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U.S. Agricultural Programs and Land Use

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Introduction and Prior Literature

U.S. policies to support farming transfer billions of dollars annually. The budgetary cost of these transfers is well known, but the incidence of these expenditures – how much is gained or lost by consumers, agribusiness, and different interests within the farm sector – is not as well known. A widely accepted view is that owners of farmland are the principal gainers. The analytical foundation for this view is that farmland is much less elastic in supply than are other inputs or the demand for farm products, so that a policy-induced increase in commodity prices, which increases the derived demand for farm inputs, ends up increasing the price of land much more than any other input. Other inputs such as specialized capital equipment may also be relatively fixed in supply in the short run, but in the long run any rents generated for the farm sector are seen as most likely to go to land.

However, land does move between the categories of cropland, pasture, forest, range, and other uses through land clearing, abandonment, or development. This is important because it is an avenue for supply response to farm programs. Such supply response has become a major issue in the World Trade Organization, primarily because developing countries believe that agricultural support by the United States (and other

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industrial countries) has increased the world supply of traded commodities and thus driven down prices received by developing-country producers.

Empirical estimation of both price and quantity effects of U.S. policies has so far generated inconclusive results. Even the most confidently expected results, notably that land rents and prices should receive the major share of program gains, have been resistant to empirical resolution (see the studies reported in Moss and Schmitz, 2003). In this paper, we provide evidence on the effects of U.S. policies on land use change using data from the U.S. National Resource Inventory (NRI), the Census of Agriculture and other county data sources. NRI data have previously been utilized by Wu (2000) to estimate the effects of the Conservation Reserve Program (CRP) in Midwest counties, and by Lubowski, Plantinga, and Stavins (2003) to estimate the effects of both the CRP and other U.S. government payments on acreage devoted to crops and other uses. Key, Lubowski, and Roberts (2005) estimate effects of program participation on acreage using individual farm data from the USDA's Agricultural Resource Management Survey.

All of these studies find significant effects of both CRP and other program payments on crop acreage, even after many payments became largely decoupled after 1996. All of them have to cope with the possibility that their payment or participation variables may be endogenous in such a way that crop acreage is associated with the programs for reasons other than programs being the causal variable (see Roberts and Bucholtz (2005) and Wu (2005) for a discussion of this issue). Our approach builds upon this literature by combining NRI, Agricultural Census and other data for 1987, 1992, and 1997 to obtain a county-level panel that permits more complete accounting for land uses and physiographic as well as economic variables that could otherwise contaminate estimated program effects. To permit identification of causality going from a county's payments to land use decisions in that county (as opposed to land use, specifically a large cropland share, causing large payments per acre in a county) we introduce an exogenous instrumental variable for payments.

The NRI provides disaggregated data on land use by agricultural and nonagricultural land-use categories. The Agricultural Census provides data on farm revenues, costs and government payments to farmers. U.S. counties are differentially affected by agricultural support programs, and we use these differences to estimate farm program effects on the allocation of land to different uses. This cross sectional analysis produces estimates that are long run in nature. We then use our estimated effects to simulate the nationwide allocation of land to cropland, pasture and other uses that would have resulted if a different farm policy had been put into place. We focus in particular on differences induced by changes in the scale of the existing federal farm programs.

Analytical Framework

NRI surveys have been conducted every five years by USDA's Natural Resources Conservation Service. The surveys are based on an area sample frame: spatially dispersed points are chosen within a defined geographic area, and resource characteristics are obtained for land parcels containing the selected sample points.[1] Land use is defined by assigning each point to a category such as forest, range, crop or pasture. These discrete data may be aggregated to the county level either by counting sample points within a particular category or by summing the acreage assigned to each sample point during the development of the sample frame. The second option gives share estimates of the form a_j/a, where a_j is the number of acres assigned in the sample frame to the sample

[1] Survey methods and results of past surveys can be found at http://www.nrcs.usda.gov/technical/NRI/.

points in category j and a represents the total number of acres assigned in the frame to the county.

Farmland Uses

Our objective is to relate these share estimates to landowner land use decisions in the presence of federal farm policy. We assume that landowners who use land as an agricultural input place that land into the enterprise that has the highest profit $\pi = max(\pi_1, \pi_2, \ldots)$ where $\pi_j = \pi_j(r_j q_j + g_j(q_j, x_j) - c_j x_j ; w)$ is maximized by choosing appropriate vectors of farm outputs q_j and non-land inputs x_j, when faced with farm product prices r_j, input prices c_j, government payments g_j and land fertility w. This profit maximization hypothesis is specific to land use categories $J^* \leq J$ for which land is a productive input. It is not applicable to public, urban or other categories where land is used for consumption or held for speculative purposes.

Measures of the variables determining profits from agricultural land use are obtained from the Census of Agriculture. This "census" is actually a sample obtained from a national survey conducted every five years by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS). The NASS survey is based on a random sample of the farms in a geographic area and is directed to farm operators. While the NRI and NASS surveys provide data for the same geographic areas, the odds are small that the sample farms in the NASS survey will be identical to the farms that have land parcels included in the NRI survey. Thus use of data from the census of agriculture will introduce both sampling error and a measurement error that results from lack of a one-to-one correspondence between the sample points of the two surveys.

Definitional differences will also affect acreages considered to be farmland in the two surveys. In 1997, for example, the NRI survey produced an estimate of 496 million acres in crop and pasture uses in the contiguous United States. The NASS survey yielded an estimate of 919 million acres of farmland. Most of this difference can be attributed to farmsteads, roads, ponds, woodlots, and other acreages that are considered to be part of the farm by NASS survey respondents but that are categorized into other land uses in the NRI. These definitional differences may also be a source of error if the share of crop and pasture within the farm varies across counties.

Our application of a commonly used econometric specification (Maddala, 1983, pp 34-37) keeps the sum of land use shares equal to one across a predetermined set of J land use categories. These categories are made exhaustive so that total land area remains constant. The specification maps a linear combination of decision determinants into a ratio of probabilities that land will be in use j:

$$\frac{P_j}{P_J} = F(\beta_j' z) \qquad j = 1, 2, \ldots, J\text{-}1.$$

Ratios are specified to resolve an indeterminacy problem in the estimation of the unknown β parameters; the scale of these parameter estimates is determined by setting $\beta_J = 0$ and by specifying J as a "residual" category. The vector z includes per-acre of farmland measures of farm revenues, costs, and government payments, consistent with the profit maximization hypothesis for farm land. Per-acre values are used because counties with more farmland will have larger totals and we do not want land use to determine the values of the variables in z. Since profits depend on land quality, the vector z will also include measures of soil fertility and of irrigation infrastructure. Prime farmland is represented by the proportion of farmland within a county that is classified as either 1 or 2 in the eight-level Soil Classification System. Irrigation infrastructure is represented by the share of farmland in a county with irrigation facilities. These facilities are considered to be durable capital assets that increase the productivity of the land when it is used in agriculture. In a region containing parcels with different values of *z*, the set of land use determinants will induce a joint distribution of the acreages in the J land uses.

Empirical analysis proceeds in this model by specifying a parametric distribution function for *F* and then using data on land use shares and *z* to estimate the parameters. A common choice for *F* is $exp(\beta_j' z)$, which leads to the multinomial logit model. Taking logs of this parametric distribution for all of the *N* counties included in a national NRI survey yields the "logits"

$$\ln\left(\frac{P_{ji}}{P_{Ji}}\right) = \beta_{ji} z_i \qquad i = 1, 2, ..., N; \; j = 1, 2, ..., J\text{-}1.$$

A regression model is obtained by replacing the unobserved *P* with the shares a_{ji} from the NRI survey:

$$y_{ji} = \ln\left(\frac{a_{ji}}{a_{Ji}}\right) = \beta_{ji} z_i + u_{ji} \,.$$

This introduces the sample error resulting from the use of the area sample frame:

$$u_{ji} = \ln(a_{ji} / a_{Ji}) - \ln(P_{ji} / P_{Ji}) \,.$$

Model elements are then organized into a "stacked" version of the multinomial logit regression model:

$$y = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} z_1 \\ z_2 \\ \vdots \\ z_N \end{bmatrix} \begin{bmatrix} \beta_1' & \beta_2' & \cdots & \beta_{J-1}' \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ \vdots \\ u_N \end{bmatrix} = z\beta' + u$$

where

$$y_i = \begin{bmatrix} y_{1i} \\ y_{2i} \\ \vdots \\ y_{J-1i} \end{bmatrix}, \quad z_i = \begin{bmatrix} z_{1i} & & & \\ & z_{2i} & & \\ & & \ddots & \\ & & & z_{J-1i} \end{bmatrix} \quad \text{and} \quad u_i = \begin{bmatrix} u_{1i} \\ u_{2i} \\ \vdots \\ u_{J-1i} \end{bmatrix}, \quad i = 1, 2, ..., N.$$

In this model, each y_i represents a J-1 x 1 vector of logits $ln(a_{ji} / a_{Ji})$ and each of the β_j is a K x 1 vector of unknown parameters associated with the K elements in the vector z_{ji}.

Amemiya and Nold (1975) and Richard Parks (1980) have modified this logit regression model to allow for the possibility that the variables in z are measured with sampling error. This is done by replacing the $\beta_j' z$ with $\beta_j' z + v_j$, where the v_j are random error terms. Model elements then become

$$y_{ji} = \ln\left[\frac{a_{ji}}{a_{Ji}}\right] = z_{ji}\beta_j' + v_{ji} + u_{ji} \qquad i = 1, 2, ..., N; \ j = 1, 2, ..., J-1.$$

In our analysis, the v_{ji} can account for the sampling error introduced by use of the agricultural census data. They can also account for measurement error and definitional differences occurring from the simultaneous use of the NRI and NASS surveys, provided these errors are random and do not lead to nonzero expected values for the v_{ji}. The sampling error from the NASS survey is random by construction, and randomness can be expected for the other sources of error if the elements of z capture all of the systematic variation between the counties in the data.

The NRI sample frame is constructed so that the observed sample aggregates can be viewed as the results of n_i independent random drawings from a multinomial population with land use probabilities P_{ji}. In this case, the errors u_{ji} will be distributed as a multivariate normal distribution with expected values of zero and covariance matrix

$$\Omega_i = \frac{1}{n_i}\begin{bmatrix} 1/P_{1i} + 1/P_{Ji} & 1/P_{Ji} & \cdots & 1/P_{Ji} \\ 1/P_{Ji} & 1/P_{2i} + 1/P_{Ji} & \cdots & 1/P_{Ji} \\ \vdots & \vdots & & \vdots \\ 1/P_{Ji} & 1/P_{Ji} & \cdots & 1/P_{Ji} + 1/P_{Ji} \end{bmatrix}.$$

Parks postulates that the covariance matrix for the v_{ji} will take the contemporaneously correlated error structure introduced by Zellner for seemingly unrelated regression equations, since the error made in predicting any land use share will be offset among the remaining shares in the multinomial logit model. If this covariance matrix is represented by Σ = [σji], then the covariance matrix for the modified multinomial logit model

becomes $$\begin{bmatrix} \Omega_1 + \Sigma & & & \\ & \Omega_2 + \Sigma & & \\ & & \ddots & \\ & & & \Omega_N + \Sigma \end{bmatrix} = V .$$

With this specification, the model's parameters may be estimated using feasible generalized least squares.

<u>Non-farm Land Uses</u>

Non-farm land uses are related to farmland using a traditional von Thünen framework: urban land uses are treated as an internal margin of higher-valued uses and forest and range land are treated as an external margin of lower-valued uses. Determinants for the urban land use are extracted from the urban growth theory developed in the urban economics literature (Fujita, 1996). Determinants for range and forest are primarily physiographic, as production from these lands is assumed to involve minimal husbandry. The primary exception is the production of timber in plantations, where the landowner is assumed to augment the natural production of trees. .

The urban economic theory derives the value of urban residential land as a sum of the rent for rural land, the cost of developing land for urban use, the location rent resulting from accessibility to an urban center, and the value of expected future rent increases resulting from growth of the urban area (Capozza and Helsley, 1989). Location rent is expressed as a function of distance from a "Central Business District" in this von Thünen model. But when the urban land market is in equilibrium, an equation that relates residential area a_u to value can be derived that has measures of population (z_p), income (z_y), and consumption of goods other than housing (z_c) replacing the distance variable (Hardie et al., 2000). This function can be expressed as

$$a_u = G(z_p, z_y, z_c, s(\pi + \rho c), s, c_t),$$

Where s is building lot size in acres, c_t is a per-mile commuting cost and $s(\pi + \rho C)$ is the equilibrium per-lot price of the land. This lot price is derived from an optimum decision rule: landowners who maximize the present net value of their land will convert to residential use when location rent is zero and the rent gained from the urban use is high enough to equal the sum of the rent from the rural use and the cost of the capital needed for the conversion. Cost of capital is measured as ρc, where ρ is an interest rate and c is a total cost. The price of agricultural land near a city anticipates this conversion: it is composed of the rent gained from the use of the land as a productive input and the value of expected future rent increases resulting from growth of the urban area. This theoretical result supports the use of the expected price of rural land as a component of z, and we include such a price in the model. Our measure is obtained from the Census of Agriculture, in which respondents are asked to estimate the current real estate value of their farm. This estimate is assumed to include any location premium and to represent the expected value of rural land held for speculative purposes. We also include a measure of the proportion of farm landowners who identify farming as their primary occupation, to allow for other differences resulting from the profit maximization and land investment motives for holding farmland.[2]

County level measures of civilian population and of average personal incomes are obtained from the Bureau of Census, U.S. Department of Commerce.[3] Population is converted to a density measure of people per acre by dividing by the counties' total land area, and income is expressed in thousand dollar units. A measure of average travel time to work for residents of a county is extracted from the U.S. Bureau of Census decennial population censuses and substituted for average commuting costs. Data are available for 1980, 1990 and 2000, and interpolated values are included in z. Since income equals the sum of consumption, commuting costs and expenditure on housing services in the urban growth theory, we implicitly account for consumption by adding median county house value as a variable (z_h). Consumption of other goods is then indirectly represented as a difference between income, commuting costs and house prices.

Aggregation of the NRI data to the county level affects the relevance of a measure of building lot size. Average lot size measured at the county level is likely to vary with the composition of urban areas within the county: average lot size can vary substantially, for example, between counties that have large metropolitan areas with apartment buildings and townhouses and counties that have small towns composed primarily of single family dwellings. We replace average lot size (for which a measure could not be

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[2] Lopez, Adelaja and Andrews (1988) find that location premiums can create an "impermanence syndrome" for owners holding rural land, and that these owners do not necessarily maximize profits from farm production.

[3] http://factfinder.census.gov/home/saff/main.html?_lang=en. These measures also contain sample error that becomes an additional component of v.

obtained) with a variable that measures within-county urban composition. The NRI surveys classify sample points as falling within large or small urban areas and we use these data to develop a variable that measures the proportion of a county's urban area that is classified as large.

We model the effect of urban growth on acreages in rural land uses by including the urban growth determinants in the equations that determine land in farm, forest and range. Urban land use is not included as an explicit category because many counties, particularly in the western part of the United States, have small urban land use shares and categories with many small probabilities are likely to result in non-normal error distributions. Since normality is a key assumption of the model, we limit our specification to land use categories for which normally distributed errors can be expected.

While shifts in acreage between farming and other land uses at the external margin are modeled as exchange between farm, forest and range, other exchange might take place between farmland and land categorized as desert, mountain, swamp, barren, etc. These are modeled as changes in use between farming and the residual land use. The residual category will also include land in rivers, water bodies, roads, public use (including National Forests and Bureau of Land Management lands), and, as noted above, urban use.

Of the 3066 counties for which data could be obtained, 2038 have no range and 400 have no forest. Logit transformations cannot be applied to these zero-share observations, so they cannot be used in a model of the contiguous United States. Cox's correction for bias will allow adjusted logits to be defined for counties with zero land use shares, but this correction will result in a national model in which many of the observations for the dependent variables measure the number of NRI sample points instead of the odds that land will be in a particular use (Cox, 1970, p.33; Maddala, 1983, p.30). To avoid this outcome, we develop two data sets by sorting the counties into those that have more range than forest and those that have more forest than range. One set is used to estimate a "range" model that has crop, pasture and range as explicit land use categories and the other is used to estimate a "forest" model that has crop, pasture and forest as explicit categories. Forest becomes part of the residual land use category in the range model and range becomes part of the residual in the forest model. After counties with no farm land are omitted, the number of counties with zero range land is reduced to 5 in the range model, and the number of counties with zero forest land is reduced to 20 in the forest model. Cox's correction is applied to the logit transformations in these models, and observations with zero land use shares are left in the data used to estimate the model parameters.

Counties in the range model are located mostly in the western part of the United States and counties in the forest model are located primarily in the east. The major exceptions are counties on the west side of the Cascade and Sierra mountains in Washington, Oregon and Northern California, which are included in the forest model, and some counties in Florida and the South, which are included in the range model. Counties included in the range model have, on average, 3 percent of their land categorized as forest and 40 percent categorized as range. Counties included in the forest model have 40 percent categorized as forest and 0.4 percent categorized as range.

Our hypothesis is that output from forest and range land depends mostly on climate, soil and other physiographic factors. Measures of physiographic features of the counties are obtained from the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS). NRCS has identified a set of geographically associated "major" land resource areas (MLRA's) that have similar soils, vegetation, elevations, topographies and climates (Agricultural Handbook 296, USDA, 1981). Descriptions of these MLRA's include minimum and maximum values for precipitation, elevation, temperature and number of frost free days. County-level values for these variables are obtained by calculating area-weighted averages across the MLRA's within each county. These averages are included as variables in z. We also construct dummy variables for each of the 185 major land resource areas within the contiguous United States and calculate county-level area-weighted averages for them; these allow us to include measures of the proportion of each county that is in each MLRA in z.

As noted above, forest land can be viewed as an input into a timber production enterprise. The forest economics literature depicts this enterprise with the Faustmann soil rent model. Recent versions of this model incorporate recreational and other uses of the standing forest as un-priced consumption goods that affect the timing of a timber sale and the profits obtained from a timber enterprise (Hardie, Parks and van Kooten, 2004). Effects of these non-timber uses on the amount of forest land are likely to depend on whether the land is in public or private ownership, for while changes in land rents and consumption values can cause private owners to shift land between forest and other land uses, shifts in timber and non-timber use of public forest land are generally accomplished by changing management of existing acreages. This difference in forest land response is accounted for in *z* by including a measure of the proportion of a county's forest land that is in private ownership.[4]

Our biggest difficulty in incorporating the determinants of forest land use is the lack of quantitative information at the county level about timber revenues and costs. While some information can be obtained for some regions within the United States, data comparable to that from the NASS surveys are not available. As a consequence, we rely on a measure of timber removals to proxy for timber production costs and revenues. Removals will also be a function of the presence of merchantable timber, timber processing facilities and access to timber product markets, but these are also valid determinants of forest land use.

Timber removal data are obtained from the Forest Inventory Analysis Data Base (FIADB) developed by the USDA Forest Service. The first county-level dataset of timber removals is the Total Product Output (TPO) dataset developed for 1997. We have converted these TPO data into per-acre values using interpolated and extrapolated values for the area of timberland reported in the FIA periodic surveys. Issuance of these timberland area data is periodic and state specific and our interpolations are based on the two periodic reports closest in time to 1987-1997.[5] Removals for 1992 and 1987 are computed using the changes in removals over time reported in Table 35 of the 1997 RPA tables.[6]

Farm Program Incentives

[4] State-level estimates of private ownership have been developed by the USDA Forest Service for 1987 and 1997 from their periodic forest inventory surveys. This data is available on the FIADB web site http://ncrs2.fs.fed.us/4801/fiadb/. We interpolate values for 1992 from the data for 1987 and 1997 and apply this state-level data to the counties in each of the 48 states.

[5] In seven cases (Arkansas, California, Idaho, Mississippi, Nevada, Oklahoma, Washington), only a single survey was available and in two (New Hampshire, Vermont) there was a periodic survey for 1997.

[6] These data are available on the FIADB web site http://ncrs2.fs.fed.us/4801/fiadb/.

Our measure of agricultural support incentives is payments received by farmers, using county data from the Census of Agriculture. Total farm program payments reported in the federal budget are substantially less than payments reported in the Census of Agriculture. This occurs, in part, because payments go to landowners who are not farm operators and who are not included in the Census of Agriculture. Since these landowners have a role in land use decisions, we scale up the payments obtained from the Census of Agriculture on a state-by-state basis until their sum equals the total program payments reported by the USDA's Economic Research Service.[7] The scaled values are converted to a per-acre of farmland basis, to remove the effect of differences in total farmland in the counties. We also introduce total county land area as a variable in z to account for any systematic differences in land use between large and small counties.

Profit maximization can explain how farm programs increase the share of land devoted to crops compared to other land uses. Causality may not run exclusively in this direction, however; since farm program payments are largely associated with cropland, counties with low cropland shares are likely to have lower government payments per acre of farmland. This reverse causality, if present, leads to inconsistent estimates of β. A possible way to mitigate this potential problem would be to convert total government payments to payments per acre of cropland; but since our measure of cropland acreage is from the NRI survey and the payments measure is from the NASS survey, doing so would result in a ratio of error terms and would violate the additive specification of the error terms in the modified multinomial logit model. We consequently choose to address the potential endogeneity of payments problem with an instrumental variable.

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[7] Data available at http://www.ers.usda.gov/Briefing/FarmPolicy/index.htm#data

Our instrument is a predicted payments per-acre of farmland obtained from regressions of the log of the measured per-acre government payments on the MLRA dummy variables, the precipitation, elevation, temperature and frost-free day variables, the average age of farm operators, and the shares of prime and irrigated farmland. Changes in government payments are not expected to cause contemporaneous changes in these variables, and their cross-sectional differences explain 72 percent of the variation in per-acre government payments in 1987, 66 percent in 1992 and 71 percent in 1997. Logarithms are employed to ensure that the predicted payments are positive, since the farm programs are not taxation programs.

Table 1 provides a list of the variables included as determinants of land use in the range and forest models. This table omits the intercept and the proportion of MLRAs in each county. Since the land use shares are interdependent, we estimate models in which all of the variables appear in all of the land use equations. The table also contains descriptive statistics for the data used in the estimation of the models' parameters.

Land Use Effects of Government Payments

Our model specification has farmers responding to total government payments by altering land-use decisions in pursuit of profits. The parameters that quantify this response are assumed to be the same throughout the contiguous United States; once non-farm land use effects are controlled, all farmers make the same farmland adjustments. But the farm program consists of particular commodity and conservation practice components, and payments for these program components are not uniformly distributed across the United States. Thus it may be that farmer response varies with location, in accord with crops that have particular locational yield and payment advantages and environmental factors that are more or less present.

To explore this possibility, we adopt a model in which regional government payment coefficients are estimated. The regional measures are developed by combining the MLRA's into 20 land resource regions (LRR's) that conform to county boundaries.[8] Dummy variables are constructed for these LRRs, and these enter *z* in the form of interactions with our measure of government payments. This provides a set of 20 variables that take the value of zero for counties outside of a LRR and the value of the government payments variable for counties within the LRR. Inclusion of the interactions allows us to estimate differential effects in how land use would change in each land resource region per dollar of increase or decrease in government farm program payments. A description of these Land Resource Regions is provided in Table 2.

The farm programs differed in the three years that the NRI data cover, 1987, 1992, and 1997. In 1987 the commodity programs were disciplined by mandated "Graham-Rudman" reductions in payments. The payments were predominantly price-support payments (called deficiency payments) making up the difference between legislated target prices and market prices for supported crops on program production (administratively determined as historical program base acreage times base yield). The effects of these payments on harvested acreage were limited not only because a program production base was needed for a farmer to be eligible, but also because the combination of financial crisis on many farms together with budget limits led to large-scale acreage idling as a means of farm income support. There were 50 million acres idled under price-

[8] These land resource regions are described in Agricultural Handbook 296. Eighty-nine percent of the counties included in the range model are in regions B - J, and ninety-seven percent of the counties included in the forest region are in regions A and K - U.

support programs in 1987 (in addition to 16 million acres idled for a longer term under the Conservation Reserve Program).[9]

In 1992 the policy situation was different, primarily because commodity markets had strengthened after the mid-1980s farm crisis, but also because the 1990 Farm Act changed the terms under which farmers could obtain deficiency payments, making it more difficult to increase their program payment bases. Formerly acreage bases were an average of past plantings to the program crop and could be increased over time by increasing plantings, but the 1990 Act foreclosed that possibility and allowed limited flexibility in switching plantings among program crops without losing payments. In 1997 further changes were implemented under the "Freedom to Farm" Act of 1996. These changes replaced deficiency payments with fixed "production flexibility contract" payments that further decoupled the payments from the farmer's planting decisions (but the land had to stay in farming to maintain payments, and in general could not be switched from program crops to horticultural crops).

In order to test for differences in the incentives for keeping land in crops between 1997, 1992, and 1987, we take 1997 as a base and introduce separate variables for payments in 1987 and 1992, which take on a value of zero if the year is not 1987 in the case of one variable and take on the value of zero if the year is not 1992 in the case of the other variable. The instrument for the county's value of payments per acre is a right-hand side variable in all observations of the pooled regressions, and appears a second time if the year is 1987or 1992. If the coefficients on the 1987 and 1992 variables are zero, that

[9] The NRI data for cropland include idled acres as well as planted acres. Our model estimates the effect of the programs in keeping land in cropland as opposed to being converted to other uses, or creating cropland to offset production declines due to idling acreage under the programs (despite programs provisions intended to forestall this response).

indicates the effects of payments on acreage allocation are no different in 1987 or 1992 than in 1997.

Table 3 presents estimates of the marginal effects of key parameters, derived from parameter estimates in the logit equations. The logit equations explain the cropland odds ratio with z variables as specified in the previous section and listed in Table 1. The coefficients of the logit model are transformed to show in Table 3 the effects of a one-unit (i.e., one dollar per acre) change in each right-hand-side variable on the cropland share in 1997 (the year when the programs were arguably the most decoupled of any of the three). Physiographic and regional/time dummy variables are omitted. As an example of how to interpret the table, the value of 0.00682 for the govpayH variable in the range model (i.e., the model estimated on the counties that have range as the predominant alternative to cropland as discussed earlier) means that in region H (Central Plains wheat and grazing area of Kansas and surrounding states) an additional dollar per acre of commodity program payments increases the share of an average county's land in cropland by .007, or at the mean cropland share for the counties of this region from 0.490 to 0.497. With a linear extrapolation this would imply that if government payments were brought to zero, since the mean value of payments in region H is $11.44 per acre in 1997, the cropland share would decrease by 0.078, or from 0.490 to 0.412.

The payment variables for the other regions are cross-products of payments times regional dummy variables. The estimated logit coefficients measure differences from the region H base, and the statistical significance tests represent the significance of the difference between payment effects in each region from region H. To get the marginal effects shown in Table 3, the cross-product effect for each region is added to the region H base effect. This region-specific effect is 0.00926 for region B (Pacific Northwest). Thus, our estimates imply a greater impact from each dollar of payments on cropland acres in the Pacific Northwest than on the Great Plains. But because the average payments are lower in the Northwest, $8.81 per acre in 1997, the total effect is not much larger.

The preceding estimates pertain to 1997. Our estimates of the difference the programs make as of 1992 and 1987 are generated by the Govpay92 and Govpay87 variables. Their marginal effects are positive but smaller than in 1997 in the range model, as shown in Table 3, .

The estimate that the programs had a larger effect on the cropland share in 1997 than in the earlier years may be surprising in view of the intention to make the program less coupled to production decisions under the 1996 Act. To understand this finding, it is important to note that the estimates do not imply that the programs caused cropland to increase over time. Total cropland was lower in 1997 than in 1987 by about 5 million acres, indicating the commodity programs did not cause an increase in cropland but rather slowed a reduction that would otherwise have occurred. The regional effects in a given year should be viewed in this context as long-run consequences of the existence of the programs, whose payment bases were well established by 1987. The program effects are largest in 1997 because by then, in the absence of the programs, the decline in crop acreage would have progressed further by 1997.

The right-hand column of Table 3 shows marginal effects for the counties included in the forest model. The effects of government payments are generally smaller than in the range model. In the base region M (Corn Belt) the estimate is that removal of

$1 per acre in commodity program payments would reduce the share of cropland by 0.00273, only half of the effect in the base range model region. In the Mississippi Delta (region O) the marginal effect of .00321, i.e., that with average payments of $24 per acre in 1997, the programs increased the share of cropland by .078, a quite substantial effect.

Estimation of Acreage Effects of Policy Options

To quantify our findings further and in more detail, we use our estimated coefficients from the range and forest logit models to simulate the effects of reduced payments. The marginal effects discussed above give a first approximation of the effects of policies, but they do not incorporate the full implications of our model, which explains not only the cropland share but also simultaneously estimates the alternative uses that a county's land goes to or comes from as a result of the payments.

We simulate the results of reducing spending on all government payments by 50 percent in 1997. County effects from the range and forest models are aggregated to show total effects for nine geographical regions, and for the contiguous 48 states, in Table 4. All regions would have less cropland with the program cuts. The percentage changes would be largest in the more marginal crop-growing regions, and smallest in the Midwestern states; but because cropland shares are lower in the marginal areas, the acreage effects are substantial in the Corn Belt as well as elsewhere. Overall, we estimate that 10 percent of all U.S. cropland, almost 40 million acres, would have been in other land uses in 1997 if the farm support programs had been half as large. The main land use to which cropland would have been devoted in the reduction of commodity support is rangeland, which would have been 22 million acres larger according to our estimates. Although some of the increased rangeland is in the South, the predominant part is in the Great Plains and Intermountain West, so much so that one may say that the single most important land-use consequence of U.S. commodity programs has been to keep marginal land in crops in the relatively arid parts of the country. Nonetheless, significant effects are widespread. Forested area would have been larger by 6 million acres and pastureland by 3.4 million acres. In terms of cropland losses in the four broad areas covered in Table 4, the Northeast loses 2.5 million acres of cropland when payments are cut 50 percent, the South loses 11 million acres, the Midwest, 6.5 million acres, and the West 19 million acres.

These findings do not imply that so much acreage would move out of cropland within a year or even several years after payments were reduced. The cross-sectional source of the model's estimated coefficients provides estimates of how a county's land-use allocation would have been different under alternative levels of payment support, given the time necessary for full adjustment to that level of support. In that sense the acreage changes should be viewed as long-run effects. The importance of the finding that U.S. commodity support programs increase cropland has two dimensions. First, with respect to the question of the incidence of gains from the programs, the implication is that landowners do not receive all the gains. Additional cropland induced by payments means more commodity output and that can be expected to have a downward effect on commodity prices. Thus, gains from the programs on the producer side are eroded and buyers of farm products will get a larger share of the economic gains generated, as compared to a situation where cropland really was fixed in supply. Second, a significantly positive effect of U.S. programs on acreage gives support to those who argue in international trade discussions that these programs are production distorting and drive down prices in world markets to the detriment of developing country producers. This is especially notable in that our findings focus on a year in which the predominant payments were made on quantities determined by fixed bases that each farm had, and thus were in theory arguably only minimally production-distorting.

Because the significance of the acreage-allocation effect is important in policy debate, we would like to be as sure as possible that our finding is not over-estimated because of bias. The most likely source of positive bias, that counties with more cropland per acre of farmland receive higher payments , is forestalled by our use of an instrument for payments that is a linear combination of exogenous physiographic and other variables.

Another source of possible bias in our estimated payments effects is specification error. If there are omitted variables that are positively correlated with both government payments and the cropland share, our estimated positive effects could be spurious. The main likelihood of left-out variables arises from factors which make crop farming profitable other than the variables we include in the model. We include crop and stock revenues and production costs per acre, which are the main candidates for relevant omission. Measurement errors in those variables could be a source of upward bias in government payment coefficient. However, for this to be the case, any left-out component of revenues or costs would have to be more highly correlated with government payments than with revenues or costs as measured, and this seems unlikely.

Another possibility is that variables influencing non-cropland uses are left out that are correlated with government payments. For example, in relatively urbanized counties, we may see more land in the residual category which means the cropland share will be lower. Agricultural production in these counties is likely to be more concentrated on high-value products. But these are the less-supported commodities, and CRP participation is likely to be less in these counties too. Therefore, we will see a tendency for counties with low payments to be associated with low cropland shares, for reasons that have nothing to do with payments causing land to be devoted to crops. It is precisely this kind of problem that provided our motivation to estimate a model that explicitly explains nonagricultural land use, with the variables shown in Table 1: population density, house values, commuting time, personal income per capita, and farm real estate value. All of these variables are statistically significant in the logit equation for cropland in the forest model, and some of them are in the range model (see Appendix). We believe that these variables capture the main factors that might confound an estimated government payment effect with some other cause of the cropland share.

Similarly, the role of the many variables related to land quality, climate and region that are included as explanatory variables is to hold constant factors that might contaminate our estimate of payment effects by being correlated with both payments and cropland share. Counties in arid regions or with low soil quality may tend to produce fewer program crops and have lower base yields. In these counties we may observe both smaller payments per acre and a smaller cropland share, but the lower payments would not be the cause of less cropland. Keeping this kind of spurious association out of our econometric results is a principal reason for using the instrumental variable for payments, while also including the variables on climate, the share of land in the highest capability classes, the share of irrigated land, and the proportionate MLRA variables in the logit equations. Many of these variables are highly significant (see Appendix).

Discussion and Policy Implications

While we cannot claim to have held constant all possibly confounding factors, we believe our procedures provide some confidence that our findings do indicate causality – that farm commodity programs have in fact significantly increased the share of U.S. land devoted to crops as compared to the counterfactual situation of no support programs. This finding is in contrast to the alternative view, that seems to be widely accepted in policy debate, that land is a fixed factor or nearly so. This alternative view lies behind the belief that the incidence of US commodity support programs heavily favors land, and that the only significant long-run result of reduction in agricultural support would be a decline in land values.

Our estimate of substantial acreage response to program payments is consistent with some recent econometric estimates that program impacts on land rental rates and prices are much smaller than fixed land supply would suggest. For example Roberts, Kirwan, and Hopkins (2003) and Kirwan (2005) estimate a 25- to 41-cent increase in land rents per dollar of government payments, which suggests sufficient acreage response to generate more output which cause farmers to have to share program benefits substantially with buyers of farm products through lower market prices. Also consistent with our findings are the conclusions of Key, Lubowski, and Roberts (2005) that participants in commodity programs increased their plantings of program crops substantially above the levels of comparable non-participants in 1987-1992. Goodwin and Mishra (2006) find significant effects of payments on land idling, but their overall estimates of acreage effects are small. However, they focus on the Corn Belt and in that region we find small effects also.

Apart from cross-sectional econometric evidence, the longer-term historical experience shows that farmers in fact have made substantial changes in land allocation between cropland and other uses. For example, in 1950 Georgia had 9.2 million acres of cropland, but by 1969 this had been reduced to 5.3 million acres. Similarly large shifts were made elsewhere in the Southeast, principally because of the replacement of cotton and other crop acreage by pine forest. Significant permanent reductions in commodity program benefits could well have similarly large effects on cropland acreage.

A complication is that because the largest acreage effects tend to be in lower-yielding areas, the production effects of payment reductions are likely to be smaller than the cropland acreage reductions would suggest. This would reduce the size of the economic impacts from a reduction in the farm support programs to smaller percentages than the acreage reductions would imply. But the size of landowner gains relative to those of non-land input suppliers and product buyers would not be changed.

With respect the broader picture of US policy, our findings provide evidence against the position that U.S. programs have been decoupled in the sense of not distorting markets or trade.

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Table 1: Variables and Descriptive Statistics

Variable Name - Description	Forest Model		Range Model	
	Sample Mean	Standard Deviation	Sample Mean	Standard Deviation
Year87 - 1 if year is 1987, zero otherwise	0.331	0.471	0.331	0.471
Year92 - 1 if year is 1992, zero otherwise	0.333	0.471	0.335	0.471
Croprev - market value of crops sold ($/acre farmland)	133.60	233.75	72.71	189.56
Stockrev - market. value of stock – poultry ($/acre farmland)	166.34	246.75	76.02	115.33
Farmcost - Direct farm expenditures ($/acre farmland)	236.59	261.94	121.65	189.29
Govpay – total government payments ($/acre farmland)	13.91	15.39	10.25	11.74
Govpay87 – 1987 total government payments ($/acre farmland)	21.13*	20.70*	14.69*	15.71*
Govpay92 – 1992 total government payments ($/acre farmland)	11.15**	11.76**	9.21**	9.78**
Gpayhat – predicted total government payments (log(govpay))	1.97384	1.08476	1.56143	1.33871
Gpyhat87 – predicted 1987 government payments (log(govpay87))	2.35071	1.17751	1.87822	1.43854
Gpyhat92 – predicted 1992 government payments (log(govpay92))	1.84255	0.96506	1.57489	1.17532
Landarea – total acres in county (thousand acres)	401.7	315.3	1,113.7	1,294.3
Primeshr – Share of area in county in Land Capability Classes 1 and 2	0.27	0.21	0.21	0.21
Irrigshr – share of farmland in county that is irrigated	0.02	0.07	0.07	0.12
Farmer – percent owners that are full time farmers	50.0	12.7	61.6	14.6
Removals – timber growing stock removed (cu ft/acre timberland)	24.8	29.9		
Private – percent timberland that is privately owned	87.2	17.9		
Estfmval – expected farm real estate value ($1000/acre)	1.447	1.199	0.646	0.715
Popden – Resident population (people per acre)	0.219	0.475	0.084	0.312
Income – per capita personal income ($1000)	16.148	4.789	16.358	4.727

Houseval –median house value ($1000)	59.882	28.280	53.216	34.978
Commute – average time of commute to work (minutes)	20.8	4.7	15.8	4.9
Urbanlge – Proportion urban area classified as large	0.82	0.20	0.741	0.365
Minrain – minimum average annual precipitation (millimeters)	947.0	191.5	454.0	206.0
Maxrain – maximum average annual precipitation (millimeters)	1251.1	332.5	701.4	273.5
Minelev – minimum elevation in meters	144.8	133.4	579.1	467.9
Maxelev – maximum elevation in meters (peaks omitted)	448.1	410.3	1241.7	881.5
Mintemp –minimum average annual temperature, degrees centigrade	11.1	4.2	10.2	5.5
Maxtemp – maximum average annual temperature, degrees centigrade	14.7	4.4	14.0	5.0
Mindday – minimum average freeze-free days	166.4	40.2	149.5	58.7
Maxdday – maximum average freeze-free days	211.9	52.3	196.8	63.1
Number of observations in model***	6248		2551	

* Forest: 2070 observations Range: 845 observations

**Forest: 2080 observations Range: 854 observations

***Counties with no crop or pasture land or no government payments are omitted.

Table 2: Land Resource Regions in the Contiguous United States

Region ID	Description	States in Region	Percent U.S. Land
LRR A	Northwestern forest, forage and specialty crop region	CA, OR, WA	2.18
LRR B	Northwestern wheat and range region	ID, OR. WA	2.56
LRR C	California subtropical fruit, truck and specialty crop region	CA	1.79
LRR D	Western range and irrigated region	AZ, CA, CO, ID, MT, NM, NV, OR, TX, UT, WY	15.61
LRR E	Rocky mountain range and forest region	CO, ID, MT, NM, OR, WA, WY	6.38
LRR F	Northern great plains spring wheat region	MN, MT, ND, SD,	3.76
LRR G	Western great plains range and irrigated region	CO, MT, ND, NE, NM, SD, WY	6.03
LRR H	Central great plains winter wheat and range region	CO, KA, NE, NM, OK, TX	6.15
LRR I	Southwest plateaus and plains range and cotton region	TX	1.88
LRR J	Southwestern prairies cotton and forage region	KA, OK, TX	1.55
LRR K	Northern lake states forest and forage region	MI, MN, WI	2.96
LRR L	Lake States Fruit, Truck and Dairy Region	IN, IL, MI, NY, OH, PA, WI	2.07
LRR M	Central Feed grains and Livestock Region	IA, IL, IN, KA, MI, MN, MO, OH, OK, SD, NE, WI	7.75
LRR N	East and Central Farming and Forest Region	AL, AK, GA, IN, KY, MD, MO, NC, OH, OK, PA, TN, VA, WV	6.54
LRR O	Mississippi Delta Cotton and Feed Grains Region	AK, MS, MO, TN	1.24
LRR P	South Atlantic and Gulf Slope Cash Crops, Forest and Livestock Region	AL, AK, FL, GA, KY, LA, MS, NC, OK, SC, TN, TX, VA	7.35
LRR R	Northeastern Forage and Forest Region	CT, MA, ME, NH, NJ, NY, RI, OH, PA, VT	3.36
LRR S	Northern Atlantic Slope Diversified Farming Region	DE, MA, MD, NJ, NY, PA, VA, WV	1.13
LRR T	Atlantic and Gulf Coast Lowland Forest and Crop Region	AL, DE, FL, GA, LA, MD, MS, NC, SC, TX, VA	2.64
LRR U	Florida Subtropical Fruit, Truck Crop and Range Region	FL	1.01

Table 3. Estimated Effects of $1 per Acre Increase in Government Payments on Share of a County's Total Land in Cropland

Range Model		Forest Model	
Explanatory Variable	Change in Cropland Share	Explanatory Variable	Change in Cropland Share
GovpayH (Cent. Plains) (base region)	.00682*	GovpayM (Corn Belt) (base region)	.00273*
GovpayB (NW)	.00926	GovpayA (Pac. NW)	.0364*
GovpayC (CA)	.00402	GovpayK (No. Gt. Lakes)	-.00230*
GovpayD (W range)	.0247	GovpayL (So. Gt. Lakes)	.00382
GovpayE (Rockies)	.0177*	GovpayN (East & Cent.)	..0179*
GovpayF (No. Plains)	.0082	GovpayO (Miss. Delta)	.00321*
GovpayG (W. Plains)	.0231	GovpayP (So Atl & Gulf)	.00533
GovpayI (TX)	.0055*	GovpayR (NE)	.01543
GovpayJ (SW)	.0229	GovpayS (No. Atl.)	.01261*
		GovpayT (So. Coastal)	.00454
		GovpayU (FL)	-.01429*
Govpay87	.00434*	Govpay87	.00129*
Govpay92	.00871	Govpay92	.00387*
Year87	.00017	Year87	..0293
Year92	-.0212*	Year92	-.00107

Table 4. Predicted Change in Land Use Resulting from a 50 Percent Decrease in Farm Program Payments, 1997, Thousands of Acres

Geographic Region	Land Use	Observed Acreage	Predicted Acreage	Change in Predicted	Percent Change
Northeast:	Crop	15,585	14,889	-2,538	-17.0
CT, DE, ME, MD, MA,	Pasture	7,334	7,473	216	2.9
NH, NJ, NY, PA,	Forest	76,026	75,914	1228	1.6
	Range	0	0	0	0
	Other	27,781	28,449	1,094	3.8
Southeast:	Crop	18,980	18,514	-2,035	-11.0
FL, GA, NC, SC, VA	Pasture	12,825	12,409	1,177	9.5
	Forest	71,168	73,201	-2,014	-2.8
	Range	2,503	2,674	-17	-0.6
	Other	41,446	40,125	2,888	7.2
North Central:	Crop	41,947	43,067	-1,499	-3.5
MI, MN, WI	Pasture	8,173	7,809	290	3.7
	Forest	44,800	44,242	733	1.7
	Range	0	0	0	0
	Other	27,153	26,955	476	1.8
Corm Belt:	Crop	92,032	89,434	-5,155	-5.8
IL, IN, IA, MO, OH	Pasture	20,556	20,528	533	2.6
	Forest	28,921	30,555	3,207	10.5
	Range	0	0	0	0
	Other	23,052	24,044	1,415	5.9
South Central:	Crop	28,726	26,709	-3,559	-13.3
AR, KY, OK, TN	Pasture	23,511	21,499	100	0.5
	Forest	42,135	44,050	582	1.3
	Range	12,642	14,728	1,117	7.6
	Other	22,079	22,105	1,760	8.0
Deep South:	Crop	45,127	45,460	-5,622	-12.4
AL, LA, MS, TX	Pasture	24,855	22,449	1,219	5.5
	Forest	59,092	61,220	-2,067	-3.4
	Range	94,691	94,629	2,975	3.1
	Other	34,247	33,644	3,495	10.4
Great Plains:	Crop	95,085	94,581	-9,762	-10.3
KS, NE, ND, SD	Pasture	7,270	6,942	599	8.6
	Forest	704	879	166	18.9

	Range	70,420	71,111	5,858	8.2
	Other	20,819	20,786	3,138	15.1
Intermountain:	Crop	43,107	41,477	-6,562	-16.1
AZ, CO, ID, MT, NV,	Pasture	8,333	7,818	-202	-2.7
NM, UT, WY	Forest	6,446	5,969	545	10.5
	Range	184,419	181,026	8,838	5.3
	Other	305,358	311,372	-2,618	-1.1
Pacific:	Crop	21,422	20,618	-2,828	-13.7
CA, OR,WA	Pasture	4,115	3,739	-441	-11.8
	Forest	29,459	29,606	3,318	11.2
	Range	28,990	37,318	2,626	7.0
	Other	119,860	112,566	-2,675	-2.4
Contiguous United States:	Crop	402,010	394,749	-39,560	-10.0
	Pasture	116,972	111,275	3,492	3.1
	Forest	358,751	365,638	5,698	1.6
	Range	393,666	401,487	21,398	5.3
	Other	621,795	620,046	8,973	1.4

Appendix Table 1: Estimated Marginal Effects on Cropland Share in Forest Model

Variable	Marginal Effect	Standard Error	t-Statistic
Croprev - market value of crops sold ($/acre farmland)	0.0001733	0.0000216	8.03
Stockrev - market. value of stock – poultry ($/acre farmland)	0.0000257	0.0000246	1.05
Farmcost - Direct farm expenditures ($/acre farmland)	-0.000109	0.00003	-3.63
Gpayhat – predicted total government payments (log(govpay))	0.04889	0.0072364	6.76
Gpyhat87 – predicted 1987 government payments (log(govpay87))	-0.021756	0.003154	-6.90
Gpyhat92 – predicted 1992 government payments (log(govpay92))	-0.005783	0.003176	-1.82
GovlrrA – interaction, Gpayhat if region is LRR A, 0 otherwise	0.08606	0.01876	4.59
GovlrrK – interaction, Gpayhat if region is LRR K, 0 otherwise	-0.06323	0.005567	-11.36
GovlrrL – interaction, Gpayhat if region is LRR L, 0 otherwise	0.002627	0.003675	0.71
GovlrrN – interaction, Gpayhat if region is LRR N, 0 otherwise	0.01544	0.004793	3.22
GovlrrO – interaction, Gpayhat if region is LRR O, 0 otherwise	0.02965	0.006556	4.52
GovlrrP – interaction, Gpayhat if region is LRR P, 0 otherwise	-0.003043	0.005127	-0.59
GovlrrR – interaction, Gpayhat if region is LRR R, 0 otherwise	0.008484	0.006524	1.30
GovlrrS – interaction, Gpayhat if region is LRR S, 0 otherwise	0.02360	0.007093	3.33
GovlrrT – interaction, Gpayhat if region is LRR T, 0 otherwise	-0.00522	0.006278	-0.83
GovlrrU – interaction, Gpayhat if region is LRR U, 0 otherwise	-0.08652	0.01965	-4.40
Landarea – total acres in county (million acres)	-0.04158	0.006290	-6.61
Primeshr – Share of area in county in Land Capability Classes 1 and 2	0.4907	0.01752	28.01
Irrigshr – share of farmland in county that is irrigated	0.2418	0.03173	7.62
Farmer – percent owners that are full time farmers	0.005790	0.0001916	30.21

Removals – timber growing stock removed (cu ft/acre timberland)	-0.000396	0.0000594	-6.66
Private – percent timberland that is privately owned	0.0005084	0.0000873	5.82
Estfmval – expected farm real estate value ($1000/acre)	-0.02523	0.002477	-10.19
Popden – Resident population (people per acre)	-0.01389	0.003884	-3.58
Income – per capita personal income ($1000)	0.004448	0.0007982	5.57
Houseval –median house value ($1000)	-0.000126	0.0001265	-1.00
Commute – average time of commute to work (minutes)	-0.003516	0.0003857	-9.12
Urbanlge – Proportion urban area classified as large	-0.003516	0.007031	2.28
Minrain – minimum average annual precipitation (millimeters)	-0.000202	0.0000285	-7.08
Maxrain – maximum average annual precipitation (millimeters)	-0.000127	0.0000224	-5.65
Minelev – minimum elevation in meters	0.0003268	0.0000494	6.62
Maxelev – maximum elevation in meters (peaks omitted)	-0.000129	0.0000142	-9.11
Mintemp –minimum average annual temperature, degrees centigrade	-0.003992	0.002641	-1.51
Maxtemp – maximum average annual temperature, degrees centigrade	0.009695	0.002913	3.33
Mindday – minimum average freeze-free days	0.001167	0.0002751	4.24
Maxdday – maximum average freeze-free days	-0.000706	0.0002568	-2.75

Ex post R-squared for this equation in its logit form is 0.80.

Appendix Table 2: Estimated Marginal Effects on Cropland Share in Range Model

Variable	Marginal Effect	Standard Error	t-Statistic
Croprev - market value of crops sold ($/acre farmland)	0.0000339	0.0000423	0.80
Stockrev - market. value of stock – poultry ($/acre farmland)	-0.000055	0.000057	-0.97
Farmcost - Direct farm expenditures ($/acre farmland)	0.0000234	0.0000632	0.37
Gpayhat – predicted total government payments (log(govpay))	0.07808	0.01124	6.94
Gpyhat87 – predicted 1987 government payments (log(govpay87))	-0.01432	0.004892	-2.93
Gpyhat92 – predicted 1992 government payments (log(govpay92))	0.002073	0.005244	0.40
GovlrrB – interaction, Gpayhat if region is LRR B, 0 otherwise	0.004110	0.01280	0.32
GovlrrC – interaction, Gpayhat if region is LRR C, 0 otherwise	-0.03732	0.02071	-1.80
GovlrrD – interaction, Gpayhat if region is LRR D, 0 otherwise	-0.02308	0.01297	-1.78
GovlrrE – interaction, Gpayhat if region is LRR E, 0 otherwise	-0.02606	0.01327	-1.96
GovlrrF – interaction, Gpayhat if region is LRR F, 0 otherwise	-0.005954	0.009683	-0.61
GovlrrG – interaction, Gpayhat if region is LRR G, 0 otherwise	0.002678	0.01103	0.24
GovlrrI – interaction, Gpayhat if region is LRR I, 0 otherwise	-0.06398	0.01264	-5.06
GovlrrJ – interaction, Gpayhat if region is LRR J, 0 otherwise	0.01323	0.01224	1.08
Landarea – total acres in county (million acres)	-0.03065	0.003663	-8.37
Primeshr – Share of area in county in Land Capability Classes 1 and 2	0.4351	0.03546	12.27
Irrigshr – share of farmland in county that is irrigated	0.2771	0.04770	5.81
Farmer – percent owners that are full time farmers	0.003250	0.0004114	7.90
Estfmval – expected farm real estate value ($1000/acre)	0.03631	0.01003	3.62
Popden – Resident population (people per acre)	-0.05387	0.01256	-4.29

Income – per capita personal income ($1000)	0.004126	0.001043	3.96
Houseval –median house value ($1000)	-0.000983	0.0001768	-5.56
Commute – average time of commute to work (minutes)	-0.000155	0.000942	-0.16
Urbanlge – Proportion urban area classified as large	0.05096	0.008419	6.05
Minrain – minimum average annual precipitation (millimeters)	0.0002816	0.0000644	4.37
Maxrain – maximum average annual precipitation (millimeters)	-0.000256	0.0000434	-5.90
Minelev – minimum elevation in meters	0.0000314	0.0000343	0.92
Maxelev – maximum elevation in meters (peaks omitted)	-0.000043	0.0000193	-2.22
Mintemp –minimum average annual temperature, degrees centigrade	-0.006643	0.004899	-1.36
Maxtemp – maximum average annual temperature, degrees centigrade	-0.002947	0.005081	-0.59
Mindday – minimum average freeze-free days	-0.000733	0.0003625	-2.02
Maxdday – maximum average freeze-free days	0.0009801	0.0004666	2.10

Ex post R-squared for this equation in its logit form is 0.88.