Agricultural Land Use Choice: A Discrete Choice Approach

Roger Claassen and Abebayehu Tegene

A discrete choice model and site-specific data are used to analyze land use choices between crop production and pasture in the Corn Belt. The results show that conversion probabilities depend on relative returns, land quality, and government policy. In general it is found that landowners are less inclined to remove land from crop production than to convert land to crop production.

Agricultural land use decisions have a significant effect on commodity supply and environmental outcomes. Accordingly, land retirement has long been used as both a short-term and long-term commodity supply management tool and as a mechanism to achieve conservation and environmental objectives. As federal policy increasingly seeks to target specific types of land for retirement, a more complete understanding of the economic and land quality factors that shape land use decisions is needed to provide policymakers with better information on the consequences of altering land use policies or programs (e.g., wetland delineation, CRP eligibility, etc.).

Most previous economic models of land use decisions have used county- or state-level data, partially obscuring the effect of site-specific land quality characteristics (e.g., productivity) in land conversions. Further, these models explain only net changes in land use within the area of observation rather than actual land use conversions (e.g., Hardie and Parks 1997; Plantinga 1996). This study uses a discrete choice model and fully disaggregated or site-specific data on land use and land quality to explain the choice of crop production, pasture or CRP land use in the Corn Belt region for the period 1980–87. Use of site-specific data allows extension of previous land use research in two ways: (1) spatial variation in land quality is represented to the fullest extent possible; and (2) the model focuses on the land use conversion decision and associated adjustment costs or rigidities since it is possible to observe the characteristics of land that actually changes use.

Given that land use policy now seeks to affect the use of land with specific attributes and that land quality varies widely, even within very small geographic areas, the use of site-specific data may be a particularly important empirical refinement. Site-specific data eliminate the need for acreage allocation equations which assume that land quality follows a definable parametric distribution. For example, Lichtenberg (1989) assumes that intra-county variation in land quality is logistically distributed around the county average for the land quality indicator used. Stavins and Jaffe (1990) assume that land quality follows a log-normal distribution but use no actual data on land quality.

Adjustment issues are also of critical importance in understanding the consequences of land use policy. It has been theorized that agricultural assets, such as land, become "fixed" to a specific sector (Johnson and Quance 1972; Edwards 1959), resulting in chronic overproduction. In other words, crop production may be slow to adjust to changing economic conditions because land does not shift out of (into) crop production rapidly enough when crop prices fall (rise). Hsu and Chang (1990) note that adjustment costs can be used to rationalize the theory of asset fixity. When adjustment costs are linear, the dynamic adjustment cost model is reduced to a static model and the size of the "asset fixity trap" is defined by the marginal cost of adjustment. Casual observation indicates that land uses changes only slowly, suggesting that there may be significant adjustment costs or rigidities associated with the process of land use change. With data on specific land use conversions (e.g., crops to pasture, pasture to crops), parameters which represent average adjustment costs and/or

---

Roger Claassen and Abebayehu Tegene are economists in the Resource Economics Division of USDA's Economic Research Service, 1800 M Street, Washington DC 20036-5828. The views expressed are those of the authors, and may not be attributed to the Economic Research Service or the U.S. Department of Agriculture.

other sources of adjustment rigidity for each specific type of land use conversion can be estimated and the potential for asymmetry in adjustment costs can be explicitly recognized.

The purpose of the paper is twofold. The first is to estimate conversion probabilities within agricultural land uses for the Corn Belt using actual land use conversions and disaggregated data. The second purpose is to assess how conversion probabilities are impacted by such factors as conversion costs, land quality, and government policies. The paper is organized as follows: the next section presents a discrete choice land allocation model; and the section following that presents the data and empirical analysis; the final section presents the conclusions.

A Discrete Choice Model of Land Allocation

Assume that land is allocated to the use with the largest discounted present value of expected future net returns. Land can be allocated to either of two uses, *i* and *j*. Land at site[1] *k* in use *i* (e.g., a noncropland use such as pasture) is converted to the alternative use, *j* (e.g., crop production), when the present value of expected returns to the land in use *j* is greater than the expected value in use *i:*

$$V_{kjt} > V_{kit}$$

where V_{kjt} is the present value of expected returns for land at site *k* in use *j* at time *t*, including conversion costs; that is:

$$V_{kjt} = \sum_{h=0}^{H} E_t \left[\frac{R_{j,t+h}(q_k)}{\prod_{m=0}^{h} (1 + r_{t+m})} \right] - c_{ktij}(1 - y_{kj,t-1}) \tag{1}$$

where H is the farmer's planning horizon; q is land quality; $Rj,\ t{+}h(q_k)$ is the net annual return for land at site *k* in use *j* at time $t + h$; r_{t+m} is the interest rate at time $t + m$; c_{ktij} is the adjustment cost involved in converting land from use *i* to use *j*, at site *k* and time *t*; $y_{kj,t-1}$ is equal to one if land at site *k* is in use *j* at time $t - 1$, zero otherwise; and E_t denotes expectation held at time *t*. With constant expected returns and constant interest rates (see, for example, Burt (1986); Tegene and Kuchler (1991), among others), equation (1) reduces to

$$V_{kjt} = \alpha E[R_{jt}(q_k)] - c_{ktij}(1 - y_{kj,t-1}) \tag{1a}$$

where $\alpha = (1 - (1/(1 + r))^H)r^{-1}$. When the farmer's planning horizon is infinite (i.e., when H approaches infinity), $\alpha = 1/r$. Similarly,

$$V_{kit} = \alpha E[R_{it}(q_k)] - c_{ktji}y_{kj,t-1}. \tag{1b}$$

While standard expectation formation models measure farmers' collective central tendency regarding expected returns, V_{kjt} and V_{kit} may vary widely from site to site. Differences in unobserved factors such as management skills, future price expectations, expectations about technology, local market conditions, location relative to the farmer's farmstead, etc., may lead the owners of land with similar productive potential to choose different land uses while each maximizes the present value of expected returns. Assuming that these differences create random and additive differences in farmer expectations regarding the present value of expected future returns, an individual farmer's subjective assessment can be written as:

$$V^*_{kjt} = V_{kjt} + u_{kjt}$$

where u is an unobserved random variable with mean zero and finite variance. Given the random term, the probability of use *j* at site *k* and time *t*, conditional on prior land use is:

$$\begin{aligned} Pr(y_{kjt} = 1 | y_{kj,t-1}) &= Pr(V_{kjt} + u_{kjt} > V_{kit} + u_{kit}) \\ &= Pr(u_{kit} - u_{kjt} < V_{kjt} - V_{kit}). \end{aligned} \tag{2}$$

Using equations (1*a*) and (1*b*), the difference in the present values of the two uses of land can be written as:

$$\begin{aligned} (V_{kjt} - V_{kit}) = {}& \alpha(E[R_{jt}(q_k) - R_{it}(q_k)]) \\ & - c_{ktij} + (c_{ktij} + c_{ktji})y_{kj,t-1} \end{aligned} \tag{3}$$

or

$$\begin{aligned} (V'_{kjt} - V'_{kit}) = \frac{1}{\alpha}(V_{kjt} - V_{kit}) = {}& (E[R_{jt}(q_k) \\ & - R_{it}(q_k)]) - \frac{1}{\alpha} c_{ktij} \\ & + \frac{1}{\alpha}(c_{ktij} + c_{ktji})y_{kj,t-1}. \end{aligned} \tag{3'}$$

Note that the second and third terms on the RHS of equation (3′) represent annualized costs of adjustment incurred for the conversion of land from use *i* to use *j* or vice versa. The entire RHS of equation (3′) represents the difference in expected annual returns between uses *i* and *j*, adjusted for annualized adjustment costs. We thus have:

$$\begin{aligned} Pr(y_{kjt} = 1 | y_{kj,t-1}) &= Pr\left(\frac{1}{\alpha}\epsilon_{kt} < V'_{kjt} - V'_{kit}\right) \\ &= F(V'_{kjt} - V'_{kit}) \end{aligned} \tag{4}$$

where F is a cumulative distribution function (cdf). The exact distribution of F depends on the distribution of the random term $(1/\alpha)\epsilon_{kt} = (1/\alpha)$

$(u_{kit} - u_{kjt})$. If the u's are normally distributed, their linear combination is also normally distributed; F is the normal cdf, and a binomial probit model is implied.

Consider how changes in the independent variables affect the probability that land will continue in, or be converted to land use j. Clearly, the probability of use j is increased by an increase in expected returns to use j and decreased by an increase in expected returns to use i. For example, an increase in crop prices which increases cropland returns would unambiguously increase the probability of continued crop production or conversion to crop production, *ceteris paribus*. A change in the interest rate or site-to-site variation in land quality will affect the value of land in both uses, requiring assessment of the relative impact of these changes on use values. For example, the marginal effect of the interest rate ($r = 1/\alpha$) is[2]:

$$(5) \quad f(V'_{kjt} - V'_{kit})(-c_{ktij} + (c_{ktij} + c_{ktji})y_{kj,t-1})$$

where f is the probability density function for $(1/\alpha)\epsilon_{kt}$. The sign of (5) depends on the previous land use, $y_{kj,t-1}$. When $y_{kj,t-1} = 1$ (i.e., land at time $t - 1$ was in use j), equation (5) reduces to

$$f(V'_{kjt} - V'_{kit})(c_{ktji}) > 0$$

(assuming positive conversion cost) implying that higher interest rates increase the probability that land will continue in use j. When $y_{kj,t-1} = 0$, equation (5) becomes

$$f(V'_{kjt} - V'_{kit})(-c_{ktij}) < 0$$

implying that an increase in the interest rate will reduce the probability of conversion from use i to use j (increase the probability that land will continue in use i). That is, an increase in interest rate unambiguously decreases the probability of land conversion.

Similarly, consider the effect of site-to-site variation in land quality. The marginal effect of land quality on the probability of land use j is:

$$(6) \qquad f(V'_{jt} - V'_{it})\left(\frac{\partial E[R_{jt}]}{\partial q} - \frac{\partial E[R_{it}]}{\partial q}\right).$$

Assuming that returns to both land uses are increasing in land quality, equation (6) is positive when returns to land use j increase more rapidly than returns to land use i in response to increasing land quality[3]:

$$(7) \qquad \frac{\partial E[R_{jt}]}{\partial q} - \frac{\partial E[R_{it}]}{\partial q} > 0.$$

Data and Empirical Model

Empirical Model

Development of the empirical model begins by specifying cropland as use j and non-crop use as use i (details below). Non-cropland use is either pasture (i.e., livestock grazing) or, when land is eligible, enrollment in the Conservation Reserve Program (CRP). In this section, we define measures of return for all three of these land uses and describe how they can be incorporated into a model of land use choice. From equation (3′) and (4):

$$(8) \qquad Pr(y_{kjt} = 1 | y_{kj,t-1}) = F\,(V'_{kjt} - V'_{kit}) =$$
$$F\left(E[R_{jt}(q_k) - R_{it}(q_k)] - \frac{1}{\alpha}c_{ktij} + \frac{1}{\alpha}(c_{ktij} + c_{ktji})y_{kj,t-1}\right).$$

The probability of cropland in year t, conditional on land use in year $t - 1$, is specified as a function of differences in expected returns from cropland and non-crop uses and conversion cost.

One common measure of return from land ownership is the rent a tenant is willing to pay to use the land (Tegene and Kuchler 1991; Burt 1986; among others.). We measure returns to cropland and noncropland uses by their respective rental rates, which is a function of the quality of land. For agricultural production, land quality can be defined by the extent to which soil chemical, physical, and topographic characteristics are conducive to crop or to noncrop production. However, site-specific measures of land rent, which capture variation in soil properties conducive to crop or other enterprizes, are not generally available. Annual state-wide average rents paid for cropland and pasture are available (Hexem and Jones), as are data on cross-sectional differences in the quality of land for agricultural production. A number of land quality indicators have been used in the agricultural economics literature, including expected yield and expected revenue (Heimlich 1989), land capability class (Plantinga 1996; Hardie and Parks 1997; Vesterby et al. 1997), and water holding capacity (Lichtenberg 1989). Here, as discussed in the section below, we use expected yield information from the SOILS-5 database to construct a land quality index.

We combine state-wide average rental rates with cross-sectional data on land quality to specify site-specific expected rental returns to cropland and pasture as:

$$(9a) \qquad E[R_{jt}(q_k)] = E[R_{sjt}] + \gamma_j(q_k - q_s)$$

and

$$(9b) \qquad E[R_{pt}(q_k)] = E[R_{spt}] + \gamma_p(q_k - q_s)$$

where $E[R_{sjt}]$ and $E[R_{spt}]$ are expected state-wide average cropland and pasture rental rates, respectively, in state s at time t, q_s is the average quality of land in state s, q_k is the site-specific land quality, and $\gamma_j > 0$ and $\gamma_p > 0$ are parameters which translate the land quality differential of a given site from the state-wide average into variations in site-specific cropland and pasture rental returns, respectively. That is, the state-wide average rental rates form the time series component of land rents while the land quality component captures cross-sectional variation in returns to land. Above average quality lands ($q_k > q_s$) command higher (than state average) rental rates.

A consideration in agricultural land use decisions between cropland and noncrop land use is the Conservation Reserve Program (CRP) which was established by the 1985 farm bill. The CRP significantly affected the value and use of eligible land. Cropland which met erodibility and other criteria was eligible for CRP enrollment beginning in 1986. In exchange for an annual payment, eligible cropland enrolled in CRP was converted to grass cover for a period of 10 years during which producers where generally prohibited from making other economic use of the land (e.g., haying or grazing). As such, CRP could be considered a third land use option. Unfortunately, the land use data available for this study do not indicate whether land converted to grass cover is actually enrolled in the CRP. Thus, it is empirically impossible to consider CRP as a third land use category.

Despite this limitation, a useful model can be developed. First, we assume that on CRP-eligible land, CRP enrollment—not pasture—is the alternative to continued crop production. CRP rental rates have historically been much higher than typical pasture rental rates so that CRP tended to supplant pasture (grazing) land use as an alternative to crop production on eligible land. Producers who were considering conversion of CRP-eligible cropland to pasture could invariably receive larger returns through CRP enrollment. Second, we assume most producers viewed CRP as a temporary diversion from crop production. For planning horizons longer than 10 years, landowners would return land to crop production in year eleven. Many producers who would not otherwise consider converting cropland to pasture also opted for CRP enrollment, because of lucrative terms. Moreover, the CRP preserved producers' farm program eligibility (base acreage) so that land returned to crop production after CRP would be eligible for program benefits. In many or even most cases, crop production will continue to be more profitable than pasture land use when CRP contracts expire.

Given these assumptions, the return to non-crop land use is:

$$(10) \quad E[R_{it}(q_k)] = E[R_{pt}(q_k)] + \phi\left(\frac{\delta}{\alpha} R_{erp,t} + \theta E[R_{jt}(q_k)] - E[R_{pt}(q_k)]\right)$$

where ϕ is equal to one for land which is CRP-eligible, zero otherwise,

$$\delta = \frac{1}{r} - \frac{1}{r(1+r)^{10}},$$

$R_{crp,t}$ is the state-wide average CRP contract rental rate in year t, $\theta = (1 + r)^{-10}$, and other terms are as defined above (e.g., $\alpha = 1/r$). The term in brackets on the RHS of equation (10) indicates that, for CRP-eligible land, return to non-crop use of land is the annualized value of the flow of returns from 10 years of CRP rental payments and from crop production beginning in the eleventh year. When land is CRP-eligible, the first term on the RHS of equation (10) and the last term in the brackets cancel, indicating that pasture land use is not a viable option with the existence of CRP.

Substituting equation (9*b*) into equation (10) and subtracting the result (expected non-crop return) from expected crop return (equation 9*a*) yields:

$$(11) \quad E[R_{jt}(q_k) - R_{it}(q_k)] = E[(1 - \phi\theta)R_{sjt} - (1 - \phi)R_{spt}] + \phi\frac{\delta}{\alpha} R_{crp,t} + (\gamma_j - \gamma_p)(q_k - q_s) + (\gamma_p - \theta\gamma_j)\phi(q_k - q_s).$$

The first two terms on the RHS of equation (11) model the expected difference between statewide average cropland and non-cropland returns. For land which is not CRP-eligible ($\phi = 0$), the expected difference is between cropland and pasture rental rates. For CRP-eligible land ($\phi = 1$), the pasture rental rate drops out of the equation and is replaced by the CRP rental rate (the second term in equation 11), because we assume that CRP is the relevant land use alternative for CRP-eligible cropland. The third and fourth terms on the RHS of equation (11) describe how cross-sectional variation in land quality affects relative returns. The fourth term allows the coefficient of the land quality variable to vary for CRP-eligible land.[4] Because $0 < \theta < 1$, the overall marginal effect of land quality variation can be smaller or larger for the cropland/CRP land use decision than for the cropland/pasture land use decision. To see this, note that the third and fourth terms can be rewritten as:

$$(12)\qquad (\gamma_j - \gamma_p + \phi\gamma_p - \phi\theta\gamma_j)(q_k - q_s).$$

When $\phi = 1$, the γ_p's cancel and the marginal effect of land quality variation in the cropland/CRP decision is $\gamma_j - \theta\gamma_j$. Only in the unlikely event that $\theta = 1$ ($r = 0$) is the marginal effect of land quality variation on the cropland/CRP decision equal to zero. When $\theta\gamma_j = \gamma_p$, marginal effects are the same for both the cropland/pasture and cropland/CRP land use decision. To select a model specification, we estimated a model (equation 16 below) using three land quality terms:

$$(13)\qquad (\gamma_j - \gamma_p)(q_k - q_s) + \phi\gamma_p(q_k - q_s) - \phi\theta\gamma_j(q_k - q_s).$$

However, the second and third terms provided no additional insight into the role of land quality in the cropland/CRP land use decision. Estimated coefficients were not individually or jointly significantly different from zero at even the ten percent level. Thus, we could not reject the hypothesis that marginal effects were the same for the cropland/pasture and cropland/CRP land use decisions. Moreover, dropping the second and third terms of (13) entirely from the estimation had virtually no effect on the value of other estimated coefficients of the model. Given this evidence, we chose a model incorporating only a single land quality term: $(\gamma_j - \gamma_p)(q_k - q_s)$. Finally, because we have only a single general indicator of land quality, γ_j and γ_p cannot be estimated separately. However, when $\gamma_j > \gamma_p$, return to crop production rises more rapidly with land quality than does return to pasture (note that equation (6) can be written as $f(V'_{kjt} - V'_{kit})(\gamma_j - \gamma_p)$, which is positive when $\gamma_j > \gamma_p$).

Turning now to how expectations are formed, a number of alternative approaches are used in the literature (see, for example, Burt 1986; Eales et al. 1990; Tegene and Kuchler 1991; Just and Miranowski 1993; among others). While there is no consensus on a best model of expectation formation, we opt for a model which incorporates distributed lags.[5] This approach is similar to that of Burt in that no specific expectation mechanism is imposed, *a priori*, but results can be consistent with a variety of formal expectation formation mechanisms. We have

$$(14)\qquad E[(1-\phi\theta)R_{sjt} - (1-\phi)R_{sit}] = \sum_{m=0}^{M} \zeta_m((1 - \phi\theta)R_{sj,t-m} - (1-\phi)R_{i,t=m}).$$

As suggested by Judge et al., (1988, p. 723) the length of the lag was determined empirically by starting with a model which included a large number of lags (large M) on the rental rate difference variable and reducing the lag length based on likelihood ratio tests. We estimated the model (equation 16) starting with five lags, and continued to trim the lag length so long as t-tests showed that the exclusion restrictions could not be rejected and other estimated coefficients remained stable.[6] The resulting specification contains current and two lagged values of the rental rate differences:

$$(15)\qquad \begin{aligned} E[R_{jt}(q_k) - R_{it}(q_k)] = \sum_{m=0}^{2} \zeta_m[(1-\phi\theta)R_{sj,t-m} \\ - (1-\phi)R_{sp,t-m}] + \frac{\delta}{\alpha}\phi R_{crp,t} \\ + \gamma(q_k - q_s), \end{aligned}$$

where $\gamma = \gamma_j - \gamma_p$.

Finally, although no adjustment cost data are available, average relative adjustment costs can be estimated.[7] In our model, adjustment costs are estimated by three parameters: the parameters of the lagged dependent variable, the interest rate, and the interaction between the lagged dependent variable and the interest rate (see equations 8 and 16). The specification allows the model to capture those adjustment costs which vary with the interest rate and those which do not. As noted by Palmquist (1989), soil characteristics which can be changed by the landowner will be changed when the potential for increased return exceeds the cost of making the change. When such changes occur in the context of land use conversion, the costs (benefits) of such changes will be reflected in the adjustment cost parameters.

Specified as outlined above, the empirical model can be written as:

$$(16)\qquad \begin{aligned} Pr(y_{kjt} = 1|y_{kj,t-1}) &= F(V'_{kjt} - V'_{kit}) \\ &= F(\beta_0 + \beta_1 y_{kj,t-1} + \beta_2 r + \beta_3 r y_{kj,t-1} \\ &\quad + \beta_4((1-\phi\theta)R_{sjt} - (1-\phi)R_{spt}) \\ &\quad + \beta_5((1-\phi\theta)R_{sj,t-1} - (1-\phi)R_{sp,t-1}) \\ &\quad + \beta_6((1-\phi\theta)R_{sj,t-2} - (1-\phi)R_{sp,t-2}) \\ &\quad + \beta_7\phi\frac{\delta}{\alpha}R_{crp,t} + \beta_8(q_k - q_s)) \end{aligned}$$

where β is a vector of unknown parameters, $\beta_4 = \zeta_0$, $\beta_5 = \zeta_1$, $\beta_6 = \zeta_2$, $\beta_8 = \gamma$, and other parameters and variables are as defined above. The parameters are estimated by maximizing the likelihood function:

(17)

$$L = \prod_{k} \prod_{t} F(V'_{kjt} - V'_{kit})^{y_{kjt}} (1 - F(V'_{kjt} - V'_{kit}))^{1-y_{kjt}}.$$

Data

The model is fitted to data from the Corn Belt. The Corn Belt region is of particular interest because it is one of the most productive agricultural regions in the world. The actions of Corn Belt farmers can have a significant impact on world-wide supply of commodities like corn and soybeans. Because a significant portion of Corn Belt acreage has a high erodibility index (Vesterby et al., 1997), soil depletion and off-site damage issues are also of particular concern.

Cropland and pasture are the principle land uses in the Corn Belt. Although the Corn Belt does contain significant acreages of wooded land and extensive development exists around larger cities, the movement of land between agriculture and forestry and from agriculture to development was very small during the study period. Because the land use margins between agriculture and forestry and between agriculture and urban land use are relatively inactive, the key decision for the purpose of this study is cropland versus pasture and cropland versus CRP land uses.[8]

Data on land use and land quality are obtained from the 1987 National Resources Inventory (NRI). For the Corn Belt (land resource region (LRR) M) the NRI data file contains observations on land use and land quality for over 48,000 sites. Land resource region M contains all of Iowa, major portions of Ohio, Indiana, Illinois, Minnesota, and Missouri, and smaller parts of South Dakota, Nebraska, Kansas, Oklahoma, and Michigan.

Only those sites which remain in crop production or pasture use (or convert from one to the other) throughout the study period (1980–87) are used.[9] A sample of 993 sites, roughly 4% of the qualifying sites, were selected at random. Using cropping history data for 1979–1981 and 1984–86, a data set including six observations at each site (1980–82 and 1985–87) was constructed; a total of 5943 observations.[10]

As noted above, land quality is represented by expected crop yields. The best available source of consistent, nation-wide information on expected crop yields is the SOILS-5 interpretative data base, collected and maintained by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture. SOILS-5 crop yields approximate those of leading commercial farmers at the management level that tends to produce the highest net economic return per acre (Heimlich, 1989). However, the SOILS-5 data base provides only a limited number of alternative crop yields for each soil. Although yields for a number of crops were available for each soil, no single crop yield was available for every soil represented in the sample. Thus, an index of several yields was devised. The index reflects the maximum expected gross revenue obtainable from the production of one of four crops: corn, soybeans, wheat, or bromegrass-alfalfa hay. Expected revenue is calculated using long term average commodity prices normalized by the corn price. That is, corn revenue always equals the corn yield, while revenue for other crops are calculated by multiplying the crop yield by the ratio of the commodity price to the corn price averaged over the season-average price for all states included in LRR M and over the years 1975 through 1992.[11] For example, the revenue for soybeans was calculated as:

$$q_k^{sb} = \omega_{sb} Y_k^{sb} \tag{18}$$

where Y_k^{sb} is the expected soybean yield for site k from the SOILS-5 data base and

$$\omega_{sb} = \frac{\sum_{t=75}^{92} \sum_{s=1}^{S} \left(\frac{SBP_{ts}}{CNP_{ts}} \right)}{N(92-75)} \tag{19}$$

where s indexes the state, S is the number of states represented in the study, *SBP* is the price of soybeans and *CNP* is the price of corn. Then the overall land quality index is defined as:

$$q_k = \max(q_k^{cn}, q_k^{sb}, q_k^{wt}, q_k^{hay}) \tag{20}$$

where *cn* = corn and *wt* = wheat. This procedure is designed to provide appropriate weights for various crop yields while avoiding the introduction of year-to-year price variation which could cause collinearity between rental rate and land quality variables.

State-wide average cropland and pasture rental rates are obtained from Jones and Hexem (1990). State-wide average Conservation Reserve Program rental rates are obtained from Osborn et al. (1989). Nominal rental rates were converted to real rental rates using the gross domestic product implicit price deflator. The interest rate is the real rate of return on ten year treasury bonds.

Finally, CRP eligibility was determined using criteria as detailed by Osborn et al. (1989) and NRI data on land capability classification, 1982 erosion rates (as estimated by Universal Soil Loss Equation), and the soil's T-level.

Results

Table 1 presents the results from estimating the model. The joint explanatory power of the overall model is measured using likelihood ratio tests in which: (1) all parameters other than the constant term are restricted to zero, where the corresponding log-likelihood function is denoted by L(C); and (2) all parameters other than the constant term and the coefficient of the lagged dependent variable are restricted to zero, with log-likelihood function L(LD). L(β) is the value of the log-likelihood function evaluated at the estimated parameters. The second test is particularly important in this case. Because land use changes are very gradual (land use changes on only 92 of 5943 observations of the study period) a great deal can be explained by the lagged dependent variable alone. The likelihood ratio statistics for each test are shown below table 2. Both tests show that the relevant set of explanatory variables are jointly significant at the 1% level.

The signs of the estimated coefficients are consistent with expectations. The distributed lag coefficients of the rental rate differences show the time profile of the effects of this variable. Coefficients of the rental rate difference are positive for the current year and the first lag and is negative for the second lag. This profile suggests that farmers expectations regarding future rental rates differences are based on an extrapolation of recent trends in rental rate differences: when cropland rental rates are large relative to pasture rental rates in the current year compared to previous years, the probability of conversion to cropland or continued cropland use rises. The sum of the current and lag coefficients of the rental rate difference is positive, implying that the total effect or long-run effect of this variable is to increase the probability of conversion to cropland or continued cropland use. Both in the short- and long-run as cropland rental rates increase relative to pasture rental rates, the probability of conversion to cropland increases.

The estimated coefficient of the CRP variable is negative and significant at the 1% level. As expected, the results indicate that as CRP rental rates increase, the probability that CRP eligible land will be retained in crop production declines. The positive and significant coefficient of the land quality variable indicates that crop profits are more sensitive to the land quality changes that underlie the variation in crop yields than are pasture profits. Note that the crop yield parameter reflects the change in cropland rental rates relative to pastureland rental rates as land quality changes (equations 6 and 7). The absolute effect of land quality on rental returns in either use cannot be obtained from the estimation.

Regarding interest rates, the theoretical model predicts that an increase in the interest rate decreases the probability of land conversion. The results show that the probability of pasture to crop-

Table 1. Parameter Estimates

Variable	Notation	Parameter	Parameter Estimate (*t*-ratio)
Constant		β_0	−0.807 (−1.520)
Lagged dependent variable	$y_{kj,t-1}$	β_1	3.27** (5.547)
Interest rate	r	β_2	−.121* (−2.343)
Interest rate × lagged dependent variable	$ry_{kj,t-1}$	β_3	0.903 (1.631)
Rental rate difference (t)	$(1 - \phi\theta)R_{sjt} - (1 - \phi)R_{sit}$	β_4	.0223* (2.053)
Rental rate difference (t − 1)	$(1 - \phi\theta)R_{sj,t-1} - (1 - \phi)R_{si,t-1}$	β_5	.0039 (.829)
Rental rate difference (t − 2)	$(1 - \phi\theta)R_{sj,t-2} - (1 - \phi)R_{si,t-2}$	β_6	−.0184 (−1.632)
CRP rental rate	$\phi(\delta/\alpha)R_{crp,t}$	β_7	−.0121** (−3.120)
Land quality index	$q_k - q_s$	β_8	.00244* (2.069)

L(C) = −3133.36; L(LD) = −460.69; L(β) = −440.05.
2[L(β) − L(C)] = 5,386.62.
2[L(β) − L(LD)] = 41.82.
**Significance at 1% level, *5% level.

Table 2. Comparison of Relative Return and Adjustment Costs for Average Quality Land in Iowa

1 Year	2 CRP Eligible?	3 Relative Return	4 Adj. Cost, $c_{ij}(r)$	5 Adj. Cost, $c_{ji}(r)$	6 Pr Convert Pasture to Cropland	7 Pr Convert Cropland to Grass Pasture (or CRP)
1980	—	.651	1.306	2.936	.072	.0027
1981	—	.654	1.555	2.873	.044	.0033
1982	—	.493	1.477	2.892	.037	.0050
1985	—	.282	1.299	2.938	.034	.0079
1986	no	.011	.983	3.017	.038	.0132
1986	yes	−.435	.983	3.017	—	.0379
1987	no	.058	1.044	3.002	.037	.0121
1987	yes	−.469	1.044	3.002	—	.0421

land conversion is in fact reduced with an increase in the interest rate. However, for land which is already in crop production, the effect of the interest rate is not significantly different from zero. When $y_{kj,t-1} = 1$ (land is cropped the previous year), the derivative of equation (16) with respect to the interest rate, r, is

$$(21) \qquad f(V'_{kjt} - V'_{kit})(\beta_2 + \beta_3).$$

Using a Wald test ($\chi^2_{(1)} = .42$), the hypothesis: $\beta_2 + \beta_3 = 0$ could not be rejected, indicating that the interest rate has no significant effect on the land use decision when land was cropped the previous year.

Adjustment costs appear to be an important factor in land use change decisions. From equations 3′ and 16, note that the relative costs of adjustment between land uses can be written as:

$$(22) \qquad -c_{ktij}(r) = \beta_2 r$$

$$\text{and} \qquad c_{ktji}(r) = \beta_1 + (\beta_2 + \beta_3)r.$$

The relative returns component of the model can be written as (the argument of F(.) in equation 16 without the constant term or the adjustment cost component):

$$(23)$$
$$\begin{aligned} E[R_{jt}(q_k) - R_{it}(q_k)] = {} & \beta_4((1 - \phi\theta)R_{sjt} \\ & - (1 - \phi)R_{spt}) \\ & + \beta_5((1 - \phi\theta)R_{sj,t-1} \\ & - (1 - \phi)R_{sp,t-1}) \\ & + \beta_6((1 - \phi\theta)R_{sj,t-2} \\ & - (1 - \phi)R_{sp,t-2}) \\ & + \beta_7 \frac{\delta}{\alpha} \phi R_{crp,t} + \beta_8(q_k - q_s). \end{aligned}$$

Consider a farmer with a specific ϵ_{kt}. Land at site k which is in pasture at time $t - 1$ will be converted to cropland when:

$$(24) \quad \epsilon_{kt} < \beta_0 + E[R_{jt}(q_k) - R_{it}(q_k)] - c_{kij}(r_t).$$

If land at site k is in crop production at time $t - 1$, the land would be converted to pasture when:

$$(25) \quad \beta_0 + E[R_{jt}(q_k) - R_{it}(q_k)] + c_{kji}(r_t) < \epsilon_{kt}.$$

Table 2 gives the values of the components of equations (24) and (25) for average crop yield potential in Iowa ($q = 124$) and associated conversion probabilities, computed using equations (22) and (23) and the estimated coefficients from table 1. The parameters in a discrete choice model are estimated only up to a scale factor, σ (see footnote 7), so that the values in columns 3, 4, and 5 can be interpreted only in relation to each other. Conversion probabilities are calculated by assuming that ϵ_{kt} follows a standard normal distribution, consistent with the assumptions of the estimation. Note that while average relative returns change significantly between 1980 and 1987, they are small relative to $c_{ij}(r)$ and $c_{ji}(r)$. Accordingly, conversion probabilities are never high, even through they do change significantly (in percentage terms) between 1980 and 1987. More interestingly, the results indicate that there is a significant asymmetry in adjustment costs/rigidities. Landowners appear to experience higher costs or are simply more reluctant to convert cropland to pasture than pasture to cropland. As a consequence, the probability of converting land from pasture to cropland is generally greater than the probability of a cropland to pasture conversion for non-CRP eligible land.

Figure 1 shows how the probability of land use conversion changes with land quality for 1987 economic conditions in Iowa. The three lines traced out in figure 1 correspond to the probability of pasture to cropland conversion, the probability of converting non-CRP eligible land from crop production to pasture, and the probability that CRP-eligible land is converted from cropland to non-cropland use (pasture or CRP). The probability of pasture to cropland conversion increases with land

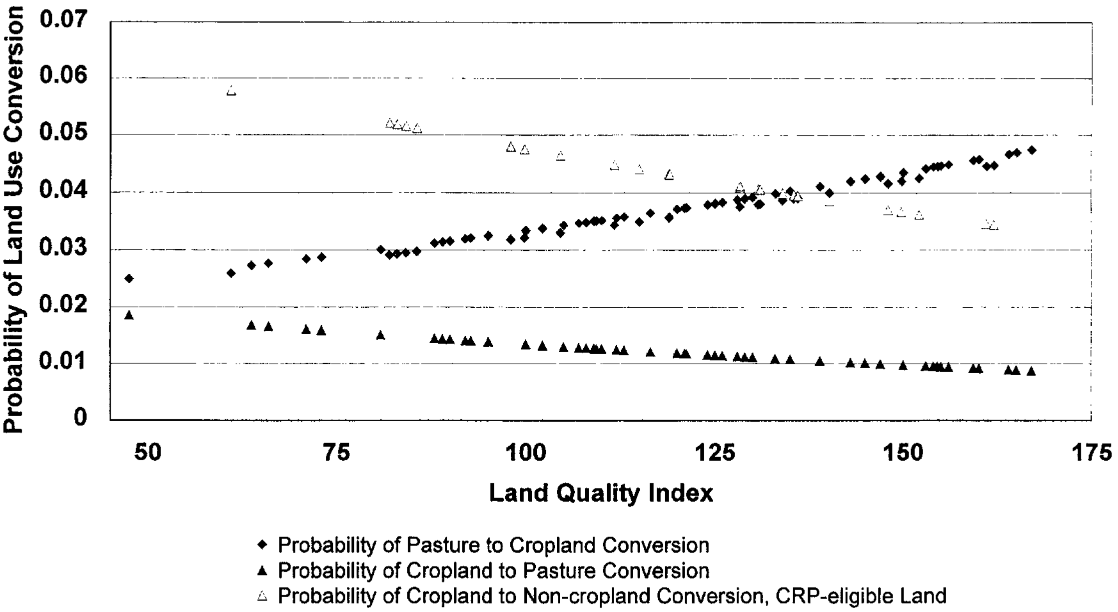

Figure 1. Probability of land use conversion.

quality while the probability of conversion from cropland to pasture or CRP decreases. At all but the very lowest levels of land quality, the probability of cropland to pasture conversion is smaller than the probability of pasture to cropland conversion for non-CRP eligible land. However, the probability of converting CRP eligible cropland to pasture or CRP exceeds the probability of converting pasture to crop production for land with a land quality index of 138 or lower. The results suggest that CRP significantly increased the retirement of highly erodible cropland in the Corn Belt, rather than simply paying producers to retire land that may have been converted to pasture in any case. Table 2 shows that the probability of conversion of cropland to pasture rose slowly during the mid-80s, but that it was always low relative to the probability of pasture to cropland conversion. Unfortunately, it is not possible to know whether points which were converted to grass cover were actually converted to grazing land or placed under CRP contract (the 1987 NRI does not indicate whether points are, in fact, enrolled in CRP). Moreover, some land placed under CRP contract may have been removed from crop production in any case. However, these scenarios seem unlikely for land with crop acreage base, given the availability of substantial deficiency payments in the late 1980s.

Note that table 2 and figure 1 show only the predicted probability of conversion. Predicted conversion also depends critically on the amount of land available for conversion at each level of quality. For example, at high levels of land quality, even a large probability of pasture to crop conversion can result in only a small change in predicted acreage if very little high quality land is devoted to pasture and, as such, available for conversion to cropland. If the distribution of land quality is heavily weighted toward medium quality land, the majority of land use conversion may take place on average quality land, even though the probability of conversion is greatest at very low and/or very high levels of land quality, depending on economic conditions.

Conclusions

This study used a discrete choice model and site-specific data to analyze land conversions between crop and pasture or CRP in the Corn Belt between 1980 and 1987. As hypothesized, the results indicate that the conversion probabilities depend on the relative returns from crop production and pasture, government policy (CRP), and land quality. The results suggest that adjustment costs/rigidities are both large (relative to other components of the estimated equation) and asymmetric. The results for Iowa showed that the probability of pasture to cropland conversion increases with land quality while conversion from cropland to noncropland uses decreases with land quality.

Estimates of conversion costs/rigidities suggest that land can become "fixed" in a particular use. The asymmetry of conversion costs/rigidities suggests that land is more likely to become fixed in crop production than in non-cropland uses. While land is converted to crop production and from crop production to another use in every year of the time series, Corn Belt landowners appear to be generally less inclined to remove land from crop production than to convert land to crop production for land that was not eligible for the CRP. This is true even for low quality land which was not eligible for the CRP. The asymmetry found here is consistent with a long term trend toward increasing cropland acreage in the Corn Belt. Results could be quite different for other regions where crop production land use has been declining over the long term.

CRP eligibility significantly increased the probability of converting land away from crop production. While the data do not allow us to distinguish between CRP and non-CRP conversions, the evidence suggests that less Corn Belt land would have been retired from crop production without the CRP program. Figure 1 suggests that, in the absence of government intervention, net retirement of land from crop production is unlikely for almost any quality of Corn Belt land, even during a period of depressed returns (e.g., 1987). Again, results may be different for regions where crop production land use is declining.

References

Burt, Oscar R. 1986. "Econometric Modeling of the Capitalization Formula for Farmland Prices." *American Journal of Agricultural Economics* 68:10–26.

Eales, James S., Brian K. Engel, Robert J. Hauser, and Sarahelen R. Thompson. 1990. "Grain Price Expectations of Illinois Farmers and Grain Merchandisers." *American Journal of Agricultural Economics* 72:701–708.

Edwards, Clark. 1959. "Resource Fixity and Farm Organization." *Journal of Farm Economics* 41:747–59.

Falk, B. 1991. "Formally Testing the Present Value Model of Farmland Prices." *American Journal of Agricultural Economics* 73:1–10.

Hardie, I.W., and P.J. Parks. 1997. "Land Use with Heterogeneous Land Quality: An Application of Area Base Model." *American Journal of Agricultural Economics* 79:299–310.

Heimlich, Ralph E. 1989. *Productivity and Erodibility of U.S. Cropland.* Agricultural Economics Report Number 604. Washington D.C.: U.S. Department of Agriculture, Economic Research Service.

Hsu, Shih-Hsun, and Ching-Cheng Chang. 1990. "An Adjustment Cost Rationalization of Asset Fixity Theory." *American Journal of Agricultural Economics* 72:298–308.

Johnson, Glenn L., and Leroy Quance, eds. 1972. *The Overproduction Trap in U.S. Agriculture.* Baltimore: Johns Hopkins University Press.

Jones, John, and Roger W. Hexem. 1990. "Cash Rents for Farms, Cropland, and Pasture, 1960–89." Statistical Bulletin 813. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.

Judge, George G., R. Carter Hill, William E. Griffiths, Helmut Lutkepohl, and Tsoung-Chao Lee. 1988. *Introduction to the Theory and Practice of Econometrics,* 2nd. ed. New York: John Wiley & Sons.

Just, Richard E. and John A. Miranowski. 1993. "Understanding Farmland Price Changes." *American Journal of Agricultural Economics* 75:156–168.

Land Resource Regions and Major Land Resource Areas of the United States. 1981. USDA-SCS, Agriculture Handbook 296.

Lichtenberg, Erik. 1989. "Land Quality, Irrigation Development, and Cropping Patterns in the Northern High Plains." *American Journal of Agricultural Economics* 71:187–194.

Osborn, C. Tim, Felix Llacuna, and Michael Linsenbigler. 1989. "The Conservation Reserve Program: Enrollment Statistics for Signup Periods 1–7 and Fiscal Year 1987–88." Statistical Bulletin 785. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.

Palmquist, Raymond B. 1989. "Land As a Differentiated Factor of Production: A Hedonic Model and its Implications for Welfare Measurement." *Land Economics* 65:23–28.

SOILS-5 Data Base (SOILS-5). Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C.

Plantinga, A. 1996. "The Effects of Agricultural Policies on Land Use and Environmental Quality." *American Journal of Agricultural Economics* 78:1082–1091.

Stavins, Robert N., and Adam B. Jaffe. 1990. "Unintended Impacts of Public Investment on Private Decisions: The Depletion of Forested Wetlands." *The American Economic Review* 80:337–352.

Tegene, A., and Fred Kuchler. 1991. "A Description of Farmland Investor Expectations." *The Journal of Real Estate Finance and Economics* 4:283–296.

Vesterby, M., R. Shoemaker, R. Heimlich, and Margot Anderson. 1997. "Land and Soil Quality," in *Agricultural Resources and Environmental Indicators.* U.S. Department of Agricultural, Economic Research Service, Agricultural Handbook No. 712, 41–49.

Notes

1. A site is a field or area of uniform quality.
2. See Maddala P.23.
3. Note that the location subscript is suppressed as a change in land quality is due to a change in location.
4. This is true of the original CRP as formulated in 1986–87, but CRP rental rates are now limited on a soil-specific basis.
5. In a model of farmland prices, adaptive expectations performed better than rational expectations in Tegene and Kuchler (1991), naive expectations

gave the best fit in Just and Miranowski (1993) relative to adaptive and rational expectations. Falk (1991) also argued that myopic behavior consistent with naive expectations underlies his land price results. It should be noted that both naive and adaptive expectations express expected value as a function of past (and current) values, where the coefficients decline geometrically with the lag length in adaptive expectations. If the information set is limited to current and past values of the variable in question, rational expectations also result in a distributed lag structure.

6. Note that lag length did not affect specification with respect to land quality variables or vice-versa.

7. Estimated adjustment costs are average because they will vary from site to site. Site specific variation in adjustment costs and rigidities become part of the error term. Estimated adjustments costs are relative because parameters in the probit model can be estimated only up to a scale factor, $1/\sigma$, where σ is the standard deviation of $(1/\alpha)(u_{kit} - u_{kjt})$.

Also note that, in this context, adjustment costs are interpreted as all costs (and other sources of inertia) not explained by other independent variables. These may include economic costs which are not accounting costs, such as the utilization of management skills. For example, landowners in a predominantly grain-growing region may choose crop production, all other things being equal, because available farm management skills will tend to be skewed toward crop production.

8. The opportunity cost of all land uses other than cropland, pasture, or CRP is assumed to be zero. Although this is a rather restrictive assumption, it is reasonable for the farm states considered in this study.

9. The sample period is dictated by the availability of consistent data. The latest NRI data is 1992. However, the 1992 NRI does not contain cropping history except for cropland.

10. The gap in the time series exists because the NRI contains no data on land use for 1983.

11. Although prices vary significantly both spatially and over time, price ratios are quite constant. For example, the mean ratio of the season average soybean price to the season average corn price over all states and year 1975–92 is 2.55. The standard deviation of these ratios is 0.39.