ABSTRACT

Title of Dissertation: LAND PRESERVATION, VOLUNTARY PROGRAMS, AND REGULATORY INSTRUMENTS

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In the US, urban sprawl and the resulting loss of farmland and habitats to residential and commercial uses have drawn increasing concerns and led to the establishment of both voluntary programs and regulatory instruments. These programs restrict a landowner's right to develop land with or without compensation. My dissertation is a study of the effectiveness and impact of those voluntary programs and regulatory instruments.

In the first essay, I develop and present an empirical test of the impact of Purchase of Development Rights programs in reducing farmland loss. I use a county-level data on the 269 counties in the six Mid-Atlantic States (Virginia, Maryland, Pennsylvania, Delaware, New Jersey, and New York) over a 50-year time period. Using a propensity score matching approach, I find strong evidence that these programs have reduced the rate of farmland loss and the acres lost.

My second essay evaluates the effect of Maryland Rural Legacy (RL) program on farmland preservation by taking into account a predisposition effect, a time effect, and a crowing effect. I use data on agricultural and forest parcels in three Maryland counties (Calvert, Charles, and St. Mary's) and match parcels based on the estimated propensity that the parcels are included in a RL area. I find that 1), the RL program crowds in the preservation efforts of other programs and 2), more parcels and more acres are preserved in RL areas than in non-RL areas due to preservation effort from RL program.

My third essay is a theoretical study on land development restriction from the Endangered Species Act and landowners' timing to develop land. I use a two-period framework and assume uncertainty of future land value and irreversibility of land development decisions. I examine the conditions under which it is optimal for regulators to compromise and the optimal strategies that allow them to balance the welfare gain and loss from compromise. Regulators should compromise only if social welfare loss from preemption is sufficiently large. Regulator can improve social welfare and reveal landowners' types through differentiated ex ante fees for differentiated regulation levels.

LAND PRESERVATION, VOLUNTARY PROGRAMS, AND REGULATORY INSTRUMENTS

by

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DEDICATION

To My Parents

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Chapter 1

Introduction

Urban sprawl and its resulting loss of farmland and habitats to residential and commercial uses have drawn increasing public concerns in the US. Those concerns lead governments to introduce both voluntary programs and regulatory instruments to slow down this trend. Since the 1970s, various regulations and land preservation programs have been initiated to preserve agricultural land and habitats. Those initiatives restrict a landowner's right to develop land with or without compensation. It is important to understand how these restrictions affect landowners' decisions to ensure effective and efficient programs and regulations. My dissertation is a study of the effectiveness of the voluntary programs and effect of regulatory instruments on landowners' behavior.

For voluntary programs, I study the effectiveness of two voluntary farmland preservation programs, 1) Purchase of Agricultural Development Rights (PDR) program, 2) Rural Legacy (RL) designation that focuses on preserving contiguous large blocks of agricultural land, habitats, and environmentally sensitive land. For regulatory instruments, I study landowners' behavior under the threat of the Endangered Species Act (ESA), one of the most strict and contradictory regulations in the US. My dissertation is therefore comprised of three essays, one theoretical and two empirical, contributing to the theoretical and empirical literature on land conversion. Empirically, I examine whether voluntary preservation programs reduce farmland conversion at both aggregate (PDR) and parcel levels (RL designation). Theoretically, I model how regulatory approaches influence the timing of land development at individual level when landowners can either negotiate or preempt (develop land before regulation takes effect) to protect their private benefits.

1.1 Purchase of Development Rights Programs

Agricultural land preservation is beneficial to the society in terms of providing sufficient food, a profitable agricultural industry, open space and environmental amenities, and a healthy urban development (Gardner, 1977). Empirical studies using various methods suggest that non-market agricultural services, environmental amenity, habitat, groundwater quality and open space are the most valuable attributes for public (Kline and Wichelns, 1996a, 1996b, 1998; Fleisher and Tsur, 2000; Duke and Ilvento, 2004; and Duke and Aull-Hyde, 2002). The communities with high development pressures, high income or education level are more likely to establish farmland preservation programs (Kline and Wichelns, 1994; Nelson et al., 2007). Individual landowners' participation increases in crop production, farm size, satisfying eligibility criteria, farmer legacy, and distance to cities, decreases with soil quality and off-farm income (Lynch and Lovell, 2003). However, individual landowners tend not to participate preservation programs at the suburban fringes, where parcels size are smaller and have higher development pressure (Duke, 2004).

Analyses are also conducted to evaluate the performance and welfare effect of farmland preservation programs. Lynch and Musser (2001) use a distance function approach to evaluate the efficiency level over the four objectives (to preserve more acres, to preserve productive farms, to preserve contiguous blocks of land, and to preserve farms most threatened by development) for the state and county preservation programs in Maryland. With a benefit transfer exercise, Feather and Barnard (2003) assess the welfare effect of PDR program nationally and suggest that even under conservative assumption, the benefits are likely to be large and may outweigh the costs. Parks and Quimio (1996) study the preferential property tax program in Wisconsin and find that economic benefit from preferential property tax program is too small compared to non-agricultural benefits and it alone is not likely to be effective in retaining farmland. McConnell et al. (2005, 2006) examine in detail the Transfer of Development Rights (TDR) program in Calvert County, Maryland, and find that development is shifted to low-density rural area which contradicts the goal of the program. Lynch and Carpenter (2003) find no impact of PDR and TDR on farmland loss rate assuming that the programs' existence is exogenous. However, Towe et al. (2008) find that the option to preserve farmland provided by PDR program may delay land development in Howard County, Maryland, that is, the parcels qualified for a preservation option have a 50% lower hazard rate of being developed than unqualified parcels.

Besides, McConnell et al. (2005, 2006) and Lynch and Carpenter (2003), the literature that examines the effectiveness of permanent preservation through PDR and TDR in retaining farmland is limited, in part because of the difficulties in identifying their effect empirically due to development pressures being endogenous with the existence of the programs and self-selection of parcels into a program. My chapter 2 is therefore an empirical study of the effect of the farmland preservation programs (PDR programs) on farmland loss using aggregate data and a Propensity Score Matching (PSM) approach. My data covers the counties in six Mid-Atlantic States (Virginia, Maryland, Pennsylvania, Delaware, New Jersey, and New York) over 50 year time periods (1949-1997). I evaluate the effectiveness of the programs by examining the rate of farmland loss and the acres lost rather than enrollment in the programs. I use a propensity score matching approach. This method has several advantages compared to regression approaches. First, it excludes outliers more explicitly; second, it does not assume that counties are equally likely to have farmland preservation programs; third, it does not impose linear functional forms on outcome equation, decision process and unobservable terms. I find strong evidence that these programs have significantly reduced the rate of farmland loss and the acres lost. Specifically, counties with programs in place have experienced, all else the same, a 48-61%, and more than 2000 acres, lower loss of farmland than the others. The results are consistent across matching over different sub-samples (e.g. matching over full sample, matching within sample after 1978 only and matching within time period), and different matching methods. This chapter, therefore, contributes to the literature as it is the first one that treats the existence of those programs as endogenous and uses a semi-parametric approach to appropriately address this issue.

1.2 Rural Legacy Program in Maryland

As voluntary farmland preservation programs have been operating in the US for 25 years and continue to proliferate, critics suggest that these voluntary programs do not prevent land conversion, do not maximize social benefits and cannot prevent land fragmentation (Pfeffer and Lapping, 1995; Daniels and Lapping, 2005; Lynch and Musser, 2001). Empirical evidences also suggest that the open space preserved by agricultural land preservation programs increases land value. Hardie et al. (2007) find that the subdivision acreage required for forest increases land value in five Maryland counties in Baltimore/Washington Metropolitan area. Geoghegan et al. (2003) and Irwin (2002) find that permanently preserving agricultural parcels increase the housing price in their adjacent areas. Therefore, agricultural preservation programs can induce more conversion of their neighboring parcels because of the preserved open spaces (Irwin and Bockstael, 2004; Roe et al., 2004). Focusing on preserving contiguous large blocks of land may provide greater benefits if threshold impact or economies of scale exist. Large blocks of undeveloped land may be needed for ecosystem services provision such as wildlife habitat and water quality. The Rural Legacy (RL) program introduced in 1997 in Maryland is a program that focuses on preserving large blocks of undeveloped land. The cornerstone of the RL program is to designate RL areas, which receive special funding to preserve farm, forest, and ecologically important resource lands in a contiguous fashion.

The chapter 3 of my dissertation is an empirical study of the impact of the RL program on farmland preservation by taking into account its interaction with existing conservation programs using a parcel level data. I use data on agricultural and forest parcels greater than 3 acres in 3 Maryland counties (Calvert, Charles, and St. Mary's). With a rich set of parcel characteristics that impact both RL area designation and farmland preservation, I conduct matches based on the estimated propensity that a parcel is included in a RL area. I find empirical evidence that, first, parcels in RL areas are predisposed to be preserved, second, RL program crowds in the preservation efforts of other programs within the RL areas, and third, RL program preserves more parcels and more acres in RL areas compared to non-RL areas due to increment in the available funding.

1.3 The Endangered Species Act

The voluntary preservation programs attract landowners to cooperate by compensating them for giving up development rights attached to their land. The Endangered Species Act (ESA), however, imposes restrictions on land development without compensation and therefore induces preemptive behavior (Leuck and Michael, 2003; List, et al., 2005).

An extensive literature has been developed to discuss the compensation or taxation schemes that address individual landowners' non-optimal incentives. Those non-optimal incentives lead landowners to develop land or make costly investments under the threat of takings. The rationale for regulation is the divergence of the private from the public value of land and the induced externalities from private land development. Starting with Blume et al. (1984), many researchers have addressed the issue of compensation for takings. Innes et al. (1998), Innes (1997, 2000), Shapiro (2003) and others show that compensation can be problematic as it might distort investment decisions. Miceli and Segerson (1996) suggest a compensation scheme that conditions payments on whether landowners' land use decision is socially optimal in the pre-regulation period.

While the mentioned studies of compensation apply directly to much of current legislation, limiting property rights under the ESA does not generally grant compensation. Instead, compromise is introduced as a strategy for hope to provide landowners enough incentive to protect listed species. In 1983, Congress amended the ESA by adding section 10(a) under which a landowner or a group of landowners can obtain an Incidental Taking Permit (ITP) from Fish and Wildlife Services (FWS) to incidentally take a listed species. The section 10(a) is a strategy of compromise and to certain extent it may reduce preemption. In exchange for an ITP, landowners have to prepare a Habitat Conservation Plan (HCP) that aims to minimize and mitigate the impact of permitted land development. That is, by bearing some costs for addressing public concerns regarding endangered species, landowners keep the right to develop their property.

The cost of developing a HCP can be substantial as the negotiation process for an ITP is long and elaborate. Some landowners, in order to avoid the cost, may choose to preemptively develop their land. Leuck and Michael (2003) and List, et al. (2005) find empirical evidence that ESA induces preemptive behavior of landowners. Alternatively, landowners or a group of landowners may also put extra effort to negotiate with FWS and the relevant parties for more favorable terms. Or landowners can submit an extensive HCP for a lower future development cost. Despite the criticism that HCP favors development over species, it is argued that this way of compromise may represent the best hope to gain landowners' cooperation to protect species.

The chapter 4 of my dissertation is therefore a study of land development restriction imposed by ESA, preemptive behavior, and the potential benefits of compromise and differentiated treatment on landowners. An ITP is issued after a multilateral negotiation among landowner, FWS, local administrations and interests groups. The cost associated with an ITP may be different among landowners, which therefore lead to differentiated regulatory stringency levels for different landowners. This chapter addresses the issue of preemptive land development and differentiated regulatory treatment on landowners. I use a two-period framework similar to Miceli and Segerson (1996). I also assume uncertainty of future land value and the irreversibility of land development decision. When regulators are perfectly informed about landowners' threshold value above which to preemptively develop land, they should compromise only if the social welfare loss from preemption is sufficiently large.

Regulators can reach an agreement with each individual landowner in a way that just makes the landowner slightly better off than if he preempts when regulators can differentiate landowners. When they cannot differentiate landowners, regulators can offer a uniform regulation level which crucially depends on the distribution of landowners' propensity to preempt. When regulators are not perfectly informed about landowner's type, a mechanism is proposed to reveal landowner's type through an ex ante fee (or an extensive HCP) for a lower regulation level. This mechanism can improve social welfare when the benefits loss from preemption and/or the difference in landowner's type is sufficiently large.

Chapter 2

Do Agricultural Preservation Programs Affect Farmland Conversion?

2.1 Introduction

Concerns about the loss of farmland and the increase in suburban sprawl led states and counties to institute programs to arrest or slow farmland conversion. Beginning in 1978, farmland preservation programs such as Purchase of Development Rights/Purchase of Agricultural Conservation Easements (PDR/PACE) have been established and funded to retain agricultural land. These programs usually attach an easement to the property that restricts the right to convert the land to residential, commercial and industrial uses in exchange for a cash payment and/or tax benefit. By 2007, more than 128 governmental entities in the US have implemented farmland preservation programs. Among them, 78 government entities have PDR program and have preserved over 1.89 out of 938.28 million acres of farmland nationwide by 2007 (American Farmland Trust (AFT), 2007a; AFT, 2007b; ERS, 2008). Spending in both state and local programs to purchase these rights was $4.467 billion (AFT, 2007a; AFT, 2007b). The total amount of money spent and the acres preserved indicate an average easement payment as $2370.

While several studies have evaluated the impact of other types of farmland preservation programs, such as (non-permanent) use-value (preferential taxation) programs (Blewitt and Lane 1988; Gardner 1994; Lynch and Carpenter, 2003; Parks and Quimio, 1996; Heimlich and Anderson, 2001) and Transfer of Development Rights programs (McConnell et al., 2005), few have studied the impact of the permanent easement conferred by the PDR/PACE programs.

Farmland preservation programs are justified on various grounds including efficient development of urban and rural land, local and national food security, viability of the local agricultural economy, and the protection of rural and environmental amenities (Gardner, 1977; Hellerstein et al., 2002). Empirical evidence has also been found that those programs provide net benefits to society (Feather and Barnard, 2003; Duke and Ilvento, 2004). However, there is very little evidence of PDR programs retaining farmland at aggregate level.

Lynch and Carpenter (2003) suggest no impact of PDR/PACE program on the farmland loss assuming that the programs' existence was exogenous. Several studies have suggested that expensive PDR/PACE programs have preserved too little land or the wrong "type" of farmland (MALPF Task Force, 2001; Lynch and Lovell, 2003; Lynch and Musser, 2001; Adelaja and Schilling, 1999). Despite Maryland's successful state preservation program which has preserved 198,276 acres, 371,000 acres have been converted to a residential or commercial use simultaneously (MALPF Task Force, 2001). Only half as much agricultural land was preserved compared to agricultural land converted. Those evidence may suggest that the impact of those programs on farmland loss is insignificant due to enrolling the parcels least likely to be converted.

Besides, recent evidence suggests that the positive amenities generated by these preservation programs may increase the demand for housing near the preserved parcels. For example, Geoghegan, Lynch and Bucholtz (2003) and Irwin (2002) find that housing prices adjacent to preserved parcels can increase due to the permanency of adjacent open space.

In this chapter, I take a comprehensive approach to study the effect of PDR/PACE program on farmland loss in a broad region over a long time period.

Assessing the impact of permanent preservation through PDR/PACE program on farmland loss can be challenging due to the endogeneity of program establishment. Farmland preservation programs may be established in those counties with rapid farmland loss and/or lower levels of farmland thus the very existence of the program itself may be predicated on farmland loss. One cannot observe the proper counterfactual, i.e. one would like to know what would have happened to farmland loss in county A if it had not implemented a program. However, county A cannot be in two states simultaneously, nor can a researcher randomly assign who has a preservation program and who does not.

I overcome some of the empirical difficulties by using a propensity score matching (PSM) method to estimate the treatment effect on treated. This method has several benefits –first, the matching protocol ensures that the counties with farmland preservation programs will be matched to the counties without programs that are most similar to them in terms of observable characteristics. This provides a more transparent mean to decrease the influence of outliers and dissimilar counties. Second, because not all counties are equally likely to have farmland preservation programs, PSM incorporates pretreatment covariates that may influence the existence of such a program as well as farmland loss into the propensity score calculation. Third, a specific functional form is not assumed for outcome equation, the decision process or the unobservable terms. Therefore, propensity score matching may be a more appropriate approach because it requires fewer assumptions than an instrumental variable approach.

Using a unique 50-year 269 county panel data set on the existence of PDR/PACE program and farmland loss for six Mid-Atlantic States, I find strong empirical evidence that these programs have had a statistically significant effect on farmland loss.

The following section 2.2 provides a conceptual framework of farmland preservation from individual to aggregate level. The Propensity Score Matching method and data are outlined in Section 2.3 and 2.4. Section 2.5 presents empirical estimation including propensity score estimation, selection of propensity score matching methods, and balancing test. Sensitivity analysis using a Rosenbaum Bounds, Hidden Bias Equivalents, and robustness checks using a two-stage regression and a difference-in-difference approach are presented in Section 2.7. Section 2.8 is the conclusion.

2.2 Theoretical Framework

In a competitive land market, risk-neutral landowners seek to maximize the economic return from their land given the stream of net returns. Ricardian theory states that the profitability of agricultural land is based on fertility or soil characteristics and this fertility determines the land rent that an agricultural producer would pay. Von Thunen, Mills and others propose that the stream of benefits of living/farming at a particular location relative to the central business district determines the rent a person would pay. Hardie et al. (2001) combine the Ricardian and Von Thunen models and find that the market values of parcels in suburban counties are the sum of the Ricardian rent and the location or accessibility rent. In the simplest form, one can think of the market price per acre P_i of the parcel i as determined by the stream of rents. The market value is thus the sum of agricultural rents given the land and locational characteristics of parcel i (X_i), $A_i(X_i, t)$ from time $t = 0$ up to an optimal conversion date $t^*(X_i)$, at which time the land is converted into a residential use, and the sum of net returns of $R_i(X_i, t)$ as shown in equation (2.1)[1]. The discount rate is r.

$$P_i = \int_{0}^{t^*(X_i)} A_i(X_i, t)e^{-rt}dt + \int_{t^*(X_i)}^{\infty} R_i(X_i, t)e^{-rt}dt \qquad (2.1)$$

I assume that agricultural rents grow more slowly than net residential rents ($\frac{\partial A_i}{\partial t} < \frac{\partial R_i}{\partial t}$) and land development is irreversible. Thus to maximize the return from the land, a landowner will set the optimal conversion date $t^*(X_i)$ such that the net returns to agriculture and net returns to residential uses are equal: $A_i(X_i, t^*) - R_i(X_i, t^*) = 0$. Let there be a cumulative density function across the land and locational characteristics that reflects potential development likelihood that I define as $F(X)$. I define $L(X)$ as the acres of land with characteristic X. Then the land in a county that would be converted from agricultural to another use up to time t, is equal to: $L_C(t) = \int_{\{X:t^*(X)\leq t\}} L(X)dF(X)$.

The land in a county that remains in agricultural production ($L_A(t)$) is equal to:

$$L_A(t) = \int_{\{X:t^*(X)>t\}} L(X)dF(X)$$

In some counties, landowners are offered the option of enrolling in a preservation program which permanently removes their option to convert their land for development. Upon enrollment, landowners receive a payment equal to the easement value,

[1]To simplify the model only two land uses are used. However, the landowner may maximize his or her present value by shifting the land use to commercial, industrial or other alternative land uses.

$EV_i(X_i)$, but retain ownership of the parcel and the stream of agricultural rent in perpetuity. If the agricultural landowner can extract the value of the development rights by selling them to a preservation program, the restricted market price will be the net present value of all future agricultural rents as shown in equation (2.2).[2]

$$P_i^R = \int_0^\infty A_i(X_i, t)e^{-rt}dt \tag{2.2}$$

The enrollment decision depends on the land characteristic X_i and easement payment $EV(X_i)$. I define $\beta(X_i, EV(X_i))$ as enrollment decision. Landowner choose ($\beta(X_i, EV(X_i)) = 0, 1)$ to maximize their economic returns according to (2.3)

$$\begin{aligned} V_i &= (1-\beta(X_i, EV(X_i)))\left[\int_0^{t^*(X_i)} A_i(X_i,t)e^{-rt}dt + \int_{t^*(X_i)}^\infty R_i(X_i,t)e^{-rt}dt\right] \\ &+\beta(X_i, EV(X_i))\left[\int_0^\infty A_i(X_i,t)e^{-rt}dt + EV(X_i)\right] \end{aligned} \tag{2.3}$$

If $\int_{t^*(X_i)}^\infty (R_i(X_i,t) - A_i(X_i,t))\, e^{-rt}dt - EV(X_i) < 0$, then $\beta(X_i, EV(X_i)) = 1$. Land i that is enrolled in the preservation program will not leave agriculture at its (previously) optimal time to develop, $t^*(X_i)$. Therefore, the number of acres converted from agriculture up to current period becomes $\int_{\{X:t^*(X)\leq t\}} (1-\beta(X, EV(X)))L(X)dF(X)$;

the total acres with an optimal time to convert $t^*(X)$ earlier than t, minus the acres that are enrolled in the preservation programs. If the preservation programs are having an impact on farmland loss, I would expect that conversion is significantly

[2] While not explicitly modeled, the landowner could sell the farmland in the future with the easement restrictions attached to the property. However, even with a new owner, no residential, commercial or industrial development would be permitted.

lower as depicted in (2.4).

$$\int\limits_{\{X:t^*(X)\le t\}} (1-\beta(X,EV(X)))L(X)dF(X) < \int\limits_{\{X:t^*(X)\le t\}} L(X)dF(X) \qquad (2.4)$$

The net effect of the agricultural land preservation programs is:

$$\int\limits_{\{X:t^*(X)\le t\}} \beta(X,EV(X))L(X)dF(X) > 0$$

Empirically, I would find this result at any point of time if the preservation programs are enrolling farms that would have left agriculture by that point. Alternatively, if the preservation programs are enrolling farms not threatened by conversion at the time of evaluation ($t^*(X) > t$), I might find the right-side of equation (2.4) equal to the left-side at that time. Alternatively, preservation programs may not be enrolling many farms due to inadequate incentives (EV is too low), insufficient time in operation (only began recently), and/or small budgets relative to the number of farmland acres in the county.

2.3 Propensity Score Matching (PSM) Method

Assessing the impacts of preservation programs is difficult because a county that have high development pressures are more likely to have a PDR program. While one can identify whether a county has a preservation program (is treated) or not (not treated, or in my analysis, a control) and the outcome (farmland loss) conditional on its treatment status, one can not observe the counterfactual, i.e. what would have happened if no farmland preservation program had been established. Thus, the fundamental problem in identifying treatment effect is constructing the unobserved counterfactuals for the counties that have establish a PDR program.

To assess the impact of farmland preservation programs on farmland loss, I employ the propensity score matching method developed by Rosenbaum and Rubin (1983). The PSM method is to use the counties that do not have a PDR program but have the same observed characteristics to construct counterfactuals for the treated counties. The observed characteristics affect both a county's treatment status and farmland loss. The impact of PDR program is therefore the difference in farmland loss between the counties that have established such programs and their constructed counterfactuals.

This method has been used in various economic studies in different contexts. It is used to evaluate the effect of job training programs (Heckman et al., 1997; Dehejia and Wahba, 1999, 2002; Smith and Todd, 2005a), labor market effects of college quality (Black and Smith, 2004), the labor market effects of migration (Ham et al., 2003) the plant birth effects of environmental regulations (List et. al, 2003) and the land market effects of zoning (McMillen and McDonald, 2002).

This method has been adopted not only in studies using micro data, but also aggregated level data depending on the empirical questions and available data. Brooks (2008) applies propensity score matching techniques to study the impact of Business Improvement Districts on crime rate using neighborhood level data in Los Angles. Ortz, Orazeman and Otto (2007) use matching techniques and county level data to study the impact of meat packing industry on local labor market, crime rate, and local government spending in the 12 Mid-Western States. List et al. (2003) apply PSM on a county level data to examine the effects of air quality regulation on economic activity. Lin and Ye (2007) use PSM and country level data to study the impact of inflation targeting (a policy that alleviates the dynamic inconsistency problem and leads to lower inflation and inflation variability), on actual inflation situation. Dehejia and Gatti (2002) use PSM to examine the relationship between child labor and access to credit at a cross-country level.

I adopt this method to estimate the impact of farmland preservation programs on farmland loss using county level panel data. I assign a observation as being treated if a county in a period has at least one acre of farmland being preserved by PDR programs ($D = 1$) and as control otherwise ($D = 0$). Let Y_1, (Y_0) denote farmland loss in rate or acres if treatment has (not) occurred in a county. The Average Treatment Effect on the Treated (ATT) would be the average difference in the outcome variables if one observes the outcomes for both treatment statuses. When one cannot observe both outcomes, the matching method can be used to estimate the ATT. The matching method compares the mean of outcomes between the treated observations with those matched controls that have the same distribution in their observed characteristics, X.

It is difficult to match the treated and control observations based on X when the dimension of X is large. The propensity score matching (PSM) method proposed by Rosenbaum and Rubin (1983) addresses this issue by matching the controls with the treated based on the estimated probability of selection into treatment groups. The probability, $P(D = 1|X) \in (0, 1)$, is estimated using the observed characteristics, X.

Conditional Independence Assumption (CIA) is the basic assumption for matching which says that the treatment status is random based on those observed characteristics. Heckman et al. (1998) relax the CIA condition by proposing a Conditional Mean Independence (CMI) assumption. This assumption assumes that the pre-treatment outcome of the matched control is the same as that for the treated based on the vector of observed characteristics, X, or the probability $P(D = 1|X)$.

The ATT is thus the expected difference in outcome Y between the treated observations and their corresponding counterfactuals constructed from the matched controls: $ATT = E(Y_1|D=1) - E(Y_0|D=1) = E(Y_1|D=1) - E(Y_0|D=0, P(X))$.

The CIA condition requires that the conditioning set of X needs to include all the key variables that may affect both the outcome and the existence of the programs except the treatment state. The weaker condition, CMI assumption, allows uncontrolled variables but requires that the unobservables have the same impact on the outcome for treated and control groups. In this study, X might include changes in agricultural profitability, demand on land for non-agricultural purposes, and alternative employment opportunities for farmers.

I first match the treatment and control observations over the full sample (no restriction) and calculate the overall treatment effect. Using the full sample may provide the best matches since counties in different geographic locations may reach the same development stage at the same time while counties within the same state may be at very different development stages at any given time. For example, counties close to metropolitan areas may have experienced development pressure at an earlier period than counties further away from a city, all else the same. Matching over the full sample therefore has the advantage of providing better controls for treated counties than matching within state or within time period. I then ran balance tests for matches and calculated the average treatment effect on the treated over the matched groups.

Second, because there may have been some unobservables that vary by time period that impact farmland loss and are not captured by my estimated propensity scores, I also conducted matching within a time period. In this case, a treated county is restricted to match control counties within the same time period. The average treatment effect on the treated is then computed using these matched groups.

I also attempted to match within state in order to control for the heterogeneity across states. I find very few matches and the matching failed the balance tests for the covariates that change over time due to small number of available control observations within some states that have state level programs. For example, all 3 out of the 3 counties in Delaware have farmland preserved by 1997, 20 out of 23 counties in Maryland have farmland preserved by 1987, 15 out of 20 counties in New Jersey have farmland preserved by 1992.

2.4 Background and Data

Six Mid-Atlantic States (Delaware, Maryland, New Jersey, New York, Pennsylvania and Virginia) experienced a 47% decrease in farmland between 1949 and 1997. The Mid-Atlantic region was one of the first to implement farmland preservation programs. Southampton City and Suffolk County, New York created the first local purchase of development rights programs in the early 1970's. Maryland and Massachusetts each introduced state-level Purchase of Development Rights/Purchase of Agricultural Conservation Easement (PDR/PACE) programs in 1977. By 1997, 5 of the 6 states had a state-level agricultural preservation program under which farmland owners could enroll their land.

These programs remove the right to convert the property to residential, commercial and industrial uses through negative easements in exchange for a monetary payment and/or income and estate tax benefits. The easements applied are perpetual restricting all future owners of the land parcels. The institutional structures of the programs vary by minimum criteria for enrolled farms (soil quality, acreage, proximity to preserved parcels), by payment mechanisms (auctions, installment, point-system), by the source of funding (taxes, bonds, developers), and by geographic specificity/designated zones. However, the easement restrictions are similar across the programs. Easement restrictions to date have been upheld by the courts (Danskin 2000) and thus these programs can be seen as permanently retaining farmland.

Two different types of preservation programs were considered: state PDR/PACE and local PDR/PACE. Data on which counties had farmland preservation programs was collected from American Farmland Trust (AFT 1997, 2001, 2002a, 2002b). States and counties with farmland preservation programs were contacted via email, snail mail and telephone to collect information on how many acres they had enrolled in 1974, 1978, 1982, 1987, 1992, and 1997. Counties were credited with having a program if any locality (township) within the county had a program that had preserved at least 1 acre. In 1974, no county had a preservation program in place. By 1997, 44% of the counties had some preservation activity through a state or local program.

Table 2.1 presents the date of implementation, the date of first easement purchase, the number of acres preserved as of January 2002, and the cost of governmentally purchased easements for the state-level programs. Table 2.2 presents the date of implementation, the date of first easement purchase, the number of acres preserved as of January 2002, and the costs of governmentally purchased easements for the 29 local programs.

Other data were compiled from the Census of Agriculture and the Census of Population and Housing at the county level for the years 1949 through 2000 (USDA, 1997, 2001; US Department of Commerce, 1950-1992, 1950-2000). I attempted to extend my data to the 2002 Census of Agriculture. However, due to the fact that the Census is now adjusting the data to a deal with non-responses, the data in 2002 were not comparable to those in 1949-50 through 1997. The analysis uses data on 263 counties[3] and 10 time periods of 4-5 years each corresponding to the years the Census

[3]Independent cities of Virginia are also included in the analysis. In several cases, due to either ag-

State	Year of inception	Year of first easement purchase	Acres protected (1/2002)	Program funds spent	Funds spent per capita
Delaware	1991	1996	65,117	$ 69,378,401	$87.14
Maryland	1977	1980	198,276	$335,001,530	$48.01
New Jersey	1983	1985	86,986	$375,180,691	$29.34
New York	1996	1998	5,085	$ 10,886,317	$0.57
Pennsylvania	1988	1989	209,338	$560,621,620	$34.12
Virginia	No program				

Table 2.1: State-level agricultural land preservation programs by 2002

of Agriculture were taken. Counties with fewer than 5 farms in 1949 were excluded from the entire analysis: Bronx, Queens, Richmond, Kings, and New York counties of New York state, and Arlington County of Virginia. The three observations that have TDR program but not a PDR program are also excluded (Burlington county in NJ in 1987, Erie county in NY in 1997, and Bucks county in PA in 1992) . This resulted in a total of 2606 observations during the 50-year period.

The data from the Census of Population and Housing, which is collected every 10 years, was adjusted to coincide with the years of the Census of Agriculture, which are collected every 4 to 5 years. I assumed that the variables changed at a constant rate between the population and housing census data years. This constant change assumption was used to interpolate the data to the years the agricultural census were collected. Table 2.3 and 2.4 provides the names and descriptive statistics for the variables by the full sample, the counties with farmland preservation programs ("treated') and those without ("control") that are included in the analysis for 1949-1997 and 1978-1997 respectively.

This study focus on two outcome variables: one is the rate of farmland loss and the other is the acres of farmland lost. The rate of farmland loss for time period t is

gregation in data or actual boundary changes during the study period, counties and/or independent cities have been combined for this analysis.

Maryland	Year of inception of first local program	Year of first easement purchase by PDR program	Acres protected (1/2002)	Program funds spent in PDR Programs
Anne Arundel	1991	1992	8,679	$25,200,000
Baltimore	1979	1981	18,537	$51,300,000
Calvert	1978	1992	8,000	
Carroll	1979	1980	37,190	$54,210,903
Charles	1992		1,183	
Frederick	1991	1993	17,296	
Harford	1993	1994	26,800	$48,900,000
Howard	1978	1984	18,176	$187,560,000
Montgomery	1980	1989-pdr	50,931	$28,079,376
Queen Anne's	1987		2,000	
Talbot	1989		500	
Washington	1991	1992	7,332	
New Jersey				
Morris	1992	1996	3,835	$46,701,384
Burlington	1996		563	
New Jersey Pinelands	1981		5,722	
New York				
East Hampton	1982	1982	281	$5,500,000
Eden	1977		31	
Perinton	1993		56	
Pittsford	1995	1996	962	$8,199,917
Southampton	1980	1980		
Southold	1984	1986	1,318	$11,512,250
Suffolk	1974	1976	8,120	$60,142,788
Pennsylvania				
Bucks	1989	1990	9,550	$50,104,299
Chester*	1989	1990	7,386	$18,500,000
Lancaster	1980	1984	40,190	$80,000,000
York	1990		240	
Plumstead Township	1996	1997	1,195	$4,362,949
Solebury Township	1996	1998	1,285	$11,500,000
Virginia				
Blackburg	1996		23	

Table 2.2: Local PDR programs begun by 1997 by state and county, 2000 acreage reported

Variable	Definition of Variables	Full Sample (N=2602) Mean	Full Sample Std.Dev.	Control (N=2422) Mean	Control Std.Dev.	Treated (N=184) Mean	Treated Std.Dev.
pcfland	Percent change in farmland acres	0.0735	0.1179	0.0761	0.1222	0.0412	0.0781
cfland	Change in farmland acres	10,013	14,520	10,423	14,847	4,406	6,970
Explanatory Variables							
fland	total acres of farmland	142,005	106,974	144,169	108,803	110,436	73,547
medfinc	median family income	29,885	11,076	28,683	10,112	46,039	10,847
met	=1 if county was a metro area since 1950	0.2206	0.4147	0.2126	0.4093	0.3424	0.4758
nprofper	net profit per acre (sales minus expenses)	215. 2	461.1	209.7	1181.2	344.7	301.2
numf	number of farms in county	981.1	895.1	994.6	906.8	782.4	698
pagffm	percent of residents employed in agriculture, forestry, fisheries and mining	0.0997	0.1061	0.1046	0.1081	0.033	0.0266
medhval	median housing value	61,128	33,495	57,249	29,131	113,757	44,033
phighsch	percent of adults with a high school education	0.4774	0.1760	0.4599	0.1690	0.708	0.074
phoffw	percent of operators working 100+ days off the farm	0.4045	0.1041	0.4023	0.1057	0.4313	0.0764
poppera	population per acre	0.5514	1.701	0.5599	1.850	0.7319	0.7936
pfulln	percent of operators who own all of the land they farm	0.6725	0.1184	0.6766	0.1203	0.6214	0.0736
presprog	= 1, if a county has at least one acre of farmland enrolled in farmland preservation programs	0.071	0.256	0	0	1	0

Source: US Census of Agriculture (1949-1997), US Census of Population and Housing (1950-2000), Personal Communication

Table 2.3: Descriptive statistics by the full sample, control counties, and treated counties, 1949-2000 for 6 Mid-Atlantic states

		Full Sample (N=1291)		Control (N=1107)		Treated (N=184)	
Variable	Definition of Variables	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
pcfland	Percent change in farmland acres	0.034	0.1024	0.033	0.106	0.0412	0.0781
cfland	Change in farmland acres	4,070	8,705	4,014	8,962	4,406	6,970
Explanatory Variables							
fland	total acres of farmland	115,707	84,289	116,583	85,943	110,436	73,547
medfinc	median family income	36,928	9,104	35,413	7,817	46,039	10,847
met	=1 if county was a metro area since 1950	0.2177	0.4128	0.1969	0.398	0.3424	0.4758
nprofper	net profit per acre (sales minus expenses)	264	476	250.2	498.3	344.7	301.2
numf	number of farms in county	643.7	521	620.6	482.3	782.4	698
pagffm	percent of residents employed in agriculture, forestry, fisheries and mining	0.0546	0.0522	0.0583	0.0545	0.033	0.0266
medhval	median housing value	78,825	36,492	73,018	31,554	113,757	44,033
phighsch	percent of adults with a high school education	0.608	0.1235	0.592	0.1222	0.708	0.074
phoffw	percent of operators working 100+ days off the farm	0.4347	0.0897	0.4352	0.092	0.4313	0.0764
poppera	population per acre	0.538	1.272	0.5061	1.333	0.7319	0.7936
pfulln	percent of operators who own all of the land they farm	0.627	0.096	0.6283	0.0995	0.6214	0.0736
presprog	= 1, if a county has at least one acre of farmland enrolled in farmland preservation programs	0.1425	0.3497	0	0	1	0

Source: US Census of Agriculture (1978-1997), US Census of Population and Housing (1970-2000), Personal Communication

Table 2.4: Descriptive statistics by the full sample, control counties, and treated counties, 1978-2000 for 6 Mid-Atlantic states

calculated as $\frac{A_{t+1}-A_t}{A_t}$, where A_t is the number of acres in the initial period. The rate of farmland loss averaged 7.35% for each 4-5 year time period.[4] The control counties had an average rate over the 50-year period of 7.61% while the treated had a rate of 4.12%. Other differences between the two groups include fewer acres of farmland in the treated counties (110,436 acres) compared to the control counties (144,169 acres). The outcome variable, the change in farmland acres, is calculated as $(A_{t+1} - A_t)$.

Demographic variables are calculated as a percentage change use the initial year of the time period as the ending year of the percent change calculation. Thus the percent change in median housing value for time period t was calculated as $\frac{HU_t - HU_{t-1}}{HU_{t-1}}$, where HU_t is the median housing value at time t.

While the census provides the most comprehensive data set over the longest period of time and largest geographic area, it does not report to what use farmland has been converted once it leaves agriculture. While I am fairly certain that much of the land was converted to residential or commercial uses (irreversible conversion for the most part), some farmland may have reverted to forest, tourism or recreational uses. Thus the loss of farmland cannot be automatically attributed to the loss of open space and in some cases this land could be returned to farmland without excessive cost. Given the matching method however, I match treatment counties to control counties where the farmland loss is irreversible. In addition, because the unit of observation is a county, one can make no inferences about the spatial distribution or fragmentation of the remaining farmland which may have an impact on the long-run viability of the agricultural sector.

[4]Farmland is defined by the U.S. Agricultural Census to consist of land used for crops, pasture, or grazing. Woodland and wasteland acres are included if they were part of the farm operator's total operation. Conservation Reserve and Wetlands Reserve Program acreage is also included in this count.

2.5 Propensity Score Matching

2.5.1 Variables included in propensity score computation

I choose a set of variables that affect both the existence of farmland preservation programs and pretreatment (pre-program) farmland loss. There are four categories of factors that would affect both participation and farmland loss. The four factors are: benefits from non-agricultural uses, agricultural profits, off-farm income, and residents' willingness-to-pay to preserve farmland.

Variables that I choose to proxy non-agricultural net returns include whether a county has been in a metropolitan area since 1950, the population level scaled by the size of the county, median family income, and median housing value.

Metropolitan counties may have difficulty retaining farmland due to shorter commuting distance to employment centers. Population increase will increase the net returns to residential and commercial uses and thus increase farmland loss. Metropolitan and growing counties may value the farmland as it becomes increasingly scarce and they may see the loss of the environmental and scenic amenities that farmland provided. These counties may be motivated to establish farmland preservation programs. Higher median incomes may have two impacts. One, higher median family income may increase the demand for larger houses. Large houses usually sit on larger parcels. Two, residents with higher income may be willing to pay more to preserve the farmland amenities. Thus, an increase in the median family income could increase the demand for farmland accelerating the farmland loss rate and generate higher willingness to pay for the programs. Median housing value is an indicator for land prices and thus returns to conversion.

Agricultural returns would impact farmland loss. As net agricultural returns increase, the relative value of conversion becomes higher. The number of farmland acres, percentage of labor force in agricultural sectors, and number of farms proxy for the local importance of agricultural sector. If the agricultural sector is strong, farmland owners may think they have a future in agricultural activities in the county. This confidence may decrease land conversion and increase enrollment in the preservation programs. A strong agricultural presence may also result in a higher level of governmental support for the agricultural land preservation programs.

The local economy may also impact farmland loss. Farmers may supplement their farm income and decrease their risk with off-farm employment, which allow them to retain their farms. Their off-farm income opportunities will be better if they are better educated. Off-farm employment benefits are proxied by the percent of the county level population that has at least a high school. The percentage of operators with more than 100 days off-farm work and the percent of farms operated by someone who owns all of the farmland he/she farms are also included as factors that may impact farmland loss. These factors can positively or negatively affect farmland loss and enrollment in the preservation programs.

I also include binary variables for the time periods: 1978-1982, 1982-1987, and 1987-1992 and 1992-1997. The period, 1992-1997, is the excluded category. Because no counties had an active farmland preservation program before 1978, I cannot include time variables for the early years.

2.5.2 Propensity score estimation

As mentioned above, CIA (CMI) condition requires that I choose a set of key variables that affects both the existence of farmland preservation programs and pretreatment (pre-program) farmland loss. No mechanical algorithm exists that can automatically choose a set of variables that satisfies the identification conditions (Smith and Todd, 2005b). Smith and Todd (2005b) summarize two types of specification tests motivated by Rosenbaum and Rubin (1983) that help choose the correct covariates to be included in the vector X. The first test examines whether there are differences in the means of the covariates in X between the treated ($D = 1$) and control ($D = 0$) groups after conditioning on $P(X)$. This strategy is implemented on the controls and treated groups that are matched based on estimated propensity score $P(X)$. The second test requires dividing the observations into strata based on the estimated propensity score before matching. Those strata are chosen so that there is not a significant difference in the means in $P(X)$ between treatment and control groups within each stratum (Dehejia and Wahba, 1999). Then, within each stratum, t-tests are used to test for mean differences in each X variable between the treated and control groups. I estimate my propensity scores using a random effect logit model controlling for county effects and using the variables outlined above (Table 2.5). The specification is selected using the balancing test strategies mentioned above: using the second method before matching and first method after matching.

The random effect logit model passes the first specification test. Figure 2.1 is the distributions of treated and control groups for all 2606 observations. The X-axis indicates the estimated propensity score, and the Y-axis indicates the percent of observations in the treated and control groups that fall in each strata. The estimated propensity scores for the treatment group follow a more even distribution although with slightly more observations having high probabilities of having a program. While the distribution of the estimated propensity scores for control group is asymmetric, with more than 60% of the observations falling in the interval between 0 and 0.00002. There are no treated observations below 0.00002. The common support ranges from

Dependent variable--presprog	Estimated Coeff.	Standard Error
fland (1000 acres)	0.014	0.019
mefinc($1000)	-0.356	0.310
medhval($1000)	0.163**	0.044
phoffw	46.476*	23.211
phighsch	71.326*	28.088
pfulln	17.788	29.839
poppera	0.818	1.476
numf	0.005**	0.002
pagffm	4.773	17.270
nprofper($1000)	11.116**	2.800
met	-16.987	8.796
fland2	-0.000**	0.000
medfinc2	0.001	0.003
medhval2	-0.0002	0.0002
phoffw2	-53.834*	26.661
phighsch2	-36.374	21.540
pfulln2	-21.965	25.069
poppera2	-0.316	0.303
numf2	9.12e-8	3.49e-7
pagffm2	22.955	36.471
nprofper2	-3.836**	1.348
nprofper_met	-2.696	2.625
fland_met	0.010	0.011
medfinc_met	0.387*	0.177
medhval_met	-0.081	0.042
poppera_met	0.206	1.361
phighsch_met	6.819	8.256
pfulln_met	2.072	7.963
=7 if year=1982 (1979-1982)	-1.833**	0.593
=8 if year=1987 (1983-1987)	-2.281**	0.561
=9 if year=1992 (1988-1992)	-1.172*	0.458
Constant	-50.629**	12.477
Observations	2606	
Number of county fips code	263	

* significant at 5%; ** significant at 1%

Table 2.5: Estimated coefficients from a random effect logit model to compute propensity scores

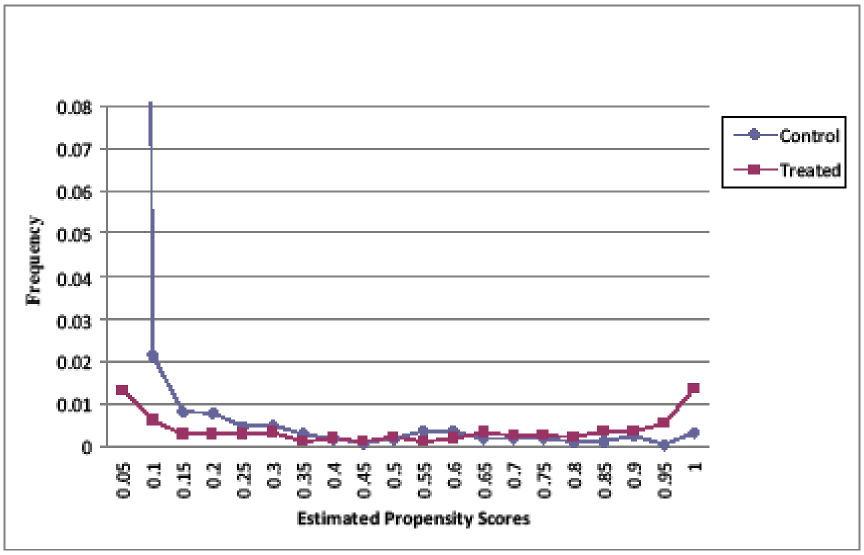

Figure 2.1: Distribution of estimated propensity scores for full sample

[0.0002, 0.999]. [5] The asymmetric distribution of the estimated propensity score for the control group requires a careful selection of the matching method to improve the efficiency of the estimated treatment effect on the treated.

2.5.3 Matching methods and bandwidth selection

Several different matching methods are available. All matching estimators have the generic form for estimated counterfactual $(\widehat{Y}_{i0}|D_i = 1)$ for a treated observation i:

$$(\widehat{Y}_{i0}|D_i = 1) = \sum_{j \in (D_i=0)} w(i,j)(Y_{j0}|D_j = 0)$$

where j is the index for control observations that are matched to the treated observation i based on estimated propensity scores ($j = 1, 2, \ldots J$). $(Y_{j0}|D_j = 0)$ is the observed outcome for a control j that are matched to the treated observation i. The

[5]The lower bound for common support is the maximum of the minimum of estimated propensity scores for treated and control; the upper bound is the minimum of the maximum of the estimated propensity scores for treated and control groups.

matrix, $w(i,j)$, contains the weights assigned to the jth control observation that is matched to the ith treated observation. Matching estimators construct an estimate of the expected unobserved counterfactual for each treated observation by taking a weighted average of the outcomes of the control observations. What differs among the various matching estimators is the specific form of the weights. The estimators are asymptotically the same among all matching methods. But in a finite sample, different methods can provide quite different estimators.

The formula for calculation of Average Treatment Effect on Treated thus is:

$$ATT = \frac{1}{N}\sum_{i=1}^{N}\left[Y_{i1} - (\widehat{Y}_{i0}|D_i = 1)\right]$$

Nearest-neighbor matching has each observation paired with the control observation whose propensity score is closest in absolute value (Dehejia and Wahba 2002). This can be implemented with or without replacing the control and allowing it to be matched again. Replacement guarantees that the nearest match is used. Dehejia and Wahba (2002) and Rosenbaum (2002) both found that matching with replacement performs as well or better than matching without replacement (in part because it increases the number of possible matches and avoid the problem that the results are potentially sensitive to the order in which the treatment observations are matched). If a control is not the nearest neighbor to any treated observation, then it is not used to compute the average treatment effect on the treated. Therefore, the control observations used to compute the treatment effect are those most similar to the treated observations in terms of their observable characteristics.

Kernel matching and local linear techniques match each treated observation with all control observations whose estimated propensity scores fall within a specified bandwidth. This bandwidth is centered on the estimated propensity score for the treated observations. The matched controls are weighted according to the density function of the kernel type. More control observations are utilized under the kernel and local linear matching as compared to nearest neighbor matching.

Selection of matching method depends on the distribution of the estimated propensity score. Kernel matching operates well with asymmetric distributions because it uses the additional data where it exists but excludes bad matches. McMillen and McDonald (2002) suggest that the local linear estimator is less sensitive to boundary effects. For example, when many observations have $\widehat{P}(X)$ near one or zero, it may operate more effectively than other standard kernel matching. Nearest neighbor matching, however, is more likely to give biased estimation if the distributions of propensity scores between treated and control groups are not compatible. When the distributions are compatible, the three matching methods give similar estimators. Given that estimated propensity scores for the control counties are asymmetrically distributed while for the treatment counties are more evenly distributed, kernel or local linear matching performs better than nearest neighbor matching.

Bandwidth and kernel type selection is an important issue when one selects the matching methods. Generally speaking, a large bandwidth leads to a larger bias but smaller variance of the estimated ATT; a small bandwidth leads to a smaller bias but a larger variance. The difference among the kernel types is embedded in the weight they assign to the control observations that are farther away from the estimated propensity score of a treated observation to which the controls are matched. A trade-off between bias and variance for the estimated effect could exist from the different weights assigned to those observations by different kernel types. As the selection of bandwidth and kernel type involves a trade-off between bias and variance, I need criteria that allow me to balance the two. The leave-one-out cross-validation mechanism proposed by Racine and Li (2004) and utilized by Black and Smith (2004) provides such a criterion: to choose the methods (the combinations of matching method, kernel type, and bandwidth) that minimize Mean Squared Error (MSE) for the estimator given the distribution of the data. I employ the leave-one-out cross-validation method taking into account balancing objectives to choose among matching methods.

I consider three alternative matching estimators: nearest neighbor estimator, kernel estimator and local linear matching estimator. I calculate the MSEs for all the possible combinations of the three matching methods, five kernel types (epan kernel, biweight kernel, uniform kernel, tricube kernel, and Gaussian kernel), and five bandwidths (bandwidth $= 0.01, 0.02, \ldots, 0.5, 0.1$). Table 2.6 are the calculated MSE for all combinations for matching without restriction, and table 2.7 for restricting matching within time period.

I find several interesting results in MSE values for matching without restriction. First, the nearest neighbor estimator performs worse than the kernel matching and local linear matching for all kernel types. The MSEs for nearest neighbor matching, which are around 0.037, are much larger than those for the other matching methods, which range from 0.013 to 0.017. This result is consistent with other empirical exercises that found the nearest neighbor matching provided a worse result with asymmetrically distributed estimated propensity score for the control group. Second, while tricube local linear matching with bandwidth 0.04 and below (0.013) performs a bit better than kernel matching, local linear matching with the other kernel types preform worse than kernel matching with all kernel types. However, the difference in MSE between the two matching methods is very small. This suggests that the two methods perform similarly.

For matching within time period, I find again that the MSEs for nearest neighbor

Matching method	Kernel Type	0.01	0.02	0.03	0.04	0.05	0.1
NN		0.03657	0.03655	0.0365	0.0365		
Kernel Matching	gaussian	0.01479	0.01471	0.01469	0.01468	0.01467	0.01467
	biweight	0.01496	0.01485	0.01478	0.01473	0.01471	0.01467
	epan	0.01492	0.01484	0.01476	0.01470	0.01469	0.01467
	uniform	0.01488	0.01480	0.01471	0.01468	0.01468	0.01466
	tricube	0.01496	0.01485	0.01478	0.01473	0.01470	0.01467
Local Linear Matching	gaussian	0.01462	0.01458	0.01457	0.01457	0.01457	0.01459
	biweight	0.01682	0.01623	0.01585	0.01456	0.01458	0.01457
	epan	0.01679	0.01622	0.01460	0.01457	0.01457	0.01457
	uniform	0.01680	0.01622	0.01581	0.01459	0.01458	0.01459
	tricube	0.01350	0.0130	0.01298	0.01293	0.01416	0.01412

Table 2.6: MSE for the combinations of matching methods, kernel types and bandwidth for matching without restriction

Matching method	Kernel Type	0.01	0.02	0.03	0.04	0.05	0.1
NN		0.03657	0.03655	0.03652	0.03652	0.03652	0.03652
Kernel Matching	gaussian	0.01226	0.01222	0.01218	0.01216	0.01215	0.01212
	biweight	0.01262	0.01241	0.01235	0.01226	0.01223	0.01212
	epan	0.01257	0.01239	0.01233	0.01224	0.01221	0.01211
	uniform	0.01247	0.01240	0.01231	0.01221	0.01217	0.01210
	tricube	0.01263	0.01241	0.01235	0.01227	0.01224	0.01212
Local Linear Matching	gaussian	0.10225	0.10129	0.10123	0.10117	0.10116	0.10135
	biweight	0.10754	0.11129	0.10353	0.10282	0.10258	0.10183
	epan	0.10752	0.11129	0.10353	0.10281	0.10255	0.10182
	uniform	0.10746	0.11131	0.10356	0.10279	0.10252	0.10182
	tricube	0.02572	0.01718	0.01517	0.01407	0.01338	0.01233

Table 2.7: MSE for the combinations of matching methods, kernel types and bandwidth for matching within time period

matching (0.037) are much larger than that for kernel and local linear matching (0.012 to 0.11). However, the local linear matching generally performs worse than kernel matching for all kernel types. The MSEs for local linear matching (0.0123 to 0.11) are larger than that for kernel matching (0.0121 to 0.0126) for all kernel type except for kernel type of tricube. Third, the MSE for kernel matching across different bandwidth are very similar. Due to the similarity in performance for matching without restriction and that local linear matching performs worse for matching within time period, I rely on the uniform kernel matching with bandwidth 0.02 and epan kernel matching with bandwidth 0.02 to construct the matched treated and control counties for both matching scenarios. The two methods also provide me with better balance between the control and treatment covariates than other methods and bandwidths.

2.5.4 Balancing test

I rely on two of the balancing tests that exist in the empirical literature: standardized difference test and a regression-based test.[6] The first method is a t-test for equality of the means for each covariate in the matched treated and control groups, which also serves as one of the specification test strategies. The regression test estimates coefficients for each covariate on polynomials of the estimated propensity scores, $[\widehat{P(X)}]^l$ and the interaction of these polynomials with the treatment binary variable, $D* [\widehat{P(X)}]^l$ (l is the order of the polynomial. I set l equals 3). If these estimated coefficients on the interacted terms are jointly equal to zero according to

[6]Hotelling test is another balancing test strategy. The strategy tests the joint null of equal means of all of the variables included in the matching between the treatment group and the matched control group. Smith and Todd (2005b) found that in some cases this test incorrectly treated matched weights as fixed rather than random. Therefore I do not use this balancing test.

an F-test, the balancing condition is satisfied.

The two balancing tests give similar results (Table 2.8 and 2.9). The balancing criteria are satisfied for most of my key covariates for matching without restriction using the regression test and the standardized difference test for both matching protocols (uniform kernel and epan kernel matching) except for percentage of county population that has at least a high school education, number of farms, percentage of operators with more than 100 days off-farm work (fails the regression test only) and time dummies. The percentage of county population that has at least a high school education for treated and control group are 0.71 and 0.72 respectively. The mean of number of farms for treated and control groups are 782 and 655 respectively. The bivariate variable for the time periods are not balanced except for of 1979 through 1982, 1983 through 1987, and 1988 through 1992.

When limiting matches to within the same time period, most covariates are balanced except the number of farms in a county. However, I find all covariates are balanced when restricting matching within common support.

2.6 Results

I compute the estimated impacts of farmland preservation programs for two different time periods: the first is post-1978 through 1997 and second, the full period from 1949 to 1997. Between 1949 and 1978, states began to introduce preferential or use-value property taxation but did so at varying points in time. By 1978, all six states had some types of preferential taxation programs. The introduction of these preferential taxation programs could confound the results for the 1949-1978 time frame. In addition, prior to 1978, no state had established and enrolled land in a farmland preservation program. Therefore, A more pure estimate could be derived

	Epan Kernel Matching (bandwidth =0.02)		Uniform Kernel Matching (bandwidth =0.02)	
	Full sample	Common support	Full sample	Common support
Matching over full sample				
T-test	phighsch (0.71:0.72)	phighsch (0.71:0.72)		
	numf (782:655)		numf (782:652)	
	tdummy7 (0.07:0.17)	tdummy7 (0.07:0.17)	tdummy7 (0.07:0.17)	tdummy7 (0.07:0.16)
	tdummy10 (0.47:0.3)	tdummy10 (0.47:0.3)	tdummy10 (0.47:0.31)	tdummy10 (0.47:0.31)
Regression Test	phoffw phighsch tdummy7 tdummy10	phoffw phighsch tdummy10	phoffw phighsch tdummy7 tdummy10	phighsch tdummy10
Matching within time period				
T-test	numf (778:584)		numf (778:590)	
			met (0.32:0.21)	
Regression Test	numf met		numf met	

1), The covariates that do not pass balancing test are the ones that one could not reject the H_0: no difference in the mean at the 95% confidence level
2), The means for the treated and control group are in parentheses
3), tdummy1 to tdummy10 indicates 1949-1954, 1955-1959, 1960-1964, 1965-1969, 1970-1974, 1975-1978, 1979-1982, 1983-1987, 1988-1992, 1993-1997 respectively.

Table 2.8: Balancing test for the distribution of the variables between matched treated and control groups for observations after 1978: covariates that are not balanced.

	Epan Kernel Matching (bandwidth =0.02)		Uniform Kernel Matching (bandwidth =0.02)	
	Full sample	Common support	Full sample	Common support
Matching over full sample				
T-test	tdummy5 (0:0.03)	tdummy5 (0:0.03)	tdummy5 (0:0.03)	tdummy5 (0:0.03)
	tdummy6 (0:0.12)	tdummy6 (0:0.13)	tdummy6 (0:0.13)	tdummy6 (0:0.13)
	tdummy10 (0.47:0.25)	tdummy10 (0.47:0.25)	tdummy10 (0.47:0.25)	tdummy10 (0.47:0.25)
Regression Test	phighsch	phighsch	phighsch	phighsch
	tdummy1	tdummy1	tdummy1	tdummy1
	tdummy3-6	tdummy3-6	tdummy3-6	tdummy3-6
	tdummy10	tdummy10	tdummy10	tdummy10

1) The covariates that do not pass the balancing test are the ones for which one could not reject the H_0: no difference in the mean at the 95% confidence level
2) the means for the treated and control group are in parenthesis
3) tdummy1 to tdummy10 indicates 1949-1954, 1955-1959, 1960-1964, 1965-1969, 1970-1974, 1975-1978, 1979-1982, 1983-1987, 1988-1992, 1993-1997 respectively.
I do not present the balancing test result for restricting matching within time period as they are the same as that for sample in the time period 1978-1997: no county has a PDR or TDR program before 1978.

Table 2.9: Balancing test for the distribution of the variables between matched treated and control groups for observations 1949-1997: covariates that are not balanced

from the post-1978 time period. The estimates of the impact of existence of an agricultural preservation program on farmland loss appear in Table 2.10 for the 1978 to 1997 time period and Table 2.11 for the 1949 to 1997 time period. The bootstrap standard errors are reported in the second row of each matching protocol in the tables.[7] All estimated treatment effects are corrected for bias and are statistically significant.

For the rate of farmland loss, the average treatment effects on the treated of each matching protocol for 1978-1997 range from -0.035 to -0.045. The treatment impacts

[7] I use a simple bootstrap procedure to construct the standard errors for the average treatment effect on the treated. I make 2,000 independent draws from the treatment and control observations and form new estimates of the treatment effect for each draw. The bootstrap standard error estimate is the standard deviation of the 2000 new values for the estimated treatment effect on the treated.

	Epan Kernel Matching (bandwidth =0.02)		Uniform Kernel Matching (bandwidth =0.02)	
	Full sample	Common support	Full sample	Common support
Matching over full sample				
Rate of loss				
ATT	-0.045	-0.043	-0.041	-0.040
	(0.01)	(0.01)	(0.01)	(0.011)
Acres lost				
ATT	-2940	-2752	-2789	-2508
	(1126)	(965)	(1052)	(971)
Number of Matched Treated Counties	184	178	184	178
Number of Matched Control Counties	846	846	846	846
Matching within time period				
Rate of loss				
ATT	-0.041	-0.037	-0.043	-0.035
	(0.010)	(0.01)	(0.01)	(0.01)
Acres lost				
ATT	-2013	-2284	-2077	-2279
	(817)	(862)	(825)	(851)
Number of Matched Treated Counties	142	132	142	132
Number of Matched Control Counties	812	812	812	812

Note: The Average Treatment Effect on the Treated (ATT) is Bias Corrected.
Bootstrapping standard errors are in the parenthesis. Bootstrapping results are based on 2000 iterations.
Bias for rate of loss outcome: Epan kernel Matching using all observations, the biases for Matching over full sample and Matching within time period 0.004 and 0.005 respectively. For uniform kernel matching using all observations, they are 0.003 and 0.005. For Epan kernel Matching using observations within common support, the biases for Matching over full sample and Matching within time period are 0.004 and 0.005 respectively. For uniform kernel matching within common support, they are 0.003 and 0.004.
Bias for acres lost outcome: For Epan kernel Matching using all observations, the biases for Matching over full sample and Matching within time period 187 and 137 respectively. For uniform kernel matching using all observations, they are 127 and 145. For Epan kernel Matching using observations within common support, the biases for Matching over full sample and Matching within time period are135 and 332 respectively. For uniform kernel matching within common support, they are 95 and 356.

Table 2.10: Average Treatment Effect on the Treated for rate of farmland loss and farmland acres lost during 1978-1997: matched over full sample and restricted to within same time period.

	Epan Kernel Matching (bandwidth =0.02)		Uniform Kernel Matching (bandwidth =0.02)	
	Full sample	Common support	Full sample	Common support
Matching over full sample				
Rate of loss				
ATT	-0.040	-0.038	-0.036	-0.034
	(0.01)	(0.01)	(0.01)	(0.01)
Acres lost				
ATT	-3039	-2695	-2926	-2668
	(1084)	(987)	(1068)	(938)
Number of Matched Treated Counties	184	178	184	178
Number of Matched Control Counties	2418	2418	2418	2418
Matching within time period				
Rate of loss				
ATT	-0.041	-0.037	-0.043	-0.035
	(0.010)	(0.01)	(0.01)	(0.01)
Acres lost				
ATT	-2013	-2284	-2077	-2279
	(817)	(862)	(825)	(851)
Number of Matched Treated Counties	142	132	142	132
Number of Matched Control Counties	812	812	812	812

Note: The Average Treatment Effect on the treated is Bias Corrected.
Bootstrapping standard errors are in the parenthesis. Bootstrapping results are based on 2000 iterations.
Bias for outcome as rate of loss: Epan kernel Matching using all observations, the biases for Matching over full sample and Matching within time period 0.003 and 0.005 respectively. For uniform kernel matching using all observations, they are 0.001 and 0.005. For Epan kernel Matching using observations within common support, the biases for Matching over full sample and Matching within time period are 0.002 and 0.005 respectively. For uniform kernel matching within common support, they are 0.001 and 0.004.
Bias for acres lost: For Epan kernel Matching using all observations, the biases for Matching over full sample and Matching within time period 97 and 137 respectively. For uniform kernel matching using all observations, they are 71 and 145. For Epan kernel Matching using observations within common support, the biases for Matching over full sample and Matching within time period are 63 and 332 respectively. For uniform kernel matching within common support, they are 56 and 356.

Table 2.11: Average Treatment Effect on the Treated for rate of farmland loss and farmland acres lost during 1949-1997: matched over full sample and restricted to within same time period.

for matching without restriction over full sample have a larger range (from -0.041 to -0.045) than that for matching without restriction but within common support (from -0.040 to -0.043). The estimated impacts for restricting matching to within time period but without imposing common support restriction (from -0.041 to -0.043) are larger than that for matching within common support (from -0.035 to -0.037). These result indicates that imposing common support could eliminate bad matches. However, the difference in the results are not very large.

For the number of acres lost, the average treatment effects on the treated of each matching protocol during 1978-1997 range from -2013 to -2940 acres. This suggests that counties with farmland preservation programs lost fewer acres per year, 403 fewer acres on the low end and 600 fewer on the high end than similar counties without farmland preservation programs. The average treatment effects on the treated from matching without restriction over full sample have a larger range (from -2789 to -2940 acres) than that for matching within common support (from -2508 to -2752 acres). However, the within time period estimators over full sample are smaller (from -2013 to -2077 acres) than that for within common support (from -2279 to -2284 acres).

The average treatment effect on the treated from 1949-1997 are very similar to those above. The average reduction in the rate of farmland loss of each matching protocol from 1949 -1997 are the almost same as that from 1978-1997. The average reduction in the acres of farmland loss has a slightly smaller range. The range is from -2926 to -3039 for matching over full sample, and -2668 to -2695 for matching over common support. The matching results for restricting matches within time period for 1949-1997 are exactly the same as that from 1978-1997 since counties start to have active program after 1978.

The similarity of the average treatment effect on the treated from 1949-1997 to that from 1978-1997 suggests that unobservable factors varying across time period before 1982 do not have significant impact on farmland loss. Given no county had a preservation program with enrolled acreage before 1978, I had some concern about not controlling for these unobservable factors in computing the propensity scores. However, the estimated ATT for the observations before 1978 are very similar to those matching over full sample as one might expect and those observations are assigned very small weights in calculating counterfactuals.

The results suggest that the existence of a farmland preservation program in a county reduces farmland loss by 3.5 to 4.5 percentage points on average, i.e. I find that equation (2.4) is satisfied. Given that the average rate of farmland loss per time period is 7.35% in the full sample, this is a $48 - 61\%$ change in the rate. The change is an even larger percentage for the 1978-1997 sample, which has an average rate of farmland loss of 3.4%. Similarly, in an absolute sense, acres converted reduced from $2,013$ to $3,039$ acres from an average acres converted of $10,013$ per period $(20-30\%)$.

2.7 Sensitivity Analysis and Robustness Check

The estimation results from a propensity score matching method show that the counties that have PDR programs have a statistically significant lower rate and acres of farmland loss than the counties that do not have such programs. The PSM method, however, can be biased if there are unobservables remaining uncontrolled or the unobserved factors have differentiated impact on control and treated groups. To check the impact of unobservables, I conduct sensitivity analysis and robustness check in this section in three ways. First, I check the effect of unobservables on the estimated ATTs by calculating Rosenbaum bounds and hidden bias equivalents. Second, I estimate the average treatment effect (ATE) estimator using the regression approach proposed by Wooldridge (2002). Third, I employ two alternative ways to estimate the effect of PDR programs and control for the unobservables. One is a difference-in-difference approach and the other is a two-stage regression approach with an inverse mill's ratio to control for the selection bias from unobservables.

2.7.1 Sensitivity analysis and hidden bias equivalents

The propensity score matching method potentially provides more reliable results than a standard regression method by comparing control and treated observations that are similar to each other, explicitly excluding outliers, and estimating the treatment effect on the treated non-parametrically. However, if there are unobserved variables that affect either the treatment assignment or the outcome variable differently for the treated and control groups, the CIA (CMI) condition does not hold and the propensity score matching estimators are no longer consistent. While I controlled for many observables, I also conducted a sensitivity analysis by looking at Rosenbaum bounds and hidden bias equivalents (Rosenbaum, 2002; DiPrete and Gangl, 2004).[8]

Rosenbaum bounds is a signed rank test to assess the potential impact of hidden bias arising from confounding variables associated with both treatment and outcome variables. It assumes that the strength of the impacts from unobservable factors on treatment selection and outcome is the same. This approach is relatively conservative in the sense that it will find bias even if the strength of unobservable factors on

[8] There are other strategies that assess the impact of hidden bias. An IV approach is proposed by DiPrete and Gangl (2004) which is less conservative than Rosenbaum Bounds approach. Another approach is proposed by Antoji and Elder (2000) which uses the bias estimated from the observables to calculate bias from unobservable variables. We use Rosenbaum Bounds as it is the most appropriate approach for our problem.

outcome is not as strong as the test assumes.

The estimated propensity score of a treated and control observation with identical characteristics (the same covariates) should be equal if all the relevant covariates that affect both the treatment assignment and outcomes are included in the propensity score model. The presence of unobserved covariates leads to discrepancies between the propensity scores of treated and control observations with identical characteristics. As a result, the odds ratio of a matched pair of treated and control observations based on these characteristics will no longer be equal to one. The larger the effect of an unobserved covariate on the treatment assignment, the larger the difference between the odds ratio and one will be.

Rosenbaum had shown that the odds ratio for matched pairs is bounded by the function of the strength of the effect. Therefore, a signed rank statistic of each strength level has its upper and lower bounds and their corresponding p-values. One can determine a critical level of the strength for a 95% confidence interval. If the unobserved covariates affect the treatment assignment and/or the outcome at a strength level greater than the critical effect strength level, the average treatment effects could include zero.[9]

Beyond finding the upper and lower bounds, following DiPrete and Gangl (2004), I also calculate the hidden bias equivalents on some key covariates. Table 2.12 reports the upper and lower bounds for Kernel matching with Epan kernel type with bandwidth=0.02 for matching without restriction as well as the hidden bias equivalents.[10] The threshold gamma measures the effect strength of unobservable variables

[9] See Rosenbaum (2002) and DiPrete and Gangl(2004) for more information.

[10] Given that fact the Rosenbaum bounds approach does not deal with stratified or cluster samples, I am not able to conduct a sensitivity analysis for matching within time periods.

on treatment assignment and equals 1.92 for the rate of farmland loss. Thus the statistical significance of the ATT for the rate of farmland loss is called into question when the odds ratio of treatment assignment between the treated and control groups differs by more than 1.92. However, while questionable, the treatment effect can still be significant if the effect on the treatment assignment is greater than the effect on the outcome.

I calculate the hidden bias equivalents on three key variables. The total acres of farmland in a county, net agricultural profit per acre and median family income. At the critical level of gamma for the rate of farmland loss, in terms of affecting the ATT results, the possible unobserved variables would have to have the same impact as changing these 3 key variables by $31,000$ acres (22%) for total acres of farmland, by \$800 (36%) for net agricultural profit per acres, and by \$5810 (10%) for median housing value. For farmland acres loss, the critical threshold gamma is 1.72. The hidden bias equivalents are a change of $24,000$ acres (17%) in total farmland, \$600 (29%) in net agricultural profit per acre, and \$4710 (8%) in median housing value. These hidden bias equivalents suggest the ATT results are not largely sensitive to changes in key variables or potential unobserved variables.

2.7.2 Regression estimation and average treatment effect

While the ATT effect that I have estimated is significant, it cannot be generalized to the entire population due to self-selection. An Average Treatment Effect (ATE) is an expected effect of treatment on a randomly selected county (Wooldridge, 2002) but it requires more restrictive assumptions. To check how general my estimators are and how well my estimation of ATT addresses the self-selection issue, I estimate the ATE of PDR programs in a regression framework following Wooldridge (2002).

Critical P-values for Gammas					Hidden Bias Equivalents					
	Rate of farmland loss		Acres lost		Median housing value ($1000)		Total acres of farmland (1000 acres)		Net profit per acre ($1000)	
Gamma	sig+	sig-	sig+	sig-	equivalent	% to sample mean	equivalent	% to sample mean	equivalent	% to sample mean
1	0.000	0.000	0.000	0.000	0.42	1	2	1	0.01	3
1.05	0.000	0.000	0.000	0.000	0.82	1	4	3	0.01	5
1.1	0.000	0.000	0.000	0.000	1.20	2	5	4	0.02	7
1.15	0.000	0.000	0.000	0.000	1.57	3	7	5	0.02	10
1.2	0.000	0.000	0.000	0.000	1.93	3	9	6	0.03	12
1.25	0.000	0.000	0.000	0.000	2.27	4	11	7	0.03	14
1.3	0.000	0.000	0.000	0.001	2.59	4	12	9	0.03	16
1.35	0.000	0.000	0.000	0.001	2.91	5	14	10	0.04	18
1.4	0.000	0.000	0.000	0.002	3.21	5	15	11	0.04	20
1.45	0.000	0.001	0.000	0.004	3.51	6	17	12	0.05	22
1.5	0.000	0.001	0.000	0.008	3.80	6	19	13	0.05	23
1.55	0.000	0.003	0.000	0.012	4.07	7	20	14	0.05	25
1.6	0.000	0.004	0.000	0.019	4.18	7	21	15	0.06	26
1.65	0.000	0.007	0.000	0.028	4.34	7	22	15	0.06	27
1.7	0.000	0.011	0.000	0.041	4.60	8	23	16	0.06	29
1.72	0.000	0.012	0.000	0.046	4.71	8	24	17	0.06	29
1.75	0.000	0.016	0.000	0.056	4.86	8	25	17	0.06	30
1.8	0	0.023	0	0.076	5.11	8	26	18	0.07	32
1.85	0	0.032	0	0.099	5.35	9	28	19	0.07	33
1.9	0	0.044	0	0.127	5.58	9	29	21	0.07	35
1.92	0	0.049	0	0.139	5.67	9	30	21	0.08	35
1.95	0	0.058	0	0.159	5.81	10	31	22	0.08	36

* gamma - log odds of differential assignment due to unobserved factors
sig+ - upper bound significance level, sig- - lower bound significance level
*hidden bias equivalents are calculated at sample mean

Table 2.12: Rosenbaum Bounds and Hidden Bias Equivalents –Epan kernel matching with bandwidth=0.02 and matching without restriction.

This approach is to include as regressors the treatment indictor, estimated propensity score, a set of variables that affect outcomes. The estimated propensity score should control all the information in the covariates that is relevant to estimate the treatment effect.

I specify a random effect model controlling for the treatment, estimated propensity score, and a set of control variables that impact farmland loss. The control factors in the random effect model include: acres of farmland and its square (possible non-linear impacts), metropolitan status, percentage change in total housing units, median housing value, population per acre, net agricultural profit per acre, and percent of operator with any off-farm work, median family income, and percentage of the population with high school education. Controls for time effects include time dummies indicating the time periods after 1978. I estimate the random effect regression for both the full sample and a post-1978 sub-sample. I do not remove outliers or those not on the common support in this exercise (Table 2.13).

For the rate of farmland loss, the estimated coefficient for the treatment indictor is -0.022 for the full sample compared to the ATTs of -0.034 to -0.040. The coefficient is -0.015 for the regression over the post-1978 sub-sample compared to the ATTs of -0.035 to -0.045. The estimated coefficient on the treatment indicator for acres of farmland lost is insignificant for full sample (ATTs range from $-2,013$ to $-3,039$) but significant for the post-1978 sub-sample. The estimated coefficient is $-1,487$ for post-1978 sub-sample compared to $-2,013$ to $-2,284$.

On a whole, my results under both approaches are significant and similar. I therefore can conclude the my estimation can be generalized to the whole population and the self-selection issue is well addressed.

	The rate of farmland loss		Acres of farmland lost	
	(1)	(2)	(3)	(4)
Independent Variables	1949-1997	1978-1997	1949-1997	1978-1997
=1 if a county has an PDR program	-0.022*	-0.015	-1,686	-1,487*
	(0.011)	(0.009)	(1,166)	(686)
Estimated propensity score	0.035*	0.033*	363.5	1,086
	(0.017)	(0.015)	(1,860)	(1,190)
Total acres of farmland (1000)	-0.00008	0.000023	61.54**	41.04**
	(0.0006)	(0.0001)	(6.33)	(7.91)
Total acres of farmland squared	0.000	-0.000	0.032**	0.004
	(0.000)	(0.000)	(0.012)	(0.021)
=1 if county in metro area since 1949	0.024**	-0.005	3,1745**	175.5
	(0.006)	(0.009)	(7277)	(690)
Percent change in total housing units	0.149**	0.033	-67.8	-370.9
	(0.035)	(0.064)	(3,815)	(4,990)
Median housing value ($1000)	-0.000	-0.000	-3.61	-7.6
	(0.000)	(0.000)	(18.6)	(16.5)
Population per acre	0.017**	0.013**	266.6	213.3
	(0.002)	(0.004)	(202)	(334.43)
Net agricultural profit per acre ($1000)	-0.012*	-0.038**	-1,061	-1,689.1**
	(0.006)	(0.008)	(680)	(628.1)
Percent of operators with any off farm work	0.044	-0.122**	9,036**	-14,042**
	(0.025)	(0.039)	(2,792)	(3,018)
Median family income ($1000)	0.000	0.001	78.75	0.477
	(0.001)	(0.001)	(74.4)	(77.4)
Percent of adults with high school education	-0.131**	0.073	-19,277**	11,456**
	(0.031)	(0.04)	(3,405)	(3,098)
=1 if year=1982 (1979-1982)	-0.040**	0.027**	-4,673**	1,788*
	(0.008)	(0.009)	(828)	(704)
=1 if year=1987 (1983-1987)	0.032**	0.084**	2,378**	7,165**
	(0.008)	(0.008)	(874)	(649)
=1 if year=1992 (1988-1992)	0.043**	0.078**	4,335**	7,194**
	(0.009)	(0.008)	(921)	(608.8)
Constant	0.108**	0.005	2,085	-2,251
	(0.017)	(0.032)	(1,864)	(2,495)
Observations	2602	1030	2602	1030
Number of county fips code	263	260	263	260

Standard errors in parentheses
* significant at 5%; ** significant at 1%

Table 2.13: Average Treatment Effect (ATE) estimation.

2.7.3 Difference-in-difference model and two-stage regression

To further check the robustness of the results, I employ two more approaches with different assumptions on the structures of unobservables to estimate the effect of PDR programs on farmland loss. The first approach is a fixed effect or a difference-in-difference model. A fixed effect regression assumes that both unobservables and the effect of the unobservables on farmland loss are constant over time. The fixed effect regression returns a consistent estimation even if unobserved fixed effects are correlated with program establishment. I control for both county and time effects in this regression. The second approach is a two-stage regression. The first stage regression is a Logit or a Probit regression of PDR establishment in a county and the second stage regression is an OLS regression of farmland loss. This approach assumes that the error terms in the program establishment equation and the farmland loss equation are jointly normally distributed. The first stage regression predicts an Inverse Mill's Ratio (IMR) and the IMR is used as a regressor in the second stage OLS regression to control for possible selections of a county having a PDR program. The estimation from the two-stage regression is consistent as long as the error terms are truly jointly normally distributed. This regression would require one to correct for heteroskedasticity introduced by the IMR.

For the purpose of result comparison, I also run an OLS regression without controlling any unobservables. Table 2.14 presents the results for the sub-sample of 1978-1997 for both the rate of farmland loss and the acres of farmland lost. The regressors for all the regressions in the table are the same as those in the random effect logit regression to estimate propensity scores. I use a different set of variables to predict the Inverse Mill's Ratio. The variables include: acres of harvested farmland, percentage change in housing value, percentage change in median family income, percentage change in population, met indicator, number of farms, percentage labors in agricultural sector, percentage of operators with more than 100 days off-farm work, net agricultural profit per acre, percentage population with high school education, their squared and interactions terms.

All regression return a negative sign for the indicator of a county having a PDR program. The estimators for most of the regressions are smaller than the estimated ATTs but similar to the ATEs for both the rate of farmland loss and acres lost.

2.8 Conclusion

Few studies have found that farmland preservation programs are having an impact on farmland loss. If a high rate of farmland loss is the reason that a county implements a program, one must take into account the identification problem that this simultaneity generates. Using the propensity score matching method to compare farmland loss among counties with and without farmland preservation programs having similar characteristics, this analysis finds that farmland preservation programs have reduced farmland loss.

This specification includes key variables that affect both farmland loss and the existence of farmland preservation program. The standardized difference test and balancing in a regression framework suggest that the average treatment effects on the treated are estimated using treatment and control groups that have similar characteristics on most variables of interest.

The conclusion appears robust that agricultural preservation programs reduce the rate of farmland loss by about $3.5 - 4.5$ percentage points for each time period for the Mid-Atlantic area. I have accounted for the key variables needed to explain the existence of farmland preservation programs and farmland loss. Sensitivity analysis

Dependent variable	The rate of farmland loss			Acres of farmland lost		
	OLS	FE	Mills	OLS	FE	Mills
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
=1 if a county has a PDR program	-0.021**	-0.016	-0.014*	-1,470**	-1,751*	-1,179*
	(0.009)	(0.013)	(0.008)	(710)	(918)	(621)
Total acres of farmland (1000)	-0.000	0.009***	-0.000	44.8***	947***	44.4***
	(0.000)	(0.001)	(0.000)	(14.8)	(67.9)	(17.2)
Median family income ($1000)	-0.013***	-0.013*	-0.012**	-802**	-149	-662***
	(0.004)	(0.007)	(0.005)	(318)	(526)	(2456)
Median housing value ($1000)	0.002***	0.002*	0.001	92.1**	64.2	28.2
	(0.001)	(0.001)	(0.001)	(40.7)	(81.9)	(32.4)
Percent of operators with 100+ days off farm work	-0.250	-0.457	-0.159	-15,427	-8,150	-14,217
	(0.291)	(0.474)	(0.381)	(22,873)	(33,722)	(19,053)
Percent of adults with high school education	-0.205	-1.223***	-0.206	-25,854	-119,296***	-24,726
	(0.302)	(0.403)	(0.287)	(23,770)	(28,683)	(20,283)
Percent of farms farmed by full owners	0.586*	1.040*	0.598	32,514	67,512	38,825**
	(0.316)	(0.621)	(0.470)	(24,894)	(44,221)	(19,213)
Population per acre	0.000	-0.543***	-0.015	1,707	-17,419*	591.9
	(0.016)	(0.145)	(0.018)	(1,271)	(10,319)	(711)
Number of farms	0.000	-0.000***	-0.000	0.049	-25.1***	-1.08
	(0.000)	(0.000)	(0.000)	(1.94)	(7.20)	(1.81)
Percent employed in agriculture, forestry, fisheries and mining	-0.124	-0.348	-0.260	-13,942	-79,543*	-26,865**
	(0.185)	(0.613)	(0.237)	(14,573)	(43,615)	(13,203)
Net agricultural profit per acre ($1000)	-0.032	-0.040	-0.032	-4,495*	-4,171	-5,485***
	(0.032)	(0.055)	(0.032)	(2,533)	(3,892)	(2,093)
=1 if county always in metro area	-0.120	0.000	-0.007	-17,307*		-6,498
	(0.118)	(0.000)	(0.176)	(9,296)		(7,750)
=7 if year=1982 (1979-1982)		-0.102***	0.024**		-15,154***	1,486**
		(0.030)	(0.010)		(2,155)	(691)
=8 if year=1987 (1983-1987)		-0.012	0.081***		-5,066***	7,259***
		(0.023)	(0.009)		(1,614)	(712)
=9 if year=1992 (1988-1992)		0.044***	0.077***		2,529***	7,141***
		(0.012)	(0.009)		(877)	(617)
Inverse Mill's Ratio			-0.026			-6,696*
			(0.056)			(4,053)
Constant	0.180	0.044	0.142	14,227	-17,291	16,250*
	(0.122)	(0.274)	(0.133)	(9,602)	(19,504)	(8,903)
Observations	1032	1032	1032	1032	1032	1032
Number of counties		260			260	
R-squared	0.10	0.33	0.21	0.30	0.46	0.43

Heteroskedasticity-robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 2.14: The effect of PDR programs on the rate of farmland loss from a Difference-in-Difference model, an OLS regression, and a two-stage regression.

suggests that key characteristics that affect farmland loss would have to change a great deal ($10 - 35\%$) to call into question the results.

My estimate is the average impact on the treated; i.e. the impact on counties with farmland preservation program. Given that counties may have different underlying causes for their farmland loss, for example, some counties in the analysis lost farmland because they lost population rather than because the land was being converted to housing, the results do not suggest that instituting a farmland preservation program may arrest farmland loss in all areas. Some farmland could have been converted to forest, tourism or recreational uses rather than residential or commercial uses. However, most counties with preservation programs were losing farmland to residential and commercial uses, thus irreversibly. Unfortunately, county-level data precludes me from knowing more about the spatial distribution or fragmentation of the remaining farmland which may have an impact on the pattern of suburban development, the open-space amenities, and the long-run viability of the agricultural sector.

Further research into the impact and the underlying reasons why these programs may impact farmland loss is important. It will be interesting to study whether farmland preservation programs shift developers to convert forest land at an increased level, i.e. whether the net loss of open space holds constant, or increases the density of housing on the farmland that continues to be converted.

Chapter 3

Evaluate the effect of Designated Preservation Areas on Agricultural Land Preservation

3.1 Introduction

Concerns about farmland loss and suburban sprawl motivated 128 state and local government entities to institute preservation programs and preserve 938.28 million acres at an overall cost of $4.467 billion (American Farmland Trust 2007a, 2007b). As mentioned above, farmland preservation programs are justified on various grounds including efficient development of urban and rural land, local and national food security, viability of the local agricultural economy, and the protection of rural and environmental amenities (Gardner, 1977; Hellerstein et al., 2002). Nickerson and Hellerstein (2003) found that PDR programs prioritize productivity (high soil quality for agricultural uses) and preserving large blocks of land. Critics suggest these programs do not lead to efficient development or limit land conversion, do not maximize social benefits by preserving the most productive farms, and do not prevent land fragmentation by preserving large blocks of land (Pfeffer and Lapping 1996, Daniels and Lapping 2001, Lynch and Musser 2001). The agricultural preservation programs have retained land in a scatter gun pattern rather than targeting specific geographic regions. Concentrated preservation in targeted preservation areas may aid in achieving the goals, decreasing both fragmentation and land conversion. The targeting effort may provide greater social benefits and help retain a viable agricultural economy if threshold impacts or economies of scale exist. For example, a critical mass of contiguous farms may be needed due to economies of scale in supporting industries and to avoid conflicts with non-farm neighbors (Lynch and Carpenter 2003). Ecological benefits will also increase if large blocks of undeveloped land are needed for ecosystem services provision such as wildlife habitat and water quality.

Although Maryland has a plethora of land preservation programs, contiguity of preserved parcels has not been achieved (Lynch and Musser 2003). In particular, the Maryland Agricultural Land Preservation Foundation (MALPF) used a ranking scheme under which contiguity received no value. In an effort to address this limitation, Maryland introduced the Rural Legacy (RL) program in 1997 under which contiguity is deemed very important. The cornerstone of the RL program is to designate RL Areas. Local governments or private land conservation organizations select the most desirable lands to be preserved. Once designated, sponsors receive special funding from the state to preserve farm, forest, and ecologically important resource lands in a contiguous fashion within these areas. Continuous fundings are provided until all of the parcels in designated RL areas are preserved with RL program or other conservation programs.

In this chapter, I evaluate the effect of RL program on agricultural land preservation using a parcel level data for 3 Southern Maryland counties: Calvert, Charles, and St. Mary's. Specifically, I study whether RL funding significantly increases land preservation in RL areas compared to non-RL areas. The preservation is measured by two outcome variables: the likelihood and acres of preservation. The likelihood of preservation is a discrete variable with its realized value as 1 if a parcel is preserved and 0 otherwise. The acres of preservation is measured as the acres of a parcel weighted by the likelihood of preservation.

I use a propensity score matching method as in Chapter 2 to evaluate the effect. Parcels out of RL areas with similar observed attributes are matched to the parcels in RL areas to construct counterfactuals. The difference in the outcomes between the RL parcels (refers to parcels in RL areas) and their constructed counterfactuals, however, cannot be credited solely as the effect of RL program.

Two issues are responsible for this. The first is a predisposition effect: the parcels in RL areas are predisposed to be preserved if they are more attractive to agricultural preservation programs due to attributes unobserved by researchers. The selected lands for RL areas designation may be desirable not only to RL program, but also to the other existing farmland preservation programs. If this is the case, the RL parcels are more likely to be preserved by existing non-RL programs even after the RL program was introduced. The difference in the outcomes between RL parcels and their constructed counterfactuals includes both the effect of RL program and the predisposition effect.

The second, which is more of problem, is a crowding effect of RL program on the existing conservation programs. The special funding should result in a higher probability or more acres of preservation in RL areas but also might interact with the existing preservation programs. Several possible interactions may occur. If the RL areas are the most desirable lands to preserve, the designation and extra funding could increase the preservation effort within the area and therefore result in even higher probability of preservation and more preserved acres. For example, if economies of scale or threshold impacts exist and contiguity increases the marginal benefits of each acres preserved, both RL and the other programs could receive higher benefits from each additional acre preserved in the RL areas relative to a non-RL parcel (refers to the parcels out of RL areas). This would be an example of crowding in preservation. The increase in marginal benefits makes preservation there higher valued. However, the RL program's efforts can also crowd out other programs' preservation from the designated area. If the programs compete for the same land, the cost of preservation per acre could increase within the RL areas, e.g. the landowners' asking price increases. Therefore, the other programs may select parcels outside the RL areas to enroll more acres.

I evaluate the effect of RL areas designation by taking into account the predisposition effect and crowding effect in this chapter. I first estimate the average treatment effect of the RL program on the parcels in RL areas assuming that there is not such effects. Second, I use a difference-in-difference approach to control for the predisposition effect. Third, I proposed complex matching methods to isolate the predisposition effect, crowding effect and the net effect of RL program.

The remainder of this chapter is organized as follows. Section 3.2 provides the background information of RL program and my study areas, and the description of data source is in Section 3.3. A "Naive" effect assuming no predisposition and crowding effects is estimated in Section 3.4. A difference-in-difference propensity score matching model that controls for the predisposition effect is presented in Section 3.5. Section 3.6 is a discussion of the crowding effect and strategies to isolate the crowding effect, and the net effect of RL program. I then conclude in Section 3.7.

3.2 Background

3.2.1 Rural Legacy program

The Rural Legacy Program was created by the 1997 Maryland General Assembly as a major element of the Smart Growth and Neighborhood Conservation initiative. Its mission is to reduce the rate of land conversion to protect areas rich in farms, forests, and natural and cultural resources. The goals of Rural Legacy are 1) to establish greenbelts of forests and farms around rural communities to preserve their cultural heritage and sense of place; 2) preserve critical habitat for native plant and wildlife species; 3) support natural resource-based economies like farming, forestry, tourism, and outdoor recreation; and, 4) protect riparian forests, wetlands, and greenways to buffer the Chesapeake Bay and its tributaries from pollution run-off. From 1998 to February 2007, 30 RL areas have been approved (Figure 3.1) in Maryland.

The Rural Legacy (RL) Program requires contiguous tracts of resource land to be identified for preservation and provides extra funding for these areas. It aims to protect $200,000$ acres by 2022. At least \$5.0 million of the annual state capital budget must be directed to the RL program. From 1997 to April 2008, the RL program has provided \$163 millions to local groups to preserve $58,217$ acres of farmland, forests, and natural areas in Maryland.

Funding for RL acquisitions is through the State Rural Legacy Grant Program. Each year the Maryland legislature and the Governor determine the annual budget for the RL program. The 11-member Rural Legacy Advisory Committee and the Rural Legacy board, which is comprised of Maryland's Agriculture, Natural Resources and Planning Secretatries, review grant applications annually. The grant application process is competitive and the State Rural Legacy Board allocates grants annually

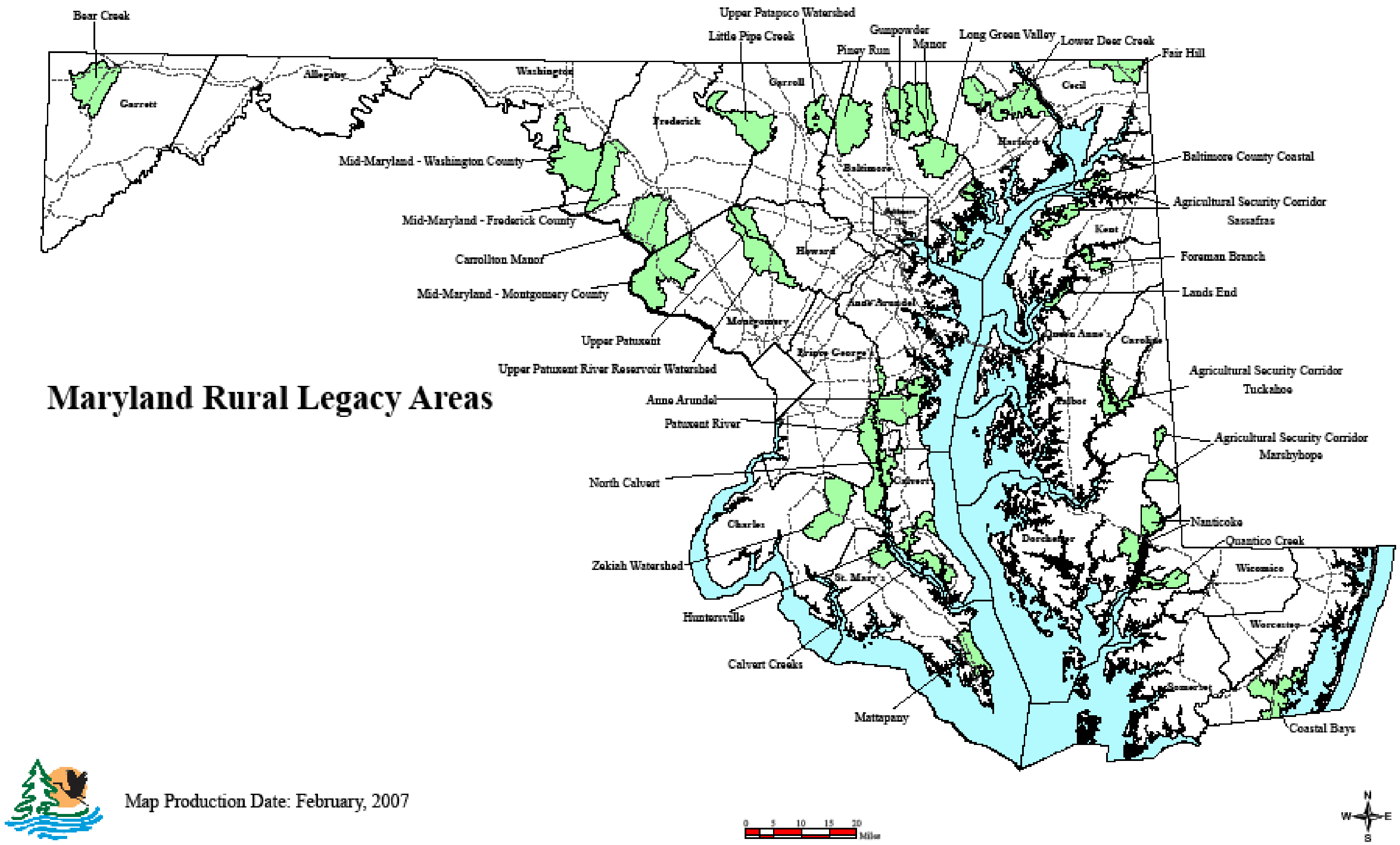

Figure 3.1: Rural Legacy Areas in Maryland

based on fund availability. If local groups or counties has not preserved land with the money allocated to them, the RL grants can be taken back by the state and reallocated to other RL areas. For example, $82 millions have been rewarded to RL areas by Fiscal Year 2001. Only $38.3, or roughly 47% of the money has been used to preserve land. The rest was recaptured and reallocated in the following years.

Governments and experienced land trusts/nonprofits may establish priority preservation areas that are eligible for RL preservation funds. RL Areas designation are prioritized based on the agricultural, forestry, natural and historical and cultural resources protected, the level of conversion pressure, and the economic value of the area's resource-based industries or services. The RL programs have focused on areas with agricultural, forestry, and ecological beneficial land-uses. Landowners in the designated RL program areas can sell or donate their development rights and retain ownership of their land. The RL program also permits purchases of the land outright for public use.

Unlike the Maryland Agricultural Land Preservation Foundation (MALPF)'s farmland protection program, Rural Legacy program does not have specific minimum requirements for soil qualities nor is it restricted to farm and forested land. Instead, the program focuses on land with multiple conservation values that may not be considered by other programs. The program allows greater flexibility in evaluating such properties and developing the appropriate easements. If a small parcel has extraordinary agricultural, environmental, or historic features on the property, the RL program will consider it for preservation as well.

Many RL sponsors use an Easement Valuation System (EVS) to set the value to be paid for a conservation easement. The EVS uses appraisals and a point system for natural resources. The EVS sets a base easement value as 50 percent of the most recent MALPF appraisals and adds value by assigning points to soil quality, biological importance, and priority preservation status and multiplying the total points by a price factor. The total easement payment for a parcel, however, is capped at 80% of the appraisal value from MALPF. The point-based payments reward ecological and other attributes such as large parcels, wetlands, endangered species and other wildlife habitat, and swamps, which are often discounted in an appraisal approach.

3.2.2 The Rural Legacy areas in Southern Maryland

Charles, Calvert, and St. Mary's counties in Maryland comprise what is known as Southern Maryland. Its eastern boundary is the Chesapeake Bay and western boundary is the Potomac River. Patuxent River separates Calvert from St. Mary's County. Both the Potomac and the Patuxent Rivers flow into the Chesapeake Bay. The area is within 2 hours of both Washington, D.C. and Baltimore, MD. It has experienced high population growth that outpaced both Maryland's growth rate and the country's growth rate in late 1990s due to job opportunity from the U.S. Navy's installations and affiliated high-tech defense contractors.

All three counties designated Rural Legacy areas soon after the program began to protect their watersheds from development and to protect the most ecologically valuable properties (Table 3.1). Southern Maryland has five approved RL areas for a total of 84,102 acres: Calvert Creeks and North Calvert in Calvert County, Huntersville and Mattapany in St. Mary's County, and Zekiah Watershed in Charles County. North Calvert area was approved in 2004, Mattapany in 2006, and the other three in 1998. This dissertation uses the RL areas designated in 1998.

The Calvert Creeks RL area (20,527 acres) seeks to protect water quality and wetland habitat as well as cultural resources. The Huntersville RL area (8,357 acres)

	Calvert County		Charles County	St. Mary's County	
	Calvert Creeks	North Calvert	Zekiah Watershed	Mattapany	Huntersville
RL approved in	1998	2004	1998	2006	1998
RL expanded in			2001		2005
RL available grants					
2008	750,000	833,590	500000	500,000	
2007			3000000	1,500,000	
2006				1,500,000	300,000
2005		350,000			
2004	600,000		202,218.56		
2003	1,500,000		1,000,000		
2001			1,500,000		3,700,000
2000	1,800,000		1,000,000		800,000
1999	2,000,000		500,000		1,500,000
Total to date	6,650,000	1,183,590	7,702,218.56	3,500,000	6,300,000

Note that the information on geographic distribution of RL grants in FY1998 and the total available grants for FY2002 are not identified.
Source: Maryland Board of Public Work –after meeting agenda summary (1998-2008).

Table 3.1: Available grants for the Rural Legacy Areas in Calver, Charles and St. Mary's Counties

includes shoreline with significant agricultural, forestry, and environmental values including endangered species habitat, wetlands, historic structures and archeological sites. The Smithsonian Center for Natural Areas has designated part of this RL area as critical wildlife habitat in need of protection. The Zekiah Watershed RL area (31,000 acres) protects farms, forests, Special State wetlands, historic and archeological sites, and deposits rich in mineral aggregates. The Smithsonian Institute considers its natural hardwood swamp to be one of the most important ecological areas on the East Coast. The boundaries of the Zekiah Watershed RL area follow, for the most part, the boundaries of the watershed itself and major road feature. The Zekiah Watershed RL sponsors decided to concentrate on the area with the most development pressure first. The other later areas include Mattapany and North Calvert. Mattapany RL area (13,703 acres) protects rich farmland, forests, wetlands, historic sites and wildlife habitat, and provides water quality benefits. The North Calvert RL area (10,515 acres) forms an 8-mile long greenway along the Patuxent River with riparian buffers: protecting the sensitive wetlands as well as farmland, forest land and wildlife habitat.

Three of the five RL areas are used in this analysis: Calvert Creeks, Huntersville, and Zekiah areas. The other two did not have data available because they were only recently approved. By 2006, the RL program has protected 1,660 acres at a cost of \$6.8 million with an average price of \$4,003 per acre in Calvert Creeks RL area. In the Huntersville RL area the RL program has preserved 2,720 acres at a cost of \$8.8 million; average cost was \$2,693 per acre. The Zekiah Watershed RL area has preserved 2,328 acres at a cost of \$9.4 million and at an average cost of \$3,866 per acre under RL program.

3.2.3 Other preservation programs in Maryland

Established 1977, the MALPF aims to preserve productive farmland and woodland as open space permanently and curb the expansion of random urban development. By 2007, over 265,691 acres are protected by about \$490 millions (Table 3.2). The program has protected 4,263 acres in Calvert, 5,872 in St. Mary's, and 3,474 in Charles by 2005. Payments were \$5,291 per acre in Calvert in 2004, \$2,937 in St. Mary's, and \$3,474 in Charles in 2005.

Districted parcels are eligible for participating MALPF. The maximum price that MALPF will pay is the lower of a landowner's asking price or the calculated easement value. A property's easement value is determined by subtracting its computed agricultural value from its fair market value. The fair market value of land (that which a developer might pay) is determined by at least two independent fee appraisers. Agricultural value of a parcel is calculated by the MALPF. The agricultural production value is determined by a formula that calculates land rent based on the soil productivity or the five-year average cash rent in the county.

Although MALPF has agreed to co-hold easement with the RL program in certain areas, this only reduces on-going monitor expenses for RL program rather than sharing easement acquisition costs for preservation. No co-held easements were identified in Southern Maryland.

Transfer of development rights (TDR) programs is also available in all three counties. A TDR program allows landowners in one area to sell the development rights associated with their property to developers who use them to develop other land more intensively than permitted by baseline zoning. Development right are transferred from an agricultural area and farmland is preserved; development occurs in the designated growth zones. By 2004, Calvert has protected almost $13,000$ acres through its TDR program; St. Mary's has 221 acres, and Charles has $1,554$ acres. Calvert county also bought TDRs from landowners and retired them in its Leveraging and Retirement Fund (LAR) and Purchase and Retirement Fund (PAR).

Maryland Environmental Trust (MET) aims to protect land from development through donated conservation easements. By 2006, MET has preserved $106,007$ acres state-wide. By 2003, the acres preserved by MET in Calvert County is 2089, 4934 in Charles, and $3,248$ in St. Mary's.

Almost 30 percent of the RL areas have been preserved compared to only 5.6% of the non-RL areas - suggesting that these areas are predisposed to be preserved. Figure 3.2 delineates the RL areas and the level of preservation under the different programs geographically. Since 1997, significant preservation activity has occurred from all the preservation programs. Rural Legacy program has preserved almost $6,500$ acres in these 3 counties since 1997. The MALPF program has preserved almost half of its acreage since 1997. The TDR programs in Calvert and Charles have preserved

Fiscal Year	Annual Net new MALPF acreage	Annual new funding for easement acquisitions ($)	Per acre acquisition costs($)	Per acre easement value($)	Per acre Fair Market Value (FMV) ($)	Per acre Agricultural Use Value (formula)($)	Per acre accepted asking price($)
1992	-29	0					
1993	8,341	11,472,760	1016*	1185*	2460*	1312*	1213*
1994	6,783	11,000,311	1617	2920	3639	718	1918
1995	7,851	11,120,874	1384	2235	3040	792	1633
1996	6,552	10,109,481	1537	2205	2977	773	1697
1997	11,797	16,324,722	1382	2193	2848	655	1470
1998	12,460	20,378,116	1634	2364	3027	666	1688
1999	14,241	23,109,183	1619	2345	3012	667	1650
2000	18,781	32,609,436	1683	2405	3129	724	1818
2001	12,966	25,246,645	1944	2511	3201	690	2223
2002	19,283	37,582,057	1958	2717	3,468	751	2676
2003	15,307	33,687,626	2199	3071	3,756	686	2400
2004	2,448	7,315,417	2982	4257	4,914	657	3779
2005	6,687	22,246,850	2802	4534	5,293	759	3189
2006	8,628	39,443,428	4492	7634	8,424	790	5475
2007	15,161	90,980,431	5952	9496	10,341	845	8010
Total	265,691	490,980,431					

* Value is for 1977-1993.

Source: The Maryland Agricultural Land Preservation Foundation five year annual reports, Fiscal Year 2003-2007.

Table 3.2: The Maryland Agricultural Land Preservation Foundation (MALPF) available funds and perservation costs per acre statewide

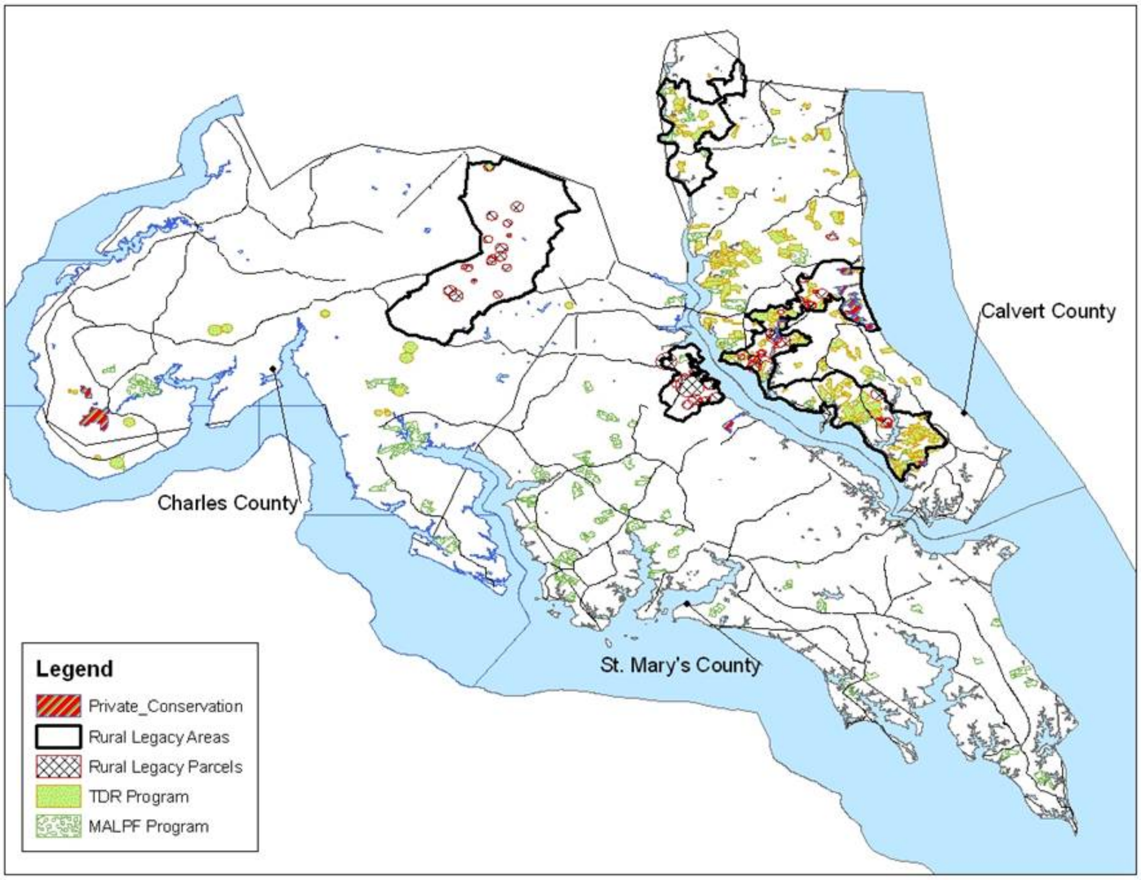

Figure 3.2: Rural Legacy Areas and preserved parcels by program type

40% of their acres since 1997. At first glance, the raw data suggest a crowding out phenomena: the TDR programs had preserved 42% of its acreage within the RL areas pre-1997; but after 1997, the TDR program preserved only 30%. Similarly, MALPF preserved 28% of its acreage in RL areas before designation but only 4.5% after 1997.

3.3 Data Sources and Parcel Attributes

Data was collected on agricultural and forest parcels greater than 3 acres in 3 Maryland counties. I collected information on variables that affect RL areas designation and preservation outcomes.

The primary data set, the MDPropertyView 2002 Database, provided parcel level information such as parcel size, zoning density, waterfront access, public sewer availability, housing construction, subdivision designation, parcel valuation, transaction, and geographic coordinates. The MDPropertyView 2002 Database (MDPVD) is created by the Maryland Department of Planning (MDP) as a series of county-level files. The files include data updated through October 2003 from the State's Department of Assessments and Taxation. The files are spatially referenced for use in GIS, allowing the data to be utilized in conjunction with other state and federal spatially referenced data sets. The parcels are spatially referenced by the x and y coordinates in NAD83 meters Maryland State Plane Coordinate System. Each parcel is also identified by a unique account number that allows parcel-level links between the various MdPropertyView 2002 data files and parcel-level data sets created by other State agencies. For each parcel, data were collected from MDPropertyView on the most current transfer date, price paid for the entire parcel at last transfer date, how the parcel was conveyed (arm's-length or non arm's-length), whether it was part of a multi-parcel sale, number of acres in the parcel, waterfront area for those counties near the Atlantic Ocean, Chesapeake Bay or major tributaries, the assessed value of the land, the assessed value of all improvements, and the total assessed value.

A wealth of data characterizing Maryland lands is linked to the MDPVD land parcels spatially through GIS techniques. For the most part, the land characteristics data is stored in maps that have been digitized by the State of Maryland. To extract this data for the specific land parcels in the MDPVD, buffer parcels are created as proxies for the true parcel boundaries.[1] A buffer parcel is a circular area whose center

[1]Exact land parcel boundaries are preferred to buffer parcels, but are currently available only for

is at the land parcel centroid and whose total area is equal to the land parcel's acreage. The MDPVD contains the exact location of each parcel centroid as spatially referenced x and y coordinates. ArcView 3.2 GIS software uses these x and y coordinates to map the parcel centroids across Maryland. Each land parcel's size in acres, as measured in MDPVD, is used to calculate the parcel's radius in meters according to the formula: $radius = [(acres * 4046.87)/3.1416]^{1/2}$. With the radius and the parcel centroid for each land parcel, the Buffer Selected Feature command in ArcView creates noncontiguous circular buffer parcels. These buffer parcels intersect with spatially referenced data to extract land characteristics for the MDPVD land parcels. This process is called buffer parcel extraction.

Land use information for 1997 were extracted and the percentage of each type of land use were computed for each parcel. Land uses are categorized into Urban Areas, Agriculture, Forest, Water, Wetlands, and Barren Land. Urban Areas includes the sub-categories low-density residential, medium-density residential, high-density residential, commercial, industrial, institutional, extractive, and open urban land uses. Agriculture includes cropland, pasture, orchards, vineyards, and agricultural buildings and storage. Forest includes deciduous, evergreen, and mixed forests as well as brush. Water and Wetlands refer to open water and intermittently wet areas, respectively. Finally, Barren Land includes beaches, bare rock, and bare ground. ArcView is used to extract the land use data for each buffer parcel as the percentage of the parcel in each land use category. These land uses sum to 100 percent.

Soil data comes from the Maryland Department of State Planning's 1973 work to classify and map all Maryland soils, completed in conjunction with the U.S. Department of Agriculture Soil Conservation Service. The two agencies developed the

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Montgomery and Howard County, Maryland.

Natural Soil Groups classification system. Soils are grouped by productivity, erosion potential, permeability, stoniness and rockiness, depth to bedrock, depth to water table, slope, stability, and susceptibility to flooding. The MDP defines these factors as most significant for land use planning purposes. The Natural Soil Groups Technical Report (Maryland Department of State Planning, 1973) provides estimated chemical and physical properties for each soil group. Each soil group is classified according to categories for each of several soil properties. ArcView is used to extract the natural soil groups present on each parcel as the percentage of the parcel in each soil category. The categories define soil slope, soil erodibility, and floodplain soils, which affect the extent of potential development on the land and agricultural returns.

Distance to Washington, D.C. in miles was computed using U.S. Census Bureau road networks. For the ecological values of each parcel, I computed the percent of Maryland's Sensitive Species Project Review Areas, which include rare, threatened, and endangered species and rare natural community types (Maryland DNR 2003), and Non-tidal Wetlands of Special State Concern (Department of the Environment and DNR 1998). The percent of the parcel in estuarine wetland status was also extracted from the Maryland Wetland Map (Maryland DNR 1998).

Preservation data was collected from the state-wide preservation program MALPF parcels through 2005, from the Maryland Environmental Trust through 2004, from the Calvert Transfer of Development Rights program through 2004, and from private conservation groups (Nature conservancy, private land trusts) through 2005. Maryland DNR provided information on RL areas designation and approved landowners who were matched to specific parcels. The number of preserved acres within a 1 mile radius was also extracted for each parcel.

3.4 "Naive" Average Treatment Effect on the Treatment

I estimate an average treatment effect on the treated in this section assuming that there is no predisposition effect and crowding effect. As mentioned in the Section 3.1, I use two outcome variables to approximate the effect of the land preservation programs: 1) the probability that a parcel is preserved, and 2) the acres that are preserved. The realized probability of preservation is either 0 (a parcel is not preserved) or 1 (a parcel is preserved). The unobserved probabilities (constructed counterfactuals), however can take any value between 0 and 1. The preserved acres is the acres of a parcel weighted by the probability that the parcel is preserved. The treatment variable is whether a parcel is in a RL area or not: 1 indicates the parcel is in a RL area, and 0 otherwise. The fundamental question is: does targeting or delineating the most desirable parcels to preserve have any impact on the preservation within that area.

The effect of RL program designation on land preservation is estimated by matching the agricultural parcels in RL areas with those most similar parcels outside the RL areas. Assuming that a conditional mean independence assumption holds, I can match the non-RL parcels (control parcels) to the parcels in RL areas (treated parcels). The matched control parcels can then be used to construct counterfactuals for the parcels that are in the RL areas. I then calculate the Average Treatment Effect on the Treated (ATT) by taking the difference in the outcomes between treated parcels and their constructed counterfactuals.

3.4.1 Empirical illustration

Assign the outcome variable of the RL program as Y_i for parcel i. The observed outcome depends on a set of exogenous variables X_i, and a dummy variable representing treatment status RL_i. The outcome equations for a parcel in its two treatment status can be written as:

$$Y_i^0 = g(X_i) + U_i^0 \tag{3.1}$$

$$Y_i^1 = g(X_i) + \alpha_i(X_i) + U_i^1 \tag{3.2}$$

Y_i^1 is the outcome when $RL_i = 1$ and Y_i^0 otherwise. U_i is a random error term. The "naive" effect of the RL program can be expressed as:

$$E_{RL} = E\left(\alpha_i | X_i, RL_i = 1\right) = E\left(Y_i^1 - Y_i^0 | RL_i = 1\right)$$

This effect is the difference in the outcome between the treated parcels and their unobserved counterfactuals. The unobserved counterfactual is constructed using a propensity score matching method.

3.4.2 Propensity score estimation and matching methods

Propensity scores are estimated with a Logit model. I include in the model all the key covariates that affect both a parcel's inclusion in RL areas and pre-treatment outcomes. I specify the Logit model to provide the best prediction of a Rural Legacy area designation. These parcel-level variables include proxies for ecological, agricultural, and forestry values, and development pressure.

The parcels that are waterfront properties, have a high percent of estuarine areas and wetland, have a higher percent of a floodplain, have a high percentage of special habitat, and land-uses of cropland and pasture, are of high ecological and agricultural value and more likely to be included in a RL area. The parcels that are on public sewer or with zoning densities permitting more houses per acres, however, are less likely to be included in RL areas as RL program also aims to slow down conversion. Solid quality indicators such as, distance to bed rock, permeability, and erodeability are also included as the RL program values those attributes. Table 3.3 reports the estimated coefficients for predicting a parcel's inclusion in a RL area.

Figure 3.3 is the distribution of estimated propensity scores for treated and control parcels. The distributions are not very compatible, with control being more left-skewed. I therefore use a leave-one-out cross-validation criterion to choose matching method. Two matching methods that perform better than others are selected to conduct matchings. The two matching techniques are: Kernel matching with normal kernel and bandwidth 0.01, and local linear matching method with biweight kernel and bandwidth 0.1.

3.4.3 Balancing test and matching results

I use only the parcels greater than 10 acres for matching since these are the ones most likely to be preserved. The parcels that are preserved before RL program was introduced are dropped. Balancing tests are conducted using the standardized difference test, a t-test for equality of the variable means in the matched treated and control groups. For the preservation outcomes, I find that the treatment and control groups (10+ acres) have equal means except for the permeability and erodeability variables for all matching protocols. The mean permeability for treated and control groups are

Pseudo R2 = 0.1779	Log likelihood = -5927.4692	
Dependent Variable	In/out of Rural Legacy areas	
Independent Variables	Estimated Coef.	Std Err.
Acres	0.0083**	0.0024
Miles to Washington DC	-0.0300	0.0204
% cropland_1997	1.0040**	0.1670
% forest_1997	-0.0634	0.1377
% special habitat (in log format)	0.9904**	0.2097
On public sewer	-0.0251	0.5053
Zoning density per acre	-3.9806	3.7404
% estuarine (in log format)	2.4142**	0.7200
Waterfront property	0.8767**	0.1387
% acres with depth to bedrock>72 inch	-4.2090	4.6463
% acres with floodplain soil	1.4719**	0.4274
% acres with soil erodebability low and very low	3.6582**	0.4052
% acres with permeability medium or rapid	-2.0566**	0.3979
Acres squared	-3.08e-06**	1.02e-06
Miles to Washington DC squared	0.0000	0.0002
Acres*miles to Washington DC	-0.0001*	0.0001
% cropland_1997 squared	0.0766	0.1859
% forest_1997 squared	0.7494**	0.1336
Acres*public sewer	-0.0581	0.0740
Zoning density squared	-0.0512	0.1293
Acres*waterfront	-0.0016	0.0018
% acres with depth to bedrock>72 inch squared	5.6530	4.0333
% acres with floodplain soil squared	-3.4399**	0.4883
% acres with soil erodebability low and very low squared	-1.1983**	0.4197
% acres with permeability medium or rapid squared	0.2076	0.3702
Zoning density*% acres with depth to bedrock>72inch	0.9366	3.7435
Zoning density*% acres with floodplain soil	-0.1758	0.5418
Zoning density*% acres with soil erodeability low and very low	-2.2449**	0.2783
Zoning density*% acres with permeability medium or rapid	2.5187**	0.2151
Constant	-1.3960	1.5416
Observations	25779	

* significant at 5%; ** significant at 1%

Table 3.3: Estimated coefficient for the propensity score logistic regression

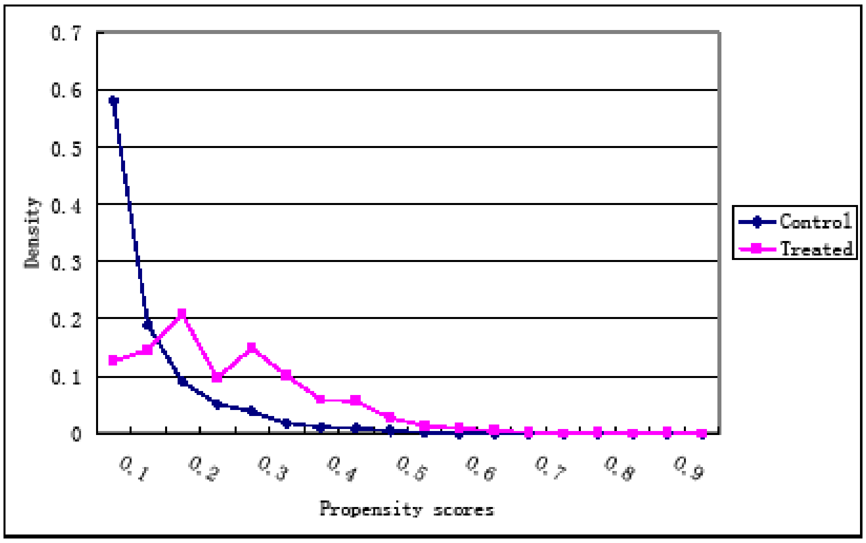

Figure 3.3: Distribution of estimated propensity scores

63% and 54%, for mean erodeability are 20% and 16%. Theoretically, parcels with higher permeability levels and low erodeability would be more likely to be developed rather than preserved. The failure of balance test for the variables permeability and erodeability may induce a downward biased estimator for the impact of RL program.

The matching results in Table 3.4 show that the parcels in RL areas have a 10.1 percentage points higher probability of being preserved than the parcels out of RL areas. On average, 11 more acres are preserved in RL areas than out of RL areas. This estimated average treatment effect on the treatment, however, cannot be claimed to be the net effect of RL program if the parcels in RL areas are predisposed to be preserved.

3.5 Predisposition Effect

The matching methods in the Section 3.4 may take account of some but not all of the selection bias. As a result, part of the difference between the matched treated

		Normal Kernel Matching (bandwidth=0.01)	Biweight Local Linear Matching (bandwidth=0.1)
Likelihood	ATT	0.101	0.101
		(0.013)	(0.013)
Acres	ATT	10.96	10.94
		(2.38)	(2.38)
Number of Matched RL parcels		672	672
Number of Matched non-RL parcels		6722	6722

Standard errors are in parenthesis

Table 3.4: The effect of RL program on land preservation assuming no predisposition effect and crowding effect

and control parcels may be due to unobserved parcel attributes rather than the RL program. I use a difference-in-difference (DID) approach to control for the potential predisposition effect in this section. I first match the control to the treated parcels in the same way as in the previous section. Second, I take the difference in the pre-treatment and post-treatment outcomes for each matched parcel. Last, I take the difference of the difference between matched treated and control parcels for the difference-in-difference estimator.

3.5.1 Empirical illustration

To illustrate the DID approach, I assign Y_{it} as the outcome for a parcel i at time t. $t = \{t_0, t_1\}$ indicates a pre- or post-treatment period. The outcome depends on a set of exogenous variables X_i, and a dummy variable representing treatment status RL_{it}. $RL^1_{it_0} = 0$, and $RL^1_{it_1} = 1$ for parcels in RL areas, while $RL^0_{it_0} = 0$, and $RL^0_{it_1} = 0$ for parcels in non-RL areas. The outcome equations for a parcel in its two treatment status can be written as:

$$Y^0_{it} = g_t(X_i) + U^0_{it} \tag{3.3}$$

$$Y_{it}^{1} = g_t(X_i) + \alpha_{it}(X_i) * RL_{it}^{1} + U_{it}^{1} \tag{3.4}$$

U_{it} is the error term and $U_{it} = \phi_i + \varepsilon_{it}$. U_{it} can be decomposed to an individual specific fixed effect ϕ_i, and a temporary individual-specific effect ε_{it}. The individual fixed effect, ϕ_i, is an unobserved parcel attribute that affect the likelihood of preservation. The selection into the treatment state is independent of ε_{it}.

The direct effect of the RL program on the outcome is:

$$E_{RL} = E\left(\alpha_{it}|X_i, RL_{it}^{1} = 1\right)$$

The effect of unobservables ϕ_i:

$$E_{\phi} = E\left(\phi_i|X_i, RL_{it}^{1} = 1\right)$$

The direct effect of the RL program on the outcome, E_{RL}, can be estimated by the following DID estimator:

$$ATT^{DID} = E((Y_{it_1}^{1} - Y_{it_0}^{1})|RL_{it}^{1} = 1) - E((Y_{it_1}^{0} - Y_{it_0}^{0})|RL_{it}^{0} = 0, P(X_i))$$

3.5.2 Pre- and Post-treatment outcomes

My data allows me to trace back the preservation status of the parcels before the RL program was introduced in 1997. I assign the pre-treatment probability of preservation as 0 for the parcels that are preserved after 1997.

Parcels are enrolled in preservation programs at different points of time. For example, a parcel that is protected after a RL area is designated can be preserved in any year after the year of designation, and the same holds for a parcel being preserved before the RL areas were designated. In order to impose the same time frame for preand post-treatment groups, I drop all the parcels with their enrollment year falling outside the relevant time period. For example, I drop the parcels that are preserved before 1989 such that the protected parcels are preserved in a 9-year period for both pre- and post-treatment groups.

The mean preservation rate and acres before matching is reported in Table 3.5. Overall, parcels are more likely to be preserved and more acres are preserved in post-treatment period in both RL and non-RL areas. However, more acres and a larger proportion of parcels are preserved within RL areas than outside RL areas in both pre- and post-treatment periods. Non-RL programs have preserved 2.48 more acres and 4.6 more percentage points in RL areas than outside RL areas in pre-treatment period. After RL program was introduced, the differences in preservation rate and preserved acres are even larger: the difference in acres increases to 13.5 and the rate of preservation to 18 percentage points. Even after excluding the parcels preserved by the RL program, parcels in RL areas still have a 13.4 percentage points higher rate of preservation and 5.33 more acres being preserved.

3.5.3 Result from a difference-in-difference approach

Table 3.6 presents the average treatment effect on the treated from the difference-in-difference approach. After controlling for the predisposition effect, the parcels in RL areas still have a 9.4 percentage points higher probability of being preserved, and have 10.2 more acres on average being preserved. This estimated average treatment effect on the treated, however, still cannot be claimed to be the net impact of RL program. The reason is that the DID approach is based on the assumption that selection bias due to unobserved parcel attribute is time-invariant conditional on observed covariates. However, there may exist time effect that bias the estimation,

		RL parcels	non-RL parcels
pre-treatment			
	preservation rate	0.067	0.021
		(0.25)	(0.143)
	preservation acres	3.195	0.714
		(18.47)	(10.89)
	# of parcels	720	6865
post-treatment include parcels preserved by RL program			
	preservation rate	0.19	0.041
		(0.39)	(0.2)
	preservation acres	16.07	2.53
		(61.2)	(19.48)
	# of parcels	720	6865
post-treatment exclude parcels preserved by RL program			
	preservation rate	0.138	0.041
		(0.35)	(0.2)
	preservation acres	7.86	2.53
		(30.9)	(19.5)
	# of parcels	676	6865

Note: The values are the proportion and acres preserved and standard deviation is in the parenthesis

Table 3.5: Rate of preservation and acres preserved in RL and non-RL areas before and after 1997

e.g. dramatic changes in development pressure or budget for non-RL programs.[2]

Besides a time effect, RL program may also interact with non-RL programs and affect their preservation efforts in RL areas. Hence, the estimated ATT also includes a crowding effect. If there is a crowding out effect, more parcels outside the RL areas are preserved than would have been if the RL program was not introduced. Therefore, the estimated ATT would be smaller than the direct impact of the RL program. If the RL program crowds in the preservation efforts of the other programs, the estimated ATT would be larger than the direct impact.

[2]The reduction in non-RL budget would be a result of crowding out effect if the operators of non-RL programs do so after observing the increment of RL funds. Budge cuts due to a bad economic situtation, however, cannot be attributed to a crowding out effect.

		Normal Kernel Matching (bandwidth=0.01)	Biweight Local Linear Matching (bandwidth=0.1)
Likelihood	ATT	0.094	0.094
		(0.013)	(0.013)
Acres	ATT	10.2	10.2
		(2.23)	(2.23)
Number of Matched RL parcels		720	720
Number of Matched non-RL parcels		6865	6865

Standard errors are in parenthesis

Table 3.6: The estimated effect of RL program on preservation from a difference-in-difference approach

3.6 Crowding Effect

Crowding effects have been studied by the researchers in various fields. Ahmed and Miller (2000) examine whether tax-financed or debt-financed government spendings crowd out or crowd in private investment. Andreoni and Bergstrom (1996) examine whether tax-financed government subsidies crowd in or crowd out voluntary private contributions to finance public goods - are people more likely to contribute to public goods when governments subsidize the cost. Brooks (2005), Andreoni and Payne (2003), and Andreoni (1993) find that government grants has a partial crowding out effect on funding-rasing efforts and donations to nonprofit groups, i.e. overall funds to the organizations increased but private donations decreased somewhat. Frey and coauthors find that regulation (extrinsic motivation) can reduce individuals' intrinsic motivation to protect environment if "the instrument damages the marginal utility of intrinsic motivation" (Frey, 1992; Frey, 1997a; Frey 1997b; Frey and Oberholzer-Gee, 1997).[3]

[3] There are also studies that focus on crowding effect on individual behavior. For example, Benabou and Tirole (2003) have studied crowding effects of extrinsic motivation on intrinsic motivation

In the field of agricultural land and open space preservation, Parker and Thruman(2008) examine whether federal land conservation and preservation programs crowd out the efforts of private land trusts in terms of retaining open space. They construct a panel data at the county level from 1990 to 2000 and evaluate the crowding effects using a panel regression framework. They examine acreage data for the Conservation Reserve Program (CRP), Wetland Reserve Program (WRP), and the national parks and forest. The private land trust acreage data are from The Nature Conservancy (TNC) and Land Trust Alliance (LTA). Crowding in effect is found from LTA data; LTA increases acres in areas with high enrollment in CRP, WRP and retained parkland. Both crowding in and crowding out effects are detected for TNC's activities.

In this section, I evaluate the effect of RL program by isolating the crowding effects of RL program on existing agricultural land preservation programs. Different from Parker and Thurman (2008), I study the crowding effects on preservation efforts from designated preservation areas measured by the likelihood and acres of preservation using micro-level parcel data including characteristics that affect a parcel's predisposition to be preserved. I specify the conditions under which crowding in or out could occur and empirically test whether there is a crowding in or out effect.

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from an economic and cognitive perspective. They find that extrinsic motivations (reward or punishment) can crowd out individuals' intrinsic motivation if the individuals (agents) infer from extrinsic motivation (reward or punishment) about some bad information privately known only by principal (regulator).

3.6.1 Theoretical framework

This section provides a conceptual framework of land preservation programs' strategies, landowners' decisions on preserving land, and the potential crowding effects of the RL program on the non-RL programs.[4] I assume in this model that a community has two areas: a RL area and a non-RL area. A non-RL program has been operating in the community to preserve farmland that otherwise would be developed in both areas. RL program enters later and only focuses on the parcels in the RL area.

Crowding effects are evaluated by comparing non-RL program's preservation efforts in two cases: when only the non-RL program exists, and when both programs exist. If the non-RL program shifts its preservation efforts from a non-RL area into a RL area after the RL program is introduced, one finds a crowding in effect; or if it shifts its preservation effort from a RL area to a non-RL area, one would find a crowding out effect.

RL program can influence non-RL program's preservation efforts within the RL area in three ways. First, the RL program can let the non-RL program move first to preserve the most affordable parcels so that the non-RL program is not forced to preserve in the non-RL area. Second, the RL program could design a payment scheme that is complimentary rather than competitive to the easement payment scheme of the non-RL program. Third, the RL program can provide matching funds for the parcels preserved by the non-RL program and reduce the marginal cost of preserving parcels in the RL area for the non-RL program.

There are M units of agricultural land in RL area and N units in non-RL area that would be developed in the future if not being preserved. A landowner is endowed with

[4] In addition to the RL program, both county and state preservation programs can operate in RL areas and I treat all those programs as one non Rural Legacy program to simplify the problem.

one unit of agricultural land. WTA_i is a landowner i's willingness-to-accept for giving up a parcel's development right permanently.[5] To induce the landowner to preserve his land, the non-RL program offers landowner i an easement payment EV_i and RL program offers an $\overline{EV}_i$. Both EV_i and $\overline{EV}_i$ are determined by land characteristics and the programs' evaluation criterions. Neither EV_i nor $\overline{EV}_i$ is affected by the available budgets of the two programs. $\gamma_i \in [0,1]$ indicates which program pays the landowner of unit i for preserving his land. $\gamma_i = 1$ if unit i is enrolled only in the RL program, and $\gamma_i = 0$ if only in the non-RL program, and $\gamma_i \in (0,1)$ if the RL program provides matching funds to non-RL program and the parcel is enrolled in both programs.

The owners of the M units of land in the RL area can either participate in the RL or Non-RL program while the owners of the parcels in the non-RL area can only participate in the non-RL program. The total easement payment for land unit $i \in M$, if being preserved, is: $\gamma_i\overline{EV}_i + (1-\gamma_i)EV_i$ and EV_i for $i \in N$. Landowner i is willing to preserve his land only if the easement payment exceeds his willingness-to-accept: $WTA_i \leq EV_i$ for $i \in N$ and $WTA_i \leq \gamma_i\overline{EV}_i + (1-\gamma_i)EV_i$ for $i \in M$. Otherwise, landowner i will not preserve but develop his land in the future. A parcel is preserved if a willing landowner is paid the easement value ($\beta_i = 1$) and is not preserved otherwise ($\beta_i = 0$).

I assume that the budget for the non-RL and RL programs are always binding.[6] This assumption implies that not all the landowners who are willing to preserve their land finally enroll their land into a conservation program. I also assume that

[5] WTA_i is determined by agricultural profits, benefits from developing land now, the option value for leaving land to be developed in the future, and the expectation for losing development rights due to future regulation.

[6] This is a realistic assumption as MALPF have run out of money in several years.

land value, and thus, WTA_i is not affected by the land preservation for simplicity purpose, i.e., there is no positive or negative amenity spillover effect of neighboring preserved parcels.[7] Land preservation programs aim to preserve all the units given their available budgets.

Baseline: no RL program

The maximization problem for the non-RL program, if the RL program does not exist, is to preserve as many parcels as possible until its available budget, B, is exhausted:

$$\sum_{i \in M \cup N} \beta_i EV_i \leq B$$

To illustrate the solutions, I assume in the rest of the paper that all the owners are willing to preserve their land ($WTA_i \leq EV_i$) and sort the easement payment EV_i in an ascending order. Non-RL program chooses an optimal cut-off value λ^* such that: $\beta_i = 1$ if $WTA_i \leq EV_i \leq \lambda^*$, and $\beta_i = 0$ if $EV_i > \lambda^*$. The value of λ^* is:

$$\lambda^* = \left\{ \lambda | \sum_{i:\{WTA_i \leq EV_i \leq \lambda^*\}} EV_i \leq B, \text{ and } \sum_{i:\{WTA_i \leq EV_i \leq \lambda^* + \varepsilon\}} EV_i > B \right\}$$

RL program interacts with non-RL program

The RL program is introduced to preserve parcels in the RL area. The RL program will preserve as many units as possible in RL area given its budget constraint $\overline{B}$:

[7] A positive spatial amenity spillover effect implies that neighboring parcels become more likely being converted later on and require higher easement payments than the same parcels that do not have its neighboring parcels being preserved. The static framework in this paper, however, is not able to capture this effect.

$\sum_{i\in M}\beta_i\gamma_i\overline{EV}_i \leq \overline{B}$. The non-RL program again maximizes total parcels preserved in and out of RL areas given its budget constraint: $\sum_{i\in M}\beta_i\left(1-\gamma_i\right)EV_i+\sum_{i\in N}\beta_i EV_i \leq B$.

As discussed earlier, the RL program can interact with the non-RL program in three ways: let the non-RL program move first to preserve low cost parcels (scenario A), offer a higher easement payment (scenario B), and provide matching funds for parcels preserved by the non-RL program(scenario C).

However, the underlying assumption for the above three scenarios is that parcels in and out of RL area are of equal value to the non-RL program. It is possible that the introduction of RL program increases the social benefits of preserving RL land and the non-RL program is willing to preserve RL parcels even if they become more expensive (Scenario D).

I discuss the solutions of the maximization problem and the possible crowding effects given these four scenarios.

Scenario A: When the RL program lets the non-RL program move first to preserve affordable parcels, the non-RL program will choose to preserve the same parcels as it did before the RL program entered. The RL program then preserves the parcels in RL area that are less affordable to the non-RL program.

However, the RL program may crowd out the preservation efforts of the non-RL program if it does not let the non-RL program select which parcels to preserve first. If not, the RL program may preserve some or all of the parcels that the non-RL program would have preserved and force the non-RL program to shift its focus to the now relatively less expensive non-RL parcels. More non-RL and less RL parcels are preserved when there is a crowding out effect.

Scenario B: When the RL program sets a higher easement payment than the non-RL program ($\overline{EV}_i \geq EV_i$), it crowds out the preservation efforts of the non-RL program. All preserved parcels in the RL area are enrolled in the RL program until its budget is exhausted. More non-RL parcels are preserved if there is a crowding out effect. However, RL program will not crowd out the preservation effort of non-RL program if the RL program only pays a higher easement payment ($\overline{EV}_i \geq EV_i$) for the parcels with $EV_i \leq WTA_i$. Furthermore, the case under which the RL program pays a lower easement payment is not incentive compatible.

Scenario C: The RL program can provide matching funds to the non-RL program to preserve RL parcels. I assume that the RL program offers the same easement payment for a parcel ($\overline{EV}_i = EV_i$) in this case. There could be a crowding in or out effect depending on the distribution of the easement value and the magnitude of the matching funds. For example, if the matching funds are not large enough to reduce the cost of enrolling the next RL parcel, the non-RL program would still preserve the relatively less expensive non-RL parcels. The RL program therefore crowds out the preservation efforts of non-RL program and more non-RL parcels are preserved.

Alternatively, if the matching funds are large enough to make the RL parcels relatively less expensive than the non-RL parcels, the non-RL program will preserve exclusively in the RL area. This can happen if the easement values of the expensive RL parcels are not prohibitively high or the matching funds are substantial. The non-RL program would shift its preservation effort from the non-RL area into the RL area in order to preserve more units of land. Less non-RL parcels and more RL parcels are preserved by the joint effort of the RL and non-RL programs.

Scenario D: In the above three scenarios, I assume that the non-RL program values RL parcels the same as non-RL parcels. However, preserving RL parcels can provide higher social benefits than preserving non-RL parcels due to concentrated preservation in the targeted area. This induces the change in non-RL program's evaluation of the environmental benefits from preserving RL parcels after the RL program was introduced. The non-RL program may be more willing to preserve the more expensive parcels in RL area than in the non-RL area. Hence, there may exist a crowding in effect even if the RL program does not allow the non-RL program to move first, offers a high easement payment, or does not provide matching funds to the non-RL program.

To summarize, if parcels in and out of RL areas are valued equally by the non-RL program, the RL program crowds out the non-RL program's preservation effort if it does not let the non-RL program select parcels first or it offers higher easement payment. When the RL program provides matching funds to the parcels in RL areas preserved by the non-RL program, crowding effects can go either way. Whether there is a crowding in or a crowding out effect depends on the magnitude of the matching funds and the distribution of the easement value. If the introduction of the RL program cause preserving parcels in RL areas to be sufficiently more valuable than preserving parcels out of RL areas, there is a crowding in effect even if the RL program compete with the non-RL programs.

3.6.2 The violation of Stable Unit Treatment Value Assumption (SUTVA) and multiple causal effects

Matching method (also randomized experiment) implicitly uses the assumption of "no interference between units" (Cox, 1958, p19) or the Stable Unit Treatment Value Assumption named by Rubin (1986). This assumption says that the potential outcomes of an individual depend on the treatment assigned to this individual but not the treatment assigned to other individuals or the allocation of other individuals to the treatment. The validity of SUTVA is assumed for matching method. The validity is warranted if the policy under consideration is rather small in size, if market effects are unlikely, or if the counterfactual world against which the policy is evaluated is such that similar distortions through market and general equilibrium effects would persist (Frölich, 2003). An ATT estimator from matching method is the net impact of a treatment only if this assumption holds. However, this assumption might be invalidated if individuals interact to each other, either directly or through market.[8]

When SUTVA is invalidated (or general equilibrium effect exists), controls can no longer provide the desired counterfactual to treated individuals for the treatment of interest. As a result, the estimated ATT from matching is no longer the accurate measure of treatment effect. Rather, it is a combination of multiple causal effects besides that of the treatment of interest. Those causal effects include the direct effect and indirect effects of treatment of interest, e.g. the effect of the treatment assignment to an individual and the treatment assignment to other individuals. The question is: can one isolate different causal effects using a matching method?

SUTVA violation makes causal inference more difficult. It will be almost impossible to identify or isolate the causal effects if treatment assignment to any individual affects any other individual's outcome. The reason is that there will be too many causal effects to be identified. However, if one can reduce the interference of treatment assignment to a limited number of groups of individuals, it is possible to identify the limited number of causal effects. For example, Hong and Raudenbush (2006) impose a structure over the interaction of individuals to reduce the number of potential outcomes in evaluating kindergarten retention policy in the US. They model the impact of treatment assignment to an individual as operating through the individual's

[8]The violation of the SUTVA, or the presence of general equlibrium is not just an issue for matching method. It also applies to all partial eqlibrium estimators.

treatment assignment and a scalar function of all the others' treatment assignment. The scalar function takes two values: 1 if a high proportion of kindergartners are retained and 0 if not. Therefore, the number if causal effects in their study is reduced to a manageable level.[9]

In the case of RL program, the violation of SUTVA, in the "conventional" way, is the possibility that inclusion or exclusion of any single parcel affecting the outcomes (preservation status) of the other parcels. However, this is less of an issue than the shifting of non-RL program's preservation efforts in or out of RL areas. The crowding effect of RL program becomes one of the multiple causal effects induced by the violation of SUTVA. As long as the CIA (CMI assumption) or ignorability of treatment assignment assumption holds, I can employ matching method and restrict matching between different sub-samples to isolate different effects.

3.6.3 Empirical specifications

Assign the outcome variables of the RL program as Y_{it}. Besides a set of exogenous variables X_i, and a dummy variable representing treatment status RL_{it}, a crowding effect of RL program, C_{it}, also affects the outcome. The impact of crowding effects

[9] There are also studies that discuss causal inference using other approaches and in different contexts. In a randomized experiment context, Sobel (2006) proposes an identification strategy and the parameters of interest in the housing mobility experiment sponsored by the US Department of Housing and Urban Development. Halloran and Struchiner (1995) study the effect of vaccine on infectious diseases by defining "conditional direct casual effects". Heckman, Lochner, and Taber (1998) use a general equilibrium approach to study the effect of national tuition subsidy on college enrollment and earnings. Their methods, as pointed out by Sobel (2006) "combine empirical information and mathematical modeling without using the potential outcomes notation that statisticians have used to clarify problems of causal inference".

on preservation in and out RL areas goes to opposite directions. $t = \{t_0, t_1\}$ indicates a pre- or post-treatment period the same as in section 3.5. $C_{it} = 0$ in period t_0 and $C_{it} = 1$ in period t_1. The outcome equations for a parcel in its two treatment status can be written as:

$$Y_{it}^0 = g_t(X_i) + \beta_{it}(X_i) * C_{it} + U_{it}^0 \tag{3.5}$$

$$Y_{it}^1 = g_t(X_i) - \beta_{it}(X_i) * C_{it} + \alpha_{it}(X_i) * RL_{it}^1 + U_{it}^1 \tag{3.6}$$

U_{it} is the error term and $U_{it} = \phi_i + \theta_t + \varepsilon_{it}$. U_{it} decomposes to an individual specific fixed effect ϕ_i, an impact from local economic growth θ_t, and a temporary individual-specific effect ε_{it}. The individual fixed effect, ϕ_i, affects the preservation effort of other programs and allows me to control their impact. The selection into treatment states is independent of ε_{it}.

The different parameters of interest can be expressed as:

Average treatment effect on the treated (ATT), or the direct effect of the RL program on the outcome:

$$E_{RL} = E\left(\alpha_{it} | X_i, RL_{it}^1 = 1\right) \tag{3.7}$$

The crowding effect of the RL program on preservation effort of the non-RL program:

$$E_C = -E\left(\beta_{it} | X_i, RL_{it_1}^1 = 1\right) = E\left(\beta_{it} | X_i, RL_{it_1}^0 = 0\right) \tag{3.8}$$

The effect of time-invariant unobservables ϕ_i:

$$E_\phi = E\left(\phi_i | X_i, RL_{it}^1 = 1\right) \tag{3.9}$$

The effect of exogenous parcel attributes :

$$E_X = E\left(g\left(X_i\right)\right) \tag{3.10}$$

The effect of local economic growth:

$$E_\theta = E\left(\theta_t | X_i, RL^1_{it} = 1\right) \tag{3.11}$$

Figure 3.4 is an demonstration of the impacts from different elements. The four quadrants define four sub-samples. The non-RL and pre-treatment quadrant defines the pre-treatment non-RL sample, whose preservation outcomes are clearly affected only by the desirability of their observed attributes to non-RL programs. The second quadrant (RL areas and pre-treatment) is the pre-treatment RL sample, which is preserved by non-RL programs. The preservation outcomes are affected by both observed and unobserved parcel attributes that are attractive to non-RL programs. The post-treatment non-RL sample, defined in the third quadrant(non-RL and post-treatment) are preserved by non-RL programs. However, its preservation outcomes are subject to the impact of crowding effects from RL program and time effect. The last quadrant defines the post-treatment RL group which can be preserved by both RL and non-RL programs. The preservation outcomes are affected by all factors: observed and unobserved parcel attributes, preservation effort from RL program, crowding effect of RL program, and time effect. The crowding effect for this sample is opposite to that for the sample of post-treatment non-RL parcels (parcels out of RL areas).

The following three equations (3.12)-(3.14) from restricting matching between different sub-samples can be used to identify different parameters:

$$E\left[\left(Y^1_{it_0} - Y^0_{it_0}\right) | X_i\right] = E_\phi \tag{3.12}$$

	Pre-treatment	Post-treatment
Non-RL areas	E_X	$E_X + E_C + E_\theta$
RL areas	$E_X + E_\phi$	$E_X - E_C + E_\theta + E_{RL} + E_\phi$

Figure 3.4: The effects from different factors for pre- post-treatment, RL and non-RL samples

$$E\left[\left(Y_{it_1}^1 - Y_{it_1}^0\right)|X_i\right] = -2E_C + E_{RL} + E_\phi \tag{3.13}$$

$$E\left[\left(Y_{it_0}^1 - Y_{it_1}^0\right)|X_i\right] = -E_C + E_\phi - E_\theta \tag{3.14}$$

Identification strategy one

It is obvious that the equations (3.12)-(3.14) are not enough to identify all the parameter of interest. However, if I can eliminate the time effect of E_θ by imposing the same time frame for pre- and post-treatment groups, the rest of the parameters can be identified. The time frames for the pre- and post-treatment groups are centered on the year when the RL program was introduced. I then rule out time-varying factors, e.g. dramatically change in the funding from other programs occurred in the pre- and post-treatment periods which is supported by the evidence in table 3.2.[10] The

[10] As shown in table 3.2, the budget of MALPF increases over time. However, the easement vlaue and acquision cost of farmland also increases over time. The increment of the two are comparable for pre- and post- treatment periods.

parameter of E_θ is cancelled out of equation (3.14).

$$E\left[\left(Y_{it_0}^1 - Y_{it_1}^0\right)|X_i\right] = -E_C + E_\phi \tag{3.15}$$

The parameters E_{RL}, E_C, and E_ϕ can then be identify from equation (3.12), (3.13) and (3.15).

For a treated and a control parcels that are observably identical, the following conditions hold.

First, the pre-treatment outcome is not affected by RL program (does not exist) and the difference in pre-treatment outcome between the two parcels captures the effect of the non-RL program (predisposition effect).

Second, post-treatment outcome of untreated parcels is indirectly affected by the RL program through the possible crowding effect. Therefore, the difference between the post-treatment outcome of untreated parcel and pre-treatment outcome of treated parcel captures the crowding effect together with the predisposition effect.

Third, the difference in post-treatment outcome captures the crowding effect and predisposition effect.

The three unknown effects can be then identified by the three conditions.

This strategy, however, cannot guarantee that the impact of local economic growth, E_θ, that affect the available budget for non-RL program, is eliminated completely. The presence of E_θ can bias the estimation of the crowding effect. As a result, the estimation returns an upper round of the crowding effect if the time effect and the crowding effect go to the same direction.

Identification strategy two

My data records whether a parcel is preserved by RL program or non-RL program and that RL and non-RL programs do not provide matching funding to each other.

I than can eliminate the net impact of RL program by excluding the parcels that are preserved by RL program. Then equation (3.13) is now restricted to a sub-sample excluding parcels preserved by RL program and becomes:

$$E\left[\left(Y_{it_1}^1 - Y_{it_1}^0\right)|X_i\right] = -2E_C + E_\phi \tag{3.16}$$

The equation (3.12) together with (3.16) identifies E_C and E_ϕ. Plug E_C and E_ϕ into equation (3.13), I can solve for E_{RL}. This strategy does not need equation (3.15) so that I can avoid the possible bias due to time effect.

3.6.4 Empirical estimation and results

I construct two treated and two control groups. The two treated groups are: pre-treatment RL group and post-treatment RL group. The two control groups are: pre-treatment non-RL group and post-treatment non-RL group. The treated and control groups are mutually exclusive. The pre-treatment and post-treatment treated (control) groups are overlapped with the parcels that are never protected by any programs. The parcels that are enrolled in any preservation programs after RL areas were designated are included in pre-treatment groups but those parcels appear as being unprotected. The post-treatment groups exclude the parcels that are enrolled in any preservation programs before the RL areas are designated.

For strategy one, I conduct matching based on estimated propensity scores in three ways across the four sub-samples. First, I match pre-treatment RL group with pre-treatment non-RL group for equation (3.12). Second, I match post-treatment non-RL group with post-treatment RL group for equation (3.13). Thirdly, I match post-treatment non-RL group to the pre-treatment RL group for equation (3.14).

For strategy two, I first match pre-treatment RL group with pre-treatment non-

	Normal Kernel Matching (bandwidth=0.01)		Biweight Local Linear Matching (bandwidth=0.1)	
pre-treatment matching				
	Permeability	(64:54)	Permeability	(64:52)
	Erodeability	(20:16)	Erodeability	(20:15)
post-treatment matching including parcels preserved by RL program				
	Permeability	(63:54)	Permeability	(63:52)
	Erodeability	(20:16)	Erodeability	(20:16)
post-treatment matching excluding parcels preserved by RL program				
	Permeability	(63:54)	Permeability	(63:52)
	Erodeability	(21:16)	Erodeability	(21:16)
pre-treatment RL vs. post-treatment non-RL group				
	Permeability	(64:54)	Permeability	(64:52)
	Erodeability	(20:16)	Erodeability	(20:16)

Means for treated and control parcels are in parenthesis

Table 3.7: Balancing test results for restricting matching between different sub-samples

RL group for equation (3.12). Second, I match post-treatment non-RL group with post-treatment RL group for equation (3.13). Third, I exclude the parcels being preserved by RL program in the post-treatment RL group and conduct matching between post-treatment RL and non-RL groups for equation (3.16).

Balancing test results are presented in Table 3.7. Most of the variables pass balance tests except for the permeability and erodeability variables for all matching protocols. Theoretically, parcels with higher permeability levels and lower erodeability would be more likely to be developed rather than preserved. The failure of balance test for the variables could induce downward bias in the estimated ATT for all matching protocols and for the impact of non-RL programs. However, its effect on the estimation of crowding effect and net impact of RL program is unclear.

Estimation results for crowding effect, E_C, predisposition effect, E_ϕ, and finally the effect of RL program, E_{RL}, are presented in Table 3.8 for identification strategy one and in Table 3.9 for strategy two.

For identification strategy one, the estimated ATTs for pre- and post-treatment

	Normal Kernel Matching (bandwidth=0.01)				Biweight Local Linear Matching (bandwidth=0.1)			
	Rate		Acres		Rate		Acres	
	ATT	Se.	ATT	Se.	ATT	Se.	ATT	Se.
Pre-treatment								
$(1) = E_\phi$								
# RL parcels: 720								
# non-RL parcels: 6865	0.026	(0.01)	1.57	(0.73)	0.026	(0.01)	1.49	(0.73)
Post-treatment								
$(2) = -2E_C + E_{RL} + E_\phi$								
# RL parcels: 672								
# non-RL parcels: 6722	0.101	(0.013)	10.96	(2.38)	0.101	(0.013)	10.94	(2.38)
Pre-treatment RL vs. post-treatment non-RL								
$(3) = -E_C + E_\phi$								
# RL parcels: 672								
# non-RL parcels: 6865	0.036	(0.01)	0.39	(0.78)	0.036	(0.01)	0.38	(0.77)
E_ϕ								
$= (1)$	0.026		1.57		0.026		1.49	
E_C								
$= (1) - (3)$	-0.01		1.18		-0.01		1.11	
E_{RL}								
$= (2) + (1) - 2*(3)$	0.055		11.75		0.055		11.67	

Table 3.8: Effect of Rural Legacy designation on land preservation from identificaiton strategy one

	Normal Kernel Matching (bandwidth=0.01)				Biweight Local Linear Matching (bandwidth=0.1)			
	Rate		Acres		Rate		Acres	
	ATT	Se.	ATT	Se.	ATT	Se.	ATT	Se.
Pre-treatment								
(1) $= E_{\phi}$								
# RL parcels:720								
# non-RL parcels: 6865	0.026	(0.01)	1.57	(0.73)	0.026	(0.01)	1.49	(0.73)
Post-treatment—exclude parcels preserved by RL program								
$(2) = -2E_C + E_{\phi}$								
# RL parcels: 628								
# non-RL parcels: 6722	0.041	(0.011)	1.97	(1.28)	0.040	(0.011)	1.94	(1.28)
Post-treatment—include parcels preserved by RL program								
$(3) = -2E_C + E_{RL} + E_{\phi}$								
# RL parcels: 672								
# non-RL parcels: 6722	0.101	(0.013)	10.96	(2.38)	0.101	(0.013)	10.94	(2.38)
E_{ϕ}								
$= (1)$	0.026		1.57		0.026		1.49	
E_C								
$= \frac{1}{2}[(1) - (2)]$	-0.008		-0.2		-0.007		-0.23	
E_{RL}								
$= (3) - (2)$	0.06		9		0.061		9	

Table 3.9: Effect of Rural Legacy designation on land preservation from identificaiton strategy two

matchings are significant at 5% level. While for matching of post-treatment non-RL group vs. pre-treatment RL group, only the ATT for likelihood of preservation is significant at 5% level. For identification strategy two, the ATTs from all matching protocols are significant at 5% level. The estimated ATTs vary little across the two matching methods and identification strategies.

The estimated predisposition effect, E_ϕ, in terms of the likelihood of being preserved, is 2.6 percentage points, and in acres is $1.49 - 1.57$. This result indicates that there exist time-invariant unobserved attributes that differentiate parcels in and out of RL areas. Such difference attracts more preservation efforts of non-RL programs before RL program was introduced. The identification strategy two finds a crowding in effect in terms of both likelihood of preservation and acres preserved. While the strategy one finds a contradictory result: a crowding in effect in terms of likelihood of preservation and crowding out effect for acres preserved. This difference in estimation results for strategy one may due to unintended time effect.

The crowded in preservation efforts increase preservation probability in RL areas by $0.7 - 1.0$ percentage points, and increases the preserved acres by $0.2 - 0.23$. In spite of the crowding in effect, RL program has positive impact on preservation outcomes on two levels: a higher likelihood of preservation and more acres/larger preserved parcels. The results show that RL designation increases the probability of preservation by $5.5 - 6$ percentage points and preserved acres by $9 - 12$.

The estimation in this section, however, implicitly assumes that the predisposition effect and time effect is separable. There may exist interaction between the two effects, e.g. predisposition effect is time variant. If this happens, the crowding effect cannot be identified using the proposed strategies. However, the net impact of RL program can still be identified.

3.7 Conclusion

In an attempt to encourage more contiguous preservation, Maryland introduced the Rural Legacy program to preserve large contiguous blocks of land with high social value. Local entities designate preservation areas and become eligible for special funding. The designation of the RL program interacts with and could crowd in or out the preservation efforts of the existing agricultural preservation programs.

The empirical analysis in this paper suggest a crowding in effect of the RL program on the other preservation programs. Overall, the designation appears to have a positive impact on acres retained and on probability of preservation for the identified areas. The program has enrolled more acres and larger parcels due to the extra funding and the new payment schemes based less on market appraisals. However, it is unclear how the crowding in effect impact land conversion, and overall whether the RL program with a crowding in effect reduces land conversion.

Empirical literature has found contradictory effects of land preservation programs on farmland conversion. On one hand, studies find that land preservation programs may impose higher development pressure to neighboring regions. For example, Irwin (2002) has found that preserving neighboring open space increases housing value by $1000 to $3300. Geoghegan, Lynch, and Bucholtz (2003) find that preserved open space increases property values on adjacent residential parcels in Calvert and Howard Counties in Maryland. Roe, Irwin, and Morrow-Jones (2004) find that preservation efforts can generate positive amenities for adjacent homeowners in the form of guaranteed open-space and therefore accelerate conversion. On the other hand, empirical evidence suggests that the option to preserve farmland provided by farmland preservation programs may delay land development. Using a real option approach, Towe, Nickerson and Bockstael (2008) find that the parcels qualified for a preservation option have a 50% lower hazard rate of being developed than unqualified parcels in Howard County, Maryland.

To certain extent, RL program is to avoid to the above-mentioned negative impact on neighboring parcels as it provides continued funding until the contiguous blocks of land are permanently protected. As written in the Rural Legacy Program Grant Manual (2001), sponsors should seek to focus or target their continued funds to protect contiguous blocks of land, rather than scattered parcels that may be individually significant, but which could be surrounded or otherwise adversely affected in the future by development or unprotected lands. Thus, it would be interesting to study the impact of RL program on landowners asking price for land preservation, market value of land and land conversion as the next step. The crowding in effect could slow down land conversion in RL areas and strengthen the effect of RL program on land conversion.

Chapter 4

Land Development Restrictions and Preemptive Action

4.1 Introduction

The Endangered Species Act (ESA), which was passed in 1973, gives federal agencies the power to limit or prohibit any activities that possibly destruct habitat for endangered and threatened species. Although the Fifth Amendment to the U.S. Constitution states that "nor shall private property be taken for public use, without just compensation", limiting property rights under the ESA does not generally grant compensation. In 1983, Congress amended the ESA by adding section 10(a) under which a landowner or a group of landowners can obtain an Incidental Taking Permit (ITP) from Fish and Wildlife Services (FWS) to incidentally "take" a listed species. A "No Surprise" policy was also issued in 1994 to protect landowners from bearing the cost from having to alter HCP due to any unforeseen future change.

Despite these provisions, developing an HCP can lead to substantial costs. This risk of being deprived of development rights or facing larger costs of development can give private landowners incentives to destroy habitat or potential habitat before a species is listed or a Critical Habitat Area takes effect. Indeed, Lueck and Michael(2003) find that the list of Red-cockaded woodpecker (RCW) in North Carolina caused significant habitat destruction. List et al. (2005) find that Critical Habitat designation boosted overall acceleration of land development by one year. The induced preemptive behaviors of landowners contradict the goal of ESA: to protect Endangered Species,[1] which might impose negative impact on society in terms of more serious habitat destruction or earlier loss of habitat for endangered species.

Alternatively to preemptively developing their land, landowners might try to put extra effort to negotiate HCPs (or to submit an extensive HCP at the first place) with more favorable terms, i.e. less costs. This negotiation approach clearly can lead to different regulation levels for different landowners. Although it reduces preemption, the negotiation approach (compromise) can induce more land development in the future.

In this chapter, I address the issue of preemptive land development, compromise, and differentiated treatment of landowners. The listing of Endangered Species or the designation of Critical Habitat can be viewed as changes of regulatory status. Such changes impose extra cost on land development in the future due to the requirement of a HCP for an ITP. In order to avoid the cost, some landowners develop land before the new regulation takes effect (preemption). The preemptive land development causes earlier habitat loss or even more serious habitat destruction than it should be. Regulator can reduce preemption through reducing the standard for HCP, therefore the extra cost for future land development. Social welfare can be improved as

[1] The listing process of a endangered species or Critical Habitat design is long and usually take about two years and even longer. Landowners, foreseeing the deprivation of their development right in the future, would take action to acquire building or construction permits before the list of endangered species or critical habitat takes effect.

compromise reduces preemptive land development. However, compromise can, at the same time, induce welfare loss as it allows more land being developed after a new regulation takes effect. A regulator, as a social welfare maximizer, will have to balance the two effects: improving social welfare from reducing preemption and harming social welfare from allowing more land being developed in the future.

I use a two-period model similar to Miceli and Segerson (1996) and assume irreversibility of development decisions. I derive the conditions under which compromise can improve welfare and, more important, demonstrate that differentiated treatment can be beneficial in order to avoid preemption by landowners. I thereby explicitly consider the case that landowners are heterogeneous in their propensity to develop land in either of the two periods or never. Furthermore, the future value of developed land is subject to ex ante uncertainty. While preemptive development reduces/eliminates the costs from future regulation, it may induce opportunity cost of landowners in second period when the realized value for developing land in the future is high.

In the analysis, I focus on how the development decision of landowners is affected by regulatory stringency levels, i.e. the costs of development in the second period. As different landowners have different thresholds above which to preempt, I show when a regulator should compromise and how he can create differentiated policies for different types of landowners to reduce preemption. The downside to such a policy are the information requirements on the side of the regulator. The case of asymmetric information is therefore addressed in this chapter. Using a mechanism design approach, I show that still a differentiated treatment of landowners might be beneficial. This mechanism allows some landowners to receive a reduced costs of development in the second period against an ex ante payment.

In the ESA context, I can interpret this mechanism as different landowners having different incentives to submit an extensive HCP or put more effort to communicate with different interests groups for a larger waiver of future land development cost imposed by the ESA. This treatment under the situation of asymmetric information provides a new and important rationale for differentiated treatment of landowners as in bilaterally negotiated HCPs.

The remainder of the paper is organized as follows. I review literature on regulatory takings, discuss ESA and the incentive for preemption in Section 4.2. Section 4.3 is the theoretical model. Section 4.3.1 gives the basic setup of the theoretical model. I discuss the case of first-best regulation in section 4.3.2 and then show how the missing regulation in the first period can lead to preemption (Section 4.3.3). The optimal regulation under perfect information is discussed in Section 4.3.4. I distinguish the case where the regulator can differentiate policies across landowners and the case where he is restricted to a one-fits-all regulation. Section 4.3.5 then discusses regulation under asymmetric information. I then discuss possible extensions to the model and conclude in Section 4.4.

4.2 Regulatory Takings and Endangered Species Act

The ESA, described as one of the most comprehensive and controversial wildlife laws, has received much discussions and opposition. According to a research by Hendrickson (2005) on the coverage of the ESA from September 2002 to September 2003 in four major newspapers (Chicago Tirbune, Los Angeles Times, the New York Times, and the Washington Post), the ESA received the second highest number of references in the year among all the major federal environmental statutes, second only to the Clean

Air Act. ESA is criticized on one hand for ineffectiveness of protecting species, and on the other hand for its lack of "fairness"–harming landowners' land development rights for public interests. According to Hendrickson (2005), ESA, on one hand, is criticized for killing construction plans for hospitals, schools, depriving of water rights, land development rights, and so on. It, on the other hand, is criticized as not doing enough and not effective to protect the mother nature.

An extensive literature has developed that discusses compensation or taxation schemes in order to deal with individual landowners' non-optimal incentives to develop land or make costly investments under the threat of takings. The rationale for regulation is the divergence of the private from the public value of land and the induced externalities from private land development. Starting with Blume et al. (1984), many authors have addressed the issue of compensation for takings in order to reflect the above notion of property rights. Innes et al. (1998), Innes (1997, 2000), Shapiro (2003) and others show that compensation can be problematic as it might distort investment decisions. Miceli and Segerson (1994) suggest a compensation scheme which conditions payments on the optimal land use decision in an earlier period. While the studies of compensation apply directly to much of current legislation, limiting property rights under the ESA does not generally grant compensation.

The ESA make it illegal to kill, harm or take a listed endangered or threatened species (ESA Section 9). The "take" for endangered animal is defined as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect". The "harm" is defined as "which actually injures or kills wildlife, including acts which annoy it to such an extent as to significantly disrupt essential behavioral patterns, which include, but are not limited to, breeding, feeding, or sheltering, and significantly environmental modification or degradation which has such effect". For plants "take" means that it is unlawful to collect or maliciously damage any endangered plant on land under Federal jurisdiction. Removing or damaging listed plants on State and private land in knowing violation of State law, or in the course of violating a State criminal trespass law, also is illegal under the ESA (ESA section 3).

The definitions link "take" and "harm" to private landowner's right to use or develop their land. A private landowner has an obligation to prevent the "taking" of the endangered species inhabit in his land. In 1975, FWS promulgated regulations defining harm to include some forms of habitat modification. If an endangered or threatened species is identified in their land or their land is identified to be potential habitat for an endangered species, it is unlawful for the landowner to harvest timber, fishing, develop land to residential or commercial use or other agricultural activities as those activities are likely to "harm" the species.

In 1983, Congress amended the ESA by adding section 10(a) under which a landowner or a group of landowners can obtain an Incidental Taking Permit (ITP) from Fish and Wild life Services (FWS) to incidentally "take" a listed species. In exchange for a ITP, landowners have to prepare a Habitat Conservation Plan (HCP) that aims to minimize and mitigate the impact of permitted land development. That is, by bearing some costs for addressing public concerns regarding endangered species, the landowners keep the right to develop their property. In 1994, Former Secretary of the Interior Bruce Babbitt issued a "No Surprise" policy. This policy allows the insertion of a provision in every HCP that if changes to the plan were necessary due to unforeseen circumstances, the private landowner would not be required to pay for the implementation of those changes. Landowners apparently appreciated the added certainty of the policy. In the year between 1982 and 1994, before the No surprise policy was adopted, a total of 21 HCPs were approved. In 1995 alone, a total of 34 were approved and by September 30, 2007, 536 plans have been approved. (FWS, Conservation Plans and Agreements Database, 2007)

In reality, most section 10(a) permits have been issued only after elaborate negotiations between applicants, FWS, local planning agencies, and other local interest groups. There are no statutory time-frames for the permit process, and most applications take years for development and approval (an average of 5 years according to the team of Etowah aquatic habitat conservation plan). Although the FWS attempted to streamline the permitted process for low-effect HCPs to 3 months and 6-12 months for HCPs that require Environmental Assessment or Environmental Impact Statement from the date they are submitted to FWS, it is time consuming and expensive to develop a HCP. For examples, the Clark County Habitat Conservation Plan (30 year for protecting desert tortoise) in the state of Nevada, takes 4 years to reach an agreement and being approved (1992-1995) (Bernazzani, 1998). A multi-species HCP in San Diego County has taken more than seven years to develop and will cost more than $400 million over 20 years to implement (Merrick, 1998). Etowah aquatic HCP in Georgia takes 5 years to develop and receive approval from FWS (Etowah aquatic habitat conservation plan).

Although being costly and time-consuming, the negotiation process allows landowners to bargain with FWS on the extent they have to protect species through HCPs through various ways. This is sometimes criticized as a shortcoming of HCPs and claimed that many of the plans favor development over endangered species and prone to influence by interest groups. Anecdotal evidence of interest groups exerting pressure to protect development rights is common: in the case of the Pygmy Owl in Arizona, the National Association of Home Builders and other associations launched a lawsuit against the U.S. Fish and Wildlife Service's critical habitat designation and the U.S. Supreme Court set aside the designation in 2001. In the case of endangered species, Ando (1999) finds that public opposition and support can substantially slow or hasten the listing process of species into endangered or threatened. McClure and Stiffler (2005a, 2005b) discuss the issue of HCP formulation in the Seattle Post Intelligencer – criticizing the major influence of interest groups and the focus on allowing investment.

Despite those criticism, this way of compromise may represent the best hope to gain landowners's willingness to protect listed species while taking their property right for public interests without compensation. According to a 1993 study by the Association for Biodiversity Information and the Nature Conservancy, half of listed species have at least 80% of their habitat on private land. About 90% of the listed species are found on private land (Brown et. al 1998). Because of the dependence of endangered species on private land, private landowner's participation in endangered species conservation is critical to successful species recovery.

4.3 Theoretical Model

4.3.1 Basic setup

The model is built upon a two-period framework and is similar to Miceli and Segerson (1996). I model a community with N landowners who each owns one unit of undeveloped land. A landowner can choose to develop his land in period 1, period 2 or never to develop his land. The value of one unit of developed land to landowners is identical for every landowner and is denoted in period 1 by V_D^1. The value in period 2, v_D^2, is uncertain in period 1, follows a distribution $G(v_D^2)$ (density $g(v_D^2) > 0$ on the support $[\underline{v}^2, \bar{v}^2]$), and is revealed before the start of the second period. Landowners differ with respect to the value of their land if left undeveloped, denoted by V_i^1 and V_i^2 in the two periods, respectively. The value of undeveloped land is known to the landowner but not necessarily to the regulator. I consider both the case of perfect information and of asymmetric information in which a regulator is not perfectly informed on the specific land values.

Land development generates negative externalities to the community. The (net present value of the) negative externality is E^1 per parcel of land if it is developed in period 1 and E^2 if in period 2. Landowners are assumed to care only about the value of their land and not about externalities.

To address these externalities, I assume that the regulator considers a taxation of development, which is equivalent to imposing a develop cost, at level τ^t in period t. The timeline of the events is: (1) the regulator proposes regulation which takes effect in period 2, (2) landowners make individual decisions whether they develop land in period 1. (3) the value of land in period 2, v_D^2 is revealed, (4) landowners decide on development in period 2.

4.3.2 Private vs. socially optimal development decisions

Given regulation (τ^1, τ^2), I first consider the private decisions of the respective landowners. I start with the decision in period 2, given that the landowner i leaves the land undeveloped in period 1.

Here, landowner i develops land if

$$v_D^2 - \tau^2 > V_i^2 \tag{4.1}$$

and leaves the land undeveloped otherwise. Taking this decision into account, leaving land undeveloped gives an option value in the first period

$$O(V_i^2, \tau^2) = \int_{V_i^2+\tau^2}^{\bar{v}^2} [v_D^2 - \tau^2] dG(v_D^2) + V_i^2 G(V_i^2 + \tau^2) \tag{4.2}$$

which leads to the following decision rule in the first period: landowner i develops the land in the first period if and only if

$$V_D^1 - \tau^1 > V_i^1 + O(V_i^2, \tau^2). \tag{4.3}$$

It is obvious, that the socially optimal land development potentially deviates from the private incentives. In period 2, it is socially optimal to develop land if

$$v_D^2 - E^2 > V_i^2 \tag{4.4}$$

and therefore, land should only be developed in period 1 if

$$V_D^1 - E^1 > V_i^1 + O(V_i^2, E^2) \tag{4.5}$$

Comparing condition (4.3) with (4.5) and (4.1) with (4.4), I obtain the well-known condition of first-best Pigouvian taxation: $\tau^1 = E^1$ and $\tau^2 = E^2$. To achieve first-best, the regulator necessarily needs to apply taxes in both periods. In this chapter, however, I focus on a situation where regulation only applies in the future (i.e. in period 2) and therefore $\tau^1 = 0$. I therefore study situations where the regulator is bound to regulate via choosing the tax level τ^2.

Equation (4.3) implies that the private option value determines the decision to preempt. To see how land development depends on τ^2 and the type of the landowner, I partially differentiate (4.2):

$$\frac{\partial O}{\partial V_i^2}(V_i^2, \tau^2) = G(V_i^2 + \tau^2) \geq 0 \tag{4.6}$$

$$\frac{\partial O}{\partial \tau^2}(V_i^2, \tau^2) = -(1 - G(V_i^2 + \tau^2)) \leq 0 \tag{4.7}$$

$$\frac{\partial^2 O}{\partial V_i^2 \partial \tau^2}(V_i^2, \tau^2) = g(V_i^2 + \tau^2) > 0 \tag{4.8}$$

From equation (4.1), (4.3), and (4.6)-(4.8), I immediately obtain the following results for the landowners' reactions to changes in the tax system:

Lemma 1 *(i) The option value $O(V_i^2, \tau^2)$ is decreasing in τ^2 but increasing in V_i^2. Landowners with a larger V_i^2 benefit less from a reduction in τ^2.*

(ii) A larger τ^2 reduces a landowner's incentive to develop land in the second period, given that land stayed undeveloped in the first period. However, a larger τ^2 generates more incentive for a landowner to develop land in the first period.

(iii) An increase in τ^1 leaves the conditional second period decision unaffected but decreases development in the first period.

Lemma 1 (iii) shows that missing regulation in period 1 ($\tau^1 = 0$) can drive landowners into preemption compared with the socially optimal level ($\tau^1 = E^1$). Since the option value of postponing the development decision is decreasing in τ^2 (Lemma 1 (i),(ii)), a way to reduce preemption is to compromise, i.e. to regulate at $\tau^2 < E^2$ instead of $\tau^2 = E^2$. This way of compromise, however, distorts land development decision in period 2 (Lemma 1 (ii)).

To analyze preemption given that $\tau^1 = 0$, it proves helpful to consider the tax level $\bar{\tau}^2$ where landowner of type i is indifferent between developing land in the first period and not developing. It is denoted by $\bar{\tau}_i^2$ and implicitly defined by:

$$V_D^1 = V_i^1 + O(V_i^2, \bar{\tau}_i^2)$$

if a finite solution exists, and $\bar{\tau}_i^2 = \infty$ if $V_D^1 < V_i^1 + O(V_i^2, \tau^2)$ for all finite τ^2.

$\bar{\tau}_i^2$ is therefore an an alternative way to indicate landowners' type (V_i^1, V_i^2): given $\tau^1 = 0$, the landowner i develops land in period 1 if and only if $\tau^2 > \bar{\tau}_i^2$. Shifting regulation from one side of $\bar{\tau}_i^2$ to the other will induce landowners of type i to change their land development decision in period 1. Note that this threshold value can take positive or negative values. That is, in the extreme case the "tax" would have to turn into a subsidy in order to prevent preemptive action of a landowner.

In order to formally discuss the effect of regulation on social welfare and thereby the optimal level of compromise, i.e. τ^2, I introduce the notion of social option value. It differs from the private option value by the expected value of externality minus the tax, as the tax payments are considered as a transfer among households:[2]

$$\begin{aligned} OS(V_i^2, \tau_2) &= \int_{V_i^2+\tau^2}^{\bar{v}^2} [v_D^2 - E^2] dG(v_D^2) + V_i^2 G(V_i^2 + \tau^2) && (4.9) \\ &= O(V_i^2, \tau_2) - (E^2 - \tau^2)(1 - G(V_i^2 + \tau^2)) && (4.10) \end{aligned}$$

Assuming that there are no shadow costs of social funds, and that taxes are redistributed lump sum to households, social welfare is then formally given by:

$$W(\tau^2) = \sum_{i:\tau^2 > \bar{\tau}_i^2} [V_D^1 - E^1] + \sum_{i:\tau^2 \leq \bar{\tau}_i^2} [V_i^1 + OS(V_i^2, \tau^2)] \quad (4.11)$$

4.3.3 Reducing preemption – increasing welfare

While optimal regulation involves $\tau^1 = E^1$ and $\tau^2 = E^2$, I now address the question how the regulator's decision on τ^2 should reflect the lack of regulation in the first period ($\tau^1 = 0$). For this, I first explore how social welfare changes with marginal changes in the regulation level τ^2 and discuss the optimal differentiated and undifferentiated taxation in the next section.

Studying conditions (4.7) and (4.9) immediately gives the following result:

$$\frac{\partial OS}{\partial \tau^2}(V_i^2, \tau^2) = (E^2 - \tau^2) g(V_i^2 + \tau^2). \quad (4.12)$$

[2]Compare with Innes (2000) who describes this value as "public use value are in private hands"

At a level where $\tau^2 \neq \bar{\tau}_i^2$ for all i, any small change of τ^2 therefore does not induce any landowner to change his development decision:

$$\frac{\partial W}{\partial \tau^2}(0, \tau^2) = \sum_{i:\tau^2 \leq \bar{\tau}_i^2} (E^2 - \tau^2) g(V_i^2 + \tau^2). \tag{4.13}$$

At tax level $\bar{\tau}_i^2 < \infty$, at which landowner i is indifferent between developing land in period 1 or waiting, a marginal change in τ^2 induces landowner i to change his development decision. This implies that the social welfare function is no longer differentiable at $\bar{\tau}_i^2$. The change in social welfare induced by the change in τ^2 at $\tau^2 = \bar{\tau}_i^2$ is:

$$\lim_{\tau^2 \uparrow \bar{\tau}_i^2} W(\tau^2) - \lim_{\tau^2 \downarrow \bar{\tau}_i^2} W(\tau^2) = k_i[E^1 - (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))] \tag{4.14}$$

where $k_i = \#\{j : \bar{\tau}_j^2 = \bar{\tau}_i^2\}$

Here, $\lim_{\tau^2 \uparrow \bar{\tau}^2} W(\tau^2)$ defines the social welfare when τ^2 is below but sufficiently close to $\bar{\tau}_i^2$ such that the landowners of type i comply with the regulation and do not preempt, $\lim_{\tau^2 \downarrow \bar{\tau}_i^2} W(\tau^2)$ when τ^2 is above and sufficiently close to $\bar{\tau}_i^2$ such that landowners of type i preemptively develop land.

Equations (4.13) and (4.14) describe how marginal changes in τ^2 affect social welfare depending on the level of τ^2 when $\tau^1 = 0$. If $\tau^2 \neq \bar{\tau}_i^2$ for all i, marginal changes in τ^2 do not change any landowner's development decision in the first period. Here, social welfare increases with τ^2 as long as $\tau^2 < E^2$ since second period development moves closer to the social 0optimum for all landowners who wait to develop land (equation 4.13). However, if τ^2 coincides with $\bar{\tau}_i^2$ for some i, social welfare reacts discontinuously to a marginal increase in τ^2: depending on the sign of equation (4.14), social welfare increases or decreases as landowners with $\tau^2 = \bar{\tau}_i^2$ change their decision from not developing land in the first period to preemptively developing land.

The effect of τ^2 on development decision and social welfare is illustrated in Figures

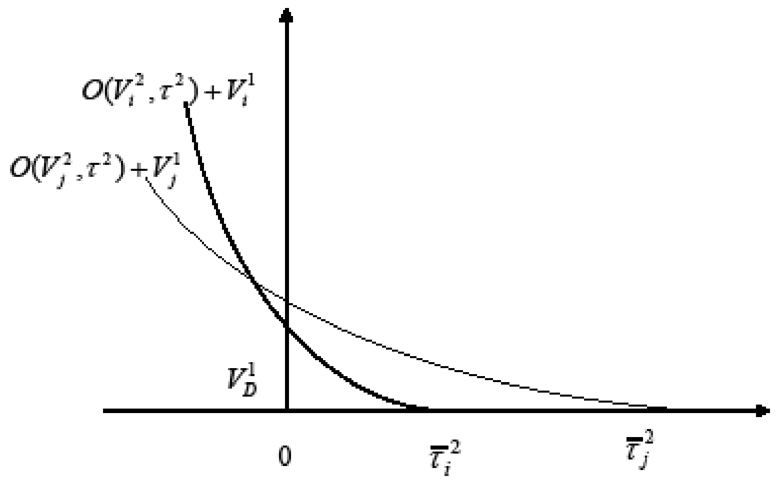

Figure 4.1: Illustration of private option values as a function of τ^2

4.1 and 4.2 with two types of landowners i and j ($V_i^2 < V_j^2$ and $\bar{\tau}_i^2 < \bar{\tau}_j^2 < E^2$). Figure 4.1 demonstrates private value functions and Figure 4.2 social value functions for each of the two types. When τ^2 takes values in the ranges of $(-\infty, \bar{\tau}_i^2)$, $(\bar{\tau}_i^2, \bar{\tau}_j^2)$, or $(\bar{\tau}_j^2, E_2)$, no landowner's first period development decision changes with a marginal change in τ^2. For example, if $\tau^2 \in (\bar{\tau}_i^2, \bar{\tau}_j^2)$, type i landowner preemptively develops land and type j complies the regulation. The social welfare function is differentiable and social welfare increases with τ^2 in the range. However, at $\tau^2 = \bar{\tau}_i^2$ or $\tau^2 = \bar{\tau}_j^2$ a marginal increase of τ^2 induces landowner i or j to change their development decision in the first period. Correspondingly, the social value function is no longer differentiable at $\bar{\tau}_i^2$ and $\bar{\tau}_j^2$. Social value jumps from $V_i^1 + OS(V_i^2, \tau^2)$ or $V_j^1 + OS(V_j^2, \tau^2)$ to $(V_D^1 - E^1)$ at $\bar{\tau}_i^2$ or $\bar{\tau}_j^2$.

From (4.13) and (4.14), I obtain the following lemma:

Lemma 2 *When the regulatory instrument is missing in period 1 ($\tau^1 = 0$),*

(i) second-best welfare $W(\tau^2)$ is increasing in τ^2 for $\tau^2 < E^2$ as long as a marginal

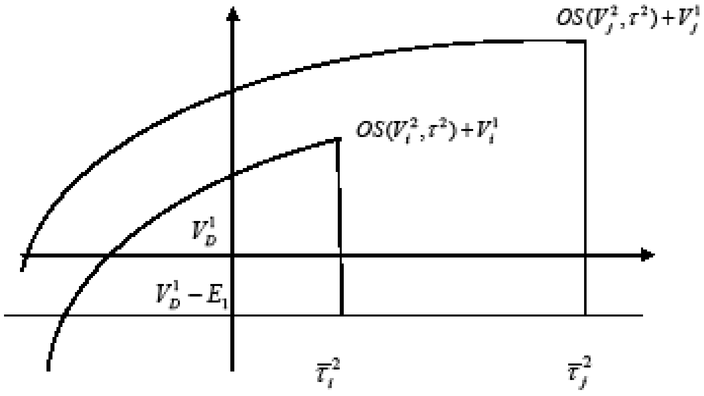

Figure 4.2: Illustration of social option values as a function of τ^2

decrease in τ^2 does not change the decision of any landowner in the first period and at least one landowner does not develop land in the first period.

(ii) a marginal decrease of τ^2 increases welfare if and only if $E^1 > (E^2 - \tau^2)(1 - G(V_i^2 + \tau^2))$ at a finite level $\tau^2 = \bar{\tau}^2$ where a landowner i is indifferent between developing the land in period 1 or waiting.

Lemma 2 demonstrates two opposing effects of changes in the second period regulation level τ^2 on welfare: (i) a reduction of τ^2 below E^2 distorts the second period development decision and thereby generally reduces welfare (equation 4.13). (ii) If, however, by a marginal decrease in τ^2, at least one landowner shifts from preemption to preserving land in period 1, welfare can increase (equation 4.14). The decision about a further reduction of the tax rate – i.e. on further compromising – must therefore evaluate whether the negative welfare from landowners who do not develop land in the first period (effect (i)) is offset by the welfare gain from changing the first period development decision of other landowners (effect (ii)).

In particular, note that no distortions occur if $\bar{\tau}_i^2 \geq E^2$ for all i, i.e. if the impossibility to regulate in the first period (i.e. $\tau^1 = 0$) while keeping the second period tax at $\tau^2 = E^2$ does not induce any landowners to change their first period decision. Here, from Lemma 2 (i) it follows that the optimal tax level is still $\tau^2 = E^2$. The case where the lack of regulation in the first period leads (some) landowners into preemption is clearly the more interesting case and the focus of the following analysis.

I distinguish different versions of the model: I first consider the case where the regulator is perfectly informed on the types (i.e. on V_i^t and therefore on $\bar{\tau}_i^2$) and (i) can, (ii) cannot use differentiated policies for different landowners. In a second step, I then consider a regulator who is not informed on the types of specific landowners but bases the policy on beliefs over a distribution of types.

4.3.4 Perfect information

I first study the case of a perfectly informed regulator who can differentiate policies across landowners. Here, Lemma 2 immediately implies that the optimal tax level for the landowner of type i is given by $\tau_i^{2*} = E^2$ if $\bar{\tau}_i^2 \geq E^2$. Further, if $\bar{\tau}_i^2 < E^2$ and

$$E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2)), \tag{4.15}$$

it is beneficial to compromise to bring landowner i out of preemption. The conditions imply that if $\bar{\tau}_i^2 < \infty$, but compromising until this level where the landowner chooses not to preempt would imply $E^1 < (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$, the landowner should be left in the preemption mode. In this case, the tax level could be chosen at $\tau_i^{2*} = E^2$. The intuition behind this result is that bringing one player out of preemption reduces the externality by E^1 but also imposes welfare losses in the second period as the landowner is more likely to develop land due to the reduced τ^2. If now, the potential distortions in the second period, $(E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$, are severe compared to those in the first period, the landowner should rather be left to preempt. Note, however, that this case cannot occur if $E^1 \geq E^2$.

Proposition 1 *A perfectly informed regulator who can differentiate policies across landowners, should either regulate a landowner at $\tau^2 = E^2$ or – if $\bar{\tau}_i^2 < E^2$ and $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$ – compromise with the individual landowner in a way which just makes him slightly better off from not developing in the first period.*

Proposition 1 shows that it is not necessarily optimal for a regulator to compromise in a way to prevent preemptive behavior. Compromising itself could be more costly to society than letting the landowner develop the land in the first period. However, when the social damage from preemptively developing land is sufficiently high, it is always beneficial to compromise to each individual landowner so to prevent them from preemption.

In general, however, it might be problematic for the regulator to differentiate policies across landowners. If he cannot differentiate τ^2 across landowners, it again follows from Lemma 2 that regulation can only be optimal at levels $\tau^2 \in \{E^2, \bar{\tau}_1^2, \ldots, \bar{\tau}_n^2\}$. Here, a reduction in τ^2 leads to welfare losses from those landowners who do not develop in period 1 and for whom a reduction in the tax rate distorts their second period decisions. One could however obtain a welfare gain from reducing the number of preempting landowners.

This immediately shows that for the determination of the optimal regulation level, the distribution of types is decisive:

Proposition 2 *A perfectly informed regulator who cannot differentiate policies across landowners, chooses $\tau^2 \in \{E^2, \bar{\tau}_1^2, \ldots, \bar{\tau}_n^2\}$. The optimal decision crucially depends on the distribution of types $(\bar{\tau}_1^2, \ldots, \bar{\tau}_n^2)$.*

To illustrate how the optimal regulation level depends on the distribution of types, I derive analytical results for the case in which landowners can only be of two different types L and H ($\bar{\tau}_L^2 < \bar{\tau}_H^2$); the number of the respective types is denoted by n_L and n_H. For simplicity, I assume that $E^1 > (E^2 - \bar{\tau}_i^2)(1 - G(V_i^2 + \bar{\tau}_i^2))$, i.e. it is always beneficial to reduce the tax rate marginally if this induces additional landowners to refrain from preemption. Furthermore, I assume $\bar{\tau}_L^2 < E^2$ such that (at least) landowners of low type preempt at $\tau^2 = E^2$.

Defining $\tau_H^2 = \min[\bar{\tau}_H^2, E^2]$, I then have to compare the welfare at $\tau^2 \in \{\bar{\tau}_L^2, \tau_H^2\}$. With conditions (4.9) and (4.11), I obtain:

$$\begin{aligned} &\lim_{\tau^2 \uparrow \tau_H^2} W(\tau^2) < \lim_{\tau^2 \uparrow \bar{\tau}_L^2} W(\tau^2) \\ \Leftrightarrow\quad & n_H \underbrace{[OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}_{>0} < n_L \underbrace{[E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2))]}_{\geq 0} \end{aligned} \tag{4.16}$$

which shows that it is welfare-maximizing to choose $\tau^2 = \bar{\tau}_L^2$ if and only if the number of low type players is sufficiently large. In other words, the benefits from preventing a sufficient number of low types from preemption must be large enough to compensate for the welfare loses from distorted second-period decisions of high type landowners. Note that condition (4.16) will also hold for a given number of high and low types, if the threshold levels $\bar{\tau}_L^2$ and $\bar{\tau}_H^2$ are sufficiently close to each other.

To further illustrate these analytical results and Proposition 2, I now discuss simulations for different distributions of types. I use the following example: $E^1 = E^2 = 50$, $V_D^1 = 55$ and second period land values v^2 uniformly distributed in $[0, 100]$. I fix $V_L = V_L^1 = V_L^2 = 5$, but consider different values of $V_H = V_H^1 = V_H^2 \geq V_L^2$.

Figures 4.3 and 4.4 illustrate the social welfare at different level of τ^2 when $V_H \in \{8, 20\}$ and $n_L = 2$, $n_H = 3$. For these values, all landowners preempt when regulator sets $\tau^2 = 50$. A reduction in τ^2 from 50 reduces social welfare until high type

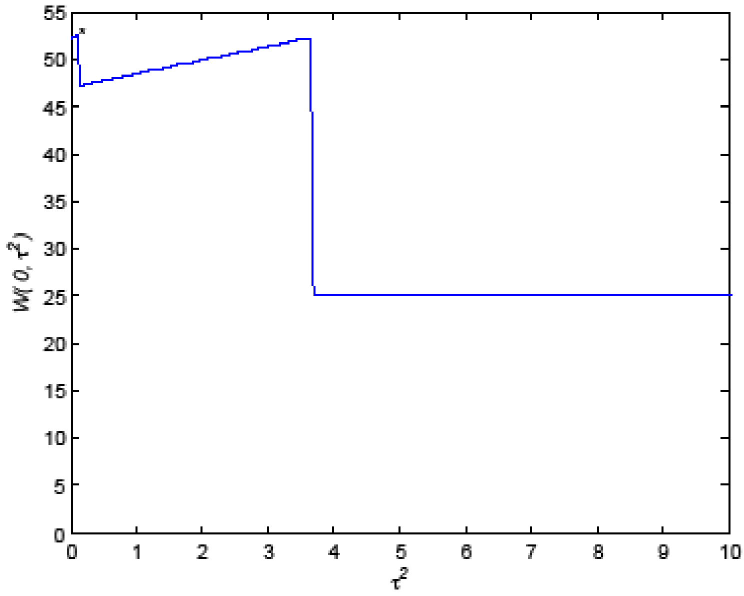

Figure 4.3: Illustration of welfare as a function of τ^2 for $V_H = 8$, $V_L = 5$, $n_H = 3$, $n_L = 2$, $E_1 = E_2 = 50$

landowners decide not to develop land in period 1, i.e. until $\tau^2 = \bar{\tau}^2_H$. Similarly, a discontinuity occurs when the preemption threshold $\bar{\tau}^2_L$ is reached for type L. It can be seen from the figures that the optimal regulation level crucially depends on the distribution of types: when $V_L = 5$ and $V_H = 8$ as in Figure 4.3, the welfare gain from preventing low type landowners from preemption just outweighs the welfare loss from reducing τ^2 to $\bar{\tau}^2_L$. It is optimal for regulator to compromise so that no landowner will preempt. However, if $V_H = 20$ and thereby V_H is sufficiently larger than V_L (Figure 4.4), the welfare gain from preventing the low type from preempting no longer outweighs the welfare loss, and it is optimal to regulate at $\bar{\tau}^2_H$ and let low type players preempt.

The optimal regulation for a given V_H and V_L crucially depends on the distribution of types, i.e. on the fraction $n_L/(n_H + n_L)$ of low types (see equation (4.16)). For any combination of V_H and V_L, condition (4.16) defines a threshold value $\tilde{f}_L$ such that

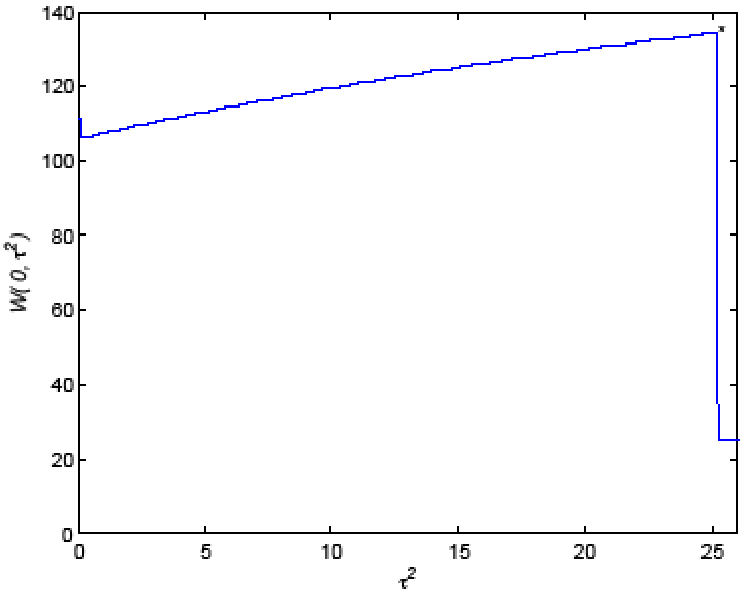

Figure 4.4: Illustration of welfare as a function of τ^2 for $V_H = 20$, $V_L = 5$, $n_H = 3$, $n_L = 2$, $E_1 = E_2 = 50$

regulation at $\tau^2 = \bar{\tau}^2_H$ is optimal for $n_L/(n_H + n_L) < \tilde{f}$ while regulation at $\tau^2 = \bar{\tau}^2_L$ is optimal for $n_L/(n_H + n_L) > \tilde{f}$. This threshold value is illustrated in Figure 4.5 for $V_L = 5$ and $V_H \in [5, 100]$. Interestingly, this threshold value is non-monotonic in V_H. The intuition is that the second-period distortions for high types from choosing $\bar{\tau}^2_L$ instead of τ^2_H, i.e.

$$OS(V_H, \tau^2_H) - OS(V_H, \bar{\tau}^2_L) = \int_{V^2_H + \bar{\tau}^2_L}^{V^2_H + \tau^2_H} [V^2_H - v^2_D + E^2] dG(v^2_D)$$

depend on both the value difference between V^2_H and the realized development value v^2_D, and the probability of development in the second period $1 - G(V^2_H + \tau^2)$ at the two regulation levels. While the former is increasing in V_H, the latter is decreasing in V_H. In the extreme, when $G(V^2_H) = 1$, changing the tax rate for H does not matter at all as these landowners will never develop land.[3]

[3]Therefore, $\tilde{f} = 0$ for $V_H + \bar{\tau}_L \geq 100$ in the example in Figure 4.5.

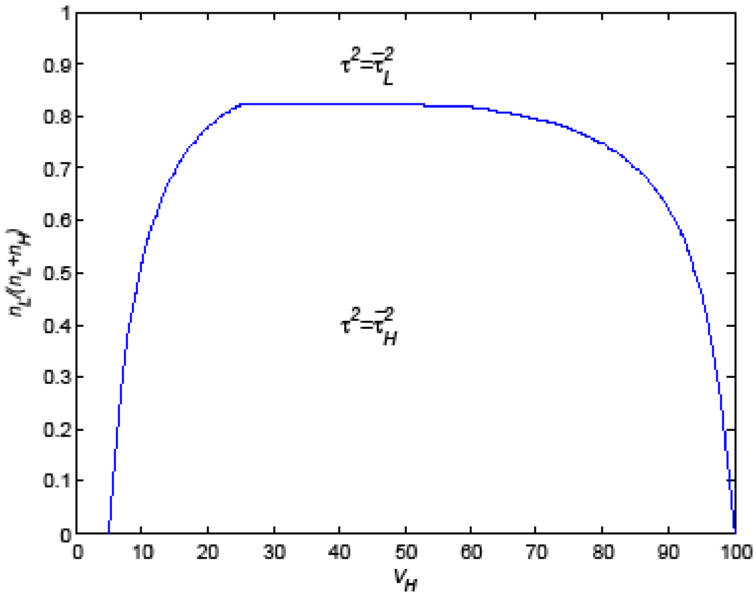

Figure 4.5: Illustration of optimal uniform regulation and threshold values $\widetilde{f_L}$ for the ratio $n_L/(n_L+n_H)$ as a function of V_H ($V_L = 5$, $E_1 = E_2 = 50$)

In Figure 4.6 and 4.7, I relax the assumption of having two types of landowners. I add a medium type V_M besides the low and high types ($n_L = 2$, $n_H = 2$, $n_M = 1$). In Figure 4.6, the median type has value $V_L = 5 \leq V_M \leq 20 = V_H^2$. From Figure 4.5, I know that the optimal regulation level is given by $\bar{\tau}_H^2$ both if $V_M = 20$ and if $V_M = 5$. However, for intermediate levels of V_M, the optimal regulation is different: it is still optimal to regulate at $\bar{\tau}_H^2$ when V_M is below approximately 10, i.e. when it would be too costly to compromise to a level which brings type M out of preemption. Compromising to $\tau^2 = \bar{\tau}_M^2$ is, however, worthwhile if V_M is sufficiently close to V_H. In this case, the optimal regulation is therefore non-monotonic in V_H as depicted in Figure 4.6. This is different for smaller levels of V_H: in Figure 4.7, I chose $V_H = 10$ such that regulation at $\tau^2 = \bar{\tau}_L^2$ is optimal if $V_M = V_L$, while $\tau^2 = \bar{\tau}_H^2$ results if $V_M = V_H$. It is again optimal to regulate at $\bar{\tau}_L^2$ if V_M is small (≤ 8.1) while it becomes optimal to regulate at $\bar{\tau}_M^2$ when V_M is sufficiently large. Intuitively, in this

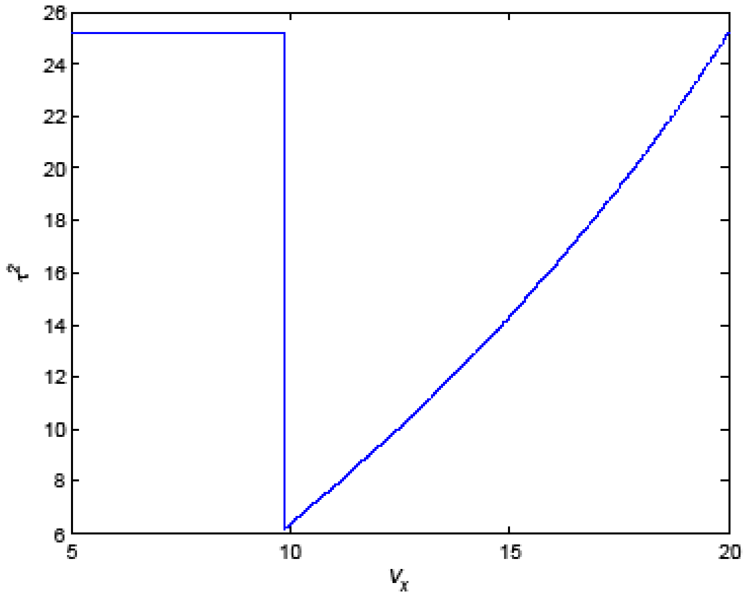

Figure 4.6: Optimal regulation τ^2 as a function of V_M ($V_H = 20$, $V_L = 5$, $n_H = 2$, $n_L = 2$, $n_M = 1$, $E_1 = E_2 = 50$)

case, the second period distortions for type H are smaller than the welfare gains from preventing M from preempting.

Figures 4.6 and 4.7 thereby nicely illustrate the sensitivity of optimal regulation to the distribution of landowners' values. Unless the regulator is perfectly informed about the landowners' types, he can therefore hardly design an optimal policy. I therefore now turn to the case when the regulator is not perfectly informed about the types of specific landowners.

4.3.5 Asymmetric information

I first consider the case of individual regulation where regulation can differ between landowners. I again concentrate on the case of two potential player types of L and H. The probability that the landowner is type $i \in \{L, H\}$ with values V_i^t in both periods and induced threshold value $\bar{\tau}_i^2$ is denoted by f_i.

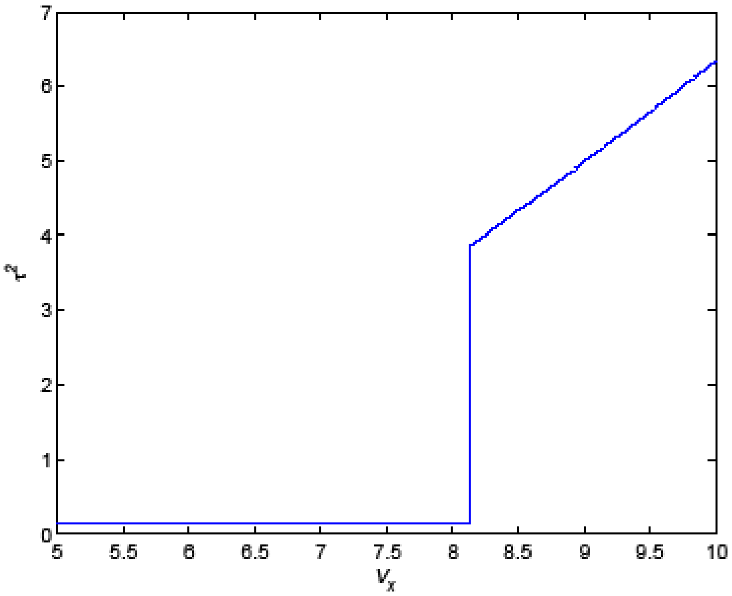

Figure 4.7: Optimal regulation τ^2 as a function of V_M ($V_H = 10$, $V_L = 5$, $n_H = 2$, $n_L = 2$, $n_M = 1$, $E_1 = E_2 = 50$)

Expected welfare when regulating at τ^2 is given by

$$\sum_{i \in \{L,H\}} f_i \left[d^1(i,\tau^2)(V_D^1 - E_1) + (1 - d^1(i,\tau^2))(V_i^1 + OS(V_i^2, \tau_2)) \right]$$

where $d^1(v_i, \tau^1, \tau^2)$ is a dummy variable for the development decision and $d^1(v_i, \tau^1, \tau^2) = 1$ if landowner i develops in the first period. Due to my assumption of linear damages, the optimality condition resembles the decision for multiple landowners in the previous section (see condition (4.16)). If $\bar{\tau}_i^2 \geq E^2$, nobody would preempt and the optimal regulation is $\tau^2 = E^2$. Again denoting $\tau_H^2 = \min[\bar{\tau}_H^2, E^2]$, and analogously to (4.16), I obtain:

$$\lim_{\tau^2 \uparrow \tau_H^2} W(0,\tau^2) < \lim_{\tau^2 \uparrow \bar{\tau}_L^2} W(0,\tau^2) \tag{4.17}$$

$$\Leftrightarrow \quad f_H [\underbrace{OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)}_{>0}] < f_L [\underbrace{E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2))}_{\geq 0}] \tag{4.18}$$

such that the regulator would lean towards regulating at level $\tau^2 = \bar{\tau}_i^2$ if the probability that a landowner is of type i is sufficiently high. Note however that there is potential for mistake: if the regulator chooses $\tau^2 = \bar{\tau}_H^2$, a low type landowner will preempt and thereby potentially cause large externalities in the first period. If $\tau^2 = \bar{\tau}_L^2$ is chosen but the landowner turns out to be of high type, his second period decisions will be distorted towards increased development such that again welfare losses result.

I therefore now study if the regulator can improve upon the welfare generated by a decision under asymmetric information (given by (4.18)). I consider a signaling approach where the regulator offers two regulation menus which the landowner can choose: (p_i, τ_i) $(i \in \{L, H\})$ where p_i is an ex ante fee that the landowner has to pay in order to face regulation $\tau^2 = \tau_i$ in the second period.

This menu must satisfy the individual incentive compatibility constraint (IC). That is, the expected profit for type i landowner should be larger under (p_i, τ_i) than under the alternative regulation schedule:

$$\text{(IC)}\ \max[V_D^1, V_i^1 + O(V_i^2, \tau_i)] - p_i \geq \max[V_D^1, V_i^1 + O(V_i^2, \tau_j)] - p_j \tag{4.19}$$

for $i \in \{L, H\}$ and $j \neq i$. I show the following lemma:

Lemma 3 *Any non-trivial incentive compatible mechanisms $(p_i, \tau_i)_i$ must satisfy either*

(i) $\tau_i < \bar{\tau}_i^2$ and, $\tau_L < \tau_H$, $p_L > p_H$, and

$$V_L^1 + O(V_L^2, \tau_L) - \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] \tag{4.20}$$

$$\geq \ p_L - p_H \geq O(V_H^2, \tau_L) - O(V_H^2, \tau_H) \geq 0 \tag{4.21}$$

or

(ii) $\tau_L \geq \bar{\tau}_L^2$ and, $\tau_L > \tau_H$, $p_L < p_H$, and

$$\max[V_D^1, V_H^1 + O(V_H^2, \tau_H)] - \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)]$$

$$\geq \ p_H - p_L \geq \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] - V_D^1$$

Proof of Lemma 3:

(a) Assume that $\tau_H \geq \bar{\tau}_H^2$. Then both types would preempt when choosing regulation (p_H, τ_H). Therefore, (IC) would imply

$$\max[V_D^1, V_L^1 + O(V_L^2, \tau_L)] - p_L \geq V_D^1 - p_H \geq \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)] - p_L$$

which contradicts Lemma 1 as $O(v^2, \tau_L)$ is increasing in v^2 and $V_H^t \geq V_L^t$ for $t = 1, 2$.

(b) Assume that $\tau_L \geq \bar{\tau}_L^2$. If $\tau_H > \tau_L$, low type would preempt under both regulation levels such that incentive compatibility requires $p_L < p_H$. This, however, would violate the (IC) for the high type since the lower tax $(\tau_L < \tau_H)$ could be achieved with a lower payment $(p_L < p_H)$. If, however, $\tau_L > \tau_H$, incentive compatibility for low types would require

$$V_D^1 - p_L \geq \max[V_D^1, V_L^1 + O(V_L^2, \tau_H)] - p_H$$

and for high types I would have

$$\max[V_D^1, V_H^1 + O(V_H^2, \tau_H)] - p_H \geq \max[V_D^1, V_H^1 + O(V_H^2, \tau_L)] - p_L$$

immediately leading to the claimed relationship in (ii).

(c) In the remaining case of $\tau_i \leq \bar{\tau}_i^2$ for $i \in \{L, H\}$, the (IC) immediately gives condition (4.21). With Lemma 1, the option value is increasing in v^2 but decreasing in τ^2 with a positive cross derivative. I therefore obtain $\tau_L < \tau_H$ and $p_L > p_H$.$\square$

Note that I allow for positive and negative values of τ_i. That is, in the extreme case the "tax" would turn into a subsidy. While Lemma 3 characterizes the set of incentive compatible mechanisms, the regulator is interested in choosing the mechanism which maximizes welfare. For this reason I can immediately rule out the mechanisms which are characterized in Lemma 3 (ii) as they would be dominated by a regulation at $\tau^2 = \max[\bar{\tau}_H^2, E^2]$ (see Lemma 2). It remains to study mechanisms given by Lemma 3

(i) and condition (4.21). Here, it is obvious that any mechanism with $\tau_H \leq \bar{\tau}_L^2$ would be dominated in welfare terms by a uniform regulation of $\tau^2 = \bar{\tau}_L^2$ (again Lemma 2).

I therefore have to compare the trivial mechanisms $\tau_H = \tau_L = \bar{\tau}_i^2$ for $i \in \{L, H\}$ with those given in Lemma 3 (i) with $\tau_L < \bar{\tau}_L^2$ and $\bar{\tau}_L^2 < \tau_H < \bar{\tau}_H^2$. I first establish existence:

Lemma 4 *For any given $\tau_L < \bar{\tau}_L^2$, there exists incentive compatible mechanisms $(\tau_i, p_i)_i$. They are characterized by:*

$$V_L^1 + O(V_L^2, \tau_L) - V_D^1 \geq p_L - p_H \geq O(V_H^2, \tau_L) - O(V_H^2, \tau_H) \tag{4.22}$$

with $\bar{\tau}_L^2 < \tau_H \leq \hat{\tau}_H^2(\tau_L)$ where $\hat{\tau}_H^2 = \hat{\tau}_H^2(\tau_L)$ is implicitly defined by

$$V_L^1 + O(V_L^2, \tau_L) - V_D^1 = O(V_H^2, \tau_L) - O(V_H^2, \hat{\tau}_H^2)$$

Proof of Lemma 4:

Define p_i such that $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1$ which is larger than zero for all $\tau_L < \bar{\tau}_L^2$. Now, with Lemma 1 $V_L^1 + O(V_L^2, \tau^2) - V_D^1 - [O(V_H^2, \tau^2) - O(V_H^2, \bar{\tau}_L^2)]$ is decreasing in τ^2 for $\tau^2 < \bar{\tau}_L^2$ and takes a value of zero at $\tau^2 = \bar{\tau}_L^2$. Therefore, $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1 > O(V_H^2, \tau_L) - O(V_H^2, \bar{\tau}_L^2)$. As the option value is decreasing in τ^2, any such mechanism with $\bar{\tau}_L^2 < \tau_H \leq \hat{\tau}_H^2$ is incentive-compatible. □

Figure 4.8 demonstrates the incentive compatible mechanisms proposed by Lemma 4. As a high tax level harms landowner's private benefit, high type of landowner always has incentives to mimic low type and low type of landowner would always want to reveal his true type. Therefore, regulator's problem is to prevent high type of landowner from claiming to be the low type. For a tax level $\tau_L < \bar{\tau}_L^2$, the private benefit from having τ_L instead of $\tau^2 > \bar{\tau}_i^2$ are given in the figure by AB for a low type landowner and by AC for the high type. When the regulator asks a price p_L =AB for

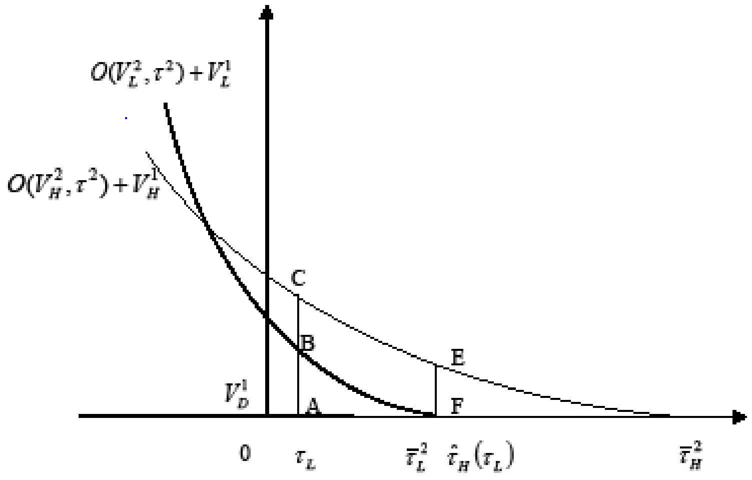

Figure 4.8: Illustration of incentive compatible mechanism

the tax level τ_L, low-type landowner's net benefit from claiming to be the low type is zero. However, high-type landowner would gain a net benefit of BC by pretending to be the low type and paying p_L.

In order to provide incentives for high-type landowners to reveal their true type, the regulator has to set tax τ_H at such level that net benefit for high-type landowner from revealing his true type is no smaller than that from claiming himself to be the low type (which is BC in Figure 4.8). Any tax level for high type that falls in the range of $(\bar{\tau}_L^2, \hat{\tau}_H^2(\tau_L)]$ can provide such net benefit level. The tax level $\hat{\tau}_H^2(\tau_L)$ with a price $p_H = 0$ make the high type indifferent between revealing his true type or pretending to be a low type. Here, high type landowners earn a net benefit EF that equals to BC from telling his true type. For any tax level that is smaller than $\hat{\tau}_H^2(\tau_L)$ but larger than $\bar{\tau}_L^2$, a positive price exists that provides high type of landowner a net benefit that is no smaller than BC or EF, such that high type landowners would be willing to reveal their type. The regulator can set the price of $p_L < AB$ such that low type of landowner gains a strictly positive net benefit from revealing his true type, which is part of the mechanism proposed by Lemma 4.

Note that in case that the landowner is type H, welfare is increasing in τ^2 for $\tau^2 < \bar{\tau}_H^2$. For a given $\tau_L < \bar{\tau}_L^2$, Lemma 4 therefore implies that the welfare optimum among mechanism with (τ_L, τ_H) is given by $(\tau_L, \hat{\tau}_H^2(\tau_L))$ with appropriate ex ante prices satisfying $p_L - p_H = V_L^1 + O(V_L^2, \tau_L) - V_D^1$.

I can use this result to analyze the conditions under which such a mechanism is welfare improving compared with a uniform tax, i.e. a trivial mechanism, of $\tau^2 = \bar{\tau}_i^2$ for $i = L$ or $i = H$.

Expected welfare under a mechanism (τ_L, τ_H) with $\tau_H = \hat{\tau}_H^2(\tau_L)$ is given as follows:

$$EW(\tau_L) = \sum_{i \in \{L,H\}} f_i \left[V_i^1 + O(V_i^2, \tau_2) - (E^2 - \tau_i)(1 - G(V_i^2 + \tau_i)) \right] \tag{4.23}$$

In order to compare the welfare with regulating at $\tau^2 = \bar{\tau}_L^2$ it proves helpful to consider the derivative of expected welfare with respect to τ_L. Here I obtain with condition (4.7):

$$EW'(\tau_L) = \sum_{i \in \{L,H\}} f_i (E^2 - \tau_i) g(V_i^2 + \tau_i)) \frac{\partial \tau_i}{\partial \tau_L} \tag{4.24}$$

where with the definition of $\tau_H = \hat{\tau}_H^2(\tau_L)$ in Lemma 4 I have

$$\frac{\partial \tau_H}{\partial \tau_L} = \frac{G(V_L^2 + \tau_L) - G(V_H^2 + \tau_L)}{1 - G(V_H^2 + \tau_H)}$$

With these preliminaries, I can show the following result:

Proposition 3 *By offering a mechanism which gives landowners the chance to receive a lower tax rate when paying an ex ante fee, the regulator can increase expected welfare if* $f_L \in (\widetilde{f_L}, \widehat{f_L})$, *where* $\widetilde{f_L} = \frac{[OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}{[E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)] + [OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}$ *and* $\widehat{f_L} = \frac{g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}{g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) + g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}$.

Proof of Proposition 3:

I derive the conditions under which social welfare can be improved. Consider a situation where a uniform regulation at $\tau^2 = \bar{\tau}_L^2$ leads to larger expected welfare than $\tau^2 = \bar{\tau}_H^2$ (see condition (4.18)). Note that, independent of the value distribution, this would be the case if E^1 is sufficiently large. The condition (4.18) implies that regulator choose to regulate at $\tau^2 = \bar{\tau}_L^2$ if the regulator's prior belief that landowner is low type is sufficient high:

$$f_L > \frac{[OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}{[E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)] + [OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}$$

Define the critical f_L above which $\tau^2 = \bar{\tau}_L^2$ dominates $\tau^2 = \bar{\tau}_H^2$ as $\widetilde{f_L}$.

$$\widetilde{f_L} = \frac{[OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}{[E^1 - (E^2 - \bar{\tau}_L^2)(1 - G(V_L^2 + \bar{\tau}_L^2)] + [OS(V_H^2, \tau_H^2) - OS(V_H^2, \bar{\tau}_L^2)]}$$

A sufficient condition under which a deviation from $\tau^2 = \bar{\tau}_L^2$ via my mechanisms is beneficial, is given by $EW'(\bar{\tau}_L^2) < 0$ as defined in (4.24):

$$\begin{aligned} EW'(\bar{\tau}_L^2)\frac{1 - G(V_H^2 + \bar{\tau}_L^2)}{E^2 - \bar{\tau}_L^2} &= f_L g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) \\ &\quad - f_H g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2)) \end{aligned}$$

My mechanism improve social welfare requires that:

$$\begin{aligned} & EW'(\bar{\tau}_L^2) < 0 \\ \Leftrightarrow\ & f_L g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) < f_H g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2)) \\ \Leftrightarrow\ & f_L < \frac{g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}{g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) + g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))} \end{aligned}$$

which shows that as long as f_L, i.e. the probability of the landowner being a low type is sufficiently small, one can improve welfare upon a undifferentiated tax regulation at $\tau^2 = \bar{\tau}_L^2$.

Define the critical value f_L below which the incentive compatible mechanisms dominate regulating at $\tau^2 = \bar{\tau}_L^2$ as $\widehat{f_L}$,

$$\widehat{f_L} = \frac{g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}{g(V_L^2 + \bar{\tau}_L^2)(1 - G(V_H^2 + \bar{\tau}_L^2)) + g(V_H^2 + \bar{\tau}_L^2)(G(V_H^2 + \bar{\tau}_L^2) - G(V_L^2 + \bar{\tau}_L^2))}$$

Combine $\widehat{f_L}$ and $\widetilde{f_L}$, it is clear that my incentive compatible mechanisms improve social welfare if and only if $\widetilde{f_L} < \widehat{f_L}$. $\square$

The proof of Proposition 3 demonstrates that when $\widehat{f_L}$ is sufficiently large or $\widetilde{f_L}$ is sufficiently small, mechanisms which offer differentiated treatments based on different ex ante payments increase welfare compared to a undifferentiated tax treatment at $\tau^2 = \bar{\tau}_L^2$ or $\tau^2 = \bar{\tau}_H^2$. A sufficiently high $\widehat{f_L}$ requires a sufficiently large difference in V_i's between high and low type. A sufficiently small $\widetilde{f_L}$ requires that the welfare gain from a lower tax rate is sufficiently larger than the welfare loss, or, E^1 is sufficiently large. The welfare gain is the avoided negative externality due to low type of landowners' decision change, or the reduction in first period distortion. The welfare loss is the reduced expected social welfare from high type of landowners' developing land in second period, or the increment in second period distortion.

Figure 4.9 demonstrates a scenario where my mechanism improves welfare and Figure 4.10 it does not. In both figures I assume again V_i^t follows a uniform distribution defined in symmetric information scenario, and $E_1 = E_2 = 50$. I set $V_L^1 = V_L^2 = V_L = 23$ and $V_H^1 = V_H^2 = V_H = 75$ in Figure 4.9. The expected social welfare curve of the incentive compatible mechanism merges into that of undifferentiated tax $\bar{\tau}_L^2$ as the f_L increases. The social welfare from the mechanism, $(\tau_L, \hat{\tau}_H^2(\tau_L))$, and undifferentiated tax $\bar{\tau}_L^2$ are smaller than that from $\bar{\tau}_H^2$ in the lower ranger of f_L. However, the difference between the two decreases and become negative with f_L. The intersection $(\widetilde{f_L})$ of the social welfare curve for the undifferentiated tax $\bar{\tau}_L^2$ and $\bar{\tau}_H^2$ is to the left of the point $(\widehat{f_L})$ where social welfare curve of $(\tau_L, \hat{\tau}_H^2(\tau_L))$

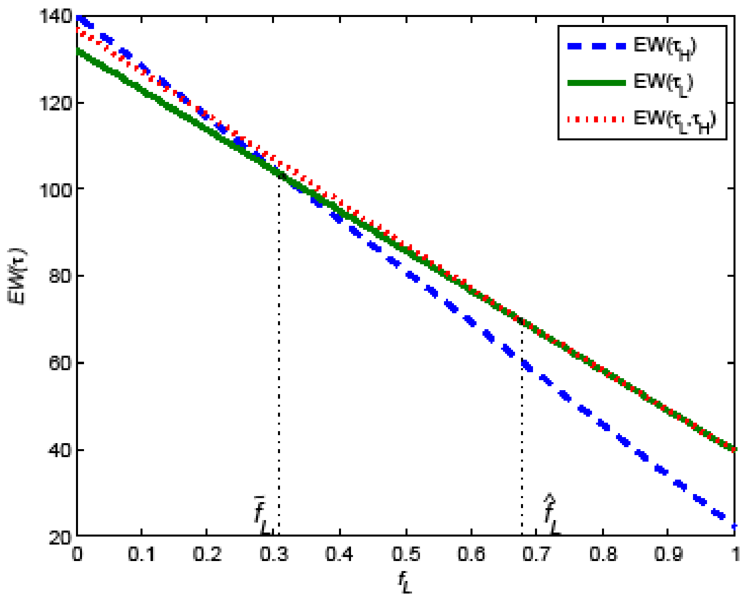

Figure 4.9: Illustration of incentive compatible mechanism improves welfare ($V_H = 70$, $V_L = 23$, $E_1 = E_2 = 50$)

merges into that from the undifferentiated tax $\bar{\tau}_L^2$. Therefore, I have a range of f_L in which the regulation $(\tau_L, \hat{\tau}_H^2(\tau_L))$ dominates the undifferentiated tax of $\bar{\tau}_L^2$ or $\bar{\tau}_H^2$. In Figure 4.10 ($V_L = 5$ and $V_H = 43$), the social welfare curve of my mechanism merges into that of regulating at $\bar{\tau}_L^2$ to the left of the point where the social welfare curve of $\bar{\tau}_L^2$ intersects with the curve of $\bar{\tau}_H^2$, which leaves no a feasible range for the mechanism.

As implied by Proposition 3, the mechanism is beneficial only when the first period negative externality or the difference in types is sufficiently large. Figure 4.11 demonstrates the optimal regulatory decisions associated with the distribution of landowners' type and regulator's prior belief of landowner's type. I fix again $E^1 = E^2 = 50$, and choose $V_L = 5$ as in the perfect information case and again allow V_H to take values $V_H \in [V_L, 100]$. Identical to Figure 4.5, the threshold value for V_H above which regulation at $\bar{\tau}_H^2$ is optimal depends on the distribution of types,

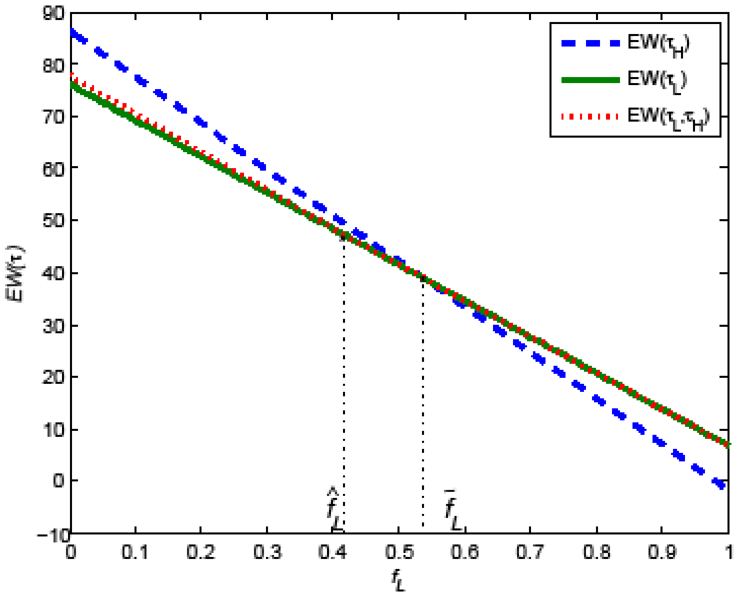

Figure 4.10: Illustration of incentive compatible mechanism does not improve welfare ($V_H = 43$, $V_L = 5$, $E_1 = E_2 = 50$)

here on the probability $f_L = 1 - f_H$ of facing a low type. The threshold value $\hat{f}$ which defines the maximal f_L for which the mechanism approach increases expected welfare compared to regulation at $\bar{\tau}_L^2$ is increasing in V_H. If V_H is sufficiently large, $\tilde{f} < \hat{f}$ such that there is a range of intermediate probabilities f_L such that my proposed mechanism can improve welfare compare with both a regulation at $\bar{\tau}_H^2$ and $\bar{\tau}_L^2$. The range for which my mechanism improves welfare is even larger, if the externality E^1 is larger that E^2, that is, if preemption leads to significantly larger social costs. This is illustrated in Figure 4.12 where I choose $E^1 = 2E^2 = 100$. Then, my mechanism dominates undifferentiated regulation for any $V_H > 20$.

Proposition 3 therefore shows that in the case of asymmetric information, the regulator should not necessarily treat landowners in an undifferentiated way. Instead, he can offer landowners reduced development costs if they pay a specified amount ex ante. By this, the landowners voluntarily sort into different tax treatments. Those

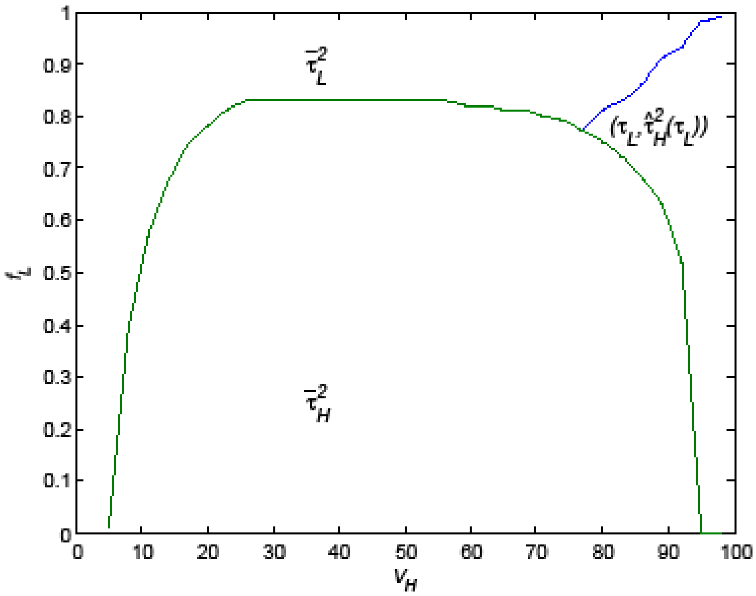

Figure 4.11: Optimal regulation (uniform at $\overline{\tau}_L^2$, $\overline{\tau}_H^2$ or mechanism $(\tau_L, \widehat{\tau}_H^2(\tau_L))$ as a function of V_H and $f_L = 1 - f_H$ ($V_L = 5$, $E_1 = E_2 = 50$)

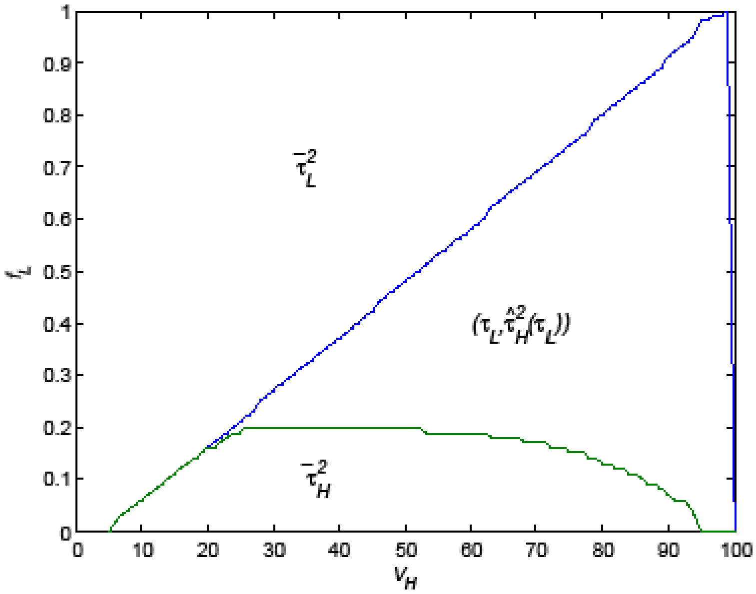

Figure 4.12: Optimal regulation (uniform at $\overline{\tau}_L^2$, $\overline{\tau}_H^2$ or mechanism $(\tau_L, \widehat{\tau}_H^2(\tau_L))$ as a function of V_H and $f_L = 1 - f_H$ ($V_L = 5$, $E_1 = 2E_2 = 100$)

who are more likely to preempt, pay money in order to receive a reduced tax for development in period 2.

With this, the structure of the signaling game resembles lobbying of landowners for a reduction in the regulatory stringency level. Note however that I assumed that the ex ante payments (alias negotiation expenses) are welfare neutral, i.e. are not associated with additional social costs. I can therefore reinterpret my result as a version of socially beneficial lobbying. Instead of announcing a undifferentiated regulation in the second period which might lead some landowners into preemption, the regulator should be open to compromise with those landowners who take on ex ante expenses to credibly demonstrate that a high regulation would lead them into preemption.

4.4 Conclusions and Discussion

The Endangered Species Act has been arousing much discussion and opposition as it takes or limits land development right without compensation. Although the ESA is somewhat tamed through introducing the section 10(a) which allows landowners to develop land after submitting a HCP, it creates incentives for preemptive habitat destruction and at the same time is criticized from environmentalists for its compromise. The questions are: is compromise the right strategy and how should the compromise be regulated?

I answer the two questions using a two-period land develop model. The condition is derived under which regulator has to compromise in order to reduce preemption and improve social welfare. When preemptive land development harms social welfare more than does developing land in post-regulation period, compromise can be better than first-best regulation. This condition, however, is difficult to apply to the real world as it requires that regulator knows perfectly the landowners' privately known propensity to preemptively develop land. A mechanism is proposed that enables regulator to reveal landowners' private information by providing differentiated regulation to different types of landowners. This mechanism allows an individual landowner to choose to pay ex ante for a less stringent regulation. It can potentially improve social welfare over undifferentiated regulation.

The mechanism provides a new rationales for the designation of HCP. HCP is the product of a long and elaborate negotiation among landowners, Fish and Wildlife Service and other interest groups. Instead of prohibiting any land development after regulation takes effect, the ESA should allow the landowners who otherwise would preemptively develop land to exert effort (time, money and so on) to submit an extensive Habitat Conservation Plan in order to gain a lower future land development cost. This type of compromise through differentiated treatment of regulation, may still be imperfect, can improve social welfare than the undifferentiated way or prohibiting any land development.

In this chapter, I simplify the problem by assuming that there are only two time periods and regulatory status jumps from no regulation at all in the first period to regulating at a specific level in the second period. If putting in a continuous time framework, the regulator can take advantage of the timing of private land development for each individual landowners: low type of landowners develop land earlier than the high types. Regulator can then set a regulatory stringency level at a time point to the threshold level for the type for whom it is optimal to develop land. By doing so, regulator can avoid preemptive development of high types of landowners due to an unnecessarily high regulatory stringency level at that time point. I therefore foresee that gradually increasing regulatory stringency level that is compatible to landowners' threshold level over time would be effective in preventing preemption.

The basic story in this paper, that changing in regulatory status induces preemptive behavior, should not be restricted only to the case of Endangered Species Act. It applies to any change in regulation, policy, rule and even price or the availability of a commodity. The uncertainty associated with those changes before they actually are realized could induce individuals to take preemptive actions to reduce the expected losses. The preemptive behavior should not be worried if it does not generate any negative externality to the society. For example, suspected increase in commodity price induces consumers to purchase more before the price is actually increased and does not cost social benefits. However, it will become a problem if the preemptive behavior is irreversible and costs social welfare, such as preemptive land development induced by any regulation or policy change. Endangered Species Act is only one case, any other land use regulations, e.g. development impact fee, or downzoning, can have the same effect.

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