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**CROWDING OUT OPEN SPACE:  
FEDERAL LAND PROGRAMS AND  
THEIR EFFECTS ON LAND TRUST ACTIVITY**

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## I. INTRODUCTION

A strand of the public finance literature analyzes the effects of government spending on nonprofit provision of public goods. Theories developed by Warr (1982), Roberts (1984), and others suggest that governmental transfers should displace, or ‘crowd-out’, private charitable giving dollar-for-dollar. Various empirical studies find a negative relationship between individual charitable contributions and government transfers payments (e.g., Abrams and Schmitz 1978, Kingma 1989, Andreoni 1993, Andreoni and Payne 2003). The estimates, however, imply that crowding-out is incomplete. A dollar of government spending is found to reduce private contributions by less than a dollar in each study. And a few empirical studies find a positive relationship. Richer (1995), for example, concludes that donations to major environmental groups are positively related to government spending, including dollars that do not come in the form of subsidies.<sup>1</sup>

In this paper, we also examine the crowding-out hypothesis empirically. Here we ask whether various federal land conservation programs have complemented, substituted, or had no effect on private land trust acquisitions. Land trusts in our data-set include the Nature Conservancy and more than 1,200 smaller organizations located in different locales across the United States. These nonprofits conserve land primarily by owning it outright or holding conservation easements. Nationwide, the acreage owned or held in conservation easements by land trusts increased from approximately 1.25 million acres in 1984 to six million acres in 2000; from an area the size of Delaware to an area the size of Delaware plus New Jersey. During the

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<sup>1</sup> To explain his less intuitive finding, Richer suggests that private donors view success in obtaining government grants as an indicator of an organization’s performance.

same period, approximately 35 million acres were enrolled in the Conservation Reserve Program (CRP), and over a million acres were enrolled in the Wetland Reserve Program (WRP). Close to three million acres were acquired by four major land agencies: the National Park Service (NPS), Bureau of Land Management (BLM), National Forest Service (NFS), and the National Fish & Wildlife Service (NFWS).

In order to analyze the effects of this federal government activity on land trust growth, we first model the demand for land trust conservation. Our analytical framework assumes there is “public” demand for amenities such as natural scenery, wildlife habitat, and outdoor recreation within a given locale. Private land trusts enter the model as intermediaries between donors of land and conservation easements and demanders of amenities. Government programs enter the model as a substitute provider of amenities. Within a given location, our model predicts that government provision of a specific amenity will reduce land trust provision of the same amenity.<sup>2</sup> The model, however, also assumes that scenery, habitat, and recreation are complements. To the extent that government programs provide less than all of these amenities, land trusts may respond by providing complementary amenities to a greater extent than they otherwise would.<sup>3</sup>

Our econometric analysis tests the predictions of the theoretical model at the county level in a unique panel regression framework. Using data from the Land Trust Alliance (LTA) and other sources, we have constructed a data set of acreage held by land trusts in 1984, 1990, 1994,

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<sup>2</sup> Because some species of wildlife roam over large tracts of land, economies of scale in wildlife habitat provision could motivate land trusts to respond positively to government activity. We consider this possibility in the empirical analysis.

<sup>3</sup> Competing hypotheses, however, are not without theoretical appeal. To the extent that government programs simply distribute pork among constituents, they provide poor substitutes or complements for land trust outputs. Wu and Boggess (1999, 318), for example, note that political pressure to allocate conservation funds evenly across constituents decrease their conservation utility.

1997, and 2000. We have also constructed a county-level panel of CRP acreage, WRP acreage, and federal government land as measured by Payments In Lieu of Taxes (PILT) records. Neither the LTA data nor the PILT data have been analyzed before at this level of spatial detail and considerable effort has gone into the construction of comprehensive and comparable data sets.

In spite of time-consuming data collection efforts, we still must overcome a unique econometric challenge in order to estimate the effects of CRP, WRP, and PILT acquisitions on land trust activity. While the government data are all at the county-level, about 40 percent of the land trust acreage is not assigned to a single county. Instead, this acreage is assigned to over 500 individual land trusts, which operate in multiple counties: anywhere from two up to 1,024. Unfortunately, the areas in which these land trusts operate overlap in ways that thwart simple aggregation to multiple-county levels. The novel econometric challenge we face concerns how to compare governmental activity with private activity in light of differences in spatial information.

Examining the response of private land trust activity to CRP, WRP, and federal land ownership contributes to the empirical understanding of how private individuals and institutions respond to government spending on public goods (e.g., Kingma 1989, Andreoni 1993, Richer 1995), and to the literature examining the unintended effects of government land policies on private land use.<sup>4</sup> Our study also adds to an infant literature on land trusts, and a virtually non-existent literature on how they are affected by government policy. Albers and Ando (2003) empirically analyze the number of trusts that operate in each state using a state-level panel of

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<sup>4</sup> For example, Wu (2000) shows that increases in CRP enrollment raises agricultural output prices thereby giving farmers incentives to bring non-cropland into cropland production. This “slippage” effect militates against the program’s explicit goal of idling cropland.

1988 and 1998 LTA data. While the issue is mostly peripheral to their model and focus, they control for the effect that “protected government acres” has on the number of land trusts in each state and find a positive relationship.<sup>5</sup> Johnson and Maxwell (2001) examine the effect of the CRP on rural residential development in Gallatin County Montana. In this very specific case study area, Johnson and Maxwell argue that CRP enrollment has slowed residential development. Our study combines the geographic specificity of Johnson and Maxwell’s work with the topical breadth of Albers and Ando.

The paper proceeds as follows. Section II describes nonprofit organizations commonly known as land trusts. Section III describes in some detail various federal land conservation programs. Section IV presents the theoretical model. Section V presents the empirical model along with a description of our data. Section VI concludes the paper.

## **II. LAND TRUSTS**

The Land Trust Alliance (LTA) defines a land trust as a “nonprofit organization that, as all or part of its mission, actively works to conserve land by undertaking or assisting direct land transactions – primarily the purchase or acceptance of donations of land or conservation easements” (LTA 2001). While a few large trusts, such as The Nature Conservancy, are national in scope, most operate at local or state levels. Land trusts enjoy charitable status and exemption from federal and state income taxes. They are typically governed by an unpaid board of trustees charged with the responsibility of managing land trust assets for land trust beneficiaries. In the broadest sense, land trust beneficiaries are the general public. The most conspicuous beneficiaries, however, are those who materially enjoy the amenities that a land trust provides. These

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<sup>5</sup> Their state-level variable combines CRP and WRP acreage with NFS, NPS, NFWS acreage and state parks and forest land acreage.

beneficiaries reside in the region in which a land trust operates and might include people who fish, hunt, or hike on trails provided or who have regular scenic access to property rights controlled by the land trust.

The first land trust was probably the Massachusetts Trustees for Reservation, which emerged in 1891. The motivation for the trust was to “establish an organization with a board of trustees that would have power to hold lands free of taxes ... for the use and the enjoyment of the public” (Abbott 1982, 150). Other organizations with similar doctrines, such as The Block Island Land Trust in Rhode Island (1896), and The Society for the Protection of New Hampshire Forests (1901) emerged shortly thereafter (LTA 1998). Rapid growth in the number of land trusts, however, did not begin until the second half of the 20<sup>th</sup> century.

There were approximately 53 land trusts in 1950, 308 in 1975, 867 in 1990, and 1,263 in 2000 (LTA 2001). Of the 1,263 local and regional land trusts identified, most are located in the Northeast (39 percent). However, from 1990 to 2000, the greatest percentage increase in the number of land trusts occurred in the South Central (127 percent) and Southwest (119 percent) regions (LTA 2001). The number of acres local and regional land trusts, along with The Nature Conservancy and Ducks Unlimited, held in fee-simple and conservation easements increased from approximately 1.25 million acres in 1984, to 2.22 million in 1990, and up to 6.05 million acres by 2000.

Relative to fee-simple ownership, conservation easements are increasingly becoming the preferred conservation instrument of land trusts. The increasing prevalence of conservation easements reflects, in part, decreasing costs of drafting, monitoring and enforcing them (Parker 2004). Conservation easements are legally binding agreements in which a landowner cedes some

of his property rights to a land trust. Most of the rights ceded are “negative” from the perspective of the landowner: conservation easements usually prevents landowners from actions such as developing, subdividing, clear-cutting, over-grazing, and erecting billboards. The property rights conveyed in conservation easements “run with the land” into perpetuity. Until an easement is formally amended or extinguished by a Judge, successor landowners and successor land trusts are bound to the terms agreed upon by the original parties (Mahoney 2002).

Finally, it is important to note that landowners donating conservation easements may be able to claim tax benefits. Federal income tax deductions have been available since 1976 and federal estate tax deductions since 1997. In either case, the IRS requires that easements meet certain conservation purposes to be eligible. The requirements include the preservation of land for outdoor recreation, wildlife habitat, scenic enjoyment, agricultural use, or historical importance (Small 2000). In addition to federal tax incentives, many states provide incentives for donating conservation easements. Seventeen states, for example, have statutes that require local assessors to reduce property value assessments when a conservation easement encumbers the land. About ten states offer income tax credits for donated easements (Defenders of Wildlife 2002). In all of these cases, the amount of taxes deductible from conservation easement donations depends (at least in part) on the appraised value of the easement (Boykin 2001).

### **III. FEDERAL LAND CONSERVATION PROGRAMS**

#### **A. The Conservation Reserve Program**

The Conservation Reserve Program (CRP), a product of the 1985 farm bill, signs contracts with farmers to leave land idle (and undeveloped) for 10-year or 15-year terms. It has been re-authorized in each farm bill since 1985: in 1990, 1996, and 2002. It now pays farmers to



idle approximately 35 million acres, a land mass larger than the state of Florida and constituting 10% of U.S. cropland, at an annual cost of \$1.7 billion (in 2001).<sup>6</sup>

The 1985 version of the CRP employed a bidding scheme to enroll acres. Owners of land deemed to be highly erosive were eligible to submit bids for annual rental payments, agreeing to take their land out of production for 10 years. In addition to land eligibility criteria, bids were deemed acceptable only if they were below locally prevailing land rental rates. Within regional bidding pools, the Dept. of Agriculture ranked acceptable bids and determined the highest bid that would meet target enrollments in the pool. Once the maximum acceptable bid was determined, all those with bids at or below the maximum were paid at the highest accepted rate.

As to the allocation of funds to the regional pools, Reichelderfer and Boggess (1988) argue that soil erosion, or even program cost, was not the most important criterion. Their point is relevant to our study because to the extent that regional CRP acreage was determined by pork barrel politics, the cross-sectional distribution can be said to be predetermined with respect to private land trust activity. In the early years (1986-1989) Smith (2000) claims that all minimally acceptable bids were accepted in order to reach target acreage enrollments.

The criteria for eligibility in the CRP has evolved over its successive reauthorizations. Initial criteria emphasized wind erosion, while 1990 revisions added water quality criteria. Bids under the CRP's current incarnation are ranked by an Environmental Benefits Index, one element of which is the non-environmental element of the annual rental payment bid by the landowner. Other than cost, the Index is an aggregation of points awarded for a combination of inherent land characteristics and practices in which the enrollee agrees to engage. USDA ranks in a national

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<sup>6</sup> See Thurman (1995), chapter 3, for a more detailed discussion of CRP and other environmentally justified agricultural programs.

pool the EBI scores and accepts all those above a cutoff, determined to achieve a target acreage. The 2002 farm bill raised the maximum CRP acreage from 36.4 million acres to 39.2 million acres.

While CRP acreage is spread across the lower 48 states, it is far from evenly distributed. Close to thirty percent of CRP acreage is found in the Northern Great Plains, primarily North Dakota and Montana. Another thirty percent is found in the more southerly Great Plains areas of Colorado, Nebraska, Kansas, Oklahoma, and Texas. In many counties in these areas, CRP enrollment equals the regulatory maximum of 25% of a county's farmland.

In what ways are the land use effects of CRP contracts similar to those of conservation easements and land trust purchases? Ultimately, we maintain that it is an empirical question. However, one can usefully distinguish between the two activities along several dimensions. First is length of commitment. Conservation easements are forever (see Mahoney, 2003) while CRP contracts are either 10 or 15 years, depending upon whether or not tree planting is involved.

Another comparison of CRP with land trust activity concerns the type of land protected. Land under CRP contract cannot be farmed or developed during the contract period, but is it likely to be land that would be the target of land trust attention? Does it provide land amenity benefits likely to be viewed as substitutes for those provided by land trusts? With regard to general CRP acreage, the question is twofold: whether marginally productive farm land is likely to be at risk of development and whether that land provides amenities valuable at the margin in its location.

While one might be *a priori* skeptical that CRP acreage displaces land trust activity, there are subcategories of CRP that are more obviously relevant to the aims of land trusts. In

particular, one of the six Environmental Benefits Index categories is wildlife habitat, a particular focus of many land trusts.<sup>7</sup> One way to become eligible for CRP is to engage in practices deemed to enhance wildlife habitat. To date, we have constructed a data base of aggregate CRP acreage only, but the potential exists to disaggregate CRP data into type of conservation practice in which land is enrolled. We could, therefore, analyze the effects of change in CRP acreage that was specifically focused on wildlife benefits. As of October 2002, 2.8 million acres were enrolled in wildlife conservation practices out of a total enrollment of 33.9 million acres. States with more than 150,000 acres of wildlife practice acreage are (in decreasing size of wildlife conservation practice acreage): North Dakota, Minnesota, Iowa, Colorado, and Washington.

**B. The Wetland Reserve Program**

**C. Growth in the Federal Estate**

**IV. A THEORY OF LAND TRUST DISPLACEMENT**

We develop in this section a model of consumers who value various land-based amenities, land trusts that produce those amenities, and a government that produces related goods through land use programs.

**A. Consumers**

A representative consumer derives utility from two land-based public goods and one private market good:<sup>8</sup>

$$u = U(W, S, Z),$$

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<sup>7</sup> As noted in Section II, 43 percent of land trusts reported that preserving wildlife habitat was one of their primary objectives.

<sup>8</sup> We recognize that many land-based amenities are not public goods by the usual criteria of the inability to exclude and non-rivalness in consumption. We maintain, however, that important aspects of what land trusts produce are public by the same criteria. In order to focus on these aspects, the model adopts the extreme position that all outputs of trusts are public.

where  $W$  is the quantity of wildlife amenities,  $S$  is the quantity of scenery amenities, and  $Z$  is the quantity of the market good. The levels of  $W$  and  $S$  are fixed in quantity and cannot be purchased on the market.

The consumer takes as given the quantities of the two public goods,  $\bar{W}$  and  $\bar{S}$ , the market price of the private good,  $P_Z$ , and income,  $I$ . Optimization by the consumer implies a mixed demand system that gives a quantity demanded of the market good and an inverse demand, or marginal value function, for each of the public goods. The direct demand for the market good is simple: all income is spent on  $Z$ :

$$Z^* = I/P_Z .$$

The marginal dollar value of  $W$  is proportional to the marginal rate of substitution between  $W$  and  $Z$ , evaluated at the fixed levels of  $W$  and  $S$  and the chosen level of  $Z$ :

$$MV_W = \frac{\frac{\partial U}{\partial W}(\bar{W}, \bar{S}, Z^*)}{\frac{\partial U}{\partial Z}(\bar{W}, \bar{S}, Z^*)} \cdot P_Z = MRS_{ZW}(\bar{W}, \bar{S}, I/P_Z) \cdot P_Z .$$

Similarly, the marginal value of  $S$  is given by:

$$MV_S = MRS_{SZ}(\bar{W}, \bar{S}, I/P_Z) \cdot P_Z .$$

If preferences are Cobb-Douglas, for example, each marginal value function is declining in the own good and increasing in income, features that one would expect to hold in more general representations of preferences for land-based amenities.

## **B. Land Trusts**

While we assume that a competitive market exists for  $Z$ , we assume that the only

producers of W and S are land trusts. There may be natural levels of W and S provided by the endowment of land in an area, but only land trusts can augment their quantities. The important distinction between W and S is that production of W requires not only land, but a non-land input as well. To turn an acre of land into wildlife habitat requires some improvement or monitoring beyond the preservation of the land. Scenery, on the other hand, is a pure land amenity, requiring only non-developed land. This distinction is captured by the following Leontief production functions for W and S:

$$S = L, \text{ and } W = \min(L, X/\alpha).$$

The land trust is a multi-output firm that produces W and S using purchased inputs L and X. (Here, we consider the placing of an easement on land to be equivalent to its purchase and management by the land trust.) The terms on which a trust can purchase land are strongly influenced by tax incentives, while the purchase of X is less complicated by such concerns.

The cost of producing a given combination of W and S is the cost of acquiring the L and X necessary to produce it. The Leontief technologies imply the following two-output cost function:  $C(W,S) = P_L \cdot \max(W,S) + P_X \cdot \alpha W$ .

Notice that the production of S is at least as great as that of W. If we assume that S is strictly greater than W ( $X < \alpha L$ ), we can write:  $C(W,S) = P_L \cdot S + P_X \cdot \alpha W$ .

The technology of production is constant returns to scale, allowing us to adopt a representative land trust view. We will speak of a single land trust but it could represent an indefinite number of trusts that behave competitively.

Next consider the efficient provision of amenities by the land trust. Efficient provision is a particular behavioral view of land trusts: that they act so as to maximize the benefits to consumers

in their area of operation. This view ignores the interests of employees of the trust and the members of its board of directors and assumes that the trust acts as a perfect agent on behalf of consumers. This view also ignores the ways in which land trusts overcome free rider problems and induce consumers of amenities to become land trust donors.

An efficient land trust chooses L and X such that the value marginal product of each input equals its market wage. Because there are two outputs, the VMP's for each input have two components. Further, because the land trust's output is not sold on a market, the trust measures the value of output at the donor's (the representative consumer's) marginal value. The VMP functions are given by:

$$\begin{aligned} \text{VMP}_L &= \text{MV}_W \cdot \text{MP}_L^W + \text{MV}_S \cdot \text{MP}_L^S = \text{MV}_W \cdot 0 + \text{MV}_S \cdot 1 = \text{MV}_S, \text{ and} \\ \text{VMP}_X &= \text{MV}_W \cdot \text{MP}_X^W + \text{MV}_S \cdot \text{MP}_X^S = \text{MV}_W / \alpha + \text{MV}_S \cdot 0 = \text{MV}_W / \alpha, \end{aligned}$$

where  $\text{MP}_L^W$  is the marginal product of land in wildlife and the other MP terms are defined similarly.

The efficiency conditions set  $\text{VMP}_L$  and  $\text{VMP}_X$  equal to their market wages:

$$\text{VMP}_L = \text{MV}_S = P_L, \text{ and } \text{VMP}_X = \text{MV}_W / \alpha = P_X.$$

Because donors' marginal values depend upon the quantities of W and S supplied, as well as I and  $P_Z$ , the two efficiency conditions implicitly define an optimal level of production of W and S. A graphical depiction of the efficient solution in the general (non-Cobb-Douglas) case is given in figure 1.

The derived demand for land and non-land inputs from the land trust are given by:

$$\mathbf{D}_L^{\text{LT}} = S^*(I, P_Z, P_L, P_X), \text{ and } \mathbf{D}_X^{\text{LT}} = \alpha W^*(I, P_Z, P_L, P_X).$$

If land trusts are price takers in the L and X markets, then their derived demands for L and X are

aggregated along with other firms' demands for L and X into market demands. The equilibrium in the market for L is depicted in figure 2. At the land trust level, the price of land is fixed, but the aggregate of land trusts influence the price of land through their influence on the aggregate demand for land.

### C. Government

Government enters the market for land in several ways. Some programs, such as the Farm and Ranchland Protection Program, subsidize the acquisition of land by land trusts. Other programs directly enter into the market for land, either by buying land for specific uses (such as National Parks) or by contractually limiting the nature of land use. A leading example of the latter is the CRP. Some CRP contracts preserve land by specifying that it be put into a cover crop and, importantly for our purposes, not be developed as residential land. Other contracts more specifically require the land owner to undertake land improvements that enhance wildlife habitat. We model these two types of CRP contracts as different programs: non-wildlife CRP and wildlife CRP.

Denote the acreage put into non-wildlife CRP as  $G_o$ . Denote the acreage put into wildlife CRP as  $G_w$ . Both  $G_o$  and  $G_w$  produce scenery in equal amounts. But  $G_w$ , by the nature of the contractual agreement with the landowner, comes along with  $\alpha$  units of X for each unit of land under contract. Given the Leontief production of land amenities described above, this implies the following production of amenities from the two programs:

$$S = G_o + G_w, \text{ and } W = G_w.$$

Under the assumptions here, the two CRP programs affect the derived demands for L and X by directly offsetting the land trusts' market demands for X and L. The adjusted land trust

factor demands are given by:

$$\mathbf{D}_L^{LT} = S^*(I, P_Z, P_L, P_X) - (G_o + G_w) , \text{ and } \mathbf{D}_X^{LT} = \alpha [W^*(I, P_Z, P_L, P_X) - G_w] .$$

Notice that a change in either type of CRP acreage affects the demand for land, while only a change in wildlife CRP acreage affects the demand for the non-land input.

The resulting equilibrium in the land market is shown in figure 2, which displays in a simple case the comparative statics effect of a change in CRP acreage. The demand for land from land trusts is displayed along with the supply of land. The supply of land for preservation is a residual demand, composed of the difference between the land base of the area,  $\bar{L}$ , and the demand for land in development,  $\mathbf{D}_L^D$ . Initially, with no CRP acreage, the equilibrium price of land is  $P_{Lo}$  and the land trust buys  $L_o^{LT}$  acres.

With the placing of  $g$  acres of land under CRP contract, the demand for land from land trusts shifts back by the amount  $g$ . But if the government buys up land for CRP from the supply of developable land, then the supply of land for preservation is also shifted back by the amount  $g$ . In this case, there is no change in the equilibrium price of land and the government acreage is offset exactly by reduced land preservation by the land trusts. This is the one-for-one effect predicted by the displacement models of Warr (1982) and Roberts (1984). However, this result is extreme. To the extent that the scenic or wildlife value of CRP acreage is less than that produced by land trusts (due to site selection aimed at maximizing those outputs) then the demand for land from land trusts will shift back less than the amount by which the supply of land shifts back. The new equilibrium would involve a less than one-for-one displacement of land trust preservation by the CRP enrollment and an increase in the equilibrium price of land.



## **V. EMPIRICAL ANALYSIS**

Our first attempt to measure the effects of government land programs on land trust activity focuses on the effects of the Conservation Reserve Program (CRP).

### **A. Land Trust Data and Conservation Reserve Program Data**

The Land Trust Alliance (LTA) conducted extensive surveys of land trusts in 1984, 1990, 1994, 1997, and 2000. The surveys attempted to identify the name and mailing address of every land trust operating in the United States. Furthermore, the surveys attempted to quantify the number of acres “protected” by each land trust. The LTA surveys forced respondents to separate their acres into several categories including fee-simple, conservation easements, and acres transferred to government agencies or unspecified third-parties. Each survey also asked land trusts to choose the primary land amenities they seek to protect from a menu of options (e.g., scenic, habitat, recreation).

Analyzing the effects of government programs on land trust activities requires conforming LTA data with government data or vice versa. Time series data on governmental activity can be had on the county level. Data on private land trust activity, however, are available on the land trust level, and many land trusts operate in multi-county, some in multi-state, regions. Some trusts operate in single counties, while others operate in up to 1,024. What we typically know about land trusts is how much acreage they preserve, either through fee simple ownership or the holding of conservation easements, across all of the counties in which they operate.

There are two ways to understand the geographic distribution of land trusts. The first is to understand the distribution of land trusts across counties. Figure 3 displays the frequency distribution of the number of land trusts operating in a county. Approximately 4% of counties (excluding Alaska in all counts) have no land trusts operating in them. The modal number of land trusts in a county is four, which describes almost 16% of counties. The largest number of land trusts in a county is 46. There are large numbers of land trusts in the Northeast; in fact, any county that has more than 23 land trusts operating in it is located in either Massachusetts,

Connecticut, or Maine. The counties that have no land trust activity are: all of the counties in North Dakota (which does not have conservation easement enabling legislation), 84 of the 93 counties in Nebraska, and three of the five counties in Hawaii.

The other way to understand the distribution of trusts is to understand the numbers of counties covered by specific land trusts. The two panels of figure 4 display the frequency distribution of counties covered by a land trust. The distribution is skewed in the extreme, making necessary the two panels: one for trusts operating in 20 or fewer counties, the other for trusts operating in more than 20 counties. The majority of land trusts (over 60%) operate in a single county, but some operate in many counties. The two largest land trusts each operate in 1,024 counties; these are civil war preservation trusts that operate across many Eastern states.

## **B. An Econometric Model**

The empirical challenge is to render consistent the county-level government activity data and the land-trust-level private activity data. The following model does so.

Let  $y_{ijt}$  be the acreage preserved by land trust  $i$  in county  $j$  in year  $t$ . There are  $I$  land trusts,  $J$  counties, and  $T$  time periods. Unless trust  $I$  operates in only a single county, then  $y_{ijt}$  is unobserved. What is observed is the sum of land trust  $i$ 's activity across all counties. Denote the observed land trust quantity as:

$$(1) \quad y_{i \cdot t} = \sum_{j=1}^J y_{ijt}.$$

Denote the quantity of land preserved by government in county  $j$  in year  $t$  as  $x_{jt}$ .

The economic model of land trust activity operates at the county level. A government intervention in a county is assumed to influence the aggregate of land trust activity in the county.

We formalize this idea as a displacement equation:

$$(2) \quad (\text{displacement}): \quad y_{jt} = \beta x_{jt} + \epsilon_{jt}, \quad \text{for } j=1, \dots, J \text{ and } t=1, \dots, T,$$

where  $\epsilon_{jt}$  is an error term originating from county  $j$ .

Our economic theory is silent on how the land trust activity in county  $j$ ,  $y_{ijt}$ , is divided among land trusts, but we make an identifying assumption that land trusts have typical sizes in individual counties. For example, it might be that the Nature Conservancy typically accounts for 60% of the land preserved in a certain county. We represent this tendency with an allocation equation:

$$(3) \quad (\text{allocation}): \quad y_{ijt} = \alpha_{ij} y_{jt} + u_{it} ,$$

where  $\alpha_{ij}$  is the typical fraction of county  $j$ 's privately preserved land accounted for by land trust  $i$  and  $u_{it}$  is an error term originating from land trust  $i$ .

The displacement and allocation equations allow us to link the observed county-level government data ( $x_{jt}$ ) with the observed land trust-level private data ( $y_{ijt}$ ) via the following substitutions:

$$(4) \quad \begin{aligned} y_{it} &= \sum_{j=1}^J y_{ijt} = \sum_j \alpha_{ij} y_{jt} + u_{it} = \sum_j \alpha_{ij} (\beta x_{jt} + \varepsilon_{jt}) + u_{it} \\ &= \beta \sum_j \alpha_{ij} x_{jt} + \sum_j \alpha_{ij} \varepsilon_{jt} + u_{it} . \end{aligned}$$

The first equality in (4) follows from the definition of  $y_{it}$ , the second from the allocation equation, and the third from the displacement equation.

The final rearrangement on the right-hand side of (4) is eminently sensible. It shows that, conditional on the  $\alpha_{ij}$ 's, the model has a linear regression structure with disturbances that are heteroskedastic and correlated across observations. The independent variable that corresponds to  $y_{it}$  (the sum of land trust  $i$ 's activity across counties) is  $\sum \alpha_{ij} x_{jt}$  (the weighted sum of government activity across counties, where the weights are the relative sizes of land trust  $i$  in the counties.)

The structure of the disturbance term mirrors the aggregation: land trusts that operate in the same

county will each share in the county's disturbance, weighted again by the  $\alpha_{ij}$ 's. If the county-level disturbances are i.i.d., then the trust-level disturbances are heteroskedastic with large error variances for land trusts with large weights in large numbers of counties.

A specific example helps to illustrate the estimation issues. Suppose there are two counties, A and B, and two land trusts, 1 and 2. Land trust 1 operates in county A only. Land trust 2 operates in both counties A and B. The situation is illustrated in figure 5.

The structure of the example leaves only one unknown land trust share. Denoting  $\alpha_{1A}$  as  $\alpha$ , the four shares are:

$$\alpha_{1A} = \alpha, \alpha_{2A} = 1-\alpha, \alpha_{1B} = 0, \text{ and } \alpha_{2B} = 1.$$

The displacement and allocation equations for the two land trusts imply the following estimating equations:

$$(5) \quad \begin{aligned} y_{1,t} &= \beta \alpha x_{At} + \alpha \varepsilon_{At} + u_{1t}, \\ y_{2,t} &= \beta[(1-\alpha) x_{At} + x_{Bt}] + (1-\alpha) \varepsilon_{At} + \varepsilon_{Bt} + u_{2t}. \end{aligned}$$

This simple example suggests an estimation strategy. The model is nonlinear in the two parameters,  $\alpha$  and  $\beta$ , but is linear in  $\beta$  given  $\alpha$  and linear in  $\alpha$  given  $\beta$ . With time series data on  $y_{1,t}$ ,  $y_{2,t}$ ,  $x_{At}$ , and  $x_{Bt}$ , one could pick an initial value for  $\alpha$  (say .5), construct the right-hand side regressors and estimate  $\beta$  via ordinary least squares (or generalized least squares, taking into account the heteroskedastic and correlated error structure.) Given the estimate of  $\beta$ , one can rewrite equations (5) as:

$$(6) \quad \begin{aligned} y_{1,t} &= \alpha \beta x_{At} + \alpha \varepsilon_{At} + u_{1t}, \\ y_{2,t} - \beta(x_{At} + x_{Bt}) &= \alpha(-\beta x_{At}) + (1-\alpha) \varepsilon_{At} + \varepsilon_{Bt} + u_{2t}. \end{aligned}$$

Equations (6) show that, conditional on  $\beta$ ,  $\alpha$  could be estimate by another linear regression

(ordinary or generalized). Iterating back and forth between estimates of  $\alpha$  and  $\beta$  until convergence will result in nonlinear (generalized) least squares solutions.

The difference between the representation of the model in equation (4) and that in equations (5) and (6) is one of specificity. All that is required to identify the parameters  $\alpha$  and  $\beta$  in equations (5) and (6) are two time series observations on each of the variables. This comes about because we know that of the over 1300 land trusts and 3000 counties, land trusts 1 and 2 specialize in the two counties A and B. That is,  $\alpha_{1j} = 0$  for all but one county and  $\alpha_{2j} = 0$  for all but 2 counties. The normalization that the shares sum to one within counties further reduces the number of shares to estimate to one.

Implementing the iterative conditional linear estimation strategy should be feasible in the large data set, but requires more development of the model to transform the general representation of the model in equation (4) into more obviously estimable representations like (5) and (6). Grounds for optimism on that score come from the fact that of the 4.2 million values of  $\alpha_{ij}$  (1,351 land trusts X 3,114 counties = 4.2 million), all but 0.4% are known to be either zero or one. Grounds for pessimism come from the fact that the 0.4% of the unknown  $\alpha_{ij}$ 's still represent 18,422 parameters. Given five cross-sections of data, the number of observations available to us are  $5 \times 1,351 = 6,755$ . While the estimates of the  $\alpha_{ij}$  are not of intrinsic interest, reasonable estimates of them are necessary to estimate  $\beta$ , the parameter of interest.

The degrees of freedom problem in estimating the  $\alpha_{ij}$  can be approached either by more attention to data or by introducing stronger identifying assumptions. The “more attention to data” approach would involve finding more detailed information on land trust activity so as to identify their land preservation activity in individual counties. An approach that introduces

stronger identifying assumptions is as follows.

Suppose that land trusts that are large in aggregate tend also to be large in individual counties. If land trust 1 protects 100 acres nationwide and land trust 2 protects 50 acres nationwide, then if they are the only two trusts operating in county A their shares in county A are  $100/(100+50) = 2/3$  and  $50/(100+50) = 1/3$ . The relative weights within states are proportional to their aggregate level of activity. In the notation of the econometric model, the estimates of  $\alpha_{ij}$  using this approach are:

$$(7) \quad \alpha_{ij} = \frac{y_{i\cdot}}{\sum_{k=1}^I d_{kj} y_k},$$

where  $d_{kj}$  equals one if trust  $k$  operates in county  $j$  ( that is, if  $\alpha_{kj} > 0$ ) and equals zero if trust  $k$  does not operate in county  $j$  ( $\alpha_{kj} = 0$ ). The time subscript has been suppressed in equation (7), leaving ambiguous which year's measure of  $y_{i\cdot}$  is to be used. A natural approach would be to use the means of  $y_{i\cdot}$  across years.

An appendix available from the authors develops a maximum likelihood approach to analyzing the full panel of five years of data. It requires an estimate of  $\alpha$ , which can be taken to be that given in (7). The procedure assumes that the county-originating disturbance,  $\epsilon_{jt}$ , and the trust-originating disturbance,  $u_{it}$ , are homoskedastic and uncorrelated with one another. Empirical analysis is proceeding using this approach. Future versions of the paper will report results.

## **VI. FUTURE WORK**

By measuring the spatial response of private land trust activity to federal programs and to federal land ownership in general we hope to make two contributions. First, such measurement should contribute to specific understanding of the real effects of government land policies, allowing for the fact that private citizens and private institutions respond to them. Second, it should contribute to a general and quantitative understanding of the interaction between government provision and private provision of public goods.

The empirical effort described here is in a preliminary stage. Our plans to build upon it include: (1) extending the econometric methodology to more reliably conform the land trust data to the county level, (2) expanding the coverage of our land trust data set to include information from The Nature Conservancy, and (3) expanding the investigation of government programs to include the Wetland Reserve Program, specific conservation practices within the Conservation Reserve Program, and changes in the size of the federal estate.

Figure 1:  
Efficient Provision of Land Amenities

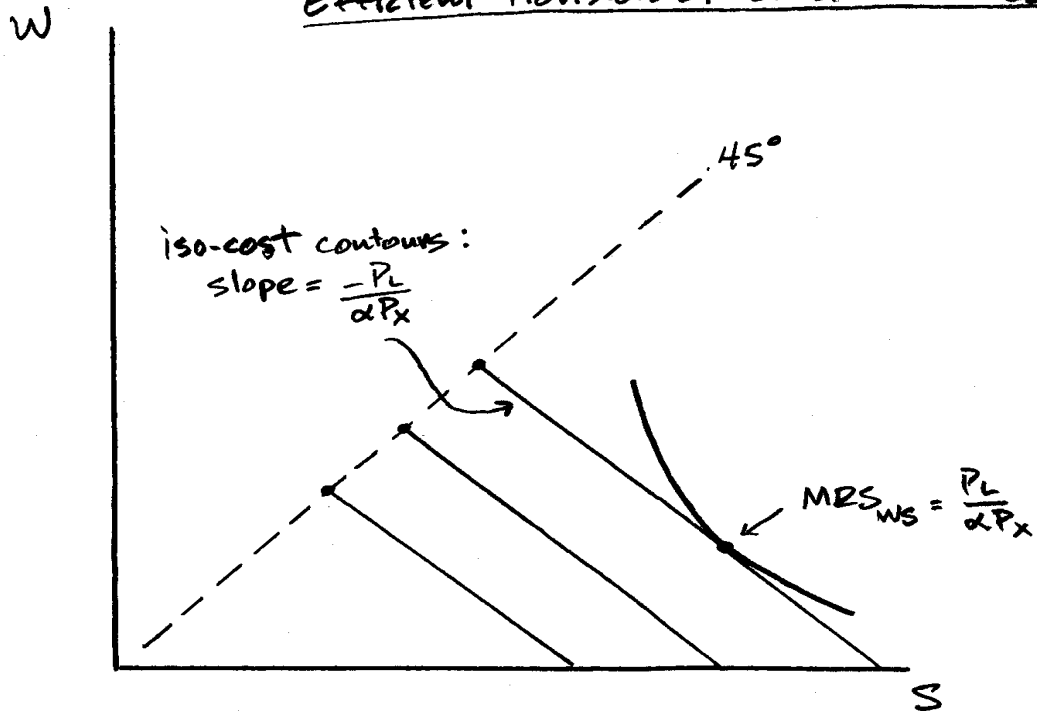


Figure 2:  
Equilibrium in the Market for Land

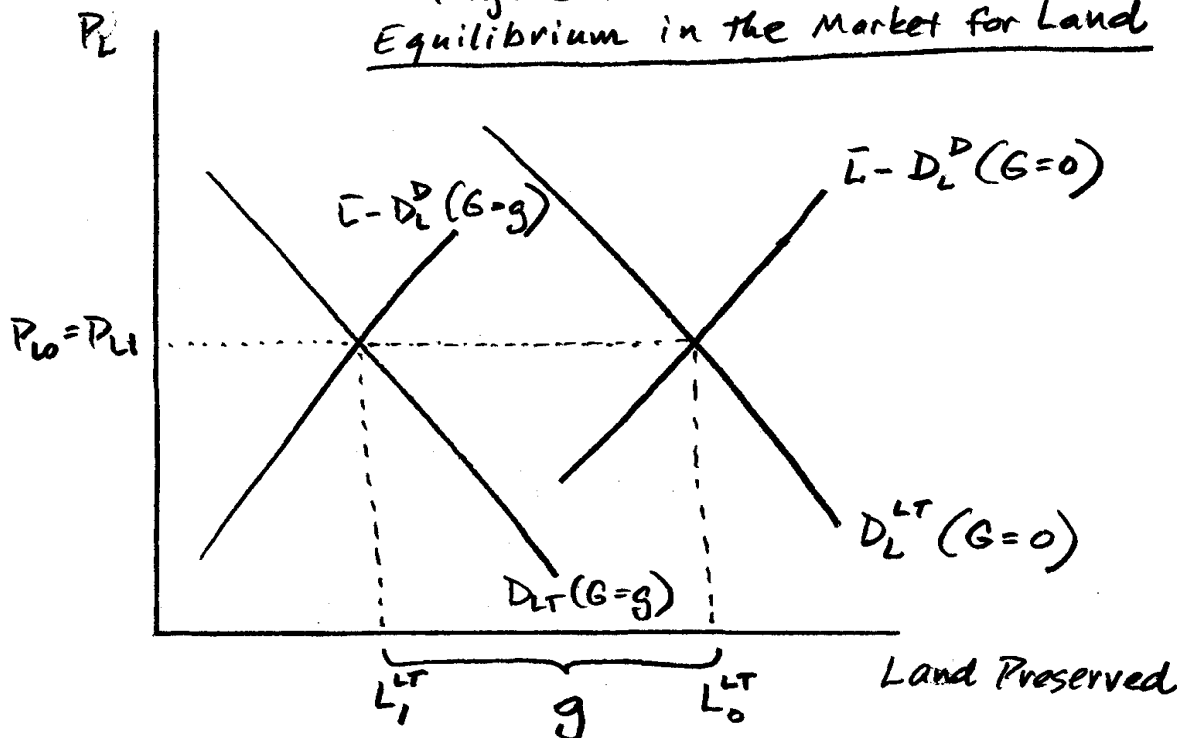




Figure 3.

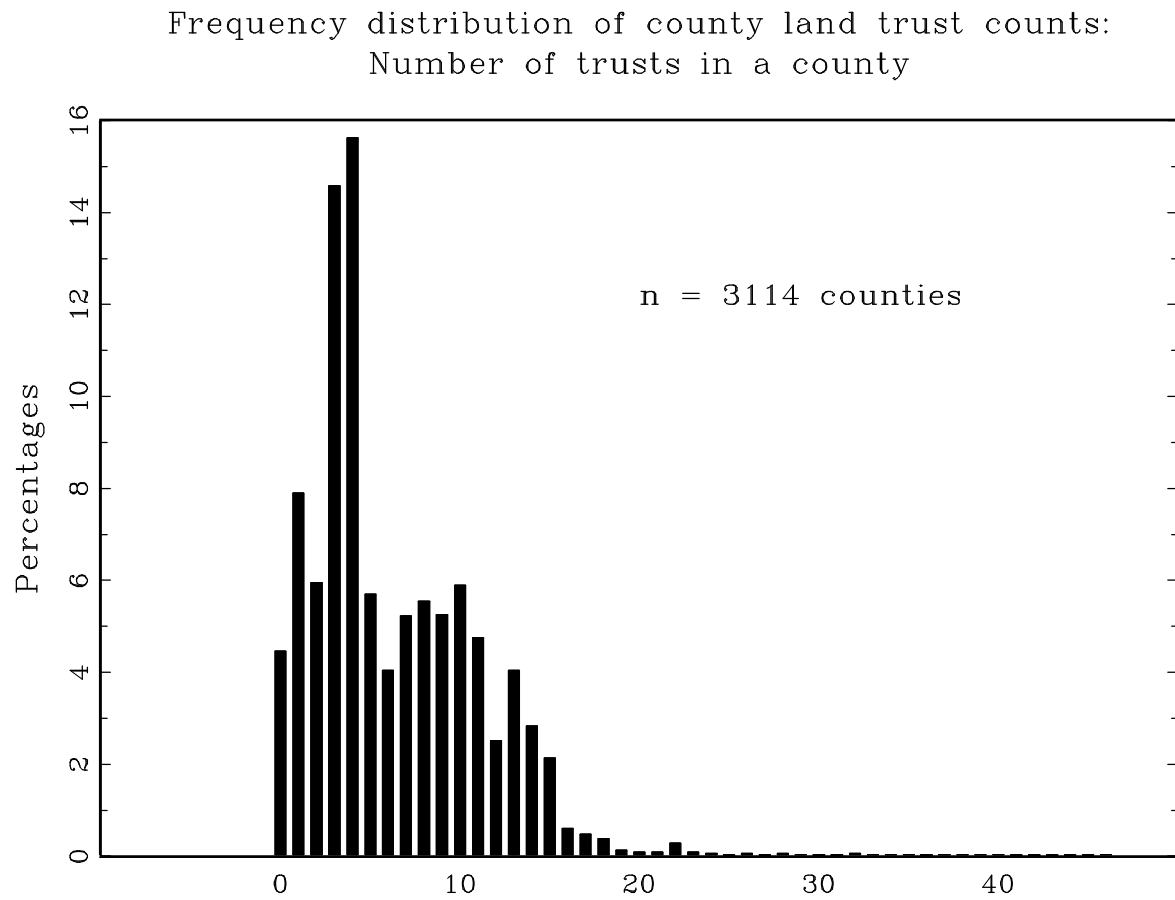


Figure 4.

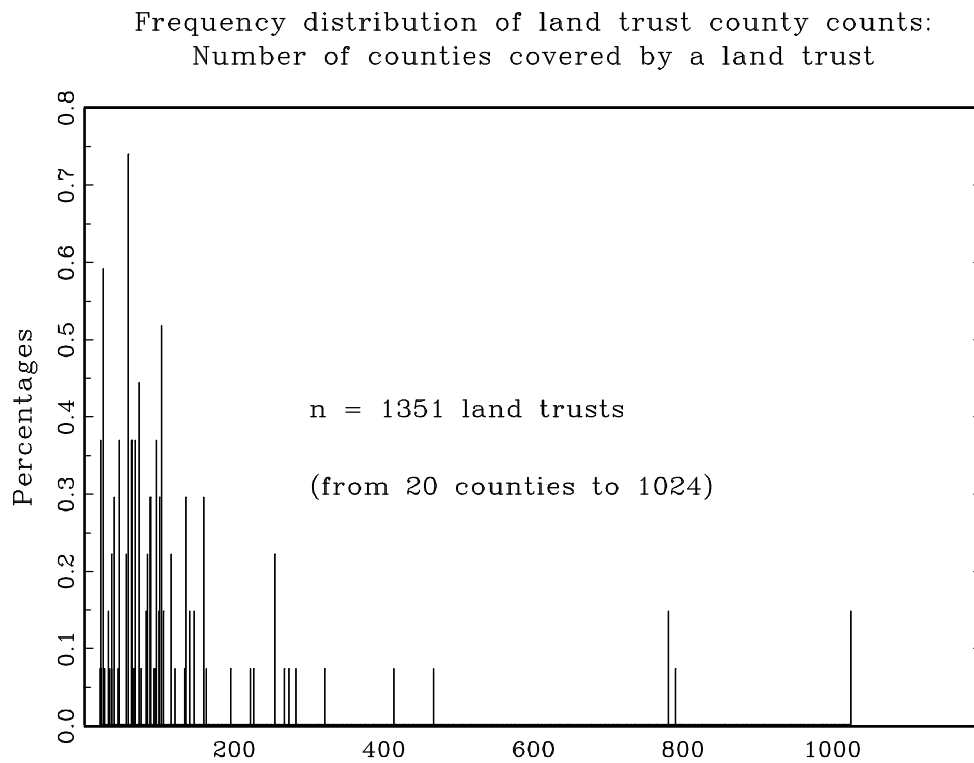
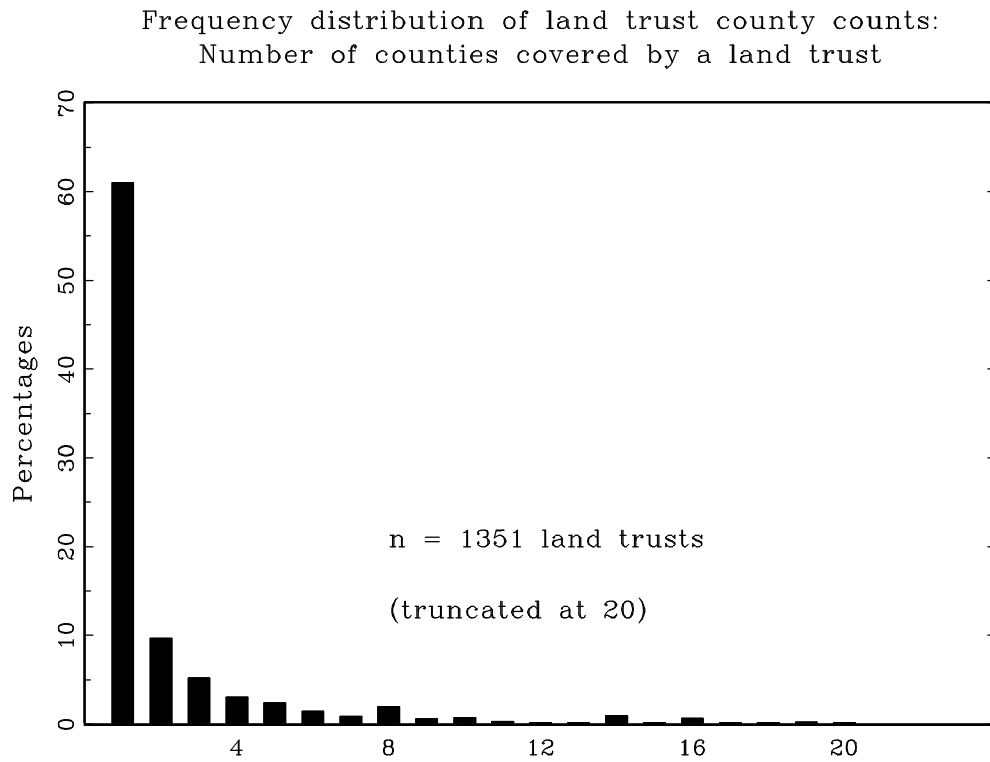
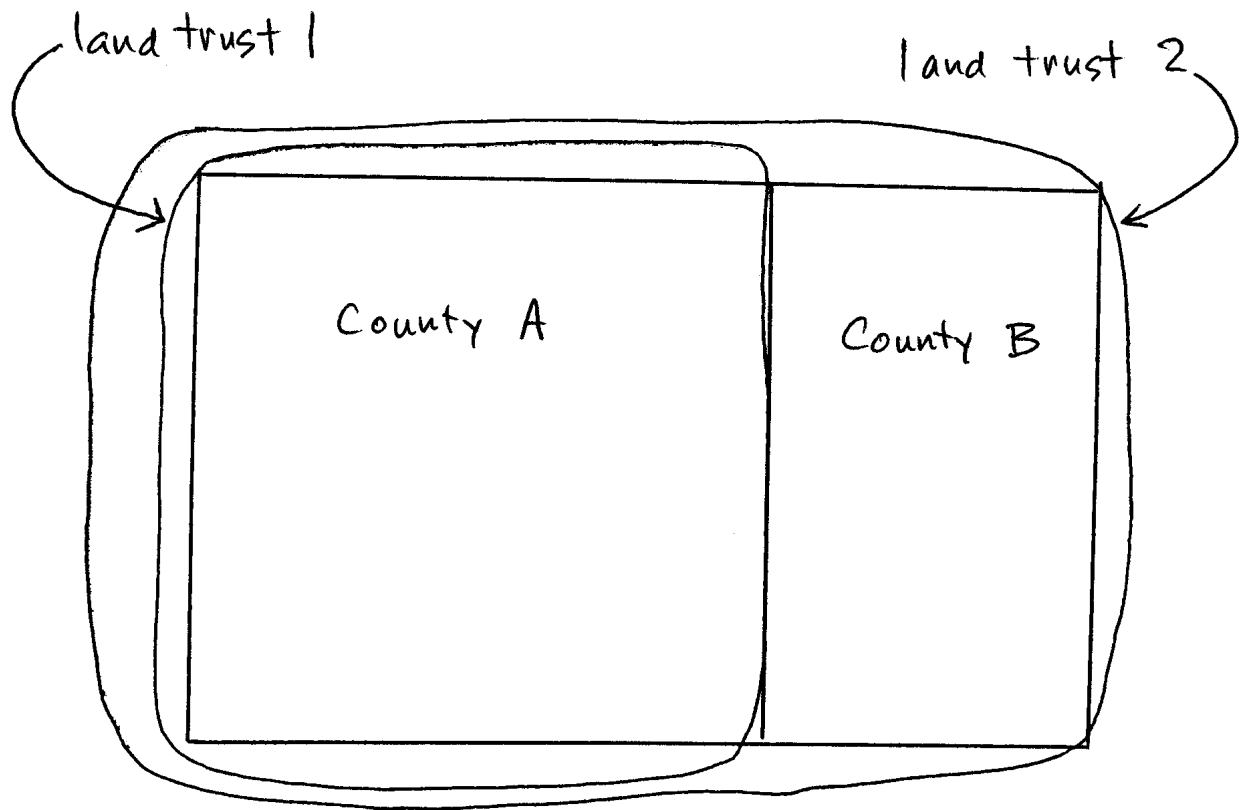


Figure 5. Two Overlapping Land Trusts Operating in Two Counties



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