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by

Lori Lynch and Wesley N. Musser

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Department of Agricultural and Resource Economics
2200 Symons Hall • University of Maryland • College Park, MD 20742-5535 • USA • Tel. (301) 405-0057

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Agricultural and Resource Economics
University of Maryland
College Park, MD 20742
(301) 405-1264
(301) 314-9091 (fax)
llynch@arec.umd.edu

ABSTRACT

While agricultural land preservation programs seek to maximize number of acres, to preserve productive farms, to preserve contiguous farms, and to preserve threatened farms, they are often evaluated solely on the number of acres preserved. Using a Farrell efficiency analysis, preserved parcels in four Maryland counties were evaluated for all four goals. Comparisons are made between program Econometric analysis used these efficiency measures as dependent variables. Parcel size and productive farms were the most frequently used criteria to determine efficiency. In addition, purchase of development right programs were most successful in trading off objectives.

I. INTRODUCTION

Food security, local economic conditions, and amenity value issues have led to research and policy interest in agricultural land preservation. Gardner (1977) proposed that four benefits can be derived from the protection of productive agricultural land: local and national food security, employment in the agricultural industry, efficient development of urban and rural land and the protection of rural and environmental amenities. Most economists have dismissed food security and employment arguments due to confidence in the market system to allocate land between uses (Crosson 1982; Gardner 1977). However, farmland preservation programs can preserve the amenity values of open space and rural character as well as for the pollution reduction potential in areas where suburban development is occurring (Bromley and Hodge 1990; Castle 1982; Fischel 1985; Gardner 1977; McConnell 1989; Wolfram 1981). States and counties use a variety of policy mechanisms to slow farmland conversion including exclusive agricultural and low-density zoning, reduced property tax rates, purchase of development rights/purchase of agricultural conservation easements (PDR/PACE), and transfer of development rights (TDR) programs (Lynch and Horowitz 1998; Parks and Quimio 1996; Duncan 1984; Mulkey and Clouser 1987; Rose 1984). Papers on the theoretical aspects of preservation tools, such as TDRs, have also been published (Barrows and Prenguber 1975; Small 1976).

Contingent valuation analysis (Pruckner 1995; Drake 1992; Beasly, Workman, and Williams 1986; Bergstrom, Dillman, and Stoll 1985; Halstead 1984; Foster, Halstead, and Stevens 1982) and public choice analysis of votes on establishing such programs (McLeod, Woirhaye and Menkhaus 1999; Kline and Wichelns 1994; Variyam et al. 1990) have been conducted. When asked about preferences regarding farmland preservation goals, citizens said that protection of groundwater and wildlife habitats and preservation of natural places were the preferred objectives (Kline and Wichelns 1996). In 1998, U.S. voters approved 72 percent of the 240 ballot measures designed to preserve parks, open space, farmland, and other amenities (Myers 1999). These measures will result in more than $7.5 billion in additional state and local spending. Professionals in the metropolitan planning departments have been surveyed regarding implementation of farmland preservation programs (Pfeffer and Lapping 1994). Models have been formulated using measures of the amenity benefits to determine the optimal number of acres to preserve (Brunstad, Gaasland, and Vardal 1999; Lopez, Shah, and Altobello 1994).

Except for Parks and Quimio's work (1996) evaluating the effectiveness of preferential property taxation on farmland preservation, economic analysis of the performance of these types of programs has been limited. Agricultural land preservation programs in Maryland provide an opportunity for such analysis. In the last decade, more than 22,000 acres of Maryland farmland per year have been converted to urban use. The Maryland Office of Planning predicts that if the current trends continue 500,000 more acres of farms, forests and other open space will be converted to development over the next 25 years (*Bay Journal*, 1997). Urbanizing counties have established PDR and TDR programs to place perpetual easements on parcels to restrict non-agricultural uses in an attempt to slow or end farmland conversion (Lynch and Horowitz, 1998). Besides county-level PDR and TDR programs, Maryland also has a state-wide program, the Maryland Agricultural Land Preservation Foundation (MALPF), which uses tax money to purchase easements similar to a PDR.

This paper presents a Farrell efficiency analysis of the characteristics of the parcels preserved in these state and county agricultural land preservation programs. The programs have similar 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. This paper considers these goals as multiple products. 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 characteristics of the preserved tracts of land are used as outputs. The analysis adapts the standard forms of efficiency analysis and concentrates on multiple outputs rather than inputs .

II. AGRICULTURAL LAND PRESERVATION PROGRAM BACKGROUND

This analysis includes land preserved by state and county programs in Howard, Carroll, Montgomery, and Calvert counties in Maryland. Three of these counties, Montgomery, Howard and Carroll made the top 12 list Montgomery and Calvert counties have both TDR and PDR programs, Howard County has a PDR program, and Carroll County relies primarily on the State program. All four counties have some MALPF easements. Number of acres preserved by state and county programs for the four counties are reported in Table 1. Montgomery County had 77,266 acres in farmland (59% in preservation), Howard had 39,846 acres (45% in preservation), Calvert had 33,450 acres (33% in preservation), and Carroll had 160,180 acres (16% in preservation) (Agricultural Census, 1997).

In the four counties studied, returns for converting farmland to other uses had increased since the early 1970s. Maryland has passed several pieces of legislation that benefit all farm landowners. For example, farmers are granted preferential taxation on land kept in agricultural production. Property taxes on this land are based on an agricultural value rather than the value in the highest and best use. In 1977, the State established the Maryland Agricultural Land Preservation Program (MALPF) as a voluntary land preservation program. MALPF is a PDR program that purchases permanent easements which prohibit residential, commercial, and industrial uses on farmland for current and all future owners. MALPF set the value of the easements on the lower of 1) the calculated easement value equal to an appraisal value minus the agricultural value and 2) a bid made by the landowner. If insufficient funds exist to purchase all offers to sell easements made by landowners in a particular year, the parcels are ranked by the ratio of the bid to the calculated easement value. Those parcels with the highest value per dollar paid are accepted first. Parcels must be at least 100 contiguous acres or be contiguous to another preserved parcel. At least 50 percent of the soil must be classified as USDA Class I, II or III soils or Woodland group I or II. Parcels in any one county compete against each other in one round of bidding. In the second round of bidding, parcels compete against parcels from the entire state. The state program had purchased easements on more than 152,288 acres by 1998 (MALPF Annual Report 1998). Landowners in all four counties in the study area can participate in MALPF. Carroll County relies primarily on the MALPF program to preserve farms.

In addition to MALPF, Calvert, Montgomery, and Howard counties have county-level programs. Calvert County began a TDR program in 1978. Under this program, farmland owners can sell their right to develop to a developer who then uses it in a “receiving” area to increase building density where development is planned. The price is determined through negotiations between the landowner and the developer. A minimum of 50 acres and 50 percent prime soil is required for eligibility. Calvert has also instituted a PDR program to purchase TDRs at the average TDR price and to then retire or not use them to keep farmland preserved and housing density low. A single parcel can have sold TDRs in both the TDR and PDR programs in Calvert and Montgomery counties. A landowner may sell a few of the TDRs attached to the land in the TDR market. He could then sell the remaining development rights to the county PDR program.

In 1981, Montgomery County established a TDR program in its agricultural reserve of 90,000 acres simultaneously with a change in the zoning from one house on five acres to one house on 25 acres. Landowners were given approximately one TDR for each five acres of land, which developers could purchase and use to increase density in designated growth areas. The TDR price is determined through negotiations between the landowner and the developer. More recently, in 1990, Montgomery County began a PDR program under which the price is set by a point system or an appraisal process. Program administrators assign points to land characteristics such as road frontage, soil quality, and proximity to developed area in order to determine the per acre price offered to purchase the development rights.

Started in 1978, Howard County's PDR program at first used two appraisals to determine the easement purchase price. However, in 1989 the program switched to using a point system based on land characteristics to determine the easement value. At the same time, the program began to use an installment plan to purchase the rights. Under the plan, the farmer receives a county bond that pays tax-exempt interest payments twice a year with a balloon payment of the principal in year 30. These bonds can be liquidated at any time. In 1994, the county changed eligibility standards to emphasize the number of acres and quality of soil. Minimum acreage is set at 100 acres unless the parcel is contiguous to another preserved parcel. On two-thirds of the farm, at least 50% of the soil must be classified as Class I, II, or III. The County has also introduced a modified TDR program, but given the limited enrollment at the time this data was compiled (404 acres), this program is not included in the analysis.

III. MODEL AND ESTIMATION

This paper uses 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 the efficiency of other firms with similar technology. The procedure evaluates both technical efficiency (TE) and overall efficiency (OE). 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 (Färe, Grosskopf, and Lovell 1994). Lovell (1993) reviews some of the applications where this approach has been used to evaluate the efficiency of public good production.

In this paper, program administrators are assumed to 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 measures the achievement of the highest possible level of outcome characteristics for one acre preserved given local conditions. While the stated overall goal of the programs is to preserve the agricultural economy, more specific goals can be delineated and are described below. 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 (1993) used percentages of students who pass proficiency tests as outputs in evaluating efficiency of school districts, and Burgess and Wilson (1993) used inpatient days, discharges, and surgery, outpatient visits, and ambulatory surgical procedures as outputs. Similarly, analysis of the Hawaiian Public Library System used numbers circulated, number of patrons, and number of requests to measure the efficiency of the library system (Sharma, Leung, and Zane 1999).

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 are compared with each other. Thus, programs are not evaluated as more efficient if local conditions allow a higher level of achievement of these goals. Lovell (1993) notes that efficiency analysis allows hypotheses to be tested about the efficiency of different programs in achieving certain goals. We hypothesize that a TDR program will maximize acreage more efficiently, while a PDR program will preserve the most productive farms.

In the general efficiency model, y_j and x_j are vectors of output and input quantities for the jth preserved parcel, T_j is a nonnegative scalar and v_j is a vector of variables. The linear programming model which produces an index of TE for the jth multiproduct firm is specified as (Paris 1991)

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

Here Y and X are matrices of outputs and inputs, respectively, for the n parcels. Given only one input, an acre of land, inputs do not have to be explicitly modeled, and the second constraint can be eliminated. The model is then similar to the analysis of only one output conducted solely in input space. The first constraint can be rewritten as $(1/(1+T_j))Yv_j \geq y_j$. With this formulation, minimizing $1/(1+T_j)$ is the same as maximizing T_j. Because $1/(1+T_j) \leq 1$ and $(1/(1+T_j))Yv_j \leq Yv_j$, it follows that $Yv_j \geq y_j$. Now, v_j is the vector of weights on the outcomes to achieve y_j and is always less than or equal to a unit vector. Using a unit vector u, uv_j measures TE: a technically efficient parcel would have a TE equal to one and an inefficient parcel would have a TE that is less than one. Thus, uv_j is a measure of TE, which can be interpreted as achieving the same mix of outcomes by purchasing an easement on one or fewer acres. Using uv_j and the modified constraint, equation (1) can then be rewritten as

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

This problem is an inverted single product-multiple input problem where *max* is replaced with *min* and the constraint has the opposite inequality (Paris 1991). Lovell (1993) discusses converting a problem from input to output space with similar transformations.

Overall efficiency (OE) is calculated 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 considers both the level of outputs achieved and cost of a parcel. If the OE for a parcel equals one, the program could not have achieved the same level of outputs for a lower price than was paid per acre for that parcel. If OE is less than one, the same level of outputs could have been purchased with a lower price per acre, or a higher level of outputs could have been purchased for the same price per acre as was paid for that parcel.

These programs have identified four important goals to ensure the survival of the agricultural economy and preserve farmland that are used to define the desirable outputs or y_j per preserved parcel as referenced above. The y_j or parcel characteristics are used to proxy each of four goals: 1) <u>Maximizing the number of preserved acres</u>. Total number of acres in the preserved parcel. 2) <u>Preserving productive farms.</u> Percent of the parcel that is crop land, negative values of percent of land in pasture and forest which is perceived to be undesirable feature of productive farms[1], and percent of the parcel that is prime soil. The Maryland soil classification system defines prime soils as having minimal slope or no drainage problems (Maryland Department of State Planning 1973). Also, total number of acres in the farm can be considered here as well. 3) Preserving farms most threatened by development. The negative value of the distance to the nearest metropolitan center, Baltimore or Washington, D.C., and distance to nearest town as measures of the potential return to land conversion and the timing of possible development. 4) Preserving large blocks of land. Distance to the closest contiguous preserved parcel as a proxy of inclusion in a large block of land which may keep farming more cost-effective.

TE and OE were calculated for all parcels with separate models for each county, which evaluates each parcel relative to those within its own borders, and then as a pooled model combining parcels from all counties. The pooled models were used to evaluate the efficiency of decentralized programs compared to the state program. Efficiency estimates from individual county models were used as dependent variables in two Tobit regressions with bounds of zero and one; regressions were also estimated using the TE and OE measures from the pooled efficiency model. Independent variables in the regressions were the characteristics of the parcels, the year of purchase of the easement, and the program under which the parcel was preserved as a binary variable. In addition, interaction variables comprised of the program and the parcel characteristics were included. Variables for TDR were excluded.

IV. DATA

Data were collected on number of acres, year of enrollment, and price paid for the development rights for each parcel in the state and county programs. Prices were discounted using the Index of Prices Paid by Farmers (USDA) to a base year of 1997. These data were merged with Maryland Division of Tax and Assessment Data that provided tax identification codes and geographic coordinates as well as data on parcel size and location. Using a Geographic Information System, parcel characteristics from Maryland Office of Planning digitized maps were added such as percent of prime soil, distance to nearest metropolitan areas, to nearest town, and to other preserved parcels, and percent of pasture, row crops, and forest. Summary statistics for the data are presented in Table 2.

These programs preserved 1005 parcels for which tax identification numbers could be identified. Over the 20-year period, parcels may have been sold, and the tax identification number been changed. Parcels for which tax identification numbers could not be found were deleted from the analysis. Montgomery had 483 parcels of land (48%) included in the analysis with Calvert having 123 (12%), Carroll 240 (24%), and Howard 159 (16%). Calvert had an average parcel size of 81 acres in the preservation program. Carroll has an average parcel size of 103 acres for the preserved parcels. Howard had an average parcel size of 101 acres, and Montgomery County had an average size of 75 acres for the preserved parcels. Howard County parcels were most likely to have high quality soils with an average of 82% of the preserved acres having prime soil. Cropping patterns varied by county with more land in crops in Carroll (69%) and Howard counties (64%) and more land in forest in Calvert County (54%). Howard's preserved parcels were closer to metropolitan areas (2838 meters) than were other counties, with Calvert's parcels on average being the furthest away (5343 meters). Montgomery County parcels tended to be nearer other preserved parcels (451 meters), with Carroll (606 meters) and Calvert County parcels (592 meters) being further away from other preserved parcels.

A parcel with a large number of acres, a high percentage of prime soil, a high percentage of crop land, near another preserved parcel, near a metropolitan area, near the closest town, and with a limited percentage of pasture and forest acres, would be expected to have a high technical efficiency measure as it achieves all of the goals of the programs. If the price per acre to purchase the easement was also relatively low, this type of parcel would also have a high overall efficiency measure.

In the Tobit regression equations, year of purchase is expected to be negatively related to technical efficiency given that administrators choose the most desirable parcels first. In some cases, programs have become more restrictive in the eligibility requirements over the years. Thus TE could be positively or negatively related to the year of purchase. However, the programs may have purchased the least expensive development rights in the early years and may now be paying higher prices as the program matures, which implies a negative sign for the coefficient in the OE equation. Parcel quality variables are hypothesized to be positively related to efficiency. Size of the parcel is expected to be positively related to technical efficiency because larger parcels are harder to duplicate with other parcels. Larger parcels also often have lower per acre easement prices which should result in a positive coefficient for OE. Distance to metropolitan area, which is entered as a negative number, is expected to be positively correlated to TE. The threat of conversion is expected to increase the purchase price negatively, affecting OE. Proximity to nearest preserved parcel is expected to be positively related to technical efficiency. Percent of crop land would increase technical efficiency but may decrease OE compared to TE. Similarly, percent of pasture and percent of forest should decrease technical efficiency but may decrease the value of the easement, resulting in a lower purchase price and increasing OE compared to TE.   The significance of the coefficients on these characteristics will indicate the effect that different characteristics had on efficiency and presumably the trade-offs program administrators must be making given their local conditions.

It is expected that TDR would have a negative relationship with 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 relationship between TDR and OE as these parcels may be inexpensive and may have some of the desirable output characteristics such as large acreage. PDRs are hypothesized to have a positive effect on TE because program administrators are expected to rank the parcels offered by their desirable attributes. The purchase price is determined by the value of these attributes to the county, which may result in a more expensive purchase price and thus a lower OE. MALPF has the most strict minimum requirements on soil type and size of the parcel so the MALPF variable is hypothesized to positively impact TE. MALPF also has a bidding system that could result in lower prices for the easements with a positive impact on OE. As TDR is the excluded binary variable in the regression, the above reasoning would imply positive coefficients in the TE equation for PDR and MALPF variables. The coefficients in the OE equations are more ambiguous. However, PDR is hypothesized to have a negative coefficient in the OE equation while MALPF is more likely to have a positive coefficient in this equation. In addition to altering the intercept of the regression for the efficiency measure, these programs may also impact the slope or the marginal contribution of the parcel characteristics to the efficiency measures. Therefore, interaction variables between parcel characteristics and the preservation program binary variables were created. The coefficients on these slope variables for acreage, prime soil and crop land are hypothesized to have positive signs for MALPF due to the minimum eligibility requirements for the TE equation and due to the bidding system for the OE equation. All the PDR slope variables are expected to be positive in the TE equations, given that desirable characteristics including development potential are given points to determine a parcel's ranking and purchase price. Because of this point process, it is more ambiguous whether these PDR slope variables will have positive coefficients in the OE equation.

V. RESULTS

Efficiency Analysis

Mean TE was 0.62 in Calvert, 0.82 in Carroll, 0.84 in Howard, 0.68 in Montgomery, and 0.70 for the pooled overall analysis. These means indicate that the levels of TE were quite high. Means were higher in Carroll and Howard counties, which used MALPF and a combination of MALPF and PDR programs, respectively. Calvert and Montgomery counties depend more heavily on TDR programs to preserve agricultural land although both have some parcels enrolled in MALPF and PDR programs. These results were consistent with the hypothesized relationships: MALPF and PDR programs explicitly consider characteristics of parcels so fewer inefficient choices are made.

Distributions of TE are given in Table 3. Each county had efficiency levels of 1.0 for over 20% of its parcels Another 28.1% of the parcels in Howard, 36.3% in Carroll, 20.8% in Montgomery, and 13.8% in Calvert of the parcels had efficiency ratings between 0.8 and 1.0. Only 4.4% of the parcels in Howard and 7.6% in Carroll were below 0.50. As the means indicate, all these programs do quite well on maximizing outputs in the parcels that are preserved; however, the counties with predominately MALPF and PDR programs were more technically efficient. The pooled analysis shows only 9 percent of the parcels had a TE equal to one, with 38 percent with an efficiency rating between 0.8-0.1.00. Almost a quarter of the pooled sample had TE of less than 0.50. Parcels receive a higher efficiency rating when compared with those in their own county than when compared to those across counties.

Mean OE was 0.87 in Howard, 0.63 in Calvert, 0.83 in Carroll, 0.69 in Montgomery, and 0.68

for the pooled analysis. These means are similar to those for TE for all the analyses. In all cases, the percent of parcels with OE equal to one is greater than the percent of parcels with TE equal to one. This result indicates that some of the less technically efficient parcels had a lower easement purchase price per acre. Distributions of OE levels are also given in Table 3. Howard had 38.7% of its parcels with a level of 1.0, which is 14% more parcels than for TE, and the next three highest categories were lower. This difference between TE and OE also was found for Carroll. About 13% more parcels in Carroll had an OE of 1.0 compared to TE, with a smaller percentage of OE being in the next two categories. In both these counties, parcels with lower TE had a lower cost than some parcels with higher TE, so they achieved a higher OE of 1.0. Some of the parcels that had fewer of the desirable characteristics than the technical efficient parcels cost less than the efficient parcels so were overall efficient; i.e., for the price paid, the program achieved the highest level of output characteristics possible. Distributions in Calvert and Montgomery counties and the pooled analysis were quite similar to their TE.

Overall, these results further support the efficiency of MALPF and PDR found in the analysis of TE. Examining means of output variables in Table 2 for Howard and Carroll counties suggests that these programs resulted in larger average acreage, higher average percent of crop land, and lower average percent of forest land. Parcels in the Montgomery and Calvert counties had a higher percent of forest per parcel, a lower percent of crop land, and fewer acres, which reduced both TE and OE levels for these parcels.

The relationship of the distribution of efficiency to the level of efficiency can be seen in Figures 1 and 2. The distributions of TE for Howard and Carroll have smaller percentages for lower levels of efficiency, i.e,. the curve climbs more steeply than for the other counties. For example, in Howard

County, less than 30% of the parcels have TE of less than or equal to 0.7, while the percentages are about 35, 50 and 65 for Carroll, Montgomery, and Calvert, respectively. Except for the TE measure of 0.9 for all the counties except Calvert, Howard is first degree stochastic dominant over Carroll; Carroll is first degree dominant over Montgomery; and Montgomery is first degree stochastic dominant over Calvert. Thus, fewer inefficient purchases were made in Howard and Carroll than in the other counties as the technical inefficiency became larger. The OE distributions have the same pattern except for in Howard and Carroll with an OE of 0.9. The distributions of OE are almost first degree dominant over the distributions of TE in the same county. When the purchase price of the easement is taken into account, these two counties have even fewer inefficient purchases when the efficiency level is lower. These results reinforce the differences in inefficiency among the counties identified above.

Tabulation of Positive Shadow Values results

The importance of the alternative output variables in the efficiency analyses were further investigated by tabulation of the percentages of positive shadow values for each output for all parcels, which is presented in Table 4. Positive shadow values identify which outputs were the most important in determining efficiency. Overall, size of parcel and quality of soil were the most constraining outputs. For all four of the counties included in Table 4 and the pooled analysis, the shadow values for number of acres ranked either first or second. Similarly, the percent of prime soil and percent of crop land were also ranked high. In Calvert and Montgomery, size of the parcel had more positive shadow values than other output variables. For these same counties, percent prime soil and percent crop land were second or third. In Carroll and Howard, percent crop land and percent prime soil, respectively, had the most positive shadow values, with acreage of land being second. In these counties with PDR programs, a quality variable was more important than size of the parcel. Differences between these counties also may have resulted from the minimum acreage requirement in the relevant programs.

Mean characteristics of the parcels in Table 2 have interesting relationships to the percent of positive shadow values. Mean acreage was larger in Carroll and Howard, being over 100 acres compared to 75, 81, and 85 acres in the other counties and in the entire sample. Because parcels in these counties had a larger number of acres, this characteristic was easier to duplicate in many parcels and thus less likely to be the limiting factor. In Montgomery and Calvert, the positive number of shadow values for parcel size indicates that this size output characteristic must have been difficult to find. Parcels with many acres were hard to duplicate so that we find more positive shadow values. Smaller parcels were unable to achieve a high level of efficiency due to their size. For Howard and Carroll counties, the quality attribute for which they have the highest mean is the most constraining on achieving efficiency. Howard parcels have a mean of 82% prime soil per parcel, the largest among all the groups, yet percent of prime soil is the most constraining output measure. Howard parcels that did not have high levels of prime soil were not able to achieve high efficiency ratings. Similarly, Carroll has a mean of 69% percent of crop land per parcel, the largest of any of the counties, yet it has the most positive shadow values. Carroll parcels that did not have a high percentage of crop land were not able to achieve high efficiency ratings. Trade-offs between quality characteristics such as percent prime soil and percent crop land may explain the high number of efficient parcels in these counties. One has to carefully interpret the relationship between positive shadow values and characteristics of the parcels.

As with the percentages of TE and OE, few counties had differences in percent positive shadow values between TE and OE. One of the exceptions was distance to city in Carroll, which had a much higher percent for TE than for OE. The lower costs of more distant parcels must reduce the importance of distance for Carroll parcels. Calvert had a larger mean distance to a city than Carroll (Table 2), but distance in OE had a low percent of positive shadow values for Calvert and limited differences between TE and OE. Howard had differences in the percentages of OE and TE for all three distance outputs, with distance to city and town having higher percentages for OE while distance to other preserved parcels was higher for TE.   Howard parcels that are more distant from preserved parcels are less likely to rate high on TE. Yet when the purchase price of these parcels is factored into the equation, this quality attribute is less likely to impact the OE measure suggesting that these parcels' easement purchase price was lower. The distance to the metropolitan centers had a different relationship between TE (10.7%) and OE (20.1%). The purchase price of a parcel nearer the metropolitan area would be higher. It is possible that a very efficient parcel was preserved with a low purchase price, and this parcel would be hard to duplicate, being close to the urban center and yet relatively inexpensive. However, in both the TE and the OE positive shadow value rankings for Howard, the distance to the urban city had the lowest number of positive shadow values. Howard also was the only county with the third and fourth ranked positive shadow values having the opposite order for TE and OE. For TE, distance to other parcels had the third highest positive shadow values, and for OE it was the percent of crop land.   If one looks at the constraining land use measures, Calvert had the highest percent of positive shadow values for pasture while all other counties had crop land as the highest percentage. Pasture has the lowest percentage of positive shadow values among the land use variables for Howard and Montgomery counties and in the pooled analysis. Forest land use was the lowest for Calvert and Carroll counties.

Econometric Estimation Results

Equations were estimated for TE and OE for the combined measures from the separate county analyses and the pooled efficiency analysis to further investigate the effect of output and program variables on efficiency (Table 5). The year the parcel was preserved was negative and significant in the two county-level regression equations and in the pooled technical efficiency equations. This suggests that programs were able to enroll the parcels that contribute the most to achieving the stated goals in the early years of the programs. The coefficient on years preserved was not significant in the pooled OE equations suggesting that even though desirable parcels were enrolled, the price may not have been low when the parcels were evaluated with parcels from other counties.

For the output variables alone, distance to town and distance to city had significant coefficients in all four equations. Parcels closer to the city were more likely to have high technical and overall efficiencies indicating development pressure on these parcels had a positive effect on efficiency. It appears that the programs have been able to preserve parcels under the threat of conversion. In contrast, people close to the nearest town were less likely to have high technical and overall efficiencies. Towns may have varied more than cities in their growth potential over the last 20 years and thus this may not be a good proxy for development pressure. Unlike the other distance variables, proximity to the nearest preserved parcel did not demonstrate a statistically significant relationship with the efficiency levels in any of the four equations. This suggests that preserved parcels may not be close together but rather are scattered around the county.

The expectation given the tabulation of shadow values was that percent of prime soil, acreage and percent of crop land would have significant coefficients, yet this did not occur. Only the coefficients on prime soil alone were significant in the two pooled regression models. These results are somewhat paradoxical. The purpose of the pooled analysis was to determine if the programs were as efficient analyzed jointly for all counties as in their individual counties; the expectation was that the pooled analysis would show that the county programs were less efficient when parcels in other counties were included as reference parcels. Local officials had developed the county-level programs and they could have better tailored these program to the local conditions than a program designed to serve the entire state. Here the percent of prime soil was significant at the pooled level and not the county level. Percent crop land, the other quality variable besides prime soil that had many positive shadow values, was not significant in any of the four equations. Parcel size also did not significantly affect technical efficiency or overall efficiency by itself in any of the four equations. The results found from the tabulation of the shadow variables that the other quality variables had limited significance also were found in the regression equations. Percent of pasture land did not demonstrate a statistically significant relationship with the efficiency levels in any of the four equations. The percentage of land in forest did have a positive and significant relationship with TE in the county level equation but not in the other three equations.

Parcel characteristic variables may have marginally different contributions under the different preservation programs given the minimum eligibility requirements and the ranking procedures. For example, percent of prime soil had a significantly positive impact on efficiency level in all four equations when interacted with MALPF and in the two pooled regressions when interacted with PDR. Acreage positively impacted the efficiency levels for MALPF parcels in the two county level equations, but not the two pooled equations. In contrast to the rest of the sample, MALPF parcels were more likely to have higher efficiency when close to the nearest town for the two county level equations and less likely to have higher efficiency when close to the nearest city for the TE county-level equation and the two pooled regression equations. The percent of crop land for MALPF parcels positively influenced efficiency in the two pooled equations and the OE county-level equation. The percent of forest for MALPF parcels was a significant explanatory variable for both the county-level equations and the OE pooled equation. As the percent of forest increased, the level of efficiency decreased.

The regressions also have other policy implications. Binary variables were included for PDR and MALPF, with TDR being the reference program. The MALPF coefficients were significant in all equations except the county-level OE equation. These coefficients had negative signs. Thus, by itself MALPF has not achieved a higher level of efficiency than a TDR program; in fact, the intercept indicates lower efficiency than exhibited by the TDR programs. However, many of the output characteristics for MALPF parcels do indicate a positive marginal contribution to efficiency different from those of TDR parcels. The coefficients on the PDR binary variable were not significant in any of the four equations. The PDR program thus appears to be have no influence relative to the TDR program on the OE and TE levels. The interaction variables were not much different—only the coefficients for PDR*Prime were significant in the pooled equations. However, likelihood ratio tests indicated that the set of coefficients for the binary and interaction variables for PDR are significantly different from zero; $?^2$ ‘s with ten degrees of freedom ranged from 33.2 in the separate TE equation to 42.2 in the pooled TE equation.

A final point concerns comparison of the state program, MALPF, to the county PDR and TDR programs. The pooled analyses allowed a consideration of the efficiency of the parcels if purchases in all four counties were jointly analyzed. The pooled efficiency equations had many of the same results as those for the separate analyses. However, the coefficients for parcel size, distance to town, and forest (in the TE equations) for the MALPF parcels were significant in the county-level analysis but not the pooled analysis. Thus MALPF was efficient in achieving these characteristics when compared to other parcels within the same county but not when compared to parcels from other counties. Given that MALPF is a state program, we would have expected the opposite results. The coefficients for prime soil and prime soil for PDR parcels were significant in the pooled equations but not the county-level equations. The preservation programs were more efficient at enrolling parcels with prime soils at the aggregate level than they were at the county-level. Perhaps soils are more homogenous within a county than between counties.

VI. CONCLUSIONS

The efficiency of agricultural land preservation programs including PDR, TDR, and the state program, MALPF, is evaluated. These programs set goals of maximizing the number of acres preserved, preserving productive farms, preserving contiguous farms, and preserving parcels most threatened by development pressure. These goals were considered multiple outputs for evaluation of technical efficiency (TE) and overall efficiency (OE) of the preserved parcels in a Farrell efficiency analysis. These analyses were conducted separately for the four Maryland counties studied and for a pooled sample of all the preserved parcels.

The efficiency analysis determines whether a combination of less than one acre of other parcels achieves the same level of the outputs as obtained from the reference parcel. Levels of both TE and OE were quite high with more than 20% considered efficient: i.e., no other parcels exist that could be combined to achieve the same level of characteristics for less than an acre. A larger percentage of the parcels had an efficiency higher than 0.80, i.e. the level of outputs could be duplicated with only 80% of an acre by combining other parcels. The mean level of efficiency was greater than 0.60 in all the counties. This high level of efficiency indicates that the programs have been able to make trade-offs between the various characteristics of the preserved parcels. For example, an efficient parcel with a high percentage of crop land may be more distant from the urban center when compared to an efficient parcel close to the urban center but with a low percentage of crop land.

Some counties appear to have fewer inefficient parcels, indicating that they have made better trade-offs among the relevant characteristics. Carroll and Howard counties have mean TE and OE greater than 0.8. They also have nearly 40% of the parcels being overall efficient, with no more than 7.6% of the parcels having an efficiency measure less than 0.50. These counties also had a higher level of OE than TE. Thus, some of the parcels preserved in these counties did not have as desirable a set of characteristics but their per acre easement purchase price was lower than the price for other parcels. These counties appeared to trade off a lower purchase price and parcel characteristics well. Howard County had a PDR program, and Carroll County had 100% participation in MALPF. In contrast, the preservation in Montgomery and Calvert counties emphasized TDR programs. In the former two counties, program administrators explicitly considered parcel characteristics when selecting among the parcels that landowners offered to preserve. In contrast, developers who purchased the TDRs did not care about parcel characteristics, preferring to purchase the least expensive development rights. In this situation, the market solution was not as efficient in preserving desirable parcels as the tax payer financed programs. TDR programs may decide to cost-share with developers if the parcel achieves some level of the desirable characteristics in order to increase the efficiency of parcels selected.

Tabulation of positive shadow values allowed consideration of the limiting characteristics in determining efficiency of the parcels. Number of acres, percent of prime soil, and percent of crop land tended to have the most positive shadow values in all the analyses. Number of acres had the most shadow values in Calvert and Montgomery counties, which focused on TDR programs, while the quality variables had higher values in the other two counties. The other two goals of the programs–threat of development modeled as distance from urban areas, and contiguousness to other preserved parcels modeled as distance to nearest preserved parcel– did not have as many positive shadow values as the maximum acres and productive farms goals. Possible explanations include that the programs do not give as much attention to these goals, many parcels have similar values of these variables, and/or variables in the analysis do not proxy these goals well. In addition, parcels closer to urban centers could have chosen not to participate in the preservation programs, or the purchase price of the easement could have been too high to select the parcel for preservation.

Regressions were estimated for the efficiency measures with the land characteristics, program participation, and year preserved as independent variables. The equations also incorporated slope variables for PDR and MALPF programs with TDR variables being excluded. Except for percent of prime soil in the OE equations, the coefficients on acres, percent of crop land, and percent of prime soil were not significant overall, although the shadow value tabulations suggested they would be. In contrast, proximity to the city was positively related to efficiency. For MALPF parcels, prime soil was positively related to efficiency for all the equations, crop land in all the equations except the county-level TE equation, and acres was positively related in both TE equations. Percent of prime soil was also positively related to OE for PDR parcels. The regression analysis suggests that MALPF parcel characteristics have a marginally different contribution to efficiency than the other parcels. Overall, all the goals except contiguous parcels are positively related to efficiency for MALPF parcels.

The pooled analysis had the purpose of evaluating efficiency of parcel decisions at the county level compared to efficiency of the four counties analyzed jointly. While the pooled analysis had fewer parcels with an efficiency level of 1.0, mean levels of efficiency were similar to the county analyses. Similar characteristics also had the most positive shadow values; distance to other parcels was more limiting in the aggregate analysis (except for Howard). The regression results for the pooled analyses were also similar to the separate analyses; therefore it appears that programs operated at the state level and at the county level are able to achieve efficiency under non-local conditions. Based on these results, the decentralized county programs seem to be as efficient as if each program were jointly administered.

Most farmland preservation programs seek to preserve more than acreage, yet often number of acres is the only measure available. The nation's top 12 local farmland preservation programs are ranked by the number of acres preserved (Bowers, 2000). It is interesting to note that three of the counties in our sample have added additional programs to achieve the full range of goals. Even though Montgomery County had preserved 49,000 acres with a TDR program at little cost to the county government, it added a PDR program funded by tax dollars when it recognized that some of its program goals were not being realized. Montgomery County's PDR program purchases easements on parcels that usually border urban areas and determines the price with a point system based on characteristics. Like Montgomery County, Calvert County realized that some of its goals were not being achieved and has just introduced a new program to pay a premium for farmland closer to towns and urban center. On the other hand, Howard County has purchased many desirable parcels but in recent years has purchased few easements due to budget constraints. A recent $15 million bond issues is expected to preserve about 2,500 acres

(Bowers, 2000) but to achieve its acreage goal it needed a new mechanism. Therefore, Howard County introduced a TDR program to exchange density between parcels in hopes of increasing the number of preserved acres.

Counties may choose to use TDR programs because they do not have a government budget constraint, but they may have different distributional consequences than PDR programs. Taxpayers fund PDR purchases through a variety of different taxes. In contrast, developers pay for TDRs and may pass on the cost to purchasers of new houses. In addition, the neighbors in these growth areas who experience higher density may find a decrease in their perceived quality of life. Therefore, the costs of the TDR program are paid not only by the developers but also housing consumers. Unless the preserved land is contiguous to the new homes, all taxpayers seem to receive benefits from the land preservation program. Oftentimes these distributional consequences are not explicitly considered in decisions about which program to initiate. Future research is planned to evaluate these distributional consequences of PDR and TDR programs to better inform policy makers.

As most public programs do have multiple objectives, the Farrell efficiency framework could also be useful for evaluation of other public programs. Several characteristics of the approach add to its usefulness. The TE analysis focuses on goals without considering costs, while the OE analysis permits the inclusion of cost. If the outputs or goals have prices, one could also conduct an economic efficiency approach, which considers the trade-offs between the values of the outputs. We were not able to do an economic efficiency analysis because our outputs had no market prices to attach. Another advantage of this approach is that one is not forced to assume a functional form to estimate efficiency. In addition, no exogenous level of efficiency needs to be specified; rather the parcels can be compared one with another, i.e., one looks at the actual results of the program rather than the possible results. The distribution of efficiency levels among the units of analysis also permits a measure of success for programs in achieving their objectives, which is particularly useful if several programs have the same objectives. Finally, the analysis identifies which objectives are being emphasized in the operation of the program. Such analysis can therefore identify which goals are important for program modification or recognize that operationally these objectives are not as important. This information can also help policymakers establishing new programs to understand how each institutional structure may impact the trade-offs.

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TABLE 1.

NUMBER OF ACRES PRESERVED BY COUNTY AND PROGRAM (2000)

	County			
Program	Calvert	Carroll	Howard	Montgomery
MALPF	3,844	31,284	3,937	2,074
County PDR	0[2]	0	12,801	6,353
County TDR	10,960	0	1,350	40,583
Total	14,804	31,284	18,088	49,010

Source: Bowers Publishing, Farmland Preservation Report, Greg Bowen, Calvert County Office of Planning and Zoning

TABLE 2.

STATISTICS OF ANALYSIS VARIABLES BY COUNTIES AND BY THE WHOLE DATA SET

Variable Name	All	Calvert	Carroll	Howard	Montgomery
Number of Observations	1005	123	240	159	483
Percent of TDR Parcels	49	64	0	0	85
Percent of PDR Parcels	23	32	0	81	13
Percent of State Program Parcels	30	20	100	19	2
Average Acres per Parcel	87	81	103	101	75
Average Year of Preservation	89	90	87	88	89
Average % of Prime Soil per Parcel	46	43	39	82	38
Average % of Cropland per Parcel	55	36	69	64	49
Average % of Pasture per Parcel	15	2	14	11	19
Average % of Forest per Parcel	25	54	12	20	24
Average Meters to Nearest City	4327	5343	5083	2838	4184
Average Meters to Nearest Town	531	610	535	452	534
Average Meters to Nearest Preserved	521	592	606	549	451

TABLE 3.

PERCENT OF PRESERVED PARCELS WITH DIFFERENT LEVELS OF TECHNICAL AND OVERALL EFFICIENCY

	Calvert		Carroll		Howard		Montgomery		All Counties	
Efficiency Level	TE	OE	TE	OE	TE	OE	TE	OE	TE	OE
1.0	21.2	26.9	26.7	40.0	24.7	38.7	28.5	30.4	8.9	10.80
.90 to .99	8.1	4.9	21.4	10.7	27.9	23.4	10.5	9.2	22.6	20.70
.80 to .89	5.7	5.6	14.9	13.2	20.2	16.4	10.3	9.7	15.1	15.70
.70 to .79	9.8	8.2	13.2	13.2	17.8	7.6	8.3	8.5	11.2	10.90
.50 to .69	21.1	21.1	16.2	15.7	5.0	10.2	13.4	13.2	18.7	18.30
.25 to .49	18.7	17.9	5.5	5.1	3.8	3.1	14.0	14.0	12.4	12.80
0 to .24	15.4	15.4	2.1	2.1	0.6	0.6	15.0	15.0	11.1	10.80

TABLE 4

PERCENT OF POSITIVE SHADOW VALUES FOR PARCEL CHARACTERISTICS BY COUNTY

AND TECHNICAL AND OVERALL EFFICIENCY

	Calvert		Carroll		Howard		Montgomery		All Counties	
Output	TE	OE	TE	OE	TE	OE	TE	OE	TE	OE
Acres of Land	85.5	84.7	62.3	61.0	63.5	57.9	70.8	70.4	64.8	65.1
Percent Prime Soils	55.6	53.2	51.7	53.4	72.3	66.0	43.0	43.8	48.0	47.7
Percent Pasture	49.2	49.2	23.7	21.6	28.9	27.7	11.7	12.3	21.5	23.4
Percent Crop Land	41.1	42.7	75.0	75.0	38.4	40.3	60.7	61.1	58.8	57.8
Percent Forestland	8.1	8.1	15.3	16.9	36.5	34.0	18.5	17.3	28.6	28.8
Distance to Town	13.7	17.7	26.3	25.0	16.4	27.0	17.1	16.0	14.0	13.6
Distance to City	7.3	8.9	34.7	15.3	10.7	20.1	7.6	7.6	4.9	4.2
Dist. to Preserved Parcels	27.4	21.0	18.6	22.5	44.0	32.7	14.2	16.7	42.4	42.1

TABLE 5.

TOBIT REGRESSION RESULTS FOR SEPARATE AND POOLED ANALYSES OF TECHNICAL AND OVERALL EFFICIENCY OF AGRICULTURAL LAND PRESERVATION PROGRAMS IN MARYLAND[a]

	Technical Efficiency		Overall Efficiency	
Variable[b]	Separate	Pooled	Separate	Pooled
Intercept	0.91*** (0.12)	0.87*** (0.099)	0.93*** (0.13)	0.88*** (0.10)
Year Purchased	-0.0078* (0.0036)	-0.0061* (0.0030)	-0.010** (0.0039)	-0.0059 (0.0031)
PDR Dummy	-0.27 (0.25)	-0.17 (0.21)	-0.13 (0.28)	-0.18 (0.22)
MALPF Dummy	-0.46* (0.22)	-0.65*** (0.18)	-0.35 (0.25)	-0.48* (0.19)
Acres in Parcel	0.00029 (0.00018)	0.00025 (0.00015)	0.00034 (0.00020)	0.00026 (0.00016)
Distance to Town	-1.52** (0.54)	-1.20** (0.45)	-1.85** (0.59)	-1.15* (0.46)
Distance to City	0.51** (0.19)	0.62*** (0.16)	0.50* (0.21)	0.64*** (0.17)
Distance to Nearest Preserved Parcel	0.79 (0.60)	0.69 (0.51)	0.88 (0.65)	0.70 (0.52)
Percent of Prime Soil	0.074 (0.038)	0.070* (0.032)	0.078 (0.041)	0.073* (0.033)
Percent of Crop Land	0.0084 (0.087)	0.21 (0.074)	0.0023 (0.094)	0.025 (0.075)
Percent of Pasture Land	0.0092 (0.098)	-0.0078 (0.082)	0.018 (0.10)	-0.0092 (0.084)

	Technical Efficiency		Overall Efficiency	
Percent of Forest Land	0.054* (0.093)	0.034 (0.079)	0.051 (0.10)	0.030 (0.080)
MALPF*Acres	0.0010** (0.00035)	0.00043 (0.00027)	0.0010** (0.00039)	0.00052 (0.00028)
PDR*Acres	0.000011 (0.00036)	-0.000040 (0.00030)	0.00014 (0.00040)	-0.000051 (0.00030)
PDR*Year	0.0082 (0.0084)	0.0036 (0.0071)	0.0040 (0.0093)	0.0050 (0.0073)
MALPF*Year	0.0092 (0.0056)	0.0036 (0.0046)	0.0083 (0.0061)	0.0031 (0.0047)
PDR*Town	1.54 (1.05)	1.08 (0.89)	2.24 (1.15)	1.22 (0.91)
MALPF*Town	2.12* (1.01)	1.37 (0.83)	2.63* (1.12)	1.37 (0.85)
MALPF*Nearest	-0.62 (0.79)	-0.10 (0.65)	-0.72 (0.86)	-0.12 (0.66)
PDR*Nearest	-0.31 (0.85)	-0.0067 (0.72)	-0.25 (0.92)	0.72 (0.74)
MALPF*City	-0.65* (0.28)	-0.74** (0.23)	-0.41 (0.31)	-0.76** (0.24)
PDR*City	-0.29 (0.27)	-0.16 (0.23)	-0.27 (0.30)	-0.17 (0.24)
MALPF*Cropland	0.32 (0.18)	0.52*** (0.15)	0.39* (0.19)	0.35* (0.15)
PDR*Cropland	0.23 (0.22)	0.23 (0.19)	0.21 (0.24)	0.23 (0.19)
MALPF*Prime	0.32*** (0.069)	0.20*** (0.057)	0.34*** (0.076)	0.19*** (0.058)

	Technical Efficiency		Overall Efficiency	
PDR*Prime	0.14 (0.074)	0.13* (0.062)	0.14 (0.080)	0.14* (0.064)
MALPF*Pasture	0.34 (0.19)	0.0097 (0.16)	0.38 (0.21)	0.18 (0.16)
PDR*Pasture	-0.21 (0.25)	-0.24 (0.21)	-0.18 (0.27)	-0.24 (0.21)
MALPF*Forest	0.45* (0.19)	0.13 (0.16)	0.44* (0.20)	0.33* (0.16)
PDR*Forest	0.15 (0.23)	0.13 (0.20)	0.20 (0.26)	0.14 (0.20)
Scale	0.30*** (0.0078)	0.26*** (0.0061)	0.32*** (0.0088)	0.26*** (0.0063)
Log Likelihood Value	-339.92	-138.26	-417.02	-172.46

[a]Standard errors of the coefficient appear in parentheses below the parameters.
[b]The slope dummy variables are labeled with the intercept dummy–shortened name of continuous variable.
[*] Indicates asymptotic significance at the .05 level. [**] Indicates asymptotic significance at the .01 level.*** Indicates asymptotic significance at the .001 level.

Footnotes

1. However, if taxpayers support these programs to preserve open-space and wildlife habitat, preserving land in forest and pasture would be desirable. These land uses however tend to purchase fewer inputs per acre and may generate lower annual receipts in the local farm economy.

2.Some of the TDR have been sold as part of the County PDR program however the acre are reported in this table as TDR acres. Greg Bowen of Calvert Office of Planning and Zoning estimates that 2,500 acres of the TDR total have been preserved under the Calvert PDR program

Figure 1. Cumulative Distribution of Technical Efficiency Measures by County

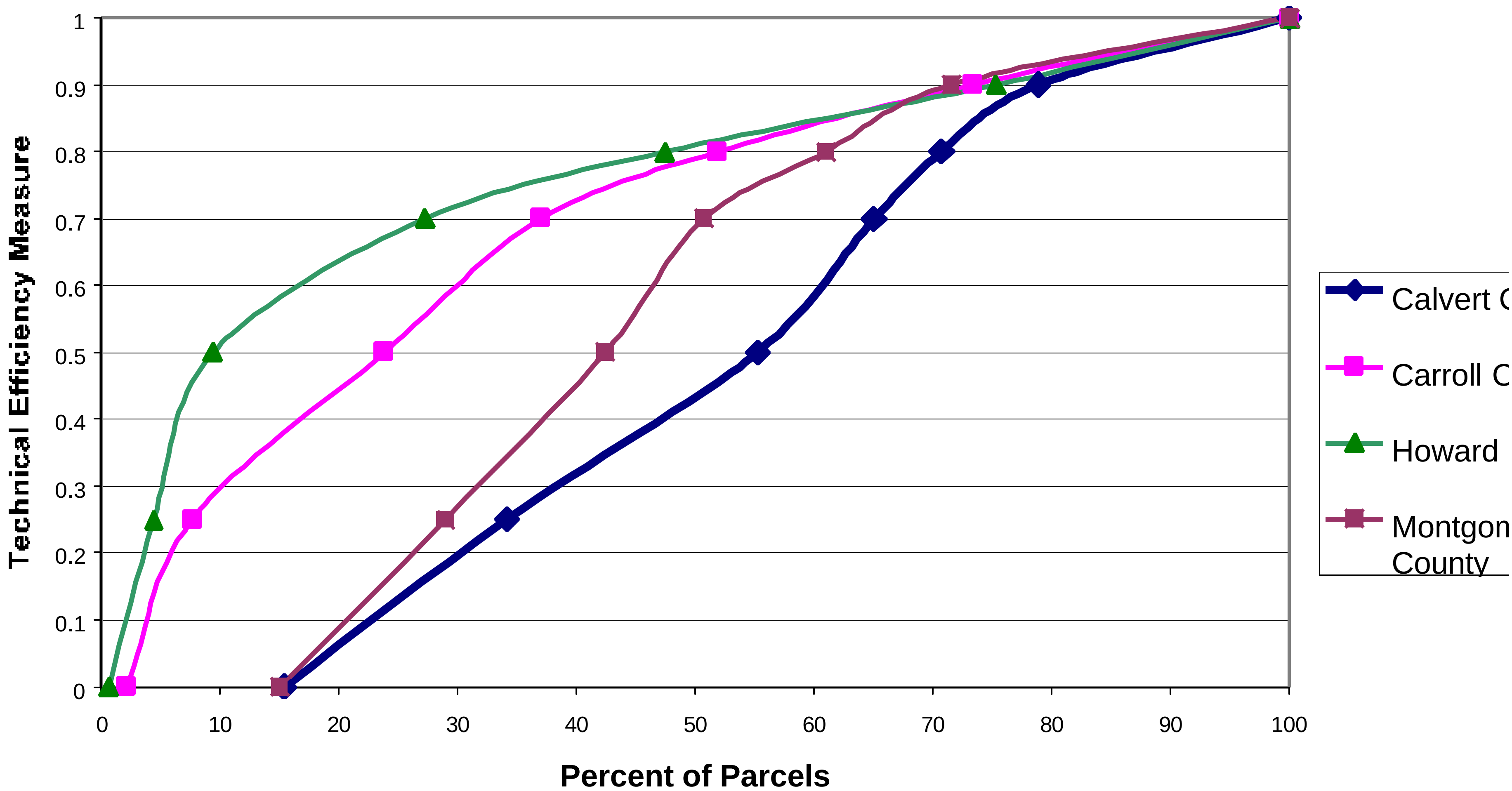

Figure 2. Cumulative Distribution of Overall Efficiency Measures by County