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DETERMINANTS OF LAND-USE CHANGE IN THE UNITED STATES, 1982-1997: RESULTS FROM A NATIONAL-LEVEL ECONOMETRIC AND SIMULATION ANALYSIS*

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ABSTRACT

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Key words: land use; econometric model; counterfactual simulation; Conservation Reserve Program (CRP).

Changes in the use of land in the United States produce significant economic and environmental effects with important implications for a wide variety of policy issues, including protection of wildlife habitat, management of urban growth, and mitigation of global climate change. In contrast to previous descriptive and qualitative analyses of the trends in national land use, this paper uses an econometric approach to isolate the importance of historical changes in land-use profits and key government policies in determining national land-use changes from 1982 to 1997. The policies we examine are the Conservation Reserve Program (CRP) and total government payments to crop producers. We estimate a national-level discrete choice model of changes among the major land-use categories (crops, pasture, forest, urban, range, and CRP) with parcel-level observations of land use and land quality from the U.S.D.A. National Resources Inventory (NRI) and measures of county-level land-use net returns from a variety of sources. We then use fitted values from the econometric model to simulate land-use change from 1982 to 1997 under a series of factual and counterfactual scenarios that isolate the effects of different economic and policy factors. The simulations suggest how changes in economic returns and government policies have driven land-use changes in the past and will continue to affect nationwide land-use changes in the future. For example, we find that the introduction of the CRP and the decline in crop profits were the most significant explanatory factors driving the decline in cropland. Our results highlight some "unintended consequences" of government policies and the importance of net returns to a range of alternative land uses as determinants of land area change for each particular use.

Determinants of Land-Use Change in the United States, 1982-1997: Results from a National-Level Econometric and Simulation Analysis

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1. Introduction

Over the past two decades, the United States has experienced historically large shifts in land use and land-use trends. From 1982 to 1997 in the contiguous 48 states, cropland decreased about 10%, urban areas increased by almost half, and forested land area began to rise after having declined since the early 1960s.[1] Such broad changes in land allocation and land-use trends produce significant economic and environmental effects with implications for a wide variety of policy issues, including maintenance of water quality, preservation of open space, and mitigation of global climate change. Economists have documented these nationwide land-use trends and identified different determinants of land-use change. However, there has been little effort to assess and compare the importance of the different economic and policy factors that are believed to affect land use in the U.S. Understanding the relative influence of these different factors is important to predict future trends and to design potential public policies aimed at land use.

In order to expand our understanding of the determinants of national-level land-use dynamics, this paper identifies the relative impact of the different factors driving changes among the major land-use categories over recent history in the 48 contiguous United States. We focus on the period from 1982 to 1997 and evaluate the effects of changes in the profitability of different land-use alternatives and the effects of two key national policies directed at land use. In particular, we examine the land-use impacts of the Conservation Reserve Program (CRP), the largest U.S. federal program targeting land use, which paid landowners to voluntarily retire about 32.6 million acres of cropland from 1985 to 1997. We also analyze the land-use impacts of total government payments to farmers, which contributed significantly to the profitability of crop production during most of our period of our analysis.

Assuming profit-maximizing landowners, the classic theory dating to the nineteenth century explains land-use patterns in terms of the relative rents to the alternative uses. These rents will vary with land characteristics, particularly soil fertility and location as first emphasized by David Ricardo and Johann von Thunen, respectively. A number of studies over the past two decades have

[1] The Appendix discusses the definitions of the different land-use categories used in this paper.

empirically examined the determinants of private land-use decisions. These studies statistically estimate the relationship between observed land-use patterns (or land-use changes) and explicit or proxy measures for land rents. This literature supports the theoretical predictions that land rents are the principal determinants of land-use patterns. In addition, because data on actual land rents are typically available only for a county or other aggregate level, studies demonstrate the importance of accounting for the heterogeneity of factors, particularly land quality, that affect land-use profits for the individual landowner (*e.g.* Lichtenberg 1986; Stavins and Jaffe 1990; Plantinga 1996). Studies examining urban development also show the importance of location, chiefly distance from cities, as a proxy for the rents to urban development (*e.g.* Mauldin, Plantinga and Alig 1999a, 1999b).[2]

While these studies identify important determinants of land-use change, there has been little analysis of the relative importance of different factors in driving historical land-use changes. A notable exception is the study by Stavins and Jaffe (1990). They use an econometric model to simulate land-use change in the Mississippi delta under a series of counterfactual scenarios that isolate the relative importance of flood control projects and other factors in driving the depletion of forested wetlands from 1935 to 1984.[3] At the national level, a series of USDA reports describe major nationwide land-use trends and provide some qualitative discussion of the principal land-use drivers. These include studies from the Economic Research Service (Daugherty 1991, 1995; Anderson and Magleby 1997; Krupa and Vesterby 2001; Heimlich and Anderson 2001) and the U.S. Forest Service (Alig and Wear 1992; Alig, Dicks, and Moulton 1998; Flather, Brady and Knowles 1999).

In contrast to these descriptive and qualitative analyses of the trends in national land use, the current paper uses an econometric approach to quantify the relative impact of different land-use drivers at the national level. The basis for our analysis is an econometric model of national land-use change among the six major land-use categories (crops, forest, pasture, urban, range, and CRP). Previous econometric-based analyses of private land-use choices have focused on relatively small geographic areas such as regions or single states. The few previous studies with national-level data have examined changes in a single land-use category without modeling the full range of land-use alternatives that simultaneously influence land-use changes at the national scale. These studies

[2] In theory, a landowner's individual characteristics, including age, skill, income, and risk preferences, might also affect the choice of alternative land uses. Although authors have argued that these factors should be included in empirical land-use models (Alig, Dicks, and Moulton 1998), few studies include these factors due to lack of data.

[3] Ahn *et al.* (2002) also use a similar approach to examine the relative importance of different factors in determining historical changes in forest area in the South Central U.S. from 1964 to 1997.

examine urban areas (Alig and Healy 1987), government conservation programs (Parks and Kramer 1987; Poe 1998; Plantinga *et al*. 2001), and timberland (Plantinga and Buongiorno 1990). Our broader geographical scope requires consideration of a comprehensive menu of land-use alternatives. We consider a greater number of land-use alternatives than previous authors with the exception of work that distinguishes among different forest ownerships in the U.S. South (Alig 1985, 1986; Alig, Dicks, and Moulton 1988) and five different urban uses in the San Francisco Bay area (Landis and Zhang 1998a, 1998b).

Due to the scarcity and cost of obtaining data on individual land-use decisions, land-use studies generally use aggregate data for a county or other geographic region. One disadvantage of these studies using aggregate data is that they examine factors affecting land disposition (*e.g.* levels in base area shares allocated to each land use) as opposed to changes in land use in terms of transitions among particular land-use categories. As a result, these analyses provide only indirect information on individuals' choices regarding particular land-use changes, which might be of interest.[4] The series of studies of land-use change that do use parcel-level data generally focus on urban use and examine the determinants of conversion from a generic non-urban (undeveloped) use to a single urban (developed) state.[5] For example, a series of studies with spatially-explicit data examine conversion from undeveloped to residential uses in Central Maryland using parcel data from county tax assessment offices (Bockstael 1996; Bockstael and Bell 1997; Irwin and Bockstael 2002).

We estimate a discrete choice model of land-use transitions among with parcel-level observations of land use and land quality from the USDA National Resources Inventory (NRI) and measures of county-level land-use net returns from a variety of sources. Our focus on land-use change among a variety of categories raises a number of empirical challenges, including the need to take into consideration the possibility of different substitution patterns among the land-use alternatives. To address this issue, we use a nested logit specification for the probability of change from one land-use category to another.

To evaluate the relative importance of the different economic and policy factors on land-use change, we conduct a version of the analytical experiment in Stavins and Jaffe (1990). Specifically,

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[4] Notable exceptions are a few studies that either examine one-way land transitions, such as transitions from agricultural to urban uses (Hsieh, Irwin and Forster 2001; Irwin, Hsieh, and Libby 2002), or explicitly use econometric methods to recover the unobserved land-use transitions (Plantinga and Ahn 2002).

[5] A few authors have used parcel-level data to study transitions among non-urban uses. Using parcel-level data from the NRI, Claassen (1993) also examines land-use changes between crops and pasture and crops and forests in South Carolina while Claassen and Tegene (1999) model changes between crops and pasture in the Corn Belt region. Schatzki (2003) uses NRI parcel-level data to study the effects of uncertainty on transitions between crops and forests in Georgia.

we use fitted values from the econometric model to simulate land-use change from 1982 to 1997 under a series of different scenarios. A simulation with the historically observed values of all variables (the "factual" simulation) provides a basis for comparison with a series of counter-factual scenarios. In these counter-factuals, one or more of the explanatory variables is set at a hypothetical value and all the other variables are kept at their historically observed values. The difference in the simulated land-use changes between the counterfactual and factual simulations provides an estimate of the land-use impact of the historical realizations of the economic or policy variable(s) of interest, relative to the hypothetical scenario.

The remainder of this paper is divided into four sections. The next section reviews our econometric model, data, and estimation results. Section 3 describes our factual and counter-factual simulations and presents our simulation results on the relative importance of the different land-use determinants. Section 4 discusses these results and provides concluding comments.

2. National-Level Econometric Model of Land Use

Our econometric modeling approach follows the land-use literature in identifying profits per acre and land quality measures as the driving factors of landowner decisions and in using a random utility specification for landowner returns. We use this framework to specify an econometric model representing land-use change as a first-order Markov process. Markov transition probabilities are specified as functions of county-level land-use returns, plot-specific land quality measures, and parameters to be estimated. Modeling transitions among a broad set of land-use options introduces the econometric challenge of accounting for potentially different substitution patterns among the various choices. We estimate the parameters of the transition probabilities using a nested logit that allows for variation in substitutability among different subgroups of the land-use choices. In this section, we first present our econometric model and then review selected estimation results.

2.1 Nested Logit Model

To motivate our econometric model, we begin with the optimization problem for an individual risk-neutral landowner faced with the choice of allocating a parcel of land of uniform quality among a set of alternative uses. Under simplifying assumptions[6], given a parcel of land i in use k at

[6] Simplifying assumptions include constant returns to scale in land and perfect land and credit markets. We also assume that landowners do not account for future conversion possibilities when evaluating alternative land-use options. A more detailed discussion of the landowner's optimization problem is provided by Lubowski (2002).

time t, a profit-maximizing landowner will choose the land use j at time $t+1$ that yields the highest expected present discounted value of an infinite stream of net returns minus conversion costs. To produce an econometrically tractable model, we assume landowners have static expectations over future net returns. It seems reasonable that landowners base at least part of their expectations of future net returns on current or historic levels of returns.[7] The landowner's decision rule is then to choose the use with the highest current one-period return minus the current one-period opportunity cost of undertaking conversion. The landowner chooses use k at time t if:

$$R_{kt} - rC'_{jkt}\left(a_{jkt}\right) > R_{jt} \tag{1}$$

for all alternatives j where R_{jt} is the instantaneous net benefits from an acre of land in use j at time t, $C_{jkt}(a)$ are the total costs of converting a acres of land from use j to use k at time t; and r is the discount rate ($r>0$).

Given that we do not have reliable data on all variables that might affect the landowner's returns to the different uses, we write the landowner's profit function to include both observed and unobserved components. Imposing different structures on the unobserved components produces different classes of probabilistic models in which the probabilities will always lie in the unit interval and sum to one. We develop a two-level nested logit specification as it is the most tractable model for problems with multiple choices that still permits for differences in the substitutability among alternatives.[8] The nested logit imposes requires "independence of irrelevant alternatives" (IIA) within but not across particular subgroups of alternatives.[9]

We assume that the choice set can be partitioned into S mutually-exclusive subgroups which share certain unobserved components, thus introducing covariance among the utilities of choices within a particular nest. A two-level nested logit model decomposes of the choice probability into two components: the marginal probability P_{ijst} of choosing a particular subgroup or "nest" s

[7] In an analysis of models of farmland price changes, Just and Miranowski (1993) report that an expectations model based on lagged values performs better than models based on forward looking price expectations.

[8] Multinomial probit models allow an unrestricted covariance matrix for the errors, but large models still face computational limits (Greene 2001). The most general model for relaxing the IIA property is the random parameters (also called "mixed" or "kernel") logit which has recently received increasing attention and application (see Train 2003 for a review). While this model is theoretically appealing, estimation requires simulation methods that are computationally very intensive. Simulation bias is also a potential problem that will be exacerbated in the case of relatively small probabilities and large numbers of observations.

[9] The assumption of independent disturbances in the logit model implies that the ratio of the probabilities of any two choices must be independent of the other alternatives. This IIA property is a well-known limitation of logit models as it imposes potentially important restrictions on the admissible types of choice behavior by precluding differences in the degree of substitutability between the different choices.

(s=1,…,S); and the conditional probability $P_{ijkt|s}$ of choosing a particular alternative *k* within the alternatives *(l=1…J_s)* in nest *s* conditional on the choice of that nest.

In particular, we assume the landowner's utility U_{ijkt} contains a component V_{ijkt} that is unique to the alternative and another component V_{ijst} that depends on each subgroup *s*:

$$U_{ijkt} = V_{ijkt} + V_{ijst} \tag{2}$$

Each of these components, in turn, included observed and unobserved components:

$$V_{ijkt} = \beta_t ' x_{ijkt} + \varepsilon_{ijkt} \tag{3}$$

$$V_{ijst} = \gamma_t ' z_{ijst} + \varepsilon_{ijst} \tag{4}$$

where x_{ijkt} are observed attributes of each land parcel, z_{ijst} are observed attributes of each nest, and γ_t and β_t are parameters. Additional model requirements are that the error terms ε_{ijkt} and ε_{ijst} are independent and further assumptions ensuring their sum is i.i.d. Gumbel-distributed (Ben-Akiva and Lerman 2000). This model yields the following expression for the probability of choosing land use *k* at time *t+1*:

$$P_{ijkt} = P_{ijst} \cdot P_{ijkt|s} = \frac{\exp(V_{ijst} + \tau_{st} ' I_{ijst})}{\sum_{s=1}^{S} \exp(V_{ijst} + \tau_{st} ' I_{ijst})} \cdot \frac{\exp(V_{ijkt})}{\sum_{l=1}^{J_s} \exp(V_{ijkt})} \tag{5}$$

where τ_{st} are parameters associated with *I,* the "inclusive value" for nest *s*, defined as:

$$I_s = \ln \sum_{l=1}^{J_s} \exp(V_{ijkt}) \tag{6}$$

The inclusive value for nest *s* is the log of the denominator of the conditional probability in (5) and is a composite measure of the utility of the alternatives within that subset of alternatives. This expression embodies the first-order Markov property since the probability of the parcel changing use depends only on decision variables in time *t*.

Specification issues

Differences in substitutability among different land-use alternatives provide a motivation for using a nested logit specification. There are different dimensions along which one can imagine patterns of substitutability for different land-use choices.[10] Different land quality requirements are potentially a key determinant of the substitutability among land uses. Land uses vary distinctly in terms of where they are found on the spectrum of land quality classes. Lands in crops have the highest average land quality, as measured by the Land Capability Class (LCC) system[11], followed by CRP, pasture, urban, forests, and range lands. Land uses with more similar land quality requirements may be considered closer substitutes for a landowner considering choices for a particular land parcel.

Following this reasoning, we specify a nested logit model with three separate nests: 1) the "farm" nest containing crops, CRP, and pasture uses; 2) the "non-farm" nest containing forests and range; and 3) the "urban" nest containing only the urban choice. We include pasture in the nest with crops and CRP as it lies closer to these uses in the land quality spectrum.[12] We model urban development as a distinctly different choice due to its much greater degree of irreversibility and because land quality is likely to be a less important determinant of the profitability of urban development.[13]

Returning to the landowner's decision rule presented in (1), the landowner for plot *i* will choose the use that yields the greatest expected future stream of discounted net returns minus conversion costs. While the landowner presumably acts after comparing the returns to the different uses on his particular plot of land, we do not have observations on the profits from each land use

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[10] To the extent that farmers operate joint crop and livestock operations, farmers may already have skills for pasture and range uses—rather than forestry, for example—so crops, pasture and range uses may be closer substitutes to each other than to other uses. Claassen (1993) argues that a landowner without access to credit might view crop and pasture production as more similar in terms of producing an annual return in contrast to longer term investment in forestry. At the same time, he points out that forest and pasture land uses may be similar in terms of lower labor requirements.

[11] The LCC system is based on a ranking of twelve different soil characteristics that are critical for crop production. The overall LCC score consists of the lowest ranking given to any of these twelve soil features based on the principle that this factor will be limiting for crop production (USDA 1973).

[12] Assigning values 1 through 4 to the ratings of LCC 1 or 2, LCC 3 or 4, LCC 5 or 6, and LCC 7 or 8, respectively, yields the following average land qualities for private lands in the contiguous 48 states: 1.5 (crops), 1.9 (CRP), 2.0 (pasture), 2.2 (urban), 2.7 (forests), and 3.0 (range).

[13] Due to the limited number of observations for some choices in some time periods, it was not possible to estimate all the parameters of a model with three nests for all of the starting land uses and time periods considered. In four out of the twelve cases where we estimate separate models by transition period, we estimate a model with two nests, including the urban choice within the farm nest. In particular, we estimate a model with two nests for land starting in pasture for

particular to each plot. Instead, we observe county-level returns, which reflect the average characteristics of the area in each land use in each county.

To account for the variation in net returns at the plot-level, we interact the profit variables for each land use with a set of dummy variables indexing plot-level land quality. Land quality will affect land-use profits principally through its effect on biomass yields. In particular, we consider the LCC ranking of the plot, which is a summary measure of the suitability of the land for crop production. To the extent that the LCC rating the relevant variation in land quality, land parcels with qualities below (above) the county average (embodied in the county-level return measures for each land use) should have their returns scaled down (up) by the coefficient on the interaction with the LCC ranking.[14]

In particular, we specify the equation in (5) for V_{ijkt}, denoting the parcel-level component of net returns to choosing use *k* on land parcel *i* in use *j* and county c, as follows:

$$V_{ijkt} = \alpha^0_{jkt} + \alpha^q_{jkt} LCC^q_{it} + \beta^0_{jkt} R_{kc} + \beta^q_{jkt} LCC^q_{it} R_{kc} + \varepsilon_{ijkt} \qquad (8)$$

where α^0_{jkt} is an alternative-specific intercept, α_{jkt} and β_{jkt} are parameters, R_{kc} denotes county-level measure of net returns to use *k*, and LCC^q_{it} is a dummy variable indicating whether land plot *i* is in land quality *q* at time *t*.[15] To ensure sufficient observations in each group, we follow Plantinga (1996) and combine the eight LCC classes into four. For identification purposes, we normalize to zero the coefficients on the dummy variables for the crop alternative and for LCC 1 or 2.

We do not include a measure of CRP profits per acre, as the CRP rental rates are highly dependent on the profitability of crop production in a region.[16] Instead, we model profits to the CRP as simply a function of the LCC dummy variables. While the criteria for CRP eligibility have varied from signup to signup period, the LCC rating has always been one of the potential criteria for enrollment. Other CRP criteria, such as susceptibility to erosion, are also highly correlated with

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the 1992-97 period, land starting in forest for the 1987-92 and 1992-97 periods, and land starting in range for the 1987-92 period.

14 The distribution of land quality across counties will differ. By estimating a single set of coefficients for all counties, the parameters, we estimate reflect the nationwide average degree of divergence of each LCC category from the county average land quality for each land use considered.

15 While LCC^q_{it} is subscripted by *t*, in practice the LCC rating changes over time on only about 1% of the sample of plots.

16 In addition, CRP enrollment criteria continued to evolve with each signup, making it unclear that extant rental rates would be an appropriate measure for payments offered in future signups. In addition, the program has been shifting away from a broad market-based program towards a strategy of targeting payments to enroll lands with particular environmental characteristics (USDA ERS 2000).

lower land quality as measured by the LCC rating (Schatzki 2003).[17] Thus, we would expect the dummies for the lower land qualities to be positively related to CRP enrollment.

For a given starting land use *j*, the parameter α^{q}_{jkt} in equation (8) is an intercept term that varies for each alternative use *k*. In combination with $\alpha^{q}_{jkt} LCC^{q}_{it}$, these provide an intercept that varies by land quality and captures unspecified factors that affect the profitability of changing from use *j* to *k* which are not measured by the terms for the parcel-level returns as a function of R_{kc}. In this sense, we interpret these constants as a measure of "conversion costs," broadly defined as the opportunity costs of moving to a different land use.

In specifying the nest-level equations that enter into the first term of (5), we include constant terms for each of the nests interacted with the different land quality groupings to capture differences in the choice of nests based upon land quality. In particular, for land parcel *i* in use *j* and county *c*, the utility to choosing a use within nest *s* is specified as:

$$V_{ijst} = \gamma^{0}_{jst} + \gamma^{q}_{jst} LCC^{q}_{it} + \tau_{st} I_{ijst} \quad (9)$$

where *s* identifies either the farm, non-farm or urban nests, and *q* indexes the LCC grouping. γ^{0}_{jst} is an intercept term specific to each of the three nests,[18] γ^{q}_{jst} is a coefficient on the LCC grouping at the nest level, and I_{ijst} is the inclusive value of the nest with coefficient τ_{st} in (5). For identification, we normalize to zero the coefficients on the farm, crops and range constants and the dummy for LCC 1 or 2.

Estimation issues

Substituting equations (8) and (9) into (5) yields our nested logit model for estimation. Our analysis relies on parcel-level data on both land-use changes and land quality from the NRI, a panel survey conducted at five-year intervals from 1982 to 1997. Our dependent variable is the choice of land-use at time *t+5*, where *t* spans one year. Our independent variables are the land use at time *t*,

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17 Following Schatzki (2003), another option would have been to develop a specification using measures of erodibility and other land characteristics from the NRI that determine CRP program eligibility. This approach was not pursued as the detailed data on land characteristics from the NRI points did not appear to reflect the eligibility of the corresponding land parcels for the CRP program. This is perhaps due to differences in the spatial scales of these particular data versus the information used for determining the eligibility of an overall land parcel.

18 We include the constant for the urban alternative at the level of the urban nest equation.

the land quality rating of the parcel, and proxies for the expected net returns from the land-use alternatives as of *t*. In the following sections, we discuss our different data sources in greater detail.

We estimate the model through maximum likelihood procedures based on cross-sectional variation of the independent variables.[19] We separately estimate parameters for transition probabilities for each of four starting land uses (crops, pasture, forest, and range) and each of the available transition periods. We use all of the observations on land parcels in each respective use at the start of each of the three periods (1982-87, 1987-92 and 1992-97).[20] Thus, in total, we estimate twelve separate equations (four land uses times three time periods).[21]

One additional econometric issue is the fact that parcels sharing a similar location might have unobserved characteristics that are correlated across space. Parcels in the same vicinity will share locational features—such as distance to urban centers, roads, and other infrastructure—as well as common zoning and regulatory regimes. If these features influence land-use decisions, the error terms in our model will be correlated across space. In the case of discrete dependent variables, spatial dependence from either spatial autocorrelation or spatial interdependence in the behavior of different agents implies heteroskedasticity, causing parameter estimates to be both inconsistent and inefficient (McMillen 1992; Beron and Vijverberg 1999). While spatial dependence is a potential problem in theory, given that our models are estimated with data from the entire country, this will tend to reduce the influence of any local spatial effects. We explored the potential importance of spatial dependence using the simple approach of attempting to purge the sample of spatial dependence by sampling observations so as to eliminate land parcels within a certain geographic

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[19] In the estimation, we weight the observations with the NRI's acreage weights in order to ensure that the estimates reflect the distribution of potentially unobserved effects in the population. To avoid shrinking the standard errors due to this weighting, we scale the weights so that they sum to the total number of actual observations as recommended by Greene (1998).

[20] We also estimated models with pooled data and found that estimation based on the separate cross-sections yielded superior fits for these particular time periods (Lubowski 2002). While parameters from pooled data might be superior for predicting future land-use changes, we use the transition-specific parameter in the current analysis given our goal of simulating land-use behavior over specific historical periods.

[21] For lands enrolled in CRP, we only observe land-use changes from 1992-97 during which time the first CRP contracts expired and lands became eligible to exit the program. Modeling land-use changes on CRP lands is complicated by a variety of factors, including the fact that re-enrollment depends on the landowner's choice as well as on the acceptance of the landowner's bid by the government. Land-use choices upon CRP contract expiration are the subject of a separate econometric study using NRI data (Lubowski and Roberts 2003). For the purpose of the historical simulations discussed in Section 4, we simulate acres dropping out of the CRP during 1992-97 using a reduced form approach. We compute transition probabilities to all uses for plots starting in the CRP using parameters estimated with observations of plots that started in CRP in 1992. The estimated coefficients are positive on all the net returns variables and significant for the profits for crops and forests. Our approach is not likely to have a significant impact on the major land-use changes during our period of analysis as the first CRP contracts did not expire until 1996 and the total acreage leaving the program was relatively small (3.5 million acres or about 10% of total enrolled acreage).

distance of each other.[22] Estimates of our models with sub-samples of data that include only a single point in each sampling cluster produced qualitatively similar results than estimates that included all points, suggesting that spatial dependence is not a critical concern for our analysis.[23]

2.2. Data

Data on land use and land characteristics

Conducted by the Natural Resources Conservation Service (NRCS), the NRI provides information on land use, land characteristics, and conservation practices for about 800,000 points of non-federal land in all counties of the contiguous U.S. plus Hawaii, Puerto Rico, and the U.S. Virgin Islands. We observe land use at each NRI point at four points in time (1982, 1987, 1992, 1997), providing information on land-use change over three five-year periods (1982-87, 1987-92 and 1992-97). Each NRI point represents a different number of acres according to an acreage weight that is inversely proportional to the sampling intensity for that location and land use. The NRI's stratified sampling design is intended to provide acceptable variances of the estimates at the level of states, 212 four-digit hydrological units, and 204 major land resource areas (MLRAs).

We focus on six different land uses: crops, pasture, forest, urban, range, and CRP. Further details on the NRI definitions of these uses are provided in the Appendix. We exclude from our analysis lands under rural roads and transportation as these land uses are likely to change through a different decision-making process than profit maximization by private landowners. We also exclude streams and water bodies, marshlands, and "barren lands" such as sand dunes, permanent snow fields, and bare rock, as these are unlikely to respond to economic incentives. Finally, we exclude other private lands which the NRI classifies under unspecified "miscellaneous" uses. With these adjustments, the land base for our analysis comprises approximately 1.4 billion acres, representing about 74% of the total land area and about 91% of the non-federal land area in the contiguous 48 states.

Table 1 reports the NRI data on land-use transitions over the entire 1982-97 period of our analysis. This table shows how much land that was in a particular use in 1982 was in that same use as well as each alternative land use in 1997. For example, of the 286 million acres in crops in 1982,

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[22] In recent years, authors have developed new approaches for estimating discrete choice models with spatial dependence, particularly in terms of spatial probit models. Nevertheless, these methods are computationally infeasible for our current study given the size of the data set and the number of alternatives in the choice problem considered.

[23] A more detailed discussion is provided in Lubowski (2002).

78% remained in crops in 1997, 10% were in pasture, 1.2% in forest, 1.5% in urban use, 0.8% in range, and 7.8% in CRP. The diagonal elements of the table show that land areas tend largely to remain in their previous use. In particular, the choice of urban is virtually irreversible, with 99.99% of urban lands remaining urbanized after fifteen years.

In addition to data on land use, the NRI provides our observations of the Land Capability Class (LCC) of the plot, which is a summary measure of the suitability of the land for crop production. The LCC system is based on a ranking of twelve different soil characteristics that are critical for crop production. The overall LCC score consists of the lowest ranking given to any of these twelve soil features based on the principle that this factor will be limiting for crop production (USDA 1973).

Data on land-use net returns

Rather than relying on data on net returns information from a single year, we assume that landowners use the average of annual profits per acre to each land use over the preceding five years in making their land-use choices at a given time period.[24] In this way, we smooth over idiosyncratic shocks from weather and other factors that affect profits in particular years. We observe land-use choices at five-year increments and do not have information on the year within that time frame that a particular land-use choice was made. Letting the time t denote a year, we specify land-use choices observed at time $t+5$ as a function of the average land-use profits between years t and t-5.

We construct county-level estimates of annual per acre profits to crops, pasture, forest, range, and urban uses for all 3,014 counties in the contiguous 48 states. This provides county-level observations for five of the six land uses considered, with the exception of the CRP which is treated differently. Lubowski (2002) provides a more detailed description of the methods and data sources used in the construction of the net return measures used in this analysis.

For cropland returns, we use a county-level weighted average of the net returns per acre from 21 major crops plus the value of direct government payments per acre (excluding CRP

[24] Particularly, we include average profits from 1978-82, 1983-87, and 1988-92 as explanatory variables for the land-use decisions from 1982-87, and 1987-92, and 1992-97, respectively. We use lags of five years to capture the general trends in the movements of land-use profits and minimize the effects of possible outlier estimates in our data by using information from all the years in between the transition periods. For the conditional logit model, results for alternate expectations structures with current and lagged three year returns yield qualitatively similar estimates.

payments).[25] The weights are the proportion that the planted acreage of a particular crop represented of the total county's crop acreage in a given year, using acreage information from the National Agricultural Statistics Service (NASS) of the USDA.. We use NASS data on state-level marketing-year-average prices and county-level yields. Data on cash costs as a percentage of revenue are obtained at the state and regional level, respectively, from the Census of Agriculture and USDA Economic Research Service's (ERS) costs and returns surveys. Estimates of direct government payments are from the Census of Agriculture and exclude payments from the Conservation and Wetlands Reserve programs.

To estimate net returns to land in pasture, we use the county-level average of annual pasture yields for different soil types from the National Cooperative Soil Survey (NCSS). Scaled county-average pasture yields are multiplied by the state price for "other hay" from NASS and state-level costs for hay production obtained from the Census of Agriculture. For range returns, we multiply county forage yields from NCSS by state-level per head grazing rates for private lands from the ERS database on cash rents. To the extent that there are any costs of range management, we assume these costs are borne by the tenant and thus already captured in the grazing rates.

As described above, county-level net returns for crops, pasture, and range are naturally computed in annual terms from data on annual yields of major crops and forage. Returns to forests and urban uses are calculated as the net present values of a perpetual stream of forest and urban returns, respectively, and then annualized with an assumed private discount rate of five percent. We compute annualized forestry returns using a weighted county-level measure of the net present value of sawtimber revenues from different forest types where the weights are determined by the species composition of each county. We use state-level stumpage prices for different timber species gathered from a variety of state and federal agencies and private data reporting services. We match forest prices with regional merchantable timber yield estimates for different forest types developed by Richard Birdsey of the USDA Forest Service. We calculate the net present value of an infinite stream of forestry revenues for each forest type based on an optimal rotation age determined with the Faustmann formula at our five percent discount rate. We assume that the forest starts at year zero in a newly planted state but include estimates of regional replanting and annual management costs constructed from Moulton and Richards (1990) and Dubois, McNabb and Straka (1999).

[25] We consider the following major crop types tracked by NASS: wheat (winter wheat, durum wheat, and other spring wheat are treated separately), rye, rice, corn, oats, barley, sorghum, cotton, sugarcane, sugar beets, tobacco, flaxseed, peanuts, soybeans, sunflowers, all dry edible beans, hay (alfalfa hay and all other hay are treated separately), and potatoes.

For urban returns, we use a county-level estimate of the average per-acre price of recently developed land as described in Plantinga, Lubowski, and Stavins (2003). Our estimates measure the average value of a developed parcel less the value of structures and thus correspond to the present discounted value of the stream of rents from improved bare land.[26] We multiply this net present value by a five percent interest rate to obtain an annualized per acre estimate of the profits from urban development.

Table 2 contains summary statistics on the different net returns variables. Average returns are listed for 1978 as well as for the three five year periods, 1978-82, 1983-87 and 1988-92. Trends over these periods are discussed in Section 4.1 on the different simulation scenarios.

2.3 Econometric Results

The estimation results suggest a good model fit, with tests for IIA and homoskedasticity supporting the nested specification. In general, the estimated coefficients are highly significant and consistent with the expected economic relationships and with the reasoning behind the specification of parcel-level land-use net returns as a function of county-level profits and parcel-level land quality. Likelihood ratio tests reject the hypothesis that all of the coefficients are simultaneously equal to zero at the .01 level. Similarly, likelihood ratio tests of the conditional logit model and Wald tests of the nested logit models strongly reject the hypothesis that just the coefficients associated with the profit variables are simultaneously equal to zero at the .01 level. For the transition-specific estimates, pseudo R^2 values (McFadden's likelihood ratio index) ranging from 0.68 to 0.95 indicate that the explanatory variables yield better predictions of the transition probabilities P_{jk} than the mean value of these variables. In all cases, values were highest for lands starting in range or forest; values were lowest for the pasture starting use, suggesting that the model was least able to explain land-use choices for lands in pasture.

Results of Hausman tests of a conditional logit (non-nested) model reinforce the theoretical arguments for a less restrictive model such as the nested specification (Hausman and McFadden 1984).[27] For all the starting land uses, the tests failed to reject the IIA hypothesis.[28] For all of the

[26] This measure is based on value of land for the construction of single-family homes, which is the primary use of developed land at the national scale.

[27] This test involves re-estimating the model with one alternative excluded (and observations dropped if that alternative was actually chosen) and comparing the parameter estimates $\hat{\beta}_F$ and $\hat{\beta}_R$ of the full and restricted models respectively. Intuitively, if the change in the coefficients between the unrestricted and restricted models is systematic, this rejects the null hypothesis that IIA is true.

starting uses, likelihood ratio tests of the nested model against the corresponding conditional logit model reject the null hypothesis of homoskedastic errors across nests at the .01 level. Estimates for the inclusive value parameters on the farm and non-farm nests are also significantly different than one at the .05 level in 21 out of 24 cases. These results do not provide evidence for our chosen nesting structure against other potential nested specifications with this same data. However, the results support this particular nested model over a conditional logit (non-nested) model for this application.[29]

For brevity, we report estimated elasticities rather than all the estimated parameters for our set of 12 equations in Table 3.[30] In general, however, the estimated coefficients are highly significant and consistent with the expected economic relationships. The net returns coefficients are generally significantly different from zero at the 0.1 level or higher and in the expected positive direction, indicating that higher net returns to a particular land use are associated with higher probabilities of choosing that alternative. In addition to validating the role of economic profits in driving land-use changes, the estimates suggest the important role of parcel-level land quality in determining the response of a land parcel to county-level land-use profits. The estimated parameters on the land quality variables are consistent with the idea underlying our specification that the LCC ratings reflect parcel-level differences in net returns for all of the different land uses, and these coefficients effectively scale up (down) the net returns on high (low) quality lands.

As expected, the estimates also reveal that lower quality lands are more likely to be enrolled in the CRP, which is consistent with the eligibility criteria as well as with the higher opportunity costs of crop production on superior land qualities. In addition, the estimated constant terms and land quality dummies indicate the presence of important conversion costs or other unobserved costs or benefits associated with the alternative uses. The signs of these variables are consistent with economic interpretations for the relative costs of converting to the different land uses relative to crops, the base category. For instance, the net costs of converting to crops versus other uses appear

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[28] For each of the twelve sets of transition-period-specific estimates (four starting uses and three time periods), excluding at least one of the categories led to a rejection of the null hypothesis that IIA is valid. Exclusion of each land-use alternative led to rejection of the null in at least two cases (for the crop choice) and as many as six cases (for the urban choice).

[29] For the current application of our model, however, the nested specification is not critical for the results. Simulations using estimates from a conditional logit (non-nested) version of our model produced similar results in both absolute and relative terms.

[30] The full set of estimates is reported in Lubowski (2002) and is available from the authors upon request.

to increase as land quality declines, which seems reasonable given that the LCC ratings are designed to measure the suitability of land for crop production.

We focus on the impacts of the net return variables on the transition probabilities as these are the key relationships exploited in our simulations. For each starting use, Table 3 reports the elasticities for the probability of choosing each particular land-use alternative with respect to the net returns to that alternative (the "own return" elasticities). These elasticities are evaluated at the means of all the variables, including land of quality, for land in each starting use. The estimated elasticities indicate the percentage change in the probability of the specified transition for a 1% change in the profits to the indicated land use. The associated standard errors are approximated through the Delta Method.

The elasticity estimates support the expectation that higher profits for a particular land use are associated with higher probabilities of changing into that use. In 35 out of 60 cases, the own-return elasticities are positive and significant as expected at the .05 level. In the 7 cases where the own-return elasticities are negative, they are never significantly different from zero at the .05 level. The cross-elasticities (not reported) are generally opposite in sign to the own-return elasticities and thus usually negative, as expected.[31]

The estimated elasticities indicate that landowners with lands in either crops or pasture are responsive as expected to the economic returns from all alternative uses. For land starting in crops, all of the own-return elasticities are positive and significant in the cross-sectional and pooled estimates, except for the elasticity with respect to pasture profits for 1982-87, which is negative but not significant. For land in pasture, most of the own-return elasticities are also positive and significant. One exception is the elasticity with respect to pasture choices for 1992-97, which is negative but not significant at the .05 level.[32] Across all of the starting uses, the pasture variable is the least significant of the land-use profit variables, reflecting perhaps the relatively lower quality of the pasture net returns estimates.

For forested lands, the own-return elasticities for crops and urban profits are all positive and significant at the .01 level, suggesting that these are the uses most competitive with forested lands.

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[31] The cross-elasticities are the elasticities of the probability of choosing a particular use *j* with respect to the profits of a different use *k*). In the nested logit model, these can be of the same sign as the own-return elasticities only when the inclusive value parameters are negative. However, this will depend on the relative strength of the variable's effect on the probability of choosing the nest versus the probability of choosing the particular land use conditional on the choice of nest.

[32] The other exceptions are the elasticity of the probability of choosing forests with respect to forest profits for 1987-92 and 1992-97, which are positive but not significantly different from zero.

Two out of three of the pasture and range own-return elasticities and all the forest own-return elasticities are positive but not significant at the .05 level. For land in range, the own-return elasticities with respect to urban profits are all positive and significant at the .05 level. None of the other own-return elasticities are significantly different from zero. These results suggest that lands in range are relatively insensitive to the profitability of alternative uses with the exception of urban and forest uses. This is reasonable given that range lands tend to be the lands of the lowest quality and thus unsuitable for any uses that depend on high quality soils.

3. Factual and Counter-Factual Simulations

In this section, we first describe the methods and then report results for our simulations that isolate the importance of particular economic and policy factors in driving the national-level changes among the major land uses from 1982 to 1997. In particular, we simulate the total amount of land transitioning between the six land-use categories (crops, pasture, forest, urban, CRP and range) under factual and counterfactual scenarios.

3.1 Simulation Methodology

We use the estimates from our econometric models for the 1982-87, 1987-92 and 1992-97 periods, the county-level profit variables corresponding to our simulation scenarios, and the parcel-level data on the land quality to estimate parcel-level transition probabilities for each of the five-year transition periods for each NRI point. Depending on the land use of the NRI point in our base year (1982), we multiply the plot-level transition probabilities for that starting use (*e.g.* crops) for the period starting in that year (1982-87) by the acreage in that use given by the sampling weights assigned to each NRI plot.[33] This produces an estimate the acres of land at each location transitioning from each use to every other use over the next five years. Using the parcel-level estimates of the total acres in each use at the start of our new base year (1987), we repeat this procedure to predict changes from 1987 to 1992. Similarly, we use the resulting estimates of 1992 acres to predict changes from 1992 to 1997. Summing together the final simulated plot-level acres provides the estimated 1997 land use totals for the 48 contiguous United States.

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[33] As discussed earlier, given that land virtually never transitions out of urban uses, we did not estimate parameters for the transition from urban to other uses. In the simulations, we assume that land in urban uses remains in urban use with 100% probability.

The "factual" simulation uses the historically observed values of all variables in simulating land use and provides a check on the predictive accuracy of the model.[34] The factual simulation also provides a baseline for comparing the historically observed land-use change against a series of hypothetical scenarios. In these counterfactual scenarios, we fix a particular variable (or set of variables) at a hypothetical level, while keeping all the remaining variables at their historically observed values. In this way, we simulate how land-use change would have diverged from the factual case if just one particular factor had diverged from its historical levels in the specified way. The difference in the simulated land-use changes between the counterfactual and factual scenarios provides an estimate of the impact of the factor being analyzed on the historical changes in land use.

Our factual and 10 counterfactual scenarios are listed in Table 4. To contrast with the factual simulation, we simulate counterfactual scenarios in which we fix a specific net return variable (or set of variables) at 1978 levels and allow all the other net return variables take on their factual values. Given our assumption that landowners consider the average values from 1978-82 when making decisions for between 1982 and 1987, 1978 is the earliest year relevant for the land-use decisions in our model. In comparison with the factual scenario, the counterfactual scenarios fixing net returns at 1978 levels thus allow us to isolate the effects of the observed changes in the specified variable(s) since the beginning of our period of analysis, all else remaining the same.[35]

The *No Change in Any Returns* scenario holds constant all of the net return variables at their 1978 values. In the scenario *No Change in Crop+Government Returns*, we fix the market-component of cropland net returns--referred to henceforth as simply the "crop net returns"--as well as government payments to crop producers at their 1978 values.[36] The scenario *No Change in Crop Market Returns* holds only the crop net returns at 1978 levels, allowing government payments (and all other variables) to take on their factual values. The scenario *No Change in Government Payments* fixes government payments at 1978 levels, allowing the crop net returns (and all other variables) to take

[34] As per our econometric specification, the factual simulations use the average real land-use returns from 1978-82, 1983-87 and from 1988-92 to compute the probabilities for 1982-87, 1987-92 and 1992-97 respectively.

[35] It is unrealistic to believe that if net returns to one land use (e.g. crops) had remained at 1978 levels, the levels of all other net returns would actually have remained at their historically observed values. Rather, the resulting changes in U.S. land use would probably have led to readjustments of prices of crops as well as other land-based commodities, such as forage and timber. Nevertheless, our objective is not to predict what would have actually happened if a particular variable had taken on the value assumed in our counterfactual scenario. Instead, by holding all other variables constant, our goal is to identify the independent impact of a change in this variable on the observed changes in land use.

[36] Our estimates of county-level crop profits include a market-component (price times yield minus variable costs) plus estimates of county-level direct government payments to crop producers from all programs (except the CRP which is treated as a separate land-use category). The effects of crop insurance and other government programs aimed at reducing the variability of crop returns are not addressed in this analysis.

on their factual values. It is important to note that in the econometric analysis we estimate a single coefficient on crop-plus-government returns, essentially assuming that landowners are indifferent to a dollar from the government and a dollar from the market.[37] Thus, landowners respond equivalently in our simulations to changes in these two sources of revenues. In *No Change in Pasture Returns*, *No Change in Forest Returns*, *No Change in Urban Returns*, and *No Change in Range Returns*, we fix at 1978 levels the net returns from pasture, forest, urban and range, respectively.

In addition to these simulations that examine the effects of changes in the net returns variables since 1978, we conduct simulations to evaluate the land-use impacts of all government payments to cropland owners as well as the land-use impacts of the CRP. In the scenario, *No Government Payments*, we set government payments at zero but keep all other variables, including market crop returns, at the historically observed values. In the scenario, *No Conservation Reserve Program*, we remove the CRP as a land-use option while keeping all the net return variables in our model at the factual levels. We remove the option of CRP enrollment by setting to zero all the variables in the CRP choice equation (the constant term and land quality dummy variables) in all the probability expressions. For each of the starting uses, this generates a zero probability of choosing CRP and reallocates this probability so that the probabilities of the remaining land-use choices sum to one. Given the nested logit specification, the probability is reallocated differentially *across* choice nests depending on the estimated nest-level parameters and distributed *within* the choice nests in equal proportion to the conditional choice probabilities.

The simulations described above exploit the changes in our estimates of land-use net returns between 1978 and the 1978-82, 1982-87, and 1988-92 periods. The left panel of Table 2 lists the values of the estimated mean annual net returns per acre over the different periods; the right panel of the table lists the changes since 1978. From 1978 to 1988-92, mean net returns declined for crops (-31.4%) and pasture (-19.9%) and, slightly, for range (-0.9%). Mean government payments increased during this period (+12.2%), offsetting in part the fall in the crop net returns. Nevertheless, mean crop-plus-government net returns still declined by 27.9% from 1978 to 1988-92. While the mean net returns to crops, pasture and range decreased between 1978 and 1988-92, they did not decrease steadily across this period. Mean crop net returns and crop-plus-government net returns decreased between 1978 and 1978-82 and increased subsequently from 1978-82 to 1983-87 and from 1983-87 to 1988-92. Mean government payments increased during the first two periods

[37] While this seems like a useful first approximation, the response might be different in reality if these two streams of net returns entail different levels of risk or if they convey different signals about expected levels of returns in the future.

but then declined dramatically from $21.8 in 1983-87 to $12.2 in 1988-92. Pasture and range mean net returns both decreased from 1978 to 1978-82 and again over the next five years, but then increased from 1983-87 to 1988-92.

In contrast to the decrease in mean net returns from crops, pasture and range from 1978 to 1988-92, the mean net returns to forest and urban uses increased from 1978 to 1988-92 by 166.2% and 29.8%, respectively. Mean forest net returns initially fell 6.2% from $6.4 to $6.0 from 1978 to 1978-82 but then rose to $9 in 1983-87 and $17.2 in 1988-92. Mean urban net returns increased over the first two five-year periods and then declined slightly by 1.7% from 1983-87 to 1988-92.

<u>3.2 Simulation Results</u>

Factual simulation

Comparing the "actual" data on land use and land-use change from the NRI with the estimates from the factual simulation indicates that the simulation model performs well in reproducing the direction and relative magnitudes of land-use changes during this period. In particular, Table 5.1 shows the totals for each land use at the end of the simulation period (1997) under the factual and counterfactual simulations, as well as the actual historical values estimated by the NRI. Table 5.2 reports the differences between these values and the estimates from the factual simulation. The actual (NRI) totals for each land use are in all cases within 1% of the factually simulated estimates, except in the case of urban acres which exhibited the most dramatic change, rising by almost half from 1982 to 1997. In this case, the factual estimate of urban acres in 1997 is still just 1.67% above the actual acreage reported in the NRI.

While Table 5.2 reports land-use *levels*, Table 5.3 reports the actual and simulated land-use *changes* from 1982 to 1997. According to the NRI, between 1982 and 1997, cropland decreased by 43.86 million acres, pasture area declined by 11.69 million acres, and range area declined by 10.75 million acres. At the same time, land area in forest, urban and CRP increased by 3.52, 24.34 and 32.69 million acres, respectively. The factual simulations predict land-use changes that are in line with the actual estimates of the NRI. The factually-simulated (actual) estimates of acreage percentage changes from 1982 to 1997 are -9.82% (-10.44%) for crops; -8.30% (-8.91%) for pasture; 0.46% (0.88%) for forest; 49.70% (47.19%) for urban; and 1.93% (2.59%) for range. Starting from zero CRP acres in 1982 before the initiation of the program, the factual simulations predict 32.43 million acres enrolled by 1997, just 0.80% below the 32.69 million acres of CRP land reported in the NRI.

Counter-factual simulations

The accuracy of the model in reproducing historical land-use changes supports our use of the factual simulation as our historical baseline and to simulate land-use changes under different scenarios. Tables 6.1-6.6 highlight the relative importance of the different factors examined through the counterfactual scenarios in driving the acreage changes for each land use. The first column of each table reports the total simulated change in acres over 1982-97 for the 48 contiguous states, as found in Table 5.3. The second column reports this acreage change as a percent of the factually simulated acreage change. The third column reports the difference in the land-use changes between the counterfactual and factual simulations as a percentage of the factually simulated acreage change. This provides an estimate of the percentage of the historic acreage change attributable to the variable that is fixed in each counterfactual scenario. We discuss these results in turn for each of the our land-use categories: crops, CRP, pasture, forest, urban, and range.

Crops

During 1982-97, the factual simulation indicates a decline in crop acres of 41.1 million acres or 9.82% from 1982 levels. Table 6.1 shows that the CRP combined with declining crop net returns were the two most significant factors contributing to this substantial decline in cropland across the contiguous U.S. The estimated decline in crop acres during this period is only 11.8 million (71.3%) of the factual outcome in the absence of the CRP. While the program was the chief driver of cropland decline during this period, our results suggest that the acreage enrolled in the program overestimates the actual impact of the CRP on cropland retirement. As shown in Table 5.3, under the *No CRP* scenario, CRP acreage declines to zero from the 32.4 million factual acres but crop acres increase by only 29.3 million acres. These 29.3 million acres are our estimate of the "additional" acres retired as a result of the CRP over and above the cropland change that would have occurred under our counterfactual baseline. In other words, we estimate that 3.1 million acres or 9.6% of the crop acres that enrolled in the CRP would have left crop production by 1997 even in the absence of the program.

The more disaggregated simulation results indicate that almost three-quarters of these 3.1 million acres that were absorbed by the CRP would have gone into pasture in the absence of the program. In addition to comparing aggregate changes in the different land uses, our simulation model permits explicit analysis of the effect of the different factors on particular land-use transitions.

Table 7.1 shows that there is a net increase in acres exiting the cropland category under *No CRP*, with the majority of these exits going to pasture (more than 2.3 million acres) and lesser amounts going to forest, urban and range.

After the CRP, the decline in crop net returns since 1978 was the most significant factor in driving the decrease in cropland acres in our simulations. Under *No Change in Crop Market Returns*, the simulations indicate that crop acres would have declined by 23.4 million rather than 41.1 million acres between 1982 and 1997. Thus, the decline in crop net returns after 1978 accounts for about 17.6 million (42.9%) of the factually simulated change. The results in Table 7.1 suggest that the decreases in crop net returns chiefly influenced cropland acres by affecting transitions between crops and pasture and between crops and CRP. Holding crop net returns at 1978 levels reduces crop-pasture transitions by 4.1 million acres and increases pasture-crops transitions by 5.4 million acres. Crop-CRP transitions decrease by 6.1 million acres and CRP-crop transitions increase by 2.4 million acres under this scenario.

The contemporaneous increase in government payments to crop producers appears to have partially blunted the effect of the crop market forces. Specifically, we estimate that without the change in government payments after 1978 (*No Change in Government Payments)*, the decline in crop acres would have been about 3.5 million acres (8.6%) greater than the factual decline. Taking this into account, the simulations indicate that the change in crop plus government net returns since 1978 accounts for about 35.6% of the cropland decline from 1982 to 1997. While government payments thus reduced the impact of declining crop returns on cropland area, the simulations suggests that government payments are still secondary to the market component of crop returns in terms of their impact on cropland acreage nationwide. Specifically, eliminating all government payments after 1978 (*No Government Payments*) leads to an additional 7.4 million acres leaving crop production. As shown in Table 5.2, this represents a 1.89% decrease in the factually simulated 1997 crop acreage for the 48 contiguous states. This compares to an increase of 17.6 million acres (4.68%) under *No Change in Crop Market Returns*.

Table 7.1 suggests that the total level (as well as the change) in government payments boosted the amount of acres in crops chiefly by increasing the retention of existing crop acres, rather than by inducing additional land conversions into crops. Specifically, we estimate that total government payments (relative to the *No Government Payments* scenario) reduced cropland transitions into the CRP (3.1 million acres) and into pasture (1.9 million acres) and, secondarily, increased conversion of pasture acres into crops (1.5 million acres). Overall, eliminating government payments in 1978 results in an additional 5.4 million acres leaving crop production and 2 million fewer acres entering crop production from 1982 to 1997.

While the simulations suggest that the CRP and the changes in crop net returns were the principal drivers of the decline in crop acres, the results also suggest that the decline in pasture net returns since 1978 was significant in restraining the cropland decrease. Particularly, the decline in crop acres would have been about 17.3% greater under *No Change in Pasture Returns*. The other variables considered in the simulations had minor impacts on crop area change from 1982-97. We estimate that the rise in forest net returns restrained the decline in crop acres by about 3.4% while the increase in urban and range returns increased the decline by 1.5% and 0.2%, respectively.

While forest net returns more than doubled from 1978 to 1988-92, in the simulations the effect of holding timber prices at the 1978 levels is to reduce crop area in 1997 relative to the factual estimate. This is contrary to what one might expect with the forestry alternative being less economically attractive. This result suggests the path-dependent character of land-use change. Specifically, crop acres decrease if forest net returns are fixed at the low 1978 levels because, as noted earlier, forest net returns did not increase steadily during the simulation period but, rather, declined initially between 1978 and 1982-87 (Table 2). Avoiding this initial decline, which increases cropland area, leads lower cropland acres under *No Change in Forest Net Returns* compared to the factual simulation, despite the dramatic increase in forest net returns after 1982-87.

Conservation Reserve Program (CRP)

The results in Table 6.1 indicate that the decline in crop net returns since 1978 was an important determinant of CRP enrollment. Specifically, under *No Change in Crop Market Returns*, there is an 18.7% reduction in CRP enrollment in 1997, all other factors held equal. In addition, by raising the profitability of crop production, government payments consequently reduced the incentives for CRP enrollment during the simulation period. Out results suggest that, all else being equal, the increase in government crop payments after 1978 reduced CRP enrollment by 5.0%. We also estimate that eliminating all government crop payments would have increased 1997 acres in CRP by 10.1%.

In interpreting these estimates of the impact of particular variables on the CRP, it is important to remember that we are holding everything else constant, including the policy aspects of the program--notably the rental rates and eligibility criteria. In the face of different economic conditions, these factors would certainly have changed to meet the acreage enrollment target established by Congress. Nevertheless, our counterfactual scenarios are intended to isolate the relative importance of particular factors, all else constant, rather than to predict the general equilibrium outcomes of a shock to one variable.

Pasture

In the factual simulation, pasture acres decrease by 10.8 million acres from 1982-97, representing an 8.3% decrease from 1982 levels. According to the results in Table 6.3, the historical decrease in pasture net returns since 1978 accounted for almost three-quarters of the pasture decline and under the *No Change in Pasture Net Returns* scenario, total pasture acreage in 1997 is 6.6% higher. Nevertheless, our results suggest that the change in crop net returns had an even greater influence on pastureland acres than the decline in pasture profits. The factual decline in pasture acres is 81.7% lower than the decline under *No Change in Crop Market Returns*. If crop prices had remained at 1978 levels, total pasture acreage in 1997 would have been about 7.4% lower than even in the factual case.

While these market factors are the major determinants of pastureland change in our simulations, government policies also appear to have had significant impacts on pasture acreage. Particularly, we find that in the absence of the CRP, the decline in pasture acreage would have been about 24% less. This results chiefly from increased cropland transitioning to pasture in the absence of the CRP option, as shown in Table 7.1. Total 1997 pasture acreage is 2.6 million acres (2.18%) greater in the *No CRP* scenario than in the factual simulation (Table 5.3).

Our results also suggest that government crop payments exert an important impact on pastureland change. The *No Change in Government Payments* scenario suggests that increasing government payments since 1978 increased the decline in pasture acres by about 14.4%. With government crop payments eliminated completely (*No Government Payments*), the simulated 1982-97 decrease in pasture acres is 32.2% lower and the total pasture acreage in 1997 is 3.3 million acres or 2.8% above the factual level (Table 5.2).

Forests

The results in Table 6.4 indicate that the rise in forest net returns after 1978 was the overwhelming factor driving the increase in forest area from 1982 to 1997 in the 48 contiguous states. Under the factual simulation, forest area increases by 1.8 million acres or 0.46%. This increase is relatively small, and we find that total forest acreage actually *decreases* by 0.6 million acres

(0.15%) between 1982 and 1997 if forest net returns are held at 1987 levels. Thus, the rise in timber prices after 1978, even given the 1978 to 1982-87 decline discussed earlier, accounts for more than the entire increase in forest acres from 1982 to 1997. Table 7.2 indicates that forest net returns had a greater influence reducing acreage changes *from* forests rather than movements of new land *into* forests.[38]

Given the small change in forest area, we find that any factors with even small impacts on total forest acres had significant impacts on the magnitude of the forest area change. Our results suggest that changes in crop and pasture net returns, though secondary to timber profits, were major factors promoting the increase in forest acres from 1982 to 1997. Without the decline in crop net returns after 1978, the increase in forest acres is 87.2% lower than in the factual case. Under *No Change in Pasture Returns*, the results suggest that forest areas would have been larger if pasture profits had not declined after 1978. This anomalous result is obtained due to the negative elasticity on the probability of choosing pasture with respect to pasture profits for lands starting in pasture during the 1992-97 period. This elasticity is not significantly different from zero at the .05 level and contrasts with positive and significant elasticities obtained for the 1982-87 and 1987-92 periods. This suggests that the actual role of falling pasture net returns on forest area change was likely to have been negative or closer to zero.[39]

The rise in urban net returns after 1978 is also an important factor restraining the increase in forest acreage. Without the rise in urban net returns, forests increase by 1.3 million acres (72.2%) more than in the factual simulation. As with pasture acres, the simulations also imply that government policies influenced the change in forest acres. Holding government payments at 1978 levels and eliminating them completely reduces the increase in forest acres by 10% and 22.3% (0.2 and 0.4 million acres), respectively. Similarly, the simulations indicate that forest acres outside the CRP would have increased about 0.2 million acres more in the absence of the program (14.8% of the factual increase).

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[38] As shown in Table 7.2, flows into forests actually increase overall when net forest net returns are held at the low 1978 levels. This is due to the avoidance of the initial decline in forest profits from 1978 to 1982.

[39] If the 1987-92 coefficients for lands in pasture are used in place of the 1992-97 coefficients, the simulations suggest that forest areas would have increased by 46% less if the decline in pasture profits had not occurred. Substituting these coefficients does not affect the relative direction or relative magnitudes of the other variables' effects.

Urban

From 1982 to 1997, urban areas increased by 25.6 million acres (49.7%) under the factual simulation. The results in Table 6.5 suggest that this increase was essentially driven by the change in urban net returns since 1978. Changes in the net returns to non-urban land uses and the different policy factors that we analyzed had minor effects on urban area. In combination, the changes in all of the net returns variables since 1978 account for about 13.9% of the factual increase in urban acres.[40] This is overwhelmingly driven by the increase in urban net returns which accounts for 12.9% of the factual increase. All the other net returns scenarios impact the urban acreage change by less than 1%, except for the decline in crop net returns which restrains the increase by just 2.2%. The simulations also suggest that government payments and the CRP restrained the increase in urban acres but the effects are trivial.

Range

Total range acres declined by 7.9 million acres or 1.93% during 1982-97 in the factual simulation. As reported in Table 6.6, we estimate that the rise in forest net returns since 1978 was the most important factor inducing the range area decline. In particular, *No Change in Forest Net Returns* induces a 4.0 million acre increase in rangeland or 49.8% of the factual range acreage decline. The simulations suggest that the decline in pasture net returns also exerted a relatively important influence, restraining the decline in range acres by 13.8%. Factors of lesser importance were the rise in urban profits and the fall in crop net returns, which increased and restrained the simulated decline in range acres by about 8.3 and 7.9%, respectively. The other variables examined through the simulation have minor effects on the change in rangeland.

4. Discussion and Conclusions

In this paper, we conduct an econometric analysis of transitions among the major land-use categories in the 48 contiguous United States. Using a nested logit specification, we estimate the parameters of a set of first-order Markov transition probabilities for six different land uses (crops, pasture, forest, urban, range, and the Conservation Reserve Program) and three different transition

[40] While the simulations suggest that the change in urban net returns was the principal determinant of urban acreage increase, the relatively low explanatory power of our variables could be a result of the coarseness of our data on the urban net returns. While our measure of urban net returns is at the county level, there is a great deal of within-county variation in urban development potential based on location and other factors that our measures do not capture. Increasing the fit of our model with more spatially-specific data is an area of on-going research.

periods (1982-87, 1987-92, and 1992-97). Simulations using our econometric estimates suggest how changes in economic returns and government policies have driven land-use changes in the past and will continue to affect nationwide land-use changes in the future.

Our findings highlight the importance of profits to a range of land-use alternatives as determinants of land area change for each particular use. In particular, the results indicate the land-use margins that are most active for particular land-use categories, and the variables that consequently have the greatest influence on the area allocated to these land uses. These variables are potentially the most effective policy levers available to the government to influence land-use change. The flip side of this, as some of our counterfactual simulations suggest, is that public policies induce some "unintended consequences." Given the fixed size of the land base, national-level policies affecting the profitability of one land-use alternative necessarily impact changes among the entire set of economically relevant land-use choices.

In terms of cropland, our results support previous arguments (Vesterby and Krupa 1995; Alig, Dicks, and Moulton 1998) that the CRP and decline in crop market conditions were the chief drivers of the decline in crop area from 1982 to 1997. We also identify the effect of government crop payments in supporting total cropland acreage but find that this is secondary in magnitude to the effect of changes in crop markets. By affecting the profitability of cropland, however, government payments may have had certain unintended environmental consequences given that we identify pasture and CRP as the most important land-use margins for crops. In particular, we find that acreage in pasture and the CRP would have been almost 3.4 and 3.3 million acres greater in 1997 if government crop payments had been zero after 1978. While these effects are not large in comparison with the impacts of market factors, this suggests that the government to an extent is directly competing with itself in providing incentives for landowners to retire environmentally sensitive cropland. In terms of the CRP, our findings illustrate the importance of measuring the impacts of a land-use policy relative to a counterfactual baseline. We find that only about 90% of the lands that enrolled in CRP actually constituted “additional” land retirements induced by the policy, with the remaining 10% comprising lands that would have left crop production anyway given the declining profitability of crop production.

Our results also support the arguments of Vesterby and Krupa (1995) and Anderson and Magleby (1997) that explain the decline in pasture and range acres in terms of factors that affect the net returns to grazing. They emphasize decreases in livestock levels and changes in production methods, notably greater concentration of animals and use of improved grasses. Nevertheless, we find that changes in crop net returns were a much greater determinant of changes in pasture acres. This illustrates the importance of considering trends in the profits to alternative land uses, and, particularly, implies that government policies that bolster cropland profits will have important impacts on pasture acreage. Vesterby and Krupa (1995) and Anderson and Magleby (1997) also cite urbanization and natural forest regrowth as causes of grazing land decline. We find that the increase in urban profits had a relatively minor influence on pasture and range acres but that the rise in profitability of forestry was the dominant determinant of the decline in rangeland acres.

In terms of forest areas, we identify the rise in timber profits as the most important factor diriving the increase in forest areas between 1982 and 1997. This is consistent with reports that the increase in forests was mostly in terms of timberland acreage (Anderson and Magleby 1997; Alig, Dicks, and Moulton 1998). In addition, our findings identify declining crop profits as a major factor affecting forest area during this period, as noted by Alig, Dicks, and Moulton (1998). This is also consistent with reports that forest areas increased due to passive regrowth on abandoned agricultural lands in the Northeast (*e.g.* Anderson and Magleby; Alig and Wear 1992; Alig, Dicks, and Moulton 1998; Flather, Brady and Knowles 1999). These findings suggest that policies targeting forest net returns, such as payment for carbon sequestration, are likely to be the most effective at promoting forest area increase. In addition, we find that the time path of forest net returns and the relative profitability of other land uses, chiefly crops, are also critical.[41] We also identify the increase in the net returns to urban use as a major factor restraining the growth in forest area.

Our results identify urban net returns as the only significant driver of urban land increase. These findings are consistent with arguments that the dramatic increase in urban land since 1982 was a response to increased housing demand driven by demographic changes and economic growth (Heimlich and Anderson 2001). Our results further suggest that efforts to restrain urban "sprawl" or to protect open space by increasing net returns to agricultural uses are likely to have limited effectiveness. Once urban development becomes feasible, development returns are so much higher than the returns to other land uses that observed changes in non-urban returns are of insufficient magnitude to make any difference. This is consistent with findings that use value assessments and other preferential tax policies, used in all U.S. states as a policy to encourage the retention of cropland, have minimal effects in restraining urban development choices (Heimlich and Anderson 2001).

[41] In simulations not reported, we find that simply avoiding the decline in forest net returns from 1978 to 1982 has a greater impact on forest acreage than increasing forest net returns by 50% in all periods.

In terms of future research, there are several potential avenues for analysis of nationwide land-use changes. Possible refinements of the model include more explicit modeling of landowners' response to government programs and uncertainty. Another area for research involves developing methods for controlling for unobserved parcel-level heterogeneity so as to refine the spatial resolution of the model for examining land-use changes at regional, state or more local levels. A potentially fruitful approach would involve implementing simulation methods for estimating a random parameters logit model of land-use transition probabilities. Such models could permit refinements in terms of more general substitution patterns among land-use choices; improved modeling of individual-level behavior through random effects panel data estimation; and incorporation of unobserved heterogeneity by allowing parameters that vary over the population.

In addition, future work could focus on applying the particular estimates and the general modeling framework developed in this study to examine a variety of potential public policy issues. Historical simulations can provide an understanding of the effects of historical changes in land-use profits on different land-use transitions. Nevertheless, given the limited size of historical changes in land-use profits, out-of-sample simulations are required to understand the possible impacts from more dramatic economic and policy scenarios. This paper develops an empirical framework and presents a set of estimated parameters that provide a basis for nationwide out-of-sample simulations to address a wide range of land-use policy issues.

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APPENDIX

Land-Use Definitions

Under the definition in the National Resources Inventory (NRI), crop areas include row and close-grown crops as well as fallow croplands, pasture and haylands in rotation with crops, permanent haylands, vineyards, fruit trees, and nurseries. CRP lands are simply those under CRP contracts while pasture lands are those areas managed for production of introduced forage plants for livestock grazing that receive cultural treatments such as fertilization and weed control. In contrast, range lands have native cover of grasses or grass-like plants suitable for grazing or else contain introduced forage species but, unlike pasture areas, do not receive any intensive management.[42]

The NRI defines areas in forests as areas more than 100 feet in width and of at least one acre in size that are at least 10% stocked with trees of any size with the potential to reach 13 feet at maturity. From an aerial perspective, this definition equates to a canopy cover of at least 25 percent. The NRI's forest classification also includes lands with evidence of natural forest regeneration.

In contrast to the Census Bureau which measures urban areas on the basis of population within an incorporated place, the NRI definition of urban/built-up areas is based on the specific use of the land and includes areas in both predominantly urban and rural areas. In particular, the NRI category includes all areas across the spectrum of residential, industrial, commercial, and institutional uses including rail yards, cemeteries, airports, golf courses, landfills, sewage plants, and water control structures. In addition, tracts of less than ten acres that do not fall under these uses (such as small parks) and highways, railroads, and other transport facilities are included if they are completely surrounded by urban and built-up land.

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[42] Possible management activities on rangelands include only deferred or rotational grazing, burning, fencing, and minimal chemical or fertilizer treatments.

Table 1

Changes in Major Non-Federal Land Uses between 1982 and 1997
in the Contiguous 48 States from National Resources Inventory (NRI) [1]
(in thousands of acres)

	Land Use in 1997						
Land Use in 1982	**Cropland**	**Pastureland**	**Forest Land**	**Urban Land**	**Rangeland**	**CRP [2]**	**1982 Total**
Cropland	286,771 78.50%	36,689 10.04%	4,532 1.24%	5,598 1.53%	3,044 0.83%	28,689 7.85%	365,322 100%
Pastureland	25,338 14.06%	128,173 71.13%	15,166 8.42%	5,272 2.93%	3,183 1.77%	3,053 1.69%	180,185 100%
Forest Land	1,434 0.36%	4,772 1.20%	380,343 95.42%	9,803 2.46%	2,099 0.53%	129 0.03%	398,579 100%
Urban Land	2 0%	2 0%	2 0%	51,946 99.99%	0 0%	0 0%	51,951 100%
Rangeland	5,602 1.36%	4,403 1.07%	3,022 0.73%	3,055 0.74%	394,617 95.91%	729 0.18%	411,427 100%
1997 Total	319,146 22.68%	174,037 12.37%	403,065 28.64%	75,673 5.38%	402,943 28.63%	32,599 2.32%	1,407,463 100%

[1] Percentages are of 1982 totals (far right column). Totals include only land parcels which were non-federal and in the six listed uses in 1982 as well as 1997. Read the table horizontally to see how land that was under a particular land use in 1982 (row heading) was subsequently allocated in terms of land use in 1997 (column heading). Read the table vertically to see how land that that was in a particular land use in 1997 (column heading) was previously allocated in terms of land use in 1982 (row heading).

[2] Note that there is no corresponding row entry for the Conservation Reserve Program (CRP) as this federal program was established in 1985.

Table 2. Own-Return Land-Use Choice Elasticities Evaluated at the Means

Starting Land Use	Own-Return Elasticity[1] by Destination Land Use and Time Period								
	Crops			Pasture			Forest		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Crops	**0.0143****	**0.0348****	**0.0110****	-0.0048	**0.0822****	**0.1828****	**0.8763****	**0.7489****	**0.3101****
	(0.0008)	(0.0011)	(0.0012)	(0.0272)	(0.0235)	(0.0312)	(0.0522)	(0.0723)	(0.0433)
Pasture	**0.2991****	**0.3799****	**0.3413****	**0.0292****	**0.0036****	-0.0119	**0.2227****	0.0784	0.0049
	(0.0232)	(0.0308)	(0.0218)	(0.0036)	(0.0012)	(0.0081)	(0.0303)	(0.0555)	(0.0267)
Forest	**0.2104****	**0.2797****	**0.2946****	0.1047	0.0396	-0.0075	0.0004	0.0007	0.0006
	(0.0656)	(0.0543)	(0.0644)	(0.0577)	(0.0910)	(0.0591)	(0.0009)	(0.0009)	(0.0547)
Range	-0.0415	0.3491	0.0655	0.2200	-0.1539	0.3986	0.0839	0.0291	0.1268
	(0.0458)	(0.1776)	(0.2290)	(0.1715)	(0.5331)	(0.4169)	(0.3601)	(0.4225)	(0.9058)

Starting Land Use	Own-Return Elasticity[1] by Destination Land Use and Time Period								
	Urban			CRP			Range		
	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97	1982-87	1987-92	1992-97
Crops	**0.3952****	**0.2482****	**0.3418****	n/a	n/a	n/a	**0.6793****	**0.2944****	**0.3765****
	(0.0236)	(0.0133)	(0.0159)				(0.0870)	(0.0703)	(0.0477)
Pasture	**0.4303****	**0.2959****	**0.3306****	n/a	n/a	n/a	**0.8509****	**0.7056****	**1.0421****
	(0.0516)	(0.0271)	(0.0259)				(0.1279)	(0.1666)	(0.0496)
Forest	**0.2313****	**0.2986****	**0.7920****	n/a	n/a	n/a	0.2852	-0.5639	0.2316
	(0.0203)	(0.0754)	(0.0576)				(0.2197)	(3.4581)	(0.3305)
Range	**0.5558****	**0.3983***	**0.4190****	n/a	n/a	n/a	-0.0018	-0.0022	-0.0015
	(0.0486)	(0.1790)	(0.0310)				(0.0059)	(0.0018)	(0.9712)

Notes: Standard errors are in parentheses. * and ** denote significance at 5%, and 1% levels respectively. Elasticities are evaluated at the means of the data for the specified starting use using the estimated parameters from the nested logit model. Standard errors are estimated using the Delta Method.

[1] This is the percentage change in the probability of choosing the destination use (conditional on being in the starting land use) for a 1% change in the profits to the destination use.

Table 3. Estimated County-Level Annual Net Returns per Acre from the Major Land Uses for the 48 Contiguous United States, 1978-1992 (Values in 1990 dollars) [1]

Net Returns ($/acre/year)	Mean, Standard Deviation				Change From 1978 ($ and %)			
	1978	1978-82	1983-87	1988-92	1978	1978-82	1983-87	1988-92
Crop net returns	102.0	43.2	52.0	70.6	0	-58.8	-50	-31.4
(market-based) [2]	(69.1)	(34.4)	(39.5)	(46.6)	0%	-57.7%	-49.0%	-30.8%
Government	8.7	15.2	21.8	12.2	0	6.5	13.1	3.5
payments [3]	(4.7)	(7.2)	(8.8)	(6.0)	0%	74.3%	149.0%	39.6%
Crop+Government	110.7	58.4	73.8	82.8	0	-52.3	-36.9	-27.9
net returns [4]	(69.8)	(38.4)	(45.0)	(48.2)	0%	-47.3%	-33.4%	-25.3%
Pasture net returns	32.6	16.1	7.9	12.7	0	-16.5	-24.7	-19.9
	(28.4)	(11.3)	(8.0)	(9.0)	0%	-50.5%	-75.6%	-61.1%
Forest net returns	6.4	6.0	9.0	17.2	0	-0.4	2.6	10.8
	(6.4)	(5.9)	(9.0)	(17.1)	0%	-7.2%	39.7%	166.2%
Urban net returns	1,809.0	1,946.3	2,389.5	2,348.8	0	137.3	580.5	539.8
	(1,808.9)	(1,946.3)	(2,389.4)	(2,348.8)	0%	7.6%	32.0%	29.8%
Range net returns	11.3	11.2	10.3	10.4	0	-0.1	-1	-0.9
	(10.5)	(10.1)	(8.9)	(9.3)	0%	-1.4%	-8.8%	-8.0%

[1] Values are averages over each five year period of weighted annual county-level returns where weights are based on the county acreage in each land use. Values are in 1990 dollars, deflated using the producer price index for all commodities from the Bureau of Labor Statistics. The construction of the different net return measures is discussed in the paper.

[2] Includes only the market-component of crop net returns (price times yield minus variable costs).

[3] Includes estimates of direct government payments per crop acre, not including the Conservation Reserve Program.

[4] Equals the sum of the market-component of crop net returns plus the government payments.

Table 4. Description of Simulation Scenarios

Scenarios	Description
1) Factual	All returns take on observed historical values.
2) No Change in Any Returns	Fix all returns at 1978 values.
3) No Change in Crop+Government Returns	Fix crop returns *and* government payments at 1978 values.
4) No Change in Crop Market Returns	Fix crop returns from market *but not* government payments at 1978 values.
5) No Change in Government Payments	Fix government farm payments at 1978 values.
6) No Government Payments	Set government farm payments at zero.
7) No Conservation Reserve Program (CRP)	Eliminate CRP as land-use option.
8) No Change in Pasture Returns	Fix pasture returns at 1978 values.
9) No Change in Forest Returns	Fix forest returns at 1978 values.
10) No Change in Urban Returns	Fix urban returns at 1978 values.
11) No Change in Range Returns	Fix range returns at 1978 values.

Table 5.1. Results for Land Use in Ending Year (1997) of Simulations

Total Land in Base Year (1982) of Simulation (thousands of acres)

Scenario	Crops	Pasture	Forest	Urban	CRP	Range	Total [2]
Actual (NRI) [1]	418,784	130,294	399,498	51,582	0	413,251	1,413,409

Total Land In Ending Year (1997) of Simulation (thousands of acres)

Actual (NRI)	376,383	119,513	404,680	75,924	32,696	404,824	1,414,019
(1) Factual Simulation	377,647	119,481	401,346	77,217	32,437	405,280	1,413,409
(2) No Change in Any Returns	384,680	120,364	399,736	73,646	26,696	408,287	1,413,409
(3) No Change in Crop+Govt. Returns	392,279	112,117	400,009	76,748	27,509	404,747	1,413,409
(4) No Change in Crop Market Returns	395,307	110,648	399,792	76,644	26,368	404,650	1,413,409
(5) No Change in Govt. Payments	374,114	121,036	401,531	77,318	34,048	405,361	1,413,409
(6) No Govt. Payments	370,157	122,859	401,758	77,436	35,718	405,480	1,413,409
(7) No CRP	406,959	122,089	401,620	77,625	0	405,117	1,413,409
(8) No Change in Pasture Returns	370,522	127,468	402,457	77,239	31,540	404,184	1,413,409
(9) No Change in Forest Returns	376,252	119,245	398,882	77,403	32,374	409,253	1,413,409
(10) No Change in Urban Returns	378,257	120,140	402,679	73,918	32,474	405,940	1,413,409
(11) No Change in Range Returns	377,723	119,509	401,360	77,285	32,439	405,094	1,413,409

[1] The *Actual (NRI)* scenario reports the actual land-use estimates according to the National Resources Inventory.

[2] *Actual (NRI)* totals declined from 1982 to 1997 due to changes in acres allocated to federal and other land-use categories not modeled in the simulations (water bodies, rural transportation, and "minor" uses).

Table 5.2. Results for Changes in Land Use over Simulation Period (1982 to 1997)

Total Changes Over Simulation Period (1982-1997) (thousands of acres, % change since 1982)

Scenario	Crops	Pasture	Forest	Urban	CRP	Range	Total [2]
Actual (NRI) [1]	-43,860 -10.44%	-11,695 -8.91%	3,529 0.88%	24,343 47.19%	32,696 n/a	-10,759 -2.59%	-5,746 -0.4%
(1) Factual Simulation	-41,137 -9.82%	-10,812 -8.30%	1,847 0.46%	25,635 49.70%	32,437 n/a	-7,970 -1.93%	0 0%
(2) No Change in Any Returns	-34,104 -8.14%	-9,930 -7.62%	237 0.06%	22,064 42.78%	26,696 n/a	-4,964 -1.20%	0 0%
(3) No Change in Crop+Govt. Returns	-26,505 -6.33%	-18,177 -13.95%	511 0.13%	25,166 48.79%	27,509 n/a	-8,504 -2.06%	0 0%
(4) No Change in Crop Market Returns	-23,477 -5.61%	-19,645 -15.08%	293 0.07%	25,062 48.59%	26,368 n/a	-8,601 -2.08%	0 0%
(5) No Change in Government Payments	-44,670 -10.67%	-9,257 -7.11%	2,033 0.51%	25,736 49.89%	34,048 n/a	-7,890 -1.91%	0 0%
(6) No Government Payments	-48,627 -11.61%	-7,434 -5.71%	2,259 0.57%	25,854 50.12%	35,718 n/a	-7,771 -1.88%	0 0%
(7) No CRP	-11,826 -2.82%	-8,205 -6.30%	2,122 0.53%	26,043 50.49%	0 n/a	-8,134 -1.97%	0 0%
(8) No Change in Pasture Returns	-48,262 -11.52%	-2,826 -2.17%	2,958 0.74%	25,657 49.74%	31,540 n/a	-9,067 -2.19%	0 0%
(9) No Change in Forest Returns	-42,532 -10.61%	-11,049 -8.48%	-616 -0.15%	25,821 50.06%	32,374 n/a	-3,998 -0.97%	0 0%
(10) No Change in Urban Returns	-40,527 -9.68%	-10,153 -7.79%	3,181 0.80%	22,336 43.30%	32,474 n/a	-7,311 -1.77%	0 0%
(11) No Change in Range Returns	-41,061 -9.80%	-10,785 -8.28%	1,861 0.47%	25,703 49.83%	32,439 n/a	-8,157 -1.97%	0 0%

[1] The *Actual (NRI)* scenario reports the actual land-use estimates according to the National Resources Inventory.
[2] *Actual (NRI)* totals declined from 1982 to 1997 due to changes in acres allocated to federal and other land-use categories not modeled in the simulations (water bodies, rural transportation, and "minor" uses).

Table 5.3. Results for Land Use in Ending Year (1997) of Simulations

Difference from Factual Simulation (thousands of acres, difference as % of factual simulation)

Scenario	Crops	Pasture	Forest	Urban	CRP	Range	Total [2]
Actual (NRI) [1]	-1,264 -0.33%	32 0.03%	3,334 0.83%	-1,293 -1.67%	259 0.80%	-456 -0.11%	610 0.04%
(1) Factual Simulation	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%
(2) No Change in Any Returns	7,033 1.86%	882 0.74%	-1,610 -0.40%	-3,570 -4.62%	-5,741 -17.70%	3,006 0.74%	0 0%
(3) No Change in Crop+Govt. Returns	14,632 3.87%	-7,365 -6.16%	-1,336 -0.33%	-468 -0.61%	-4,928 -15.19%	-533 -0.13%	0 0%
(4) No Change in Crop Market Returns	17,659 4.68%	-8,833 -7.39%	-1,554 -0.39%	-572 -0.74%	-6,069 -18.71%	-631 -0.16%	0 0%
(5) No Change in Government Payments	-3,533 -0.94%	1,555 1.30%	185 0.05%	102 0.13%	1,611 4.97%	81 0.02%	0 0%
(6) No Government Payments	-7,490 -1.98%	3,378 2.83%	412 0.10%	220 0.28%	3,281 10.12%	200 0.05%	0 0%
(7) No CRP	29,311 7.76%	2,607 2.18%	274 0.07%	408 0.53%	-32,437 -100%	-163 -0.04%	0 0%
(8) No Change in Pasture Returns	-7,126 -1.89%	7,986 6.68%	1,111 0.28%	22 0.03%	-897 -2.77%	-1,096 -0.27%	0 0%
(9) No Change in Forest Returns	-1,396 -0.37%	-237 -0.20%	-2,464 -0.61%	186 0.24%	-63 -0.19%	3,973 0.98%	0 0%
(10) No Change in Urban Returns	610 0.16%	659 0.55%	1,333 0.33%	-3,299 -4.27%	37 0.12%	659 0.16%	0 0%
(11) No Change in Range Returns	75 0.02%	27 0.02%	14 0.00%	69 0.09%	1 0.00%	-187 -0.05%	0 0%

[1] The *Actual (NRI)* scenario reports the actual land-use estimates according to the National Resources Inventory.

[2] *Actual (NRI)* totals declined from 1982 to 1997 due to changes in acres allocated to federal and other land-use categories not modeled in the simulations (water bodies, rural transportation, and "minor" uses).

Table 6.1. Simulated Change in Crop Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in Crop Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	-41,136.8	100.0%	0.0%
(2) No Change in Any Returns	-34,103.9	82.9%	-17.1%
(3) No Change in Crop+Govt. Returns	-26,505.1	64.4%	-35.6%
(4) No Change in Crop Market Returns	-23,477.4	57.1%	-42.9%
(5) No Change in Govt. Payments	-44,670.1	108.6%	8.6%
(6) No Government Payments	-48,626.9	118.2%	18.2%
(7) No CRP	-11,825.7	28.7%	-71.3%
(8) No Change in Pasture Returns	-48,262.3	117.3%	17.3%
(9) No Change in Forest Returns	-42,532.3	103.4%	3.4%
(10) No Change in Urban Returns	-40,526.7	98.5%	-1.5%
(11) No Change in Range Returns	-41,061.3	99.8%	-0.2%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the crop acreage *decrease* was smaller (greater) in the factual versus counterfactual simulation.

Table 6.2. Simulated Change in Conservation Reserve Program (CRP) Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in CRP Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	32,437.2	100.0%	0.0%
(2) No Change in Any Returns	26,696.3	82.3%	-17.7%
(3) No Change in Crop+Govt. Returns	27,508.7	84.8%	-15.2%
(4) No Change in Crop Market Returns	26,367.9	81.3%	-18.7%
(5) No Change in Govt. Payments	34,048.2	105.0%	5.0%
(6) No Government Payments	35,718.3	110.1%	10.1%
(7) No CRP	0.0	0.0%	-100.0%
(8) No Change in Pasture Returns	31,539.8	97.2%	-2.8%
(9) No Change in Forest Returns	32,374.2	99.8%	-0.2%
(10) No Change in Urban Returns	32,474.5	100.1%	0.1%
(11) No Change in Range Returns	32,438.6	100.0%	0.0%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the CRP acreage in*crease* was smaller (greater) in the factual versus counterfactual simulation.

Table 6.3. Simulated Change in Pasture Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in Pasture Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	-10,812.0	100.0%	0.0%
(2) No Change in Any Returns	-9,929.6	91.8%	-8.2%
(3) No Change in Crop+Govt. Returns	-18,177.0	168.1%	68.1%
(4) No Change in Crop Market Returns	-19,645.3	181.7%	81.7%
(5) No Change in Govt. Payments	-9,257.4	85.6%	-14.4%
(6) No Government Payments	-7,434.1	68.8%	-31.2%
(7) No CRP	-8,205.0	75.9%	-24.1%
(8) No Change in Pasture Returns	-2,826.0	26.1%	-73.9%
(9) No Change in Forest Returns	-11,049.0	102.2%	2.2%
(10) No Change in Urban Returns	-10,153.3	93.9%	-6.1%
(11) No Change in Range Returns	-10,784.6	99.7%	-0.3%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the pasture acreage *decrease* was smaller (greater) in the factual versus counterfactual simulation.

Table 6.4. Simulated Change in Forest Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in Forest Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	1,847.4	100.0%	0.0%
(2) No Change in Any Returns	237.1	12.8%	-87.2%
(3) No Change in Crop+Govt. Returns	511.0	27.7%	-72.3%
(4) No Change in Crop Market Returns	293.4	15.9%	-84.1%
(5) No Change in Govt. Payments	2,032.9	110.0%	10.0%
(6) No Government Payments	2,259.2	122.3%	22.3%
(7) No CRP	2,121.6	114.8%	14.8%
(8) No Change in Pasture Returns	2,958.2	160.1%	60.1%
(9) No Change in Forest Returns	-616.2	-33.4%	-133.4%
(10) No Change in Urban Returns	3,180.8	172.2%	72.2%
(11) No Change in Range Returns	1,861.1	100.7%	0.7%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the forest acreage *increase* was smaller (greater) in the factual versus counterfactual simulation.

Table 6.5. Simulated Change in Urban Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in Urban Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	25,634.8	100.0%	0.0%
(2) No Change in Any Returns	22,064.3	86.1%	-13.9%
(3) No Change in Crop+Govt. Returns	25,166.4	98.2%	-1.8%
(4) No Change in Crop Market Returns	25,062.3	97.8%	-2.2%
(5) No Change in Govt. Payments	25,736.3	100.4%	0.4%
(6) No Government Payments	25,854.5	100.9%	0.9%
(7) No CRP	26,043.1	101.6%	1.6%
(8) No Change in Pasture Returns	25,657.1	100.1%	0.1%
(9) No Change in Forest Returns	25,820.9	100.7%	0.7%
(10) No Change in Urban Returns	22,335.9	87.1%	-12.9%
(11) No Change in Range Returns	25,703.5	100.3%	0.3%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the urban acreage *increase* was smaller (greater) in the factual versus counterfactual simulation.

Table 6.6. Simulated Change in Range Acreage in Contiguous 48 United States: 1982 to 1997

Scenario	Change in Range Acreage (1,000s of acres)	Percentage of Factually Simulated Change	Percentage of Acreage Change Attributable to Variable Fixed[1]
(1) Factual Simulation	-7,970.5	100.0%	0.0%
(2) No Change in Any Returns	-4,964.2	62.3%	-37.7%
(3) No Change in Crop+Govt. Returns	-8,503.9	106.7%	6.7%
(4) No Change in Crop Market Returns	-8,601.0	107.9%	7.9%
(5) No Change in Govt. Payments	-7,889.8	99.0%	-1.0%
(6) No Government Payments	-7,770.9	97.5%	-2.5%
(7) No CRP	-8,134.0	102.1%	2.1%
(8) No Change in Pasture Returns	-9,066.8	113.8%	13.8%
(9) No Change in Forest Returns	-3,997.7	50.2%	-49.8%
(10) No Change in Urban Returns	-7,311.2	91.7%	-8.3%
(11) No Change in Range Returns	-8,157.1	102.3%	2.3%

[1] The difference between the counterfactual and factual simulation divided by the factual simulation. Positive (negative) values indicate that the range acreage de*crease* was smaller (greater) in the factual versus counterfactual simulation.

Table 7.1. Cropland Transitions, 1982 to 1997: Differences from Factual Simulation for Selected Scenarios (1,000s of acres)

Scenario	Crops-Pasture	Crops-Forest	Crops-Urban	Crops-CRP	Crops-Range	Total *From* Crops
No Change in Crop+Govt. Returns	-3,457	-133	-206	-4,857	-94	-8,748
No Change in Crop Market Ret.	-4,118	-159	-248	-6,095	-107	-10,728
No Change in Govt. Payments	934	27	44	1,722	14	2,741
No Government Payments	1,986	60	94	3,288	38	5,466
No CRP	2,365	262	329	-34,209	284	-30,969
No Change in Pasture Returns	4,503	-37	-56	-298	-41	4,072

Scenario	Pasture-Crops	Forest-Crops	Urban-Crops	CRP-Crops	Range-Crops	Total *To* Crops
No Change in Crop+Govt. Returns	4,581	850	0	156	297	5,884
No Change in Crop Market Ret.	5,490	963	0	92	387	6,932
No Change in Govt. Payments	-714	-66	0	58	-71	-792
No Government Payments	-1,573	-151	0	-82	-217	-2,024
No CRP	315	18	0	2,482	490	-1,658
No Change in Pasture Returns	-1,826	-149	0	-71	-1,007	-3,054

Table 7.2. Forest Transitions, 1982 to 1997: Differences from Factual Simulation for Selected Scenarios (1,000s of acres)

Scenario	Forest-Crops	Forest-Pasture	Forest-Urban	Forest-CRP	Forest-Range	Total *From* Forest
No Change in Crop+Govt. Returns	850	-163	-87	-7	-2	591
No Change in Crop Market Ret.	963	-184	-104	-8	-2	666
No Change in Pasture Returns	-149	669	-98	-4	-3	415
No Change in Forest Returns	15	45	247	1	5,147	5,454
No Change in Urban Returns	976	2,483	-16,074	42	44	-12,529

Scenario	Crops-Forest	Pasture-Forest	Urban-Forest	CRP-Forest	Range-Forest	Total *To* Forest
No Change in Crop+Govt. Returns	-133	-600	0	-11	-1	-745
No Change in Crop Market Ret.	-159	-705	0	-23	-2	-888
No Change in Pasture Returns	-37	1,569	0	-2	-4	1,526
No Change in Forest Returns	1,834	570	0	-128	714	2,991
No Change in Urban Returns	97	654	0	10	45	806