Measuring the effect of farmland preservation on farm profitability

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1. Introduction

The displacement of agriculture as a dominant element of American society and the national economic landscape is among the most significant transitions of the past century (Jackson-Smith and Jensen 2009; Lobao and Meyer 2001). Evidence of this decline includes the falling number of United States counties designated as farming dependent, the fact that fewer than two percent of Americans are now engaged in farming, and the large number of farms operating without a profit motive (so-called "lifestyle farms") (Dimitri et al. 2005; Ghelfi and McGranahan 2004). However, it is the conversion of farmland to build infrastructure attendant to residential, commercial or industrial development that is the most visible manifestation of farm decline. These land use changes have elevated concern about the retention of agricultural lands, resulting in significant public investments in farmland preservation.

Protection of the nation's farm sector has long been a federal policy objective, rationalized in part by the priority of maintaining domestic food production capacity and reflective of inherent value Americans place on rurality and the Jeffersonian ideal of small family farms (Danborn 1996). Since the mid-1900s, urban expansion and the low-density, exurban growth pattern commonly identified as "sprawl" have joined the vagaries of market fluctuations, weather, pests and disease as a significant threat to farming in many parts of the nation (Rudel et al. 2011; Heimlich and Anderson 2001; Sorensen, et al. 1997; Daniels and Bowers 1997; Lopez et al. 1988; Berry 1978). Research in the late 1970s conducted as part of the National Agricultural Lands Study increased awareness of the pressures on the nation's agricultural resources and concerns over the loss of farmland to development. The rate of land conversion to developed uses has been exceeding the rate of population growth and one-third of the total developed land area in the continental United States (approximately 40 million acres) was developed between 1982 and 2007 (USDA 2009).

Jackson-Smith and Sharp (2008) find that more than half of national farm sales are derived by farms now operating at the rural-urban interface. An estimated 91 percent of the nation's fruit production and 78 percent of vegetable production occurs in counties designated by the USDA's Economic Research Service as "urban-influenced" (American Farmland Trust 2013). Notwithstanding these land use trends, farmland remains an abundant resource on a national scale and domestic food self sufficiency is not imminently imperiled. However, at state and local levels, concern over farmland fragmentation and conversion (and the loss of associated non-market amenities) has assumed an elevated position in public policy discourse, particularly in the Northeast region. In the 1970s, states began creating purchase of development rights (PDR) programs to preserve farmland and rural amenities, advance growth management objectives, and support farming as a business.[1] As of May 2012, 27 states have created PDR programs as a tool to preserve farmland. These programs have preserved nearly 2.3 million acres at a cost of $5.7 billion (AFT 2012). Program activity has been heavily concentrated in the New England and greater Mid-Atlantic states.

Despite these substantial investments in PDR, empirical assessment of program success in effectuating the legislative intent of publically funded farmland preservation is limited. Common metrics of progress (e.g., acreage enrollment statistics) provide little insight, for example, into the effects of public farmland preservation investments on the economic performance and viability of preserved farms. Previous research has focused on the effects of easement restrictions on preserved farmland values (Nickerson and Lynch 2001; Lynch, Gray, and Geoghegan 2007; Anderson and Weinhold 2008; Lynch, Gray, and Geoghegan 2010) and whether landowners invest easement monies in farm improvements and modernization (Lynch 2007; Lynch and Duke 2007; Duke and Invento 2004). Important questions, however, remain unanswered. Among them is whether farmland preservation is having a meaningful impact on the economic viability of farms, particularly in urban-influenced areas where farming and associated support infrastructure has undergone significant decline.

The objectives of this study are therefore to empirically examine the impact of PDR program participation on farm profitability and evaluate whether effects of participation are heterogeneous across different farm types. This is accomplished by estimating the average "treatment effect" of participating in farmland preservation on per-acre farm profitability. A challenge with this type of observational study lies in an inability to assume that treatment assignment (i.e., voluntary participation in a PDR program) is random. We employ a propensity score matching approach (Rosenbaum and Rubin 1983a) to address issues of selection bias arising from a landowner's self-assignment into the treatment by controlling for inherent differences that may exist between preserved and unpreserved farms. New Jersey, a leader in farmland preservation, provides the geographic context for the analysis.

The balance of the paper is organized as follows. The following section provides background on the use of PDR as a farmland preservation technique. The third section introduces the propensity score matching technique and provides theoretical examination of factors that may influence a landowner's decision to preserved farmland. The fourth section describes data and matching estimators used in the analysis. The fifth section presents empirical results. The final section provides concluding remarks and policy implications.

2. Background on PDR Programs

Over the past several decades, the unquestioned acceptance and encouragement of growth has shifted to a more tempered realization of the potential negative effect development has on rural economies, land use, and culture (Fodor 1999; Libby 2005). This has led to substantial academic discourse and planning practitioner attention centered on land use (Burchell et al. 2005). Farm retention and the cycle of decline predicted as urban expansion and exurban growth pressures expand into rural-agricultural regions has been a specific thread of academic research since the 1970s (Berry 1978; Fischel 1982; Lisansky 1986; Lopez, Adelaja, and Andrews 1988; Daniels and Bowers 1997; Daniels and Lapping 2003; Lynch and Carpenter 2003; Oberholtzer, Clancy, and Esseks 2011). Embedded within this thread is the concept of a critical mass in agriculture, the premise that a local farming industry will become unsustainable once agricultural infrastructure (e.g., farms, farmland, agricultural suppliers and markets) declines to a certain level (Daniels and Lapping 2001; Lynch and Carpenter 2003). The "impermanence syndrome" is one symptom of this problem in urbanizing areas, as uncertainty about the long-term viability of agriculture causes farmers to reduce their planning horizons in farming and, subsequently, curtail investments in farm technology and modernization (Berry 1978; Lopez et al. 1988; Adelaja et al. 2011).

Various farm retention mechanisms have been adopted in all fifty U.S. states to mitigate the adverse impacts of development on agriculture, including use-value assessment for farmland, right to farm legal protections, agricultural zoning, and farmland preservation programs. Support for farm retention in urban-influenced areas is commonly rooted in the public's interest in maintaining rural amenities conferred by farms that are often quasi-public goods under-provisioned in land markets (i.e., ecological and environmental services, cultural heritage, local food availability, and outdoor recreational opportunities), growth management, and retention of capacity for local food production (Gardner 1977; Bromley and Hodge 1990; Lopez, Shah and Altobella 1994; Kline and Wichelns 1996; Hellerstein et al. 2002; Nickerson and Hellerstein 2003; Duke and Ilvento 2004a; Bergstrom et al. 2011).

While zoning and use value assessment programs may slow farmland loss and support the economic viability of farming, neither is a permanent form of land preservation. In contrast, a purchase of development rights program affords permanent protection of farmland from conversion to non-agricultural development. Participation in a PDR program requires a landowner to forfeit the right to develop farmland for nonagricultural purposes and a conservation easement (a negative easement) is placed on the land. In exchange, the landowner receives a monetary payment (or, in some cases, a tax incentive) and retains ownership and all other land rights.

PDR programs are an attractive public policy from a property rights perspective because landowner equity is protected due to the voluntary and compensatory nature of program participation, thus avoiding political and legal challenges to the constitutionality of regulatory-based land management approaches (Daniels and Bowers 1997; Echeverria 2005). In addition to the permanence of farmland protections, PDR programs offer several other advantages. It is theorized that the infusion of easement monies may help reverse the impermanence syndrome which Berry (1978) identified as afflicting urban-influenced farms. However, Duke and Ilvento (2004b) find that the majority of preserved farmland owners in Delaware used easement monies for personal savings or investments. Further, restricting future non-agricultural development options should, again in theory, reduce the cost of farmland. However, empirical research has yielded mixed results on the presence and extent of price reductions (see, for example, Nickerson and Lynch 2001; Anderson and Weinhold 2008; Lynch, Gray, and Geoghegan 2010).

A downside of PDR programs is the large public expenditures required to purchase easements and the uncertainties regarding public funding availability. More than 10 years ago, it was estimated that the cost of preserving U.S. cropland faced with urbanization pressure would cost $130 billion (Heimlich and Anderson 2001). Further, PDR deeds of easements restrict future nonagricultural development, but do not require that land be actively farmed (Daniels & Bowers 1997). Lastly, Liu and Lynch (2011) observe that PDR programs are less able to protect large contiguous blocks of farmland and industry agglomeration benefits than zoning policies.

2.1 Farmland Preservation in New Jersey

New Jersey is a highly urbanized state bordered by the major New York City and Philadelphia metropolitan centers. Approximately 16 percent of the state land base (733,000 acres) remains in agricultural production (USDA-NASS 2009). Most of this farmland lies on the western half of the state in areas under significant urban influence (Figure 1). The most agriculturally productive region of the state lies southwest of Philadelphia and includes Cumberland, Gloucester and Salem counties wherein the state's high-value horticultural production is concentrated. Another farming intensive region lies in the central/western region of the state and comprises northern Burlington County, a nationally recognized leader in farmland preservation, and parts of western Monmouth, Mercer, and southern Middlesex counties.

Since its creation in 1983, 2,200 farms and approximately 205,000 acres of farmland have been preserved under New Jersey's farmland preservation program (SADC 2013). New Jersey has preserved the highest proportion (28%) of its farmland base among all fifty states (AFT

2012). More than 83 percent of preserved farmland acreage is contained within three large clusters of program activity (Figure 2). The largest is in the northwest part of the state (approximately 70,000 acres). The central and southwest clusters comprise roughly 55,000 acres 48,000 acres, respectively.

3. Methodology

In experimental studies, treatment assignment can be randomized and, therefore, comparison of potential outcomes between treated and control groups can provide statistically reliable estimates of treatment effects. Farm enrollment in a PDR program, however, is not random due to the voluntary nature of the program. Estimation of the effect of participation in a PDR program on farm profitability may be confounded by the possible correlation between farm profitability outcomes and factors influencing a landowner's decision to preserve farmland. For example, the owner of a more (or less) profitable farm may hypothetically be less (or more) likely to sell development rights.

To overcome the problem of selection bias, we can use the potential outcome framework with two potential outcomes Y^1 (a profitability outcome for preserved (treated) farms) and Y^0 (a profitability outcome for unpreserved, or control, farms). The observed profitability outcome for any individual farm *i* can be written as: $Y_i = T_i \cdot Y_i^1 + (1-T_i) \cdot Y_i^0$, where $T \in \{0,1\}$ indicates treatment status, with *T*=1 if a farm is preserved. The gain/loss of individual farm *i* from participating in the program is $\Delta_i = Y_i^1 - Y_i^0$. Because we cannot observe both outcomes for individual farm *i*, estimating the individual farm treatment effect Δ_i is not possible and we have to concentrate on (population) average treatment effects (Caliendo and Kopeinig 2008). The most commonly-used evaluation parameter is the “average treatment effect on the treated"

(ATT), which in our context represents the difference between the expected profitability of preserved farms and the expected profitability of unpreserved farms had they been preserved. Algebraically, this can be explained as $ATT = E(Y^1|T=1) - E(Y^0|T=1)$.

As a practical matter, we cannot observe $E(Y^0|T=1)$ because treatment assignment is mutually exclusive; a farm is either preserved or it is not. Estimating the ATT associated with PDR program participation by comparing the mean difference between $E(Y^1|T=1)$ and $E(Y^0|T=0)$ will be erroneous due to selection bias (i.e., there may be inherent differences between farms that enter a PDR program and those that do not).

To address selection bias, a growing number of studies have used the propensity score matching (PSM) technique proposed by Rosenbaum and Rubin (1983a) (see, for example, Liu and Lynch (2007) and Uematsu and Mishra (2012) for examples within an agricultural policy context). To evaluate whether the profitability impacts of PDR program participation are heterogeneous across farm types and to lessen the possibility of mismatching, we implement a perfect match as first applied in Heckman et al. (1997; 1998) by splitting the full sample into three subgroups of farm types according to the differences in economic scale and operator characteristics. The first subgroup (residential lifestyle/retirement farm) includes small family farms operated by individuals for whom farming is not a primary occupation or retired persons. The second subgroup (small farms with low sales) includes small family farms with low sales ($\leq$\$100,000 gross sales) that are operated by individuals for whom farming is a primary occupation. The last subgroup (commercial farms) includes family farms with high sales (>\$100,000 gross sales) that are operated by individuals for whom farming is a primary occupation.

To ensure that the covariates balancing property is satisfied, we employ the method suggested by Becker and Inchino (2002) as a prematching test. We also conduct a post-matching balancing test.[2] Once the post-matching balancing test is satisfied, the matching of preserved and unpreserved farms based on estimated propensity scores is utilized to derive the impact of the PDR programs on profitability outcomes. To ensure overlap in the distributions of covariates X in the preserved and unpreserved farms, this study imposes the common support criterion. In addition to the imposition of common support, we address the problem of limited overlap in the covariate distributions between preserved and unpreserved farms using the trimming method proposed by Crump et al. (2009).

Application of the PSM technique requires the estimation of the predicted probability of being in the treatment group, based on observed factors that simultaneously influence the landowner's enrollment in a PDR program and farm profitability. This is achieved through the estimation of a probit model wherein a farm's preservation status (a binary treatment variable) is regressed on independent variables linked to a landowner's PDR program participation decision and farm profitability. The set of independent variables in this study is derived from theoretical underpinnings advanced by Nickerson and Lynch (2001) and Lynch and Lovell (2003). Generally, a farm owner is assumed to be an economically rational agent seeking to maximize the present value of utility derived from owning the land over a given planning horizon, which is determined by agricultural returns per acre, various farm and operator characteristics, off-farm income, non-consumptive values derived from land ownership, and expectations of development proceeds. We extend this conventional framework by explicitly accounting for empirical observations that the prices of preserved farms sold in arms-length market transactions may be higher than those predicted by economic theory due to capitalized value of amenities or retained development opportunities (see, for example, Nickerson and Lynch 2001, Anderson and Weinhold 2008, Schilling, Sullivan and Duke 2013).[3] More specifically, we hypothesize that a landowner's decision to enroll land in a PDR program may be influenced by expectations that preserved farmland may be sold for prices in excess of capitalized agricultural rents in certain land markets due to demand for rural residences. More details on the theoretical framework are provided in the Appendix.

4. Data

Data in our analysis are derived primarily from respondent-level 2007 Census of Agriculture records collected by the National Agricultural Statistics Service (NASS) and administrative records of the State Agriculture Development Committee (SADC), the administrative agency responsible for the New Jersey farmland preservation program. Additional data for covariates used in the first-stage probit model were collected from the New Jersey Department of Environmental Protection's Bureau of Geographic Information Systems, the Office of the New Jersey State Climatologist, U.S. Bureau of Labor Statistics, and U.S. Census Bureau.

The federal Census of Agriculture is conducted every five years, providing detailed information on agricultural land use, farm and operator characteristics, farm income and expenses, and other information needed to understand the structure and trends of the United States farm sector. The initial Census of Agriculture dataset, accessed through the New Jersey Field Office of NASS, contained 7,575 complete respondent-level records for New Jersey farms. Through March 2007, SADC records documented 1,621 farmland preservation closings.[4] Each PDR closing was aligned to a corresponding Census record based on examination of block and lot designations and secondary validity checks (e.g., parcel acreage, physical address, owner name, etc.). PDR closings for which Census records are unavailable (i.e., the farm owner did not participate in the Census) were omitted. In many instances, multiple farmland preservation closings were combined to link to a single farm management unit in Census.[5] In the resulting merged dataset, 789 of 7,575 Census records were identified as having preserved acreage.

In the first stage of PSM analysis, a probit model is estimated with a dependent variable (*PRESERVED*) defined as '1' if any portion of a subject farm was enrolled in the farmland preservation program between 2003 and April 2007, and '0' otherwise. This definition was predicated on the practical challenges of including pre-2003 farmland preservation closings (i.e., less complete or accessible program records) and the need to limit potential causality problems between the treatment variable and observed covariates in the propensity score estimation. Further, this timeframe marked a period of significant enrollment in the state's PDR program due to the availability of stable state funding for land preservation. The dataset was therefore refined to exclude 351 records for farms preserved prior to 2003. Farms that do not meet the SADC's minimum eligibility criteria for PDR program enrollment (n=2,735) were also excluded from the final dataset to reduce the problem of mismatching farms.[6] Lastly, since the farmland owner decides whether or not to enroll in the PDR program and receives the direct financial benefits of participation (e.g., an easement payment), we also exclude 460 farm records (66 of which are preserved farms) associated with individuals that do not own any of the land they farm. The final dataset used in the analysis comprised 4,029 farms, of which 372 were classified as preserved farms.

Table 1 summarizes the outcome measure used to calculate average treatment effects and variables used in the probit model of factors affecting the probability of a farm entering New Jersey's PDR program. The farm profitability outcome measure used for estimating ATTs is agricultural profit per acre (*PROFIT*), which is derived as total farm sales per acre minus total farm expenses per acre. Following the theoretical framework discussed in section 3 and the Appendix, three categories of independent variables are constructed: farm and landowner characteristics, agricultural returns, and development potential of land.

Farm and landowner characteristics include farm acreage and the gender, age, and farming experience of the primary farm operator. The presence of an heir interested in farming (*HEIR*) was proxied by a constructed binary variable with an assigned value of '1' if the farm has at least two operators and at least one additional farm operator spends the majority of his/her time employed in agriculture (and is not a hired manager). Two additional binary variables are included to capture whether the operator works off-farm for more than 100 days and whether rental income comprised the largest source of farm income.

Agricultural returns were proxied by a series of agricultural price or expense indices (i.e., crop, cattle, poultry, and labor) and a binary variable indicating whether the farm engaged in direct-to-consumer sales. Underlying farm productivity factors include the percentage of the farm's soils classified as prime, average seasonal growing temperature, and annual precipitation. Two variables were included to capture potential industry agglomeration effects, the number of farms located within the subject farm's municipality and the change in municipal agricultural land area recorded between 1986 and 2007.

Land development potential was captured by population density variables, median housing value and the distance between the farm and nearest major city. *RESIDUAL_VALUE* is a municipal-level variable capturing the difference between the average estimated deed restricted value of preserved farms (i.e., the estimated "after value" calculated by the SADC for purposes of calculating easement payments) and sales prices of preserved farms observed between 1990 and 2007. All values are converted to 2007 dollars by using the urban consumer price index of owners' equivalent rent of primary residence provided by the Bureau of Labor Statistics.

Table 2 presents the summary statistics for variables used in the analysis for preserved and unpreserved farms across the full sample of farms and the three farm type subgroups. As the first data row demonstrates, per-acre farm profitability is higher for preserved farms, relative to unpreserved farms, in the full sample and the 'small farms/low sales' subsample. A test of mean difference between preserved and unpreserved farms reveals no statistically significant difference between preserved and unpreserved farms across the full sample and all subgroups. However, conclusions about the effect of farmland preservation on farm profitability based upon these simple means comparisons are to be avoided because of underlying differences between the two cohorts of farms.

5. Empirical Results

5.1 Probit Model Estimation

To address the bias problem from self selection into the New Jersey PDR program, we employ the propensity score matching technique. The propensity score is the probability of a farm receiving the treatment (i.e., being preserved). In our analysis, this is derived by estimating a probit model regressing the binary dependent variable (*PRESERVED*) on a multi-dimensional vector of covariates that economic theory and empirical literature predict will influence the landowner participation decision and farm profitability. The propensity score for each farm is calculated as the predicted value from the regression. Farms are matched based on their propensity scores using several matching estimators, as described in section 5.2.

Probit models were estimated using the full sample of farms and subsamples comprising residential lifestyle/retirement farms, small farms with low sales, and commercial farms. Table 3 provides the parameter estimates obtained from each model. All four models perform well according to hit rate, as shown in the last row, and results generally converge with profit theory and existing literature on farmland preservation.

Model results show that having an heir interested in farming, operator age, reliance on off-farm employment, generation of direct marketing revenue, total annual precipitation, and the percentage change in agricultural land area do not influence the probability of program participation. An inverted U-shape relationship is found between the likelihood of program participation and farm acreage in all groups. While New Jersey is geographically small, there is noted microclimatic and soil variability across the state. Farms in areas with higher mean temperatures during the growing season are more likely to enroll in farmland preservation. Not surprisingly given the importance of soil quality in the prioritization of farms for preservation, farms with greater proportions of prime soil are more likely to participate in the PDR program; however, this parameter is only significant for the residential lifestyle/retirement and commercial subsamples.

Farms in municipalities with a greater number of farms are more likely to participate in farmland preservation. However, this influence diminishes in municipalities with very large numbers of farms, perhaps reflecting the disinclination of landowners in rural areas to preserve farmland due to the absence of intense development and lower prevailing easement values. In a similar manner, the probability of a farm participating in the PDR program tends to increase as the residual value rises and again diminishes at high levels of residual value in the full sample and the subsample of residential lifestyle/retirement farms.

5.2 Matching Estimators

The selection of appropriate matching algorithms depends on the number of observations in the treatment and the control groups and the distribution of estimated propensity scores (Caliendo and Kopeinig 2008; Heckman, Ichimura, and Todd 1997). We estimate the distributions of the estimated propensity scores for the full sample and each subgroup for preserved and unpreserved farms using estimated coefficients from the probit model. As reflected in Figure 3, the distributions across preserved and unpreserved farm groups are generally different. Although distributions tend to be similar at the lower range of the estimated propensity scores, they become more divergent at the higher range.

To ensure the robustness of our findings, we utilize several matching algorithms. We first use the most straightforward matching estimator, the nearest neighbor matching (NN1) with replacement. However, NN1 matching may result in poor matches if the closest neighbor is far away. Therefore, we also use the radius matching with caliper recommended by Dehejia and Wahba (2002) to increase matching quality.[7] However, as discussed in Smith and Todd (2005), it is difficult to know *a priori* what tolerance level is reasonable. We use the calipers of 0.02 and 0.05 in this study. Because there are a large number of comparable untreated (unpreserved farm) observations in the full sample and subgroups, we also use oversampling with ten matching partners (NN10), kernel and local linear matching algorithms.[8] For kernel and local linear matching, a Gaussian kernel function is used. The optimal bandwidth is selected using the rule of thumb suggested by Silverman (1986).[9]

The quality of matching outcomes was evaluated for each matching estimator on the basis of percent reduction of pseudo R^2, Chi-square, and mean standardized bias. [*Reviewer note: Supplemental document table S1 summarizes these matching quality indicators for the full sample and each farm type subgroup.*] Overall, all matching estimators yielded relatively good matching quality; NN1 provided the poorest matching quality in all groups. There are no statistically significant differences between mean values of preserved and unpreserved farms after matching based on all covariates *X* in the full sample or subgroups, providing confidence that our matching results satisfy the balancing property. [*Reviewer Note: The results of the balancing test for mean difference of all covariates X before and after matching are provided in supplemental document table S2.*]

5.3 Average Treatment Effects on the Treated (ATTs)

Average treatment effects on the treated in the full sample and farm type subgroups are shown in Table 4. Standard errors are reported in parentheses under each estimated treatment effect. We present the estimated ATTs and their associated standard errors by imposing common support and the trimming approach (thick support) suggested by Crump et al. (2009) in all cases.[10]

Estimated ATTs in the full sample are positive across all matching techniques (except for NN10 matching method with usual common support), but not statistically significant at the 10 percent level. For the residential lifestyle/retirement subgroup, estimated ATTs derived using four of the six matching indicators are negative and statistically significant at the 10 percent level when imposing common support. The profitability of preserved farms ranges from $196 to $202 less per acre than matched unpreserved farms. However, after addressing the problem of limited overlap in the covariates distributions between preserved and unpreserved farms (i.e., the imposition of thick support), the ATTs are not statistically significant across all matching estimators.

The negative or insignificant effects of PDR participation on residential lifestyle/retirement farms are not altogether unexpected. Owners of small farms seeking to fulfill rural lifestyle preferences or farmers wishing to spend their retirement years on their farms may have diminished profit motives. For them, agricultural income may be supplemental to off-farm or retirement income or scaled to qualify their property for the tax advantages of agricultural use value assessment. While not empirically tested in this study, participation in a PDR program may also serve as an exit strategy from agriculture for retirement age landowners. A large easement payment may provide financial liquidity needed for estate planning and transfer purposes, or serve to extract capital to support retirement.

All matching estimators yielded statistically significant ATTs for farms in the small farm/low sales subsample. Preserved farm profitability is estimated to be between $266 and $453 higher per acre than it is for observationally equivalent unpreserved farms. Refining the results to those generated from the matching algorithms having the best matching quality narrows the profitability differentials to a range of $414 to $436. One explanation for the improved profitability of preserved farms may be the influx of capital into farm businesses afforded by selling development rights. The infusion of easement payments to these relatively small farms (farms in this subsample have annual sales of less than $100,000) may expand opportunities to increase farm acreage, restructure debt, mechanize and modernize operations, diversify products and markets, or transition into value added enterprises.

For the commercial farm subgroup, the matching estimators produced ATTs that are widely variable, but not statistically significant. This result is interesting and warrants additional research. The authors speculate that farms in this subgroup may pursue alternative profit-enhancing strategies. For example, rather than intensifying production on existing acreage (earning more profit per acre), anecdotal evidence from southern New Jersey suggests that large, multigenerational horticulture farms are actively expanding landholdings to achieve higher profitability.

Using a recent simulation-based sensitivity analysis employed in Ichino, Mealli, and Nannicini (2008), we confirm that results are robust to unobserved factors influencing the participation decision and farm profitability.[11] [*Reviewer Note: The results of the sensitivity analysis conducted on the subgroup of small farms with low sales are provided in supplemental* *document tables S3 and S4 with detailed explanation.*] We also use Rosenbaum bounds with 1x1 matched pairs (see details in Rosenbaum 2002) and find that our results are robust with the threshold gamma measuring the effect strength of unobserved variables on treatment assignment equal to 1.25 (with 95% confidence interval). This means that the statistical significance of the ATT for profit per acre would be questionable if the odds ratio of having a PDR program between enrolled and non-enrolled farms differs by more than 1.25.

6. Conclusions and Policy Implications

As a policy evaluation, this study examines whether New Jersey's PDR program is strengthening the agricultural industry, a legislative goal articulated in the enabling statute [NJSA 4:1C-11 et seq]. In practice, this is often interpreted as enhancing the economic viability of farming. Farmland preservation is theorized to aid the farm economy in several ways. The retention of large contiguous areas of farmland can provide agglomeration economies, reduce location conflicts (i.e., right to farm disputes), enhance operational efficiency, and remove speculative pressures from farmland markets. In theory, deed-restricted farmland should be less expensive than unpreserved farmland, thus reducing a substantial new farmer entrance barrier and enabling less costly expansion of existing farms. Easement payments provide farmers with financial liquidity that may be used to expand or modernize agricultural operations, or restructure debt, although such funds are also used for household consumption and personal investments (Esseks and Schilling, 2013; Duke and Ilvento, 2004b).

Sokolow (2006), in his national assessment of leading U.S. farmland preservation programs concluded that the agricultural economic impacts of PDR programs are unclear. Focusing primarily on the effects of agricultural land retention on farm supplier and market infrastructure, he argues that the “accumulation of permanently preserved farmland through easements by itself has had little direct impact so far on the overall condition of local agricultural economies.” However, he qualifies this generalization with the perspectives of county and state farmland preservation program administrators that PDR participation does benefit individual farm economics in the form of capital for expansion and debt retirement, infrastructure improvements, or transition to other commodities and alternative agricultural business ventures. The extent to which these theorized economic benefits of PDR participation are being realized by farms has not been well studied empirically.

To the authors' knowledge, this study is the first to directly measure the impact of farmland preservation on farm profitability, while controlling for program self-selection effects. As such, it represents a useful extension to the PDR program evaluation literature. Public expenditures on PDR programs in the U.S. (particularly in the eastern states) have been substantial, totaling several billion dollars. In a climate of fiscal austerity, many state programs are facing uncertainties over future funding and increasing accountability to policy makers seeking evidence of program impacts. Progress reports relying on farm and acreage enrollments are self-evident metrics. However, PDR program administrators faced with the need to justify further program funding would benefit from credible information on their programs' impacts on farm-level viability and broader economic development. Our results suggest that farmland preservation is advancing farm economic development objectives, at least for small to mid-sized commercial farms. This is encouraging because of the concentration of the state's agricultural output among commercial farms, notwithstanding the lack of statistically significant ATTs found within the sub-category comprising the state's largest farms.

Analysis within our sample shows that the majority of farmland preserved in New Jersey is associated with farms operated by persons for whom farming is a principal occupation (Table 2).[12] Our findings suggest that the profitability of "low sales" farms (farms with <$100,000 in annual sales that are operated by individuals for whom farming is a principal occupation) is enhanced by farmland preservation. Our most conservative estimates reveal that preserved farms in the 'small farms/low sales' cohort earn $414 to $436 more per acre in profit than their unpreserved counterparts. This finding comports with program administrator accounts reported by Sokolow (2006) and provides optimism that PDR participation may be a gateway through which small farms may modernize, expand, or transition into more lucrative ventures. It casts an optimistic light on long-standing, and often bleak, national dialogue on the challenges facing small-scale farms, as encapsulated in a 1988 Council for Agricultural Science and Technology, which notes: "[t]he future viability of the adequate size, well-managed commercial farms, and the part-time smaller farms is not in doubt. The future is much in doubt, however, for full-time family farms lacking a strong financial or managerial base, too small to realize economies of size, and too demanding of labor and management for the operator and family to earn substantial off-farm income."

A fundamental observation emerges from this study regarding the use of PDR funding to preserve smaller "lifestyle" farms. We find some evidence that the profitability of lifestyle/retirement farms is lower for preserved farms, relative to their unpreserved counterparts. This may be a signal that farmland preservation, and ostensibly the infusion of capital into the farm household, further dampens what in many cases is an already limited agricultural profit motive. In other instances, it may reflect the use of PDR as an exit strategy for retiring farmers. PDR easement payments, rather than being invested in the farming operation, may provide financial liquidity needed for estate planning and transfer. However, New Jersey's conservation easements are perpetual, raising an important question about the future disposition of these preserved farms. Who will farm them? Will they be made accessible to farmers seeking expansion, or new farmers? From a policy perspective, this suggests the importance of having programs aimed at facilitating farmland access, linking owners of preserved farmland with individuals interested in farming. For example, the State Agriculture Development Committee and the New Jersey chapter of the Northeast Organic Farming Association recently collaborated on a farmland leasing project. Key components of the initiative include networking meetings between owners of farmland (preserved and unpreserved) and farmers interested in leasing land, and associated online land linking resources.

A related policy question surfaces regarding the desirability of using limited public resources to preserve small farms presently supporting rural-residential lifestyles. Holding all else constant, economic theory predicts (and observation supports) that per-acre easement costs will be higher for smaller properties, relative to larger farms. Should very small acreage "lifestyle" farms be de-prioritized for preservation, allowing the reallocation of funding resources toward larger farms? For example, the current eligibility criteria for small (under 10 acre) farms to enter farmland preservation require documented annual sales of at least $2,500. This criterion could be made more stringent; however, the consequences of such policy revisions need to be carefully contemplated. A prime farmland parcel may be minimally farmed today (for purposes of discussion, assume a purely "hobby" agricultural venture) but could be more intensively farmed in the future. Is it a viable policy alternative to preclude preserving this parcel on the basis of low current productivity when the underlying soil resources are of high quality?

While ostensibly rational from a purely cost-effectiveness perspective, it may be politically unpalatable to forego preservation of small acreage lifestyle farms (or implement a policy change, such as a per-acre easement cap, that has the practical effect of reducing the likelihood of such farms being preserved) , which are often located in suburban or urbanizing parts of the state. As farms in these areas become more scarce, remaining farms become more valued on the basis of their amenity benefits (e.g., open space, access to produce at farm markets, etc.). The retention of these urban fringe farms may be necessary for maintaining the political support needed to secure additional statewide funding for land preservation.

Avoiding the preservation of smaller farms may also be incongruent with state farmland preservation goals. When Governor Christine Todd Whitman signed the landmark Garden State Preservation Trust Act into law in 1998, she articulated an ambitious (and ultimately unattained) goal of preserving 500,000 acres of farmland within ten years. To that point, the average size of farms preserved under the state PDR program was 148 acres. In the second and third decades since, preserved farms averaged 86 and 75 acres in size, respectively. In most preservation project areas, early efforts focused on acquiring easements on large, keystone properties. Now effort is shifting toward "filling in" preservation gaps to achieve the goal of protecting large, contiguous clusters of farmland and minimizing further fragmentation of the state's farmland base. Comprehensive county farmland preservation plans developed in recent years target an additional 4,314 farms and 242,000 acres of farmland for preservation. Taking a simple average, this implies a further drop in the average size of targeted farms to 56 acres.

Lastly, another consideration that surfaces when considering the implications of preserving low-intensity lifestyle farms is the fact that New Jersey's standard deed of easement requires that preserved farmland remain available for agriculture, not remain in agriculture. This is a long-standing topic of debate in the state's agricultural policy circles. Our findings suggest that this "available for" clause allows farmland preserved at considerable public expense to be diverted from active, more intensive farming. If strengthening the farming industry is a goal of PDR programs, policy makers may be justified in revisiting deed of easement provisions requiring farmland be kept in active agriculture.

It is important to conclude with limitations of this study that may warrant further academic consideration. First, our study design defines a farm to be preserved if any of its acreage is preserved under the state PDR program. Land tenure, particularly among very large farms, is complex. It is common for a large farm owner to aggregate multiple farms parcels under one farm management unit. This raises the question whether the extent to which a farm's acreage is preserved matters. It is interesting to consider whether there is a dose-response function evident when farms participate in farmland preservation. In other words, does the size of treatment (i.e., the percentage of a farm that is preserved) influence farm profitability? Second, 2003-2007 marked a period of significant farm enrollment in the New Jersey PDR program. Data challenges made it impractical to examine farms preserved prior to 2003 and the truncated time frame in our analysis may not fully capture profitability impacts stemming from the sale of farm development rights. Third, it is theorized that the observed lack of statistically significant ATTs for the commercial farms subgroup may result from larger farms operating at higher levels of technical efficiency than smaller farms due to greater financial liquidity or scale economies that enable investments in equipment and technology adoption. For these operations, farm expansion may be a more dominant strategy for achieving higher profits than production intensification (i.e., increasing profits per acre). This implies the need to examine a different outcome measure to evaluate whether and how PDR participation affects the economics of larger farms. Finally, cost-related data limitations precluded examination of the potential effects of agglomeration benefits that may accrue as large contiguous blocks of preserved farmland are created. The incorporation of spatial data on preserved farmland contiguity into future assessments of PDR program impacts would be valuable from a policy evaluation perspective.

Appendix: Theoretical Framework of Landowners' Participation Decision

In the framework, we assume that a landowner has two options. First, a landowner may choose to farm until an optimal farm sale date, at which time all rights to the farmland are sold in a market transaction. Alternatively, the landowner may select to participate in a PDR program, selling only rights to develop the land for non-agricultural purposes in exchange for an easement payment. In the latter case, the landowner may continue to farm or sell the deed-restricted farmland at an optimal date for a net payment equivalent to the sum of the future stream of net agricultural returns and residual non-agricultural consumptive value (i.e., utility derived from living in a rural residence), which is the difference between the preserved farm sales price and its agricultural value.

Let the participation decision of landowner *i* be represented by φ. A decision to participate in a PDR program is denoted by φ = 1 (φ = 0 if the landowner does not participate). We assume that the participation decision, φ, maximizes the present value of his/her utility over the planning horizon given the discount rate *r* and the landowner *i*'s time preference, ρ. Allowing, X_i, to represent landowner and farm characteristics in each period τ, the utility of the landowner *i* can be modeled as a function of: the net agricultural returns per acres, $R_i^{ag}(X_i,\tau)$; off-farm income, $R_i^{off}(X_i,\tau)$; the non-consumptive value of participation, $R_i^{nonconsum}(X_i,\tau)$; the net payment from selling farmland in the market for the developed use at optimal date t_1^*, $V_i^{dev}(X_i,t_1^*)$; the net easement payment from selling non-agricultural development rights at the beginning period, $E_i(X_i,0)$; and the residual value of preserved farmland sold at optimal date t_2^*, $V_i^{resid}(X_i,t_2^*)$ [13] (Equation A1). A landowner will participate in the PDR program if the present value of utility derived from participation is greater than the present value of utility associated with farming until the optimal sales date and then selling their land.

$$\text{(A1)} \quad V_i = \underset{\varphi}{Max}\,(1-\varphi)\left[\int_0^{t_1^*} U_i\left(R_i^{ag}(X_i,\tau), R_i^{off}(X_i,\tau), R_i^{nonconsum}(X_i,\tau)\right)e^{-\rho\tau}d\tau\right.$$

$$\left. + \int_{t_1^*}^{\infty} U_i\left(R_i^{off}(X_i,\tau), rV_i^{dev}(X_i,t_1^*)\right)e^{-\rho\tau}d\tau\right]$$

$$+\varphi\left[\int_0^{t_2^*} \mathrm{U}_i\left(\mathrm{R}_i^{ag}(\mathrm{X}_i,\tau), \mathrm{R}_i^{off}(\mathrm{X}_i,\tau), \mathrm{R}_i^{nonconsum}(\mathrm{X}_i,\tau), \mathrm{rE}_i(\mathrm{X}_i,0)\right)e^{-\rho\tau}d\tau\right.$$

$$\left. + \int_{t_2^*}^{\infty} U_i\left(R_i^{ag}(X_i,\tau) + rV_i^{resid}(X_i,t_2^*), R_i^{off}(X_i,\tau), R_i^{nonconsum}(X_i,\tau)\right)e^{-\rho\tau}d\tau\right]$$

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Table 1. Description of variables

Variables	**Description**
Potential Outcome and Treatment	
PROFIT	Profit per acre derived as total sales minus total farm expenses per acre
PRESERVED	Whether any portion of the farm was preserved between 2003-2007 (equal to 1 if preserved)
Farm and Landowner Characteristics	
GENDER	Gender of the principal operator (equal to 1 if male)
AGE	Age of the principal operator
EXPERIENCE	Number of years the principal operator operated on the farm
HEIR	Whether the principal operator has an heir to continue farming (equal to 1 if yes)
OFF-FARM	Whether the principal operator worked off farm more than 100 days (equal to 1 if yes)
RENTAL_INC	Whether the largest source of farm income was rental income (equal to 1 if yes)
ACRES	Total acres of farmland operated
Agricultural Returns	
DIRECT_SALES	Whether the farm has revenue from direct sales (equal to 1 if yes)
CROP_PRICES	Prices received by each farm from selling crops in $/acre
CATTLE_PRICES	Prices received by each farm from selling cattle including their dairy products in $/head
POULTRY_PRICES	Prices received by each farm from selling poultry in $/head
LABOR_COSTS	Labor cost per acre
PRIME	Percent of farm acreage with soils classified as “prime”
TEMPERATURE	Municipality-level average growing seasonal temperature (°F) from April to September
PRECIPITATION	Municipality-level total annual precipitation (inches)
NO_FARMS	Number of farms in the municipality
CHG_AGLAND	Percent change in agricultural land area for municipality in which farm is located from 1986 to 2007
Development Potential of Land	
POP_DENSITY	Population density per square mile for municipality in which farm is located
CHG_POPDEN	Percent change in population density per square mile for municipality in which farm is located from 1987 to 2007
DISTANCE	Euclidian distance, in miles, of the farm to the nearest city (New York City or Philadelphia)
RESIDUAL_VALUE	Average percent difference between preserved farm sales price and after value for municipality in which farm is located
HOUSINGVAL	Median housing value of municipality in which farm is located

Table 2. Summary statistics of preserved and unpreserved New Jersey farms

	Full Sample				Residential/Retirement				Small Farms with Low Sales				Commercial			
	Preserved		Unpreserved		Preserved		Unpreserved		Preserved		Unpreserved		Preserved		Unpreserved	
Variables	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.	Mean	Std. D.
Profitability Outcome																
PROFIT ($1,000)	0.54	4.55	0.20	8.06	-0.20	0.87	-0.01	4.01	-0.13	0.54	-0.79	3.95	1.91	7.49	3.53	21.20
Farm and Landowner Characteristics																
GENDER	0.89	0.31	0.80	0.40	0.87	0.34	0.83	0.37	0.86	0.35	0.69	0.46	0.93	0.26	0.95	0.22
AGE	59.08	12.80	58.38	12.62	60.87	13.41	59.76	12.48	57.14	12.19	55.68	12.03	57.58	11.88	56.37	11.61
EXPERIENCE	25.56	15.66	21.76	14.63	22.24	16.08	21.38	14.43	24.00	14.62	20.28	14.63	29.29	13.69	27.65	13.93
HEIR	0.11	0.32	0.07	0.26	0.07	0.25	0.06	0.24	0.07	0.26	0.08	0.27	0.20	0.40	0.15	0.36
OFF_FARM	0.52	0.50	0.48	0.50	0.49	0.50	0.49	0.50	0.47	0.50	0.47	0.50	0.56	0.50	0.46	0.50
RENTAL_INC	0.02	0.15	0.01	0.09	0.05	0.22	0.01	0.10	0.02	0.13	0.01	0.09	0.00	0.00	0.00	0.00
ACRES	317.56	472.26	79.35	183.76	96.84	113.47	43.95	73.12	176.78	177.67	69.25	116.36	661.54	639.73	257.28	370.44
Agricultural Returns																
DIRECT_SALES	0.16	0.37	0.18	0.39	0.18	0.39	0.20	0.40	0.14	0.35	0.18	0.39	0.13	0.34	0.14	0.35
CROP_PRICES ($1,000)	5.89	27.39	6.27	52.98	2.36	14.36	2.80	17.21	10.90	50.97	3.94	24.91	8.57	27.41	29.09	145.53
CATTLE_PRICES ($1,000)	3.02	1.78	2.89	1.13	2.63	1.19	2.81	0.86	3.16	3.21	2.86	0.79	3.40	1.52	3.39	2.24
POULTRY_PRICES	43.08	7.65	44.08	27.30	43.35	9.46	44.23	26.74	42.32	7.01	46.09	45.74	43.43	5.85	42.85	5.18
LABOR_COSTS ($1,000)	0.44	1.47	0.73	7.84	0.05	0.20	0.15	1.37	0.12	0.61	0.34	2.19	0.99	2.24	4.28	22.35
PRIME	32.88	17.61	27.85	16.33	32.15	16.45	27.28	16.31	33.05	18.24	28.70	16.26	35.81	17.76	29.22	17.15
TEMPERATURE	66.42	1.69	66.17	1.75	66.24	1.78	66.00	1.74	66.37	1.67	66.24	1.73	66.72	1.54	66.91	1.63
PRECIPITATION	48.86	6.02	49.08	6.27	49.30	6.16	49.67	6.23	49.75	5.78	49.06	6.09	47.69	5.87	46.19	5.72
NO_FARMS	84.60	51.35	74.52	54.04	85.12	49.27	74.12	52.10	83.55	51.62	76.79	53.85	84.58	51.92	75.60	61.61
CHG_AGLAND	-27.57	16.64	-29.51	35.28	-27.48	16.26	-29.37	44.23	-27.73	16.80	-29.42	18.23	-28.87	16.68	-28.13	18.82
Development Potentials of Land																
POP_DENSITY (1,000)	0.62	1.40	1.26	5.82	0.52	0.95	1.44	6.97	0.48	0.54	1.21	5.23	0.67	1.31	0.92	2.64
CHG_POPDEN	41.01	45.90	32.05	34.03	42.64	46.92	33.30	35.17	44.20	47.79	30.03	29.98	41.51	48.45	27.11	34.96
DISTANCE	36.29	10.43	37.07	11.07	37.87	11.45	37.53	11.08	35.32	9.42	36.99	10.62	35.05	9.15	34.33	11.36
RESIDUAL_VALUE	66.27	66.30	59.34	64.74	59.50	49.85	55.81	59.27	73.83	88.95	59.75	68.87	69.53	76.51	73.76	79.24
HOUSINGVAL ($1,000)	200.00	86.87	190.00	87.16	192.63	71.61	196.03	87.13	217.24	110.66	191.48	83.01	185.60	85.28	153.26	74.35
No. Observations	372		3,657		138		2,052		58		580		127		410	

Table 3. Estimated coefficients from probit models

	Full		Residential/ Retire.		Low Sales		Commercial	
	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Farm and Landowner Characteristics								
GENDER	0.2318**	0.1010	0.0600	0.1284	0.3895*	0.2403	-0.6118**	0.2681
AGE	-4.0E-05	0.0033	0.0020	0.0051	0.0069	0.0082	-0.0010	0.0078
EXPERIENCE	0.0004	0.0028	-0.0243***	0.0090	-0.0032	0.0073	-0.0007	0.0067
EXPERIENCE^2	-	-	0.0003**	0.0002	-	-	-	-
HEIR	0.0792	0.1008	-0.1602	0.1868	-0.1560	0.3433	0.2824	0.1840
OFF_FARM	0.0822	0.0601	0.0010	0.0899	0.2466	0.1685	0.1449	0.1353
RENTAL_INC	0.6845***	0.2332	1.0087***	0.2623	0.9556	0.6236	-	-
ACRES	0.0035***	0.0007	0.0080***	0.0011	0.0077***	0.0013	0.0017***	0.0003
ACRES ^2	-6.9E-07***	1.3E-07	-1.0E-05***	2.4E-06	-7.1E-06***	1.8E-06	-3.4E-07***	9.0E-08
*GENDER*ACRES*	-0.0012	0.0007	-	-	-	-	-	-
Agricultural Returns								
DIRECT_SALES	0.0675	0.0791	-0.0060	0.1147	0.1926	0.2244	0.2540	0.2102
CROP_PRICES	2.1E-06**	1.0E-06	1.3E-06	2.0E-06	1.6E-05***	5.7E-06	2.4E-06	2.1E-06
CROP_PRICES^2	-	-	-	-	-2.8E-11**	1.5E-11	-	-
CATTLE_PRICES	-4.3E-06	2.4E-05	-4.8E-05	0.0001	0.0001***	4.8E-05	-1.8E-05	2.6E-05
POULTRY_PRICES	-0.0017	0.0016	-0.0010	0.0018	-0.0155	0.0111	0.0112	0.0131
LABOR_COSTS	-2.8E-05***	1.1E-05	-0.0001	0.0001	-0.0002	0.0001	-0.0001**	2.4E-05
PRIME	0.0042	0.0027	0.0087**	0.0037	-0.0038	0.0075	0.0138**	0.0060
TEMPERATURE	0.0947**	0.0400	0.0524	0.0572	0.3644***	0.1248	0.0739	0.0994
PRECIPITATION	-0.0082	0.0119	-0.0051	0.0166	-0.0127	0.0390	-0.0226	0.0350
NO_FARMS	0.0077***	0.0023	0.0092**	0.0036	0.0087	0.0061	0.0026**	0.0013
NO_FARMS^2	-2.9E-05***	1.1E-05	-3.6E-05**	1.7E-05	-0.0001*	2.7E-05	-	-
CHG_AGLAND	0.0006	0.0005	0.0005	0.0005	-0.0025	0.0054	-0.0059	0.0059
Development Potential of Land								
POP_DENSITY	-1.9E-05*	1.1E-05	-4.5E-05**	2.1E-05	-0.0001	0.0001	-1.4E-05	2.7E-05
CHG_POPDEN	0.0019**	0.0009	0.0013	0.0012	0.0097***	0.0027	-0.0006	0.0021
DISTANCE	-0.0297	0.0192	-0.0507*	0.0266	-0.0189	0.0122	-0.0071	0.0122
DISTANCE^2	0.0004*	0.0002	0.0006**	0.0003	-	-	-	-
RESIDUAL_VALUE	0.0029***	0.0010	0.0026*	0.0015	0.0013	0.0010	-0.0002	0.0008
RESIDUAL_VALUE^2	-4.6E-06**	1.9E-06	-7.2E-06*	4.1E-06	-	-	-	-
HOUSINGVAL	4.5E-07	4.8E-07	5.2E-06	3.7E-06	-1.4E-05**	6.0E-06	1.4E-05***	5.4E-06
HOUSINGVAL^2	-	-	-1.2E-11*	6.9E-12	2.3E-11**	9.1E-12	-2.1E-11**	8.7E-12
Constant	-8.2448***	2.7883	-5.3159	4.0615	-25.4600***	8.1412	-7.6038	6.9713
Pseudo R^2	0.1580		0.1350		0.2645		0.2401	
Hit Rate	0.5647		0.7374		0.7500		0.7183	
% Correct Predict	91.04		93.74		92.48		82.12	
Area under ROC curve	0.7744		0.7705		0.8518		0.8179	

Note: ***, **, * are significant at the 1, 5, and 10 percent level, respectively. Robust standard errors are in parentheses. Models also include fixed effect dummy variables of six regions in New Jersey including

Delaware River, Gateway, Great Atlantic, Shore, Skylands and South Shore. Moreover, for the full sample model, dummy variables of farm types discussed in the methodology are also included. "Area ROC" captures the area under the ROC curve. A model with no predictive power has area 0.5, while a perfect model has area 1 (see Green and Swets 1966).

Table 4. Effect of PDR program participation on farm's profit per acre (ATTs)

	Matching Algorithms					
	NN1	NN10	Kernel	Local Linear	Radius 0.02	Radius 0.05
	Full Sample					
Common Support	220	-35	87	79	67	107
	(268)	(285)	(262)	(273)	(267)	(243)
Thick Support	213	47	94	82	64	107
	(278)	(289)	(267)	(503)	(286)	(282)
	Residential Lifestyle/Retirement Subsample					
Common Support	-228	-133	-200*	-196*	-198*	-202*
	(184)	(87)	(113)	(118)	(117)	(113)
Thick Support	-213	-77	-132	-190	-135	-131
	(187)	(89)	(114)	(146)	(122)	(122)
	Small Farms with Low Sales Subsample					
Common Support	425*	414**	313**	298*	322*	266**
	(232)	(174)	(132)	(165)	(179)	(129)
Thick Support	453*	436**	334**	318**	322*	279**
	(246)	(181)	(144)	(154)	(197)	(132)
	Commercial Farm Subsample					
Common Support	986	-53	-160	-43	57	-8
	(1291)	(881)	(912)	(902)	(1029)	(953)
Thick Support	946	-105	-131	-7	-42	19
	(1305)	(888)	(876)	(936)	(1101)	(946)

Note: ***, **, * are significant at the 1, 5, and 10 percent level, respectively. Standard errors are reported in parentheses. The standard errors for all matching algorithms are estimated using bootstrapping with 1,000 replications, except for the nearest neighbor (NN1) and oversampling (NN10) in which we use the analytical standard error suggested by Abadie and Imbens (2006).

Fig. 1. Geographic context map of New Jersey's agricultural lands.

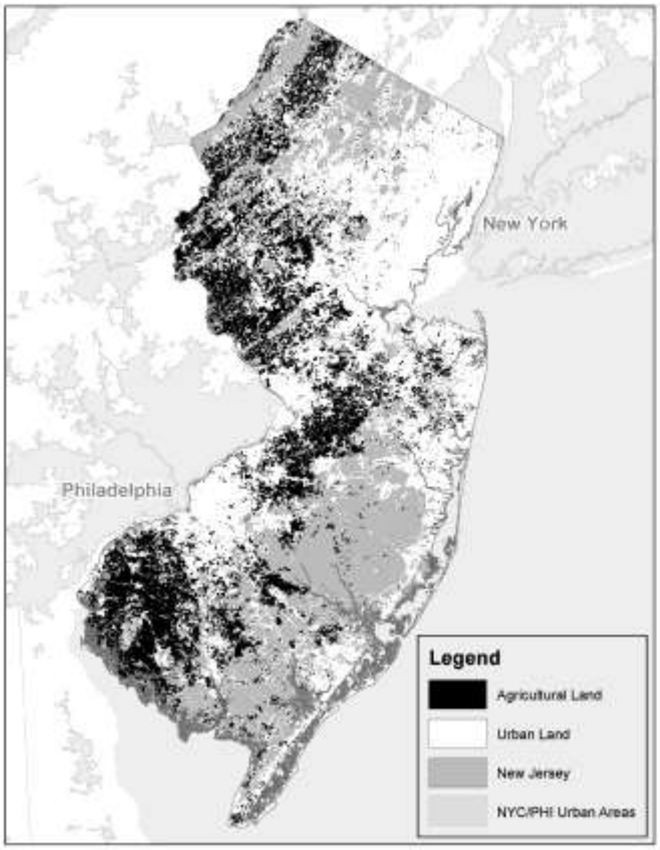

Fig. 2. Regional distribution of preserved farmland in New Jersey.

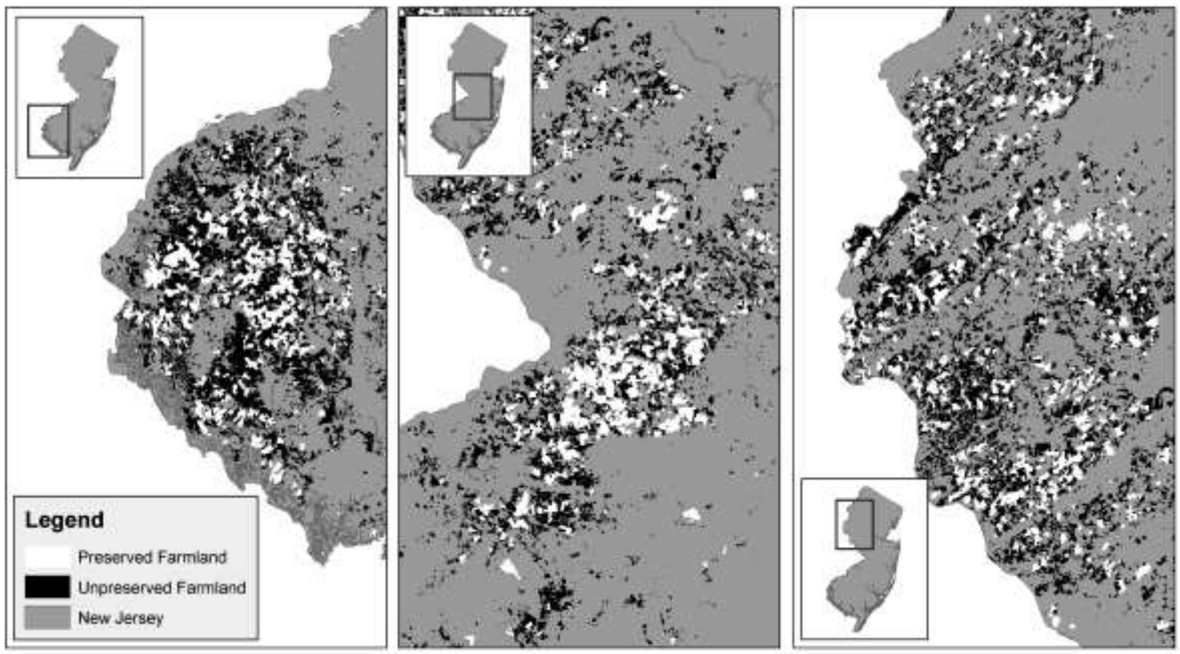

Fig. 3. Distributions of estimated propensity scores

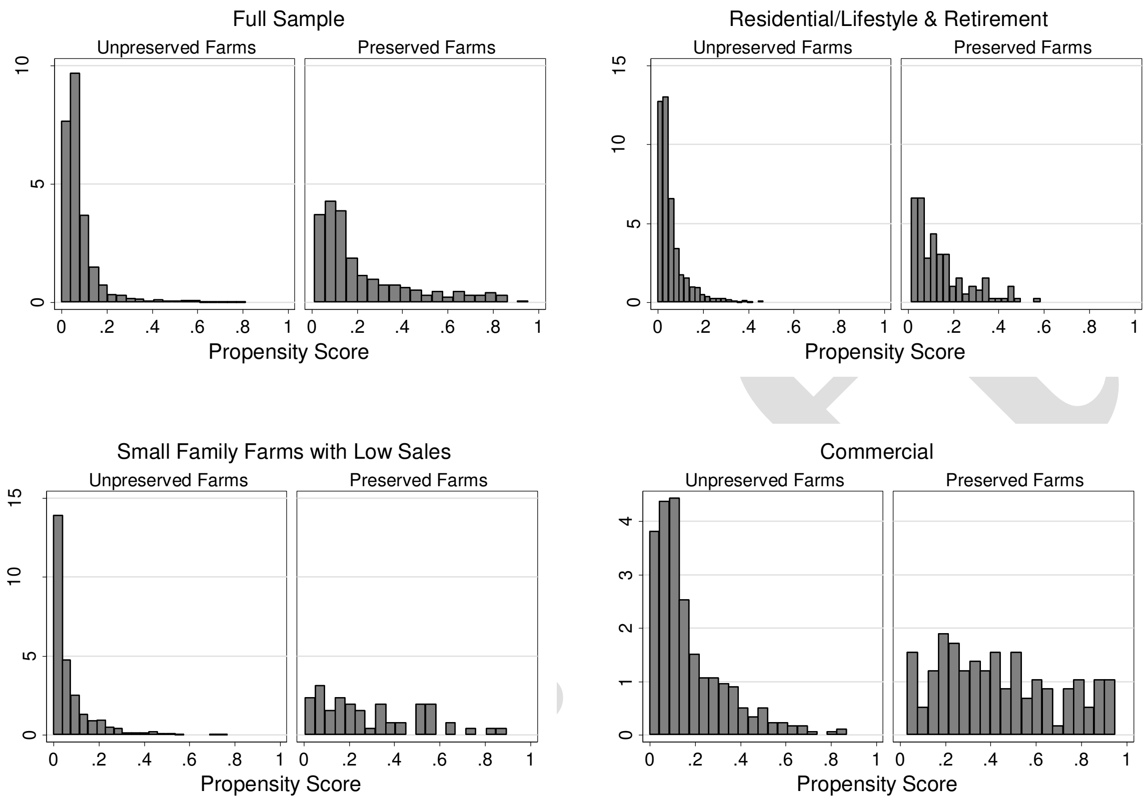

Table S1. Matching quality indicators with imposition of common support

	Before Matching			After Matching		
	Mean Bias	Pseudo R2	Chi2	%Mean Bias Reduction	%Chi2 Reduction	% Pseudo R2 Reduction
Full Sample						
NN1	15.26	0.16	392.07	-66.06	-72.15	-88.66
NN10	15.26	0.16	392.07	-86.19	-95.57	-98.14
Kernel	15.26	0.16	392.07	-85.61	-95.57	-98.15
Local Linear	15.26	0.16	392.07	-84.41	-94.30	-97.78
Radius 0.02	15.26	0.16	392.07	-88.20	-96.20	-98.54
Radius 0.05	15.26	0.16	392.07	-83.02	-94.94	-97.96
Residential/Lifestyle and Retirement Subsample						
NN1	11.50	0.14	139.01	-37.22	-31.85	-75.20
NN10	11.50	0.14	139.01	-79.77	-94.81	-98.06
Kernel	11.50	0.14	139.01	-83.90	-97.04	-98.91
Local Linear	11.50	0.14	139.01	-87.13	-97.04	-98.96
Radius 0.02	11.50	0.14	139.01	-83.56	-97.04	-98.90
Radius 0.05	11.50	0.14	139.01	-76.88	-92.59	-97.19
Small Farm with Low Sales Subsample						
NN1	18.47	0.26	102.81	-39.22	-41.67	-77.59
NN10	18.47	0.26	102.81	-66.43	-87.88	-95.13
Kernel	18.47	0.26	102.81	-62.46	-87.88	-95.16
Local Linear	18.47	0.26	102.81	-53.72	-86.74	-94.76
Radius 0.02	18.47	0.26	102.81	-54.74	-77.27	-91.41
Radius 0.05	18.47	0.26	102.81	-57.26	-82.58	-93.15
Commercial Farm Subsample						
NN1	19.73	0.24	141.04	-63.98	-67.92	-82.40
NN10	19.73	0.24	141.04	-78.94	-90.83	-95.08
Kernel	19.73	0.24	141.04	-80.82	-92.08	-95.55
Local Linear	19.73	0.24	141.04	-81.01	-90.42	-94.75
Radius 0.02	19.73	0.24	141.04	-75.02	-86.67	-93.17
Radius 0.05	19.73	0.24	141.04	-78.91	-87.50	-93.17

Note: Kernel function for kernel and local linear matching is Gaussian. Optimal bandwidth associated with the kernel function in each sample is obtained using the rule of thumb suggested by Silverman (1986). Results with thick support are very similar. The mean standardized bias (SB) before matching is given by

$SB_{before} = 100 \cdot \frac{\overline{X}_1 - \overline{X}_0}{\sqrt{0.5 \cdot (V_1(X) + V_0(X))}}$ and the SB after matching is given by

$SB_{after} = 100 \cdot \frac{\overline{X}_{1M} - \overline{X}_{0M}}{\sqrt{0.5 \cdot (V_{1M}(X) + V_{0M}(X))}}$ where X_1 (V_1) is the mean (variance) in the treatment group before matching and X_0 (V_0) the analogue for the control group. X_{1M} (V_{1M}) and X_{0M} (V_{0M}) are the corresponding values for the matched samples.

Table S2. Balancing test for mean difference – before and after matching

Variable	Sample	Full	Resident& Retire	Low Sales	Commercial
*GENDER*ACRES*	Unmatched	233.7550***	-	-	-
	Matched	-2.7700	-	-	-
GENDER	Unmatched	0.0872***	0.0377	0.1759***	-0.0221
	Matched	0.0047	0.0051	0.0090	-0.0098
AGE	Unmatched	0.7000	1.1130	1.4540	1.2120
	Matched	-0.1860	-0.1810	-2.0310	-0.8760
EXPERIENCE	Unmatched	3.8000***	0.8580	3.7240*	1.6370
	Matched	-0.1120	0.0420	-1.1930	-1.2500
EXPERIENCE^2	Unmatched	-	86.1500	-	-
	Matched	-	-5.7700	-	-
HEIR	Unmatched	0.0385***	0.0019	-0.0069	0.0432
	Matched	0.0085	0.0080	-0.0117	-0.0089
OFF_FARM	Unmatched	0.0410	0.0020	-0.0035	0.1005**
	Matched	-0.0093	0.0068	0.0365	0.0176
RENTAL_INC	Unmatched	0.0130**	0.0415***	0.0086	-
	Matched	-0.0020	-0.0004	0.0057	-
ACRES	Unmatched	238.2120***	52.8920***	107.5320***	404.2600***
	Matched	-4.0500	1.5520	-17.5900	27.6900
ACRES^2	Unmatched	2.8E+05***	1.5E+04***	4.4E+04***	6.4E+05***
	Matched	-2.0E+04	1.2E+03	-7.6E+03	5.0E+04
DIRECT_SALES	Unmatched	-0.0173	-0.0201	-0.0431	-0.0100
	Matched	-0.0120	0.0113	0.0250	-0.0267
CROP_PRICES	Unmatched	-377.0000	-440.5000	6958.9000*	-20514.9000
	Matched	-737.9000	452.8000	4103.5000	-3972.7000
CROP_PRICES^2	Unmatched	-	-	2.1E+09	-
	Matched	-	-	1.2E+09	-
CATTLE_PRICES	Unmatched	123.6000*	-174.1000**	300.2000*	13.6000
	Matched	4.3000	-28.1000	179.4000	75.9000
POULTRY_PRICES	Unmatched	-1.0090	-0.8810	-3.7710	0.5820
	Matched	-0.0750	-0.1350	-0.9510	0.1370
LABOR_COSTS	Unmatched	-291.2200	-97.0980	-225.8700	-3292.3900*
	Matched	-17.3400	-10.5350	6.5200	-439.2000
PRIME	Unmatched	5.0250***	4.8630***	4.3470*	6.5870***
	Matched	0.7530	0.6540	-0.9280	0.2380
TEMPERATURE	Unmatched	0.2550***	0.2350	0.1360	-0.1920
	Matched	0.0410	0.0510	0.0040	0.0550
PRECIPITATION	Unmatched	-0.2210	-0.3790	0.6920	1.5010**
	Matched	-0.1300	0.0060	-0.0600	-0.2390
NO_FARMS	Unmatched	10.0760***	10.9930**	6.7660	8.9810
	Matched	1.3090	1.2890	5.2770	-0.4370
NO_FARMS^2	Unmatched	1313.4000**	1447.1000	808.5000	-
	Matched	-4.0000	112.7000	1133.6000	-
CHG_AGLAND	Unmatched	1.9400	1.8960	1.6910	-0.7390
	Matched	0.1360	-0.0520	-0.0840	0.1970

Table S2. Continued

Variable	Sample	Full	Resident& Retire	Low Sales	Commercial
POP_DENSITY	Unmatched	-640.7300**	-911.7300	-731.6200	-243.3100
	Matched	-70.5700	-128.8100	-111.6900	-75.2900
CHG_POPDEN	Unmatched	8.9610***	9.3450***	14.1630***	14.3950***
	Matched	-0.6320	0.1240	4.2850	0.2580
DISTANCE	Unmatched	-0.7800	0.3410	-1.6720	0.7160
	Matched	0.0160	-0.0300	-0.8700	0.2620
DISTANCE^2	Unmatched	-71.2000	33.2000	-	-
	Matched	-8.2000	-6.8000	-	-
RESIDUAL_VALUE	Unmatched	6.9270**	3.6840	14.0790	-4.2280
	Matched	1.5580	0.5440	7.7130	7.5510
RESIDUAL_VALUE^2	Unmatched	1063.3000	-619.4000	-	-
	Matched	629.8000	-7.8000	-	-
HOUSINGVAL	Unmatched	1.0E+04	-1.0E+04	3.0E+04**	4.0E+04***
	Matched	0.0E+00	0.0E+00	1.0E+04	1.0E+04
HOUSINGVAL^2	Unmatched	-	-4.0E+09	1.5E+10**	1.3E+10***
	Matched	-	1.0E+09	9.0E+09	2.0E+09
RETIREMENT	Unmatched	-0.0367*	-	-	-
	Matched	0.0006	-	-	-
RESIDENT/RETIRE	Unmatched	-0.1535***	-0.0967**	-	-
	Matched	0.0035	0.0018	-	-
LOWSALES	Unmatched	-0.0027	-	-	-
	Matched	0.0047	-	-	-
HIGHSALES	Unmatched	0.0532***	-	-	-
	Matched	0.0008	-	-	-
LARGE	Unmatched	0.0446***	-	-	-0.0527
	Matched	-0.0004	-	-	-0.0080
VERYLARGE	Unmatched	0.1315***	-	-	0.1099**
	Matched	-0.0015	-	-	0.0242
NONFAMILY	Unmatched	0.0040	-	-	-
	Matched	-0.0096	-	-	-
GATEWAY	Unmatched	0.0086	0.0113	0.0207	-0.0276
	Matched	-0.0166	-0.0045	0.0216	-0.0037
GREATALTANTIC	Unmatched	0.0046	-0.0162	-	-0.0147
	Matched	0.0084	-0.0018	-	0.0054
SHORE	Unmatched	0.0104	0.0073	-0.0293	0.0631**
	Matched	-0.0028	0.0004	0.0043	0.0108
SKYLANDS	Unmatched	-0.0285	-0.0304	0.0776	0.1047**
	Matched	0.0144	0.0054	-0.0014	0.0110
SOUTHSHORE	Unmatched	-0.0219	0.0013	-	-0.0792**
	Matched	-0.0048	-0.0012	-	-0.0081

Note: Matching algorithm used for the balancing test in each sample is the one that provides the best matching quality (See Table S1). ***, **, * are significant at the 1, 5, and 10 percent level, respectively. *RETIREMENT, RESIDENT/RETIRE, LOWSALES, HIGHSALES, LARGE, VERYLARGE,* and *NONFAMILY* are dummy variables capturing farm types according to the ERS typology. *GATEWAY, GREATALTANTIC, SHORE, SKYLANDS,* and *SOUTHSHORE* are fixed effect dummy variables capturing regions in New Jersey.

Detailed explanation of sensitivity analysis for Tables S3 and S4

Each row of the first four columns of Table S3 contains parameters p_{ij} characterizing the distribution of the unobserved binary variable *U*. Controlling for the observable covariates *X*, the estimated Γ provides an indication of the "outcome effect" (Out. Eff.) of *U* (the effect of *U* on the profit per acre of unpreserved farms) and the estimated Λ measures the "selection effect" (Sel. Eff.) of *U* (the effect of *U* on the decision to participate in the PDR programs). The first row shows the baseline ATT estimate obtained with no confounder. The second row of each subgroup reveals the ATT estimate obtained with a neutral confounder, where Γ and Λ are equal to one. The other rows of each subgroup of Table S3 report variations in the baseline estimate when the binary confounding factor *U* is calibrated to mimic different observable covariates. Overall, the baseline estimate changes only slightly, affirming that our simulated results are robust to unobserved factors.

Since the above findings may be driven by the behavior of the covariates, we search for the characteristics of *U*s (i.e., "killer" confounding factors) that would have to exist to render the point estimate of the ATT close to zero. We simulate the distribution of *U* associated with the values of *d* (the difference in the binary confounding factor *U* among unpreserved farms that did and did not have profit per acre above the mean value) and *s* (the difference in the binary confounding factor *U* between preserved and unpreserved farms) designed to drive down the estimate of ATT to zero. We find the baseline ATT to be robust. For the highest values of the selection effect (s=0.5) and the outcome effect (d=0.5), the point estimate obtained when *U* is included in the matching set is still positive (Table S4).[1]

[1] As discussed in Nannicini (2007), the sensitivity conclusions should be drawn more in terms of the comparison of the point estimates than in terms of the significance of the simulated ATT.

Table S3. Sensitivity analysis of profitability outcome for small farm with low sales subsample: Effect of "calibrated" confounders

	Fraction U=1 by Treatment/Outcome				Out. Eff.	Sel. Eff.	ATT	SE
	p_{11}	p_{10}	p_{01}	p_{00}	(Γ)	(Λ)		
No confounder	0.00	0.00	0.00	0.00	-	-	313	132
Neutral confounder	0.50	0.50	0.50	0.50	1.00	1.00	328	212
Confounder-like								
GENDER	0.87	0.67	0.77	0.48	4.10	3.21	277	212
HEIR	0.07	0.00	0.07	0.10	0.71	1.07	320	215
OFF FARM	0.44	1.00	0.45	0.51	0.79	1.08	330	212
RENTAL_INC	0.02	0.00	0.01	0.01	272.51	7.35	318	216
DIRECT_SALES	0.15	0.00	0.23	0.07	4.95	0.66	339	215

Note: U is a binary confounding factor. p_{ij} is the probability that U=1 defined by treatment and outcome status where $i \in \{0,1\}$ indicates treatment status with i=1 as enrollment in the PDR program and $j \in \{0,1\}$ indicates outcome status with j=1 if the value of the profitability outcome (profit per acre) is greater than its mean value. On the basis of these parameters, a value of U is imputed and the ATT is estimated by kernel matching with U in the set of matching variables. A gaussian kernel function is used; its associated bandwidth is equal to 0.039. The process is repeated 500 times. "SE" is the standard error. Outcome effect (Γ) is the average estimated odds ratio of U in the logit model of $\Pr(Y=1|T=0, U, X)$ and selection effect (Λ) is the average estimated odds ratio of U in the logit model of $\Pr(T=1|U, X)$. "ATT" is the average of the simulated ATTs. In the 'confounder-like' rows, U has been calibrated to match the distribution of the corresponding covariate.

Table S4. Sensitivity analysis of profitability outcome for small farm with low sales subsample: Characterizing "killer" confounders

	s=0.1 Λ ∈ [1.34, 1.61]	*s*=0.2 Λ ∈ [2.22, 2.75]	*s*=0.3 Λ ∈ [3.92, 4.72]	*s*=0.4 Λ ∈ [8.81, 11.46]	*s*=0.5 Λ ∈ [42.37, 47.62]
d=0.1	325	315	302	281	237
Γ ∈[1.57, 1.62]	(212)	(217)	(223)	(225)	(243)
d=0.2	313	301	268	242	181
Γ ∈[2.41 2.50]	(218)	(216)	(209)	(222)	(246)
d=0.3	307	280	245	193	128
Γ ∈[4.03, 4.10]	(215)	(212)	(208)	(208)	(231)
d=0.4	304	263	213	161	78
Γ ∈[6.89, 7.79]	(213)	(205)	(202)	(196)	(212)
d=0.5	304	249	189	118	22
Γ ∈[13.95, 17.81]	(216)	(203)	(197)	(187)	(201)

Note: We assume that Pr(*U*=1)=0.50 and that $p_{11}-p_{10}=0$. $s=p_{1.}-p_{0.}$captures the difference in the binary confounding factor *U* between farms that enrolled and did not enroll in the PDR program. $d = p_{01} - p_{00}$ captures the difference in the binary confounding factor *U* among unpreserved farms that did and did not have profit per acre higher than the mean. Standard errors are in parentheses.[2]
All ATTs are averaged over 500 iterations. Γ is the average estimated odds ratio of *U* in the logit model of Pr(*Y*=1|*T*=0, *U*, *X*) and Λ is the average estimated odds ratio of U in the logit model of Pr(*T*=1|*U*, *X*). The baseline estimate without the confounder is equal to $313.

[2] With different predetermined values of Pr(*U*=1) and $p_{11}=p_{10}$, we can still obtain similar results qualitatively.

References

Nannicini, T. 2007. Simulation-based sensitivity analysis for matching estimators. *Stata Journal* 7 (3), 334.

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[1] A PDR program imposes a negative easement on an enrolled property that "runs with the land" and prohibits non-agricultural development in perpetuity, or a specified period of time. Unlike fee simple acquisition, whereby full interest of land is conveyed to a purchaser, PDR programs establish a non-possessory interest in land.

[2] This test involves comparison of the characteristics of preserved and unpreserved farms before matching and evaluation of whether any significant differences in the characteristics of the two farm groups remain after matching.

[3] Capital asset pricing theory predicts that the sale price of a preserved farm will be a function of only the present value of the net returns in an agricultural use, if the restrictions imposed on the farmland by the sale of development rights are fully capitalized into the farmland values (Lynch, Gray, and Geoghegan 2007).

[4] These data contain some duplicative entries. For example, a few dozen farms have acreage in two or more municipalities. In such instances, acreage preserved in each municipality is recorded, resulting in multiple closing entries for each farm.

[5] For example, assume a 300-acre farm that is enumerated in the Census comprises three 100-acre tax lots. Assume also that the farm owner chooses to preserve one tax lot (100 acres) in each of three separate years. These will be reflected as three different preserved farms in the

SADC dataset, since the closings occurred separately. In some instances, one SADC closing record matched perfectly with a respective Census record. In others, there were multiple SADC closings that were combined to match a Census record.

[6] To qualify for state funding for farmland preservation, a farm must be eligible for the state's differential agricultural assessment program, be located in an agricultural development area (an area deemed by a county agriculture development board as one in which farming is viable in the long-term), targeted for preservation in a county comprehensive farmland preservation plan, and exhibit development potential based on zoning and environmental conditions. Additional eligibility criteria are as follows. A farm 10 or less acres in size must earn $2,500 in annual sales and 75% of its area (or a minimum of 5 acres) must be tillable and comprise soils capable of supporting agricultural or horticultural production. For a farm greater than 10 acres in size at least 75% of its area (or a minimum of 25 acres, whichever is less) must be tillable and comprise soils capable of supporting agricultural or horticultural production. Due to data limitations, a simplified set of eligibility screening criteria were used in our study. For farms 10 acres or less in size, a farm was deemed eligible if it sold at least $2,500 worth of farm products and was at least 75% tillable (or 5 acres were tillable, whichever is less). Farms that were at least 10 acres in size were considered eligible if at least 50% of the land (or 25 acres, whichever is less) was tillable.

[7] The basic idea of the radius matching is to use not only the nearest neighbor within each caliper (propensity range), but all of the unpreserved farms within the caliper. A benefit of this approach is that it uses only as many unpreserved farms as are available within the caliper and therefore allows for usage of extra (fewer) units when good matches are (not) available (Caliendo and Kopeinig 2008).

[8] Kernel matching and local linear matching are nonparametric matching estimators that use weighted averages of (nearly) all farms in the unpreserved farm group to construct the counterfactual outcome. Thus, one major advantage of these approaches is the lower variance.

[9] We also estimate kernel and local linear matching algorithms using the Epanechnikov kernel function and find slightly different results.

[10] We trim any observations with a propensity score below 0.034 in the full sample, 0.027 in the residential/lifestyle and retirement farm subsample, 0.015 in the small family farm with low sales, and 0.077 in the commercial farm subsample.

[11] The method simulates the binary variable *U* ("the confounder") from the data, which is used as an additional matching variable to estimate the propensity score and the ATT. A comparison of the estimates obtained with and without matching on this simulated variable demonstrates the extent to which the estimator is robust to the unobserved factors.

[12] Roughly 84,016 acres of preserved land is associated with the "commercial" farms (average farm size in the subgroup is 661.54 acres * 127 farms). This equates to 78% of the acreage summed across the three farm subgroups. The respective sample acreages for residential lifestyle/retirement farms and low sales farms are 13,364 acres and 10,253 acres, respectively.

[13] $V_i^{resid}(X_i, t_2^*) = V_i^{presold}(X_i, t_2^*) - \int_{t_2^*}^{\infty} R_i^{ag}(X_i, \tau) e^{-\rho\tau} d\tau$ where $V_i^{presold}$ is the actual price of preserved farm sold at optimal date t_2^*.