equation than in the TE equation. In addition, the Calvert coefficients were larger than the Howard coefficients unlike the mean and percentage's discussions. Obviously, some other variables are accounting for the differences perceived above. The coefficients on acres also were positive, which indicates that larger parcels had higher efficiency levels. Size of parcel is one of the output variables, which may account for this significance. Smaller parcels can obviously not be combined to give the same characteristics, including acres, in an efficient manner. Whether larger parcels had higher levels of the other outputs and/or had a lower cost per acre needs more investigation. Other output characteristics may be needed in the regressions.

The insignificant variables are also interesting. The year variable did not support the hypothesis that the parcels with the highest outputs and/or lower costs would be purchased in the earlier years of the program. In fact, the sign on Year Purchased in the TE equation was even inconsistent with this hypothesis. The program dummies, where PDR is the deleted dummy, also indicated no differences between TDR and MALPF and PDR, despite the speculations above. However, the use of the programs is related to the counties so that perhaps the county dummies partially reflect program differences. The county dummies are measures of a combination of programs and characteristics. If more of these characteristics were included in the regressions, perhaps these two influences could be disentangled.

| Table 3. Tobit Regression Results for Technical and Overall Efficiency of Agricultural Land Preservation Programs in Maryland[a] | | |
|---|---|---|
| Variable | Technical Efficiency | Overall Efficiency |
| Intercept | .807*** (.071) | .849*** (.086) |
| Year Purchased | .001 (.003) | -.004 (.004) |
| TDR Dummy | .015 (.057) | .032 (.071) |
| MALPF Dummy | -.040 (.053) | -.013 (.065) |
| Calvert County Dummy | .186*** (.049) | .202** (.060) |
| Howard County Dummy | .144* (.049) | .167* (.060) |
| Acres in Parcel | .0008*** (.0002) | .001*** (.0003) |
| Scale | .197 (.011) | .215 (.013) |
| Log Likelihood Value | -140.61 | -178.06 |

[a]Standard errors of the coefficient appear in parentheses below the parameters.
* Indicates asymptotic significance at the .05 level
** Indicates asymptotic significance at the .01 level
*** Indicates asymptotic significance at the .001 level

**Conclusions**

Efficiency analysis of farmland preservation programs in Maryland gave some interesting results. Such analysis allowed consideration of a number of goals of preservation in a multiple output framework. Compared to such analyses of farms, the level of TE and OE was quite high. It also varied considerably among counties. Howard, the most urbanized of the three counties analyzed here, had the highest levels of TE and OE. In this paper, it was not possible to determine if programs, land characteristics, or costs accounted for this difference. Carroll, the most rural, had a much higher level of OE than TE; while some of the parcels preserved in this county maybe did not have as desirable set of characteristics, their per acre cost was low. The regression analysis affirmed that differences existed among counties, but not necessarily in the same relative manners as implied from the tabulations of the efficiency ratings. Parcel size was also positively related to efficiency. However, the year of purchase and program type were not significant. Extensions of this research will focus on introducing additional output characteristics into the regressions.

Other interesting issues could also be analyzed within this framework. A pooled efficiency analysis would evaluate how well county programs would perform in other counties. For example, how much would efficiency levels in Howard change if parcels in this county were analyzed in a pooled model. If the Howard program is designed specifically for the conditions and land prices in that county, the level of efficiency would not be much lower than separate analyses. Another issue concerns the tradeoffs among characteristics or goals of the programs. While some of the tradeoffs, such as distance to cities and size and cost of parcels, may exist in both urban and rural counties, the tradeoffs may also differ. In addition, some of the characteristics may dominate other characteristics, suggesting that some goals are either not as important as others or that a particular program weights decisions toward certain goals. This weighting may be purposeful or inadvertent, but it would be helpful for policy makers to know it exists. Finally, other public programs with multiple goals could be analyzed with this framework such as the USDA Conservation Reserve Program.

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