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Acreage allocation in the presence of various commodity and conservation programs: The case of conservation reserve program and crop production in the Midwest

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ABSTRACT

A multinomial fractional logit model is developed in this article to examine the effects of various market variables, commodity and conservation program payments and county physical attributes on crop acreage allocation and CRP enrollment simultaneously in the Midwest region of the United States. Nine states and eleven years county level panel data are employed to estimate the acreage allocation among corn, soybeans, wheat, hay, and CRP participation simultaneously. The estimation results suggest that crop profits, CRP rental payment, and physical characteristics of cropland together determine the acreage allocation among alternative crops and CRP. Crop profits have significant, negative impacts on CRP enrollment, while current year CRP rental rate plays only a limited role. Total commodity program payment received in a county is positively related with program crop acreage and negatively related with non-program crop and CRP acreage. No statistical evidence is found that EQIP has an adverse impact on CRP participation.

CHAPTER 1. INTRODUCTION

How land owners' acreage allocation decision among various crops responds to commodity prices and government programs has long been a topic of interest in agricultural economics. Reliable estimates of crop acreage elasticities to prices and farm programs are of particular importance when predicting the impacts of changing conservation policies on the U.S. agricultural production. Although there are numerous works on acreage response to price, uncertainty, and government programs (e.g. Chavas and Holt, 1990; Wu and Brorsen, 1995; Guyomard, *et al.*, 1996; Adhikari, *et al.*, 2008), limited research has analyzed the crop mix variation and program (especially CRP) participation simultaneously. Since about ten percent of total cropland in the U.S. is currently enrolled in CRP,[1] omitting it from a cropland acreage allocation model may result in biased estimates. Hence, determining the response of crop mix and CRP enrollment to commodity prices and CRP payments is one of the primary objectives of this paper.

Although land retirement programs remain the largest conservation programs in the U.S., the funding allocated to working land conservation programs, such as Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP), have increased sharply since the 2002 farm bill.[2] As more and more emphases have been put on working land programs, their impacts on environment,

[1] The number is higher in some states.
[2] EQIP budget was scheduled to increase from $200 million in 2002 to $1.1 billion in year 2007 through 2011 in the 2002 farm bill. The 2008 farm bill further increased the funding from $1.2 billion in 2008 to $1.75 billion in 2012.

agricultural production, and land retirement program participation attract larger attention in agricultural policy analysis. Despite of the considerable amount of works discussing the environmental impacts of working land conservation programs, few have been done to address their effects on agricultural land allocation decision. Therefore, the other major objective of this paper is to examine how EQIP and various commodity programs affect land owners' acreage allocation and CRP participation decisions.

CHAPTER 2. REVIEW OF LITERATURE

2.1 Studies on Acreage Allocation and Government Programs

Substantial efforts have been devoted to the study of the influence of government policies on agricultural land use and acreage allocation in the past two decades, among which acreage model and share model were most widely used. Acreage models focus on the real planting acreage, and predict the acreage supply of one or multiple crops in the study area, given output/input prices, production risk and/or various farm programs. (eg. Chavas and Holt 1990; Chembezi and Womack 1992; Orazem and Miranowski 1994; Wu and Brorsen 1995; Krause *et al.* 1995; Wu *et al.* 1996; Goodwin *et al.* 2004). Share models focus on the crop mix variation, and explain the shares of cropland devoted to alternative crops by a set of economic and policy variables, and/or land characteristics. See, for example, Wu and Segerson (1995), Miller and Plantinga (1999), Tanaka and Wu (2004), and Wu *et al.* (2004). Simultaneous equation system, seeming unrelated regression (SUR), and logistic transformation are mostly used technique in the research of multiple-crop acreage response. Due to limited availability of micro data, the majority of literature employs aggregate data. For those studies based on micro-level decisions and farm/plot level data, NRI and various regional surveys are the major data sources, such as Tanaka and Wu (2004), and Wu *et al.* (2004).

2.1.1 Acreage Models

Chavas and Holt (1990) analyzed corn and soybeans acreage response to government price support program, corn diversion payment, yield uncertainty and wealth with nation level time-series data. They paid particular attention to the effect of wealth and the truncation effects of target price on the distribution of corn and soybeans prices. Both risk and wealth effects were important in the U.S. corn and soybeans acreage allocation decision according to their results.

Chembezi and Womack (1992) presented a two step approach to discuss the acreage responses for U.S. corn and wheat with multiple policy options. They first estimated a program participation function, then estimated separate response functions for program and non-program planted acres conditional on the program participation decision. They found higher expected market prices of corn and wheat discouraged acreage reduction program (ARP) [3] participation, while increased total planting acres of the two crops. The target price and diversion payment were positively related with ARP participation, and negatively related with total planting acres of corn in Cornbelt and Lake States, and wheat in Northern Plains.

Orazem and Miranowski (1994) estimated a dynamic acreage allocation model considering impacts of current crop production on future soil productivity. Using county level corn, soybeans, hay, and oats production data of Iowa from 1952 through 1991, they found price support policies removed incentives for farmers to take future soil

[3] Acreage Reduction Program (ARP) is an annual cropland retirement program for wheat, feed grains, cotton, or rice in which farmers participating in the commodity programs (in order to be eligible for nonrecourse loans and deficiency payments) were mandated to idle a crop-specific, nationally-set portion of their base acreage during years of surplus. The idled acreage (called the acreage conservation reserve) was devoted to a conserving use. The goal was to reduce supplies, thereby raising market prices. ARP was no longer authorized since the Federal Agriculture Improvement and Reform (FAIR) Act of 1996 since it was criticized for diminishing the U.S. competitive position in export markets. ARP differed from a set-aside program in that under a set-aside program reductions were based upon current year plantings, and did not require farmers to reduce their plantings of a specific crop.

productivity effects into account in making current cropping decisions. Given crop rotation effects, the future price of soybeans in the next year was found to be positively related with current year corn acreage.

2.1.2 Share Models

Wu and Brorsen (1995) and Wu and Segerson (1995) studied the impact of government programs and land characteristics on cropping patterns and groundwater pollution in Wisconsin by estimating a multi-crop acreage allocation model. They assumed logistic functional form and combined HEAR model[4] with SUR technique to correct for heteroscedasticity, auto-correlation and contemporaneous correlation existed in the model. County level crop acreage and site characteristics data and state level prices and policy instruments data between 1972 and 1990 were used. Target price for corn and ARP rates for corn, oats and wheat were found to have significant effect on the acreage allocation of nine major crops of Wisconsin.

Wu *et al.* (1996) examined the impact of government commodity programs, especially price supports and ARP, on nitrate water pollution through changes in crop mix for the High Plains. SUR-HEAR procedure and 1987 NRI data were used to estimate the acreage response equations for corn, sorghum, wheat and alfalfa. They found crop acreage was very inelastic with respect to (target) prices and was statistically significantly affected by the ARP rates, although the impact was small.

[4] The cross-sectionally heteroscedastic and time-wise autoregressive model (HEAR) was proposed by Kmenta (1986)

Wu *et al.* (2004) predicted the joint distribution of crop and tillage choice at more than 42,000 agricultural sites in the upper-Mississippi river basin under alternative conservation policies through a multinomial logit model. They found government green payments did affect farmers' cropping practice and the resulting levels of agricultural runoffs. However, the acreage response was inelastic and the green payments for corn-soybeans rotation and conservation tillage were not cost effective based on their results.

2.2 Studies on Acreage Allocation and CRP

Most of the literature mentioned above concentrated on commodity programs, such as price support, direct payment, set-aside, and ARP, limited research has been done to capture the effect of the Conservation Reserve Program (CRP) on land owners' land use and acreage allocation decisions. CRP was introduced in 1986, under the Conservation Title of the 1985 Food Security Act and re-authorized in subsequent Farm Bills. It is a farmland retirement program aimed to provide multiple environmental benefits and income support for its participants, and control supply of agriculture commodities. Under this voluntary program, USDA agrees to pay agricultural producers and land owners to retire highly erodible and environmentally sensitive cropland and pasture from production on a year-by-year basis for a period of 10-15 years with renewal option. The enrolled lands are required to be planted with grasses, trees, and other covers to reduce soil erosion, enhance water quality, sequester Carbon, expand and improve wildlife habitats. CRP retired approximately 35 million acres of cropland with an annual cost of over 1.76 billion, reduced about 615 million pounds of Nitrogen, 123 million pounds of

Phosphorus, 445 million tons of soil erosion from 1982 levels, and resulted in the equivalent of 56 million metric tons of Carbon Dioxide reduction in 2008.[5]

The current literature on the impact of CRP participation on crop acreage allocation basically falls into three categories. First is to consider CRP total outlays and/or total enrollment acres as explanatory variables in estimating acreage response equations. Then the elasticity of CRP on crop acreage can be calculated. For instance, Krause *et al.* (1995) evaluated and contrasted the responses of regional and national program and non-program wheat acreage to expected prices of wheat and competing crops, price risk, and farm programs. They found the expected wheat price had a strong negative effect on program-complying acreage and had a strong positive effect on non-program planted acreage, while the impacts of support price and price risk were reversed. And CRP acres had significant negative effect on non-program-planted wheat acres. Miller and Plantinga (1999) developed and estimated four unconditional and conditional (on land quality) land use share models using county level data of three Iowa counties over the sample period 1981-1994. The estimated elasticities of total CRP payment in the three counties range from -0.0087 to -0.412 for corn, and -0.0094 to -0.212 for soybeans. Those estimates may be biased given the fact that the single equation model omitted the interaction between CRP enrollment and crop acreage shift (among various crops) and treats total enrollment acres as exogenous.

Second is to construct CRP enrollment functions to quantify the effect of CRP on agricultural land use. Parks and Schorr (1997) established a dynamic optimization model

[5] Data Source: CRP Annual Summary, FY 2008 (http://www.fsa.usda.gov/Internet/FSA_File/annualsummary2008.pdf)

to analyze Northeastern land owners' decisions to continue agricultural use, participate in CRP, or sell land. The estimation results indicated significant differences in enrollment between metropolitan and nonmetropolitan counties in the region, and CRP was relatively unimportant to agricultural land owners in metropolitan counties. Claassen and Tegene (1999) employed a discrete choice model and sit-specific data to analyze agricultural land allocation among cropland, pasture and CRP in the Corn Belt between 1980 and 1987. Their results indicated that the conversion probabilities depend on returns from different uses, CRP rental rate, and land quality. They concluded that less Corn Belt land would have been retired from crop production without CRP. Although these studies estimated CRP participation equations to study the impact of CRP on agricultural land use, they did not analyze land owners' acreage allocation decision among alternative crops.

Due to the limitations of these two approaches, a third method which intends to correct the drawbacks of them is proposed. Tanaka and Wu (2004) estimated two logit models to evaluates quantitatively the effect of three policies (CRP, fertilizer use taxes and payments for crop rotations) on agricultural land use in the upper Mississippi River basin using data from the 1982, 1987, 1992 and 1997 NRI. They first used CRP participation model to predict which sites would be enrolled in CRP, then used the crop choice model to predict acreage allocation and crop rotation on sites that would not be enrolled in CRP. They found that CRP participation decisions were highly responsive to CRP rental rate, cropping history and wage rate. Goodwin *et al.* (2004) studied a multi-equation structural model of acreage response, insurance participation, CRP enrollment, and input usage for corn and soybeans production in the Corn Belt, and wheat and barley production in the Upper Great Plains. The model was estimated with GMM and made use of county level cross-sectional, time-series data from 1986 to 1993. They found increases in insurance participation leaded to increased crop acreage, and greater enrollment in CRP resulted in less acreage being devoted to crops, although these effects were very modest. However, they reported no evidence of shifting among the alternative crops with changes in CRP enrollment.

Since all these studies used aggregate or site-specific data before 1997, none of them have compared the influence of CRP with working land conservation programs, such as EQIP, in determining the agricultural land use and acreage allocation. EQIP was established under the Farm Bill in 1996 and it is the Nation’s primary agricultural conservation program for working farms and ranches. It provides financial and technical assistance to encourage adoption of farming systems that conserve resources and enhance environmental performance. Under EQIP, cost-share and incentive payments are available for eligible practices under short-term (1- to 10-year) contracts. Cost-share rates range from 50 to 75 percent of installation cost for structural and vegetative practices, with incentive payments for management practices (e.g. nutrient, pesticide, irrigation, and habitat management) established at the county level (Aillery, 2006). Although CRP remains the largest conservation programs in the U.S., the recent shift of budgets toward conservation programs on working lands, such as EQIP, indicates an emphasis on working land in the conservation policy design. Therefore, understanding the interactive effects of CRP and EQIP on farm land use and acreage allocation decision is important in the future policy design. The model developed in this article enhances the literature by incorporating alternative conservation and commodity programs into land owners’ acreage decision and program participation problem, estimating the impacts of alternative government conservation and commodity programs on crop mix and CRP enrollment, and examining to some extent the substitution effect of working land conservation programs on land retirement program participation.

In the rest of the article, we first develop a theoretical model to analyze land owners' optimal acreage decision rule and the impacts of government programs on the acreage allocation. Then two multinomial fractional logit models are estimated to quantify the effects of various market variables, government program variables and county physical attributes on crop acreage allocation and CRP enrollment decision. Finally, one of the estimated models is used to simulate the impacts of government program payments on agricultural land use.

CHAPTER 3. METHODOLOGY AND CONCEPTUAL FRAMEWORK

In this section, I develop a theoretical model to study how land owners allocate agricultural land with heterogeneous quality among a set of alternative crops, in the presence of commodity, land retirement, and working land conservation programs. Following Lichtenberg (1989), I extended the model by allowing more than two crops and government programs enrollment. Suppose a land owner owns A acres of heterogeneity land whose quality can be represented by a normalized scalar measure $q \in [0,1]$. Assuming $g(q)$ is a continuous function representing the distribution of the land according to the quality q, i.e. $\int_0^1 g(q)\,dq = 1$, then the acreage for land of quality q is $A(q) = g(q)A$. The objective of the land owner is to allocate the A acres of cropland across various crops, indexed as $j = 1, 2, \cdots J$, to maximize his profit. First assume a twice continuously differentiable per acre production function for crop j: $f^j(\tilde{x}_j, q)$, where $\tilde{x}_j = (x_1^j, x_2^j, \cdots, x_K^j)$ is a vector of K inputs used to produce crop j other than land, $j = 1, 2, \cdots J$. Further assume the standard assumptions of production function holds in this case, which means f^j is jointly strictly concave in both x_k^j and q, $k = 1, 2, \cdots K$. That is to say, $f_{x_k^j}^j > 0$, $f_q^j > 0$, $f_{x_k^j x_k^j}^j = \dfrac{\partial^2 f^j}{\partial x_k^{j2}} < 0$, $f_{qq}^j = \dfrac{\partial^2 f^j}{\partial q^2} < 0$, and $f_{x_k^j x_k^j}^j f_{qq}^j - \left(f_{x_k^j q}^j\right)^2 > 0$, where $f_{x_k^j q}^j = \dfrac{\partial^2 f^j}{\partial x_k^j \partial q}$. Then a restricted per acre profit function $\pi^j(p_j, \tilde{w}, q)$ for crop j grown on land with quality q can be derived by maximizing $p_j f^j\left(\tilde{x}_j, q\right) - \tilde{w}\tilde{x}_j{}'$ with respect to x_k^j, $k = 1, 2, \cdots K$, where p_j is the price of crop j and $\tilde{w} = \left(w_1, w_2, \cdots, w_K\right)$ is a vector of input prices. Here we assume all prices are exogenous.

The land owner's problem then becomes to:

$$\max_{\{a_j(q)\}}\left\{\pi = \int_0^1 \sum_{j=1}^{J} \pi^j\left(p_j, \tilde{w}, q\right) a_j(q)\, dq\right\}$$

$$\text{subject to } \sum_{j=1}^{J} a_j(q) = A(q)$$

where $a_j(q)$ is the acres of land for a given quality q, allocated to crop j. Since the objective function is linear in $a_j(q)$, the first order necessary conditions indicate the following corner solution for any given land:

$$a_j^*(q) = \begin{cases} \mathrm{c}_j^*(q) \in \left[0, A(q)\right] & \mathit{if} \quad \pi^j\left(p_j, \tilde{w}, q\right) = \max\left\{\pi^j\left(p_j, \tilde{w}, q\right) : j = 1, 2, \cdots J\right\} \\ 0 & \mathit{o.w.} \end{cases}$$

$$\sum_{j=1}^{J} a_j^*(q) = A(q) \qquad (*)$$

I.e. all land of the same quality should be allocated to the crops that give the highest per acre profit. Therefore, if all crops are profitable to be grown, each crop should be grown on land of a unique, compact range of qualities, given the assumption that the production functions are concave in land quality. Re-indexing the crops according to the quality of land that they are grown, the optimal share of cropland allocated to crop j can be expressed as:

$$s_j^* = \frac{\int_{q_{j-1}}^{q_j} a_j^*(q)\, dq}{A} = \frac{\int_{q_{j-1}}^{q_j} A(q)\, dq}{A} = \int_{q_{j-1}}^{q_j} g(q)\, dq$$

where q_j is defined as $\pi^j\left(p_j,\tilde{w},q_j\right)=\pi^{j+1}\left(p_{j+1},\tilde{w},q_j\right)$, $j=1,2,\cdots J-1$, $q_0=0$, and $q_J=1$. Hence, the share of a piece of heterogeneity land devoted to crop *j* depends on the prices of crop *j* and some alternative crops, input prices, and the distribution of land quality of the entire land. If more than one crop is planted on a piece of homogeneity land, then per acre profit of those crops must be the same.

Now consider the impact of government programs on acreage allocation under such a framework. The impact of a commodity program, especially a price support program, is similar to the impact of an increase in the price of the program crop. Consider a price support program affecting only crop j, by implicit function theorem, one can get

$$\begin{aligned}\frac{\partial s_j^*}{\partial p_j}&=g\left(q_j\right)\frac{\partial q_j}{\partial p_j}-g\left(q_{j-1}\right)\frac{\partial q_{j-1}}{\partial p_j}=-g\left(q_j\right)\frac{\partial\pi^j/\partial p_j}{D_j}-g\left(q_{j-1}\right)\frac{\partial\pi^j/\partial p_j}{D_{j-1}}\\&=-f^j\left(\tilde{x}_j^*,q_j\right)\left[\frac{g\left(q_j\right)}{D_j}+\frac{g\left(q_{j-1}\right)}{D_{j-1}}\right]>0\end{aligned}$$

where $D_j=\dfrac{\partial\pi^j}{\partial q}\left(q_j\right)-\dfrac{\partial\pi^{j+1}}{\partial q}\left(q_j\right)=p_j f_q^j\left(\tilde{x}_j^*,q_j\right)-p_{j+1}f_q^{j+1}\left(\tilde{x}_{j+1}^*,q_j\right)<0$, since

$\pi^j-\pi^{j+1}>0$ for $q<q_j$, and $\pi^j-\pi^{j+1}<0$ for $q>q_j$. Similarly, one can get

$$\frac{\partial s_{j+1}^*}{\partial p_j}=g\left(q_{j+1}\right)\frac{\partial q_{j+1}}{\partial p_j}-g\left(q_j\right)\frac{\partial q_j}{\partial p_j}=g\left(q_j\right)\frac{\partial\pi^j/\partial p_j}{D_j}=f^j\left(\tilde{x}_j^*,q_j\right)\frac{g\left(q_j\right)}{D_j}<0$$

$$\frac{\partial s_{j-1}^*}{\partial p_j}=g\left(q_{j-1}\right)\frac{\partial q_{j-1}}{\partial p_j}-g\left(q_{j-2}\right)\frac{\partial q_{j-2}}{\partial p_j}=-g\left(q_{j-1}\right)\frac{-\partial\pi^j/\partial p_j}{D_{j-1}}=f^j\left(\tilde{x}_j^*,q_j\right)\frac{g\left(q_{j-1}\right)}{D_{j-1}}<0$$

The above three inequalities together with $\dfrac{\partial s_{j-1}^*}{\partial p_j}+\dfrac{\partial s_j^*}{\partial p_j}+\dfrac{\partial s_{j+1}^*}{\partial p_j}=0$ indicates that a price change of the *j* th crop only affect the planting acreage of that crop and crops cultivated on land of adjacent quality. An increase of the price of crop j increases the share of cropland allocated to crop j , decreases the shares of cropland allocated to crop $j-1$ and $j+1$, and has no effect on the cultivating acreage of all the other crops given crop $j-1$ and $j+1$ are still produced.[6] Therefore, the impact of a price support program targeting on one or several crops is to change the optimal shares of the program crops and crops competing with the program crops on land of similar quality.

The introduction of a land retirement program such as CRP is equivalent to the introduction of a crop that gives fixed per acre profit $\pi_{CRP}(q) = B(q) - C(q)$ for a given land quality q , where $B(q)$ and $C(q)$ are the annual discounted per acre rental payment and maintenance cost for land with quality q enrolling in CRP, respectively. According to the decision rule represented by (*), we can get the optimal level of CRP enrollment:

$$a_{CRP}^{*}(q) = \begin{cases} A(q) & if \quad \pi_{CRP}(q) > \max\left\{\pi^{j}\left(p_j, \tilde{w}, q\right) : j = 1, 2, \cdots J\right\} \\ 0 & o.w. \end{cases}.$$

That is to say, all land of quality q should enroll in CRP if the per acre discounted return of the program is greater than that from growing the most profitable crop on that land; otherwise, no land of quality q will enroll. Given the assumption that the representative land owner is a price taker (i.e. his land allocation decision can not affect crop supplies), CRP does not affect the profitability of alternative crops. The share of cropland allocated to crop j decreases if part of the land planted to that crop enrolls in

[6] In case the crop $j-1$ or $j+1$ is not profitable to be produced after the price support program of crop j , the cultivating acreage of crop $j-2$ or $j+2$ may also decrease and so on.

CRP; otherwise, the share remains the same. Hence, the new share of cropland allocated to crop *j* with the presence of CRP can be expressed as:

$$s_j^* = \begin{cases} \int_{q_{j-1}}^{q_j} g(q)\,dq & if \quad \pi_{CRP}(q) < \pi^j(p_j, \tilde{w}, q) \\ \int_{q_{j-1}}^{q_j} g(q)\,dq - \sum_{i=1}^{n} \int_{q_{j-1}(i)}^{q_{j(i)}} g(q)\,dq & if \quad \begin{cases} \pi_{CRP}(q) > \pi^j(p_j, \tilde{w}, q),\, q \in \left[q_{j-1(i)}, q_{j(i)}\right],\, i = 1,\cdots,n \\ \pi_{CRP}(q) < \pi^j(p_j, \tilde{w}, q),\, o.w. \end{cases} \end{cases}$$

where q_j s take the same value as before without CRP; $\left[q_{j-1(i)}, q_{j(i)}\right]$, $i = 1,\cdots,n$, are n intervals of land quality on which the per acre discounted return of CRP is greater than that from growing crop j, and $q_{j-1} \le q_{j-1(1)} < q_{j(1)} < q_{j-1(2)} < q_{j(2)} < \cdots < q_{j-1(n)} < q_{j(n)} \le q_j$.

However, the supply of crop *j* decreases substantially if all land owners take the same action: enrolling part of the land previously allocated to crop *j* in CRP. The decrease in supply then leads to a rise in the price of crop j, making it more profitable to be grown. Therefore, the values of q_j s do change if the introduction of CRP results in un-neglected decrease in supplies of some crops.[7] In summary, by taking previously active land out of production, CRP reduces acreage allocated to all crops whose returns are less than the fixed CRP rental payment as well as alters the relative profitability of multiple crops, thus leads to reallocation of the whole landscape.

The introduction of a working land conservation program such as EQIP has a much different impact on the optimal land allocation. EQIP payment provides land owners incentives and cost share to install conservation practices and use more environmental friendly tillage method, which in turn result in changes of both production and profit

[7] One of the purposes of CRP when it was first introduced in 1985 was supply control.

functions. There are many practices that are eligible to be funded by EQIP, among which funding is allocated according to the environmental benefit of each practice. Since various practices target on land with different quality and affect profits of crop production through different ways, it is impossible to analyze the impact of EQIP as a whole. In the following analysis, conservation tillage is used to represent EQIP eligible practice.[8] Similar analysis can be done to other practices.

Assume only conventional tillage is used before EQIP was introduced. Now with EQIP, land owners can receive an incentive payment or cost share E if they enroll in EQIP and switches to conservation tillage. Then land of quality q currently planting to crop j will be enrolled in the program if and only if $\pi_E^j\left(p_j,\tilde{w},q,E\right)>\pi_C^j\left(p_j,\tilde{w},q\right)$, $q\in\left[q_{j-1},q_j\right]$, where $\pi_E^j\left(p_j,\tilde{w},q,E\right)$ and $\pi_C^j\left(p_j,\tilde{w},q\right)$ are profit functions of crop j with conservation and conventional tillage respectively, $\dfrac{\partial\pi_E^j\left(p_j,\tilde{w},q,E\right)}{\partial E}>0$. In such case, q_j is defined as

$$\pi^j\left(p_j,\tilde{w},q_j,E\right)=\pi^{j+1}\left(p_{j+1},\tilde{w},q_j,E\right)$$

where $\pi^j\left(p_j,\tilde{w},q_j,E\right)=\max\left\{\pi_E^j\left(p_j,\tilde{w},q_j,E\right),\pi_C^j\left(p_j,\tilde{w},q_j\right)\right\}$.

[8] Conservation tillage (CT) is one of the most common funded EQIP practices. CT is defined as a farming process that leaves more than 30 percent of the soil surface covered with crop residue. CT systems reduce soil compaction, conserve moisture, and increase organic matter and water penetration, so that improve soil productivity by incorporating most crop residue into the soil. Crop residues also reduce wind erosion and less tillage trips result in less dust, so that less air pollution. CT affects the crop production by reducing the demand for labor/time, fuel, while increasing the demand for chemical and capital investment on specialized seeding equipment, so that the form of profit function.

By changing the relative profitability of alternative crops, EQIP affect the allocation of land among various crops. These effects are summarized as follows.

The share of crop 1 increases, if crop 1 enrolls in the program while crop 2 does not; the share of crop 1 decreases, if crop 2 enrolls in the program while crop 1 does not; the share of crop 1 remains the same, if neither crop enrolls in the program. The change of s_1^* is ambiguous if both crops enroll in the program, and it depends on the relative magnitudes of the marginal effect of subsidy on the profits of both crops. In summary, the share of crop 1 will increase if conservation tillage has a greater marginal effect on its profit than that on the profit of crop 2.

$$\frac{\partial s_1^*}{\partial E} = g(q_1)\frac{\partial q_1}{\partial E} = g(q_1)\frac{\frac{\partial \pi^2}{\partial E} - \frac{\partial \pi^1}{\partial E}}{\frac{\partial \pi^1}{\partial q}(q_1) - \frac{\partial \pi^2}{\partial q}(q_1)}\begin{cases} = 0 & \text{if } \pi^1 = \pi_C^1, \pi^2 = \pi_C^2 \\ < 0 & \text{if } \pi^1 = \pi_C^1, \pi^2 = \pi_E^2 \\ > 0 & \text{if } \pi^1 = \pi_E^1, \pi^2 = \pi_C^2 \\ \gtrless 0 & \text{if } \pi^1 = \pi_E^1, \pi^2 = \pi_E^2 \end{cases}$$

Similar relationship exists for crop J :

$$\frac{\partial s_J^*}{\partial E} = -g(q_{J-1})\frac{\partial q_{J-1}}{\partial E} = -g(q_1)\frac{\frac{\partial \pi^J}{\partial E} - \frac{\partial \pi^{J-1}}{\partial E}}{\frac{\partial \pi^{J-1}}{\partial q}(q_{J-1}) - \frac{\partial \pi^J}{\partial q}(q_{J-1})}$$

$$\begin{cases} = 0 & \text{if } \pi^J = \pi_C^J, \pi^{J-1} = \pi_C^{J-1} \\ < 0 & \text{if } \pi^J = \pi_C^J, \pi^{J-1} = \pi_E^{J-1} \\ > 0 & \text{if } \pi^J = \pi_E^J, \pi^{J-1} = \pi_C^{J-1} \\ \gtrless 0 & \text{if } \pi^J = \pi_E^J, \pi^{J-1} = \pi_E^{J-1} \end{cases}$$

The share of crop *j* decreases in case it does not enroll in the program and the total share of the first $(j-1)^{\text{th}}$ crops increases; the share of crop *j* increases in case it enrolls in the program and the total share of the first $(j-1)^{\text{th}}$ crops decreases. The change of s_j^* is undetermined for all the other cases.

$$\frac{\partial s_j^*}{\partial E} = g\left(q_j\right)\frac{\partial q_j}{\partial E} - g\left(q_{j-1}\right)\frac{\partial q_{j-1}}{\partial E} = g\left(q_j\right)\frac{\dfrac{\partial \pi^{j+1}}{\partial E}-\dfrac{\partial \pi^{j}}{\partial E}}{\dfrac{\partial \pi^{j}}{\partial q}\left(q_j\right)-\dfrac{\partial \pi^{j+1}}{\partial q}\left(q_j\right)}$$

$$-g\left(q_{j-1}\right)\frac{\dfrac{\partial \pi^{j}}{\partial E}-\dfrac{\partial \pi^{j-1}}{\partial E}}{\dfrac{\partial \pi^{j-1}}{\partial q}\left(q_{j-1}\right)-\dfrac{\partial \pi^{j}}{\partial q}\left(q_{j-1}\right)} = g\left(q_j\right)\frac{\dfrac{\partial \pi^{j+1}}{\partial E}-\dfrac{\partial \pi^{j}}{\partial E}}{\dfrac{\partial \pi^{j}}{\partial q}\left(q_j\right)-\dfrac{\partial \pi^{j+1}}{\partial q}\left(q_j\right)} - \sum_{l=1}^{j-1}\frac{\partial s_l^*}{\partial E}$$

$$\begin{cases} \left\langle \begin{array}{ll} <0 & if\ \pi^j = \pi_C^j \\ \gtrless 0 & o.w. \end{array} \right. , \quad given \displaystyle\sum_{l=1}^{j-1}\frac{\partial s_l^*}{\partial E} > 0 \\ \left\langle \begin{array}{ll} >0 & if\ \pi^j = \pi_E^j \\ \gtrless 0 & o.w. \end{array} \right. , \quad given \displaystyle\sum_{l=1}^{j-1}\frac{\partial s_l^*}{\partial E} < 0 \end{cases} , \quad j = 2,\cdots,J-1$$

Overall, the introduction of a working land conservation program affects the acreage allocation of all crops. A subsidy on conservation tillage gives land owners an incentive to expand the cultivating acreage of crops whose profits increase most with new tillage method and government payment. When both CRP and EQIP are introduced, there is potential substitution effect between the two programs given the assumption that EQIP improves the return of crop j on given land quality q, where $\pi_{CRP}\left(q\right) > \pi^j\left(p_j, \tilde{w}, q\right)$, i.e., $\pi^j\left(p_j, \tilde{w}, q, E\right) > \pi_{CRP}\left(q\right) > \pi^j\left(p_j, \tilde{w}, q\right)$.

Finally, consider the impact of an increase in the price of input k (w_k). Assuming production on poor land needs to use input k more intensively for the same crop $\frac{\partial x_k^j\left(q\right)}{\partial q} < 0$ and crops planting on lower quality land use that input more intensively than crops planting on higher quality land $x_k^1(q) > x_k^2(q) > \cdots > x_k^J(q)$. Then we have $x_k^{j-1}(q_{j-1}) > x_k^j(q_{j-1}) > x_k^j(q_j) > x_k^{j+1}(q_j)$ and the effect of an increase in w_k on the optimal share of crop *j* can be summarized as follows:

(1) $\frac{\partial s_1^*}{\partial w_k} = g(q_1)\frac{\partial q_1}{\partial w_k} = g(q_1)\frac{x_k^1(q_1) - x_k^2(q_1)}{D_1} < 0$, the share of crop 1 decreases, since it is the crop using the input most intensively.

(2) $\frac{\partial s_j^*}{\partial w_k} = g(q_j)\frac{x_k^j(q_j) - x_k^{j+1}(q_j)}{D_j} - \sum_{l=1}^{j-1}\frac{\partial s_l^*}{\partial w_k} < 0$, $j = 2, 3, \cdots J-1$, if $\sum_{l=1}^{j-1}\frac{\partial s_l^*}{\partial w_k} \geq 0$.

That is, the share of crop *j* decreases in case the total share of the first $(j-1)^{\text{th}}$ crops increases or remains unchanged. If the total share of the first $(j-1)^{\text{th}}$ crops decreases, s_j^* may increase or decrease depending on the relative magnitudes of $\frac{\partial s_j^*}{\partial w_k}$ and $g(q_j)\frac{x_k^j(q_j) - x_k^{j+1}(q_j)}{D_j}$.

(3) $\frac{\partial s_J^*}{\partial w_k} = -g(q_{J-1})\frac{x_k^{J-1}(q_{J-1}) - x_k^J(q_{J-1})}{D_{J-1}} > 0$, the share of crop *J* increases, since it is the crop using the that input the least intensively.

The above framework suggests that input and output prices, distribution of land characteristics, and government commodity and conservation programs together determine the cropping patterns of multiple crops. In the next section, this framework is applied to develop an empirical model analyzing the impacts of government programs on the cropping patterns in the Midwest. The empirical analysis consists of two steps. First, acreage response/share equations for major crops in the Midwest are estimated. Then the estimated equations are used to evaluate impacts of policy changes.

CHAPTER 4. EMPIRICAL MODEL AND DATA

Multinomial logit model (MLM) and its variant, such as nested multinomial logit model, are widely used in empirical research to model individual's choices among a set of discrete alternatives, such as crop choice and land allocation decisions, choice of technologies and tillage practices, transportation modes selection, recreation demand decision, and choice of occupations (e.g., Claassen and Tegene, 1999; Herriges and Kling, 1999; Herriges and Phaneuf, 2002; Wu and Adams, 2002; Wu *et al.* 2004). Due to the underlying random utility assumption, the use of MLM always require "micro" data on individual behavior, such as site-specific observations of land use choice and physical attributes of soil, trip data to one or several recreation sites for each survey subject, and individual observations of travel method.

Although field-level data seem more suitable to the nature of this study, as suggested in Wu and Adams (2002), aggregate models were not necessarily inferior to the micro model in predicting acreage response, even though the micro models contained substantially more information on site-specific characteristics. In Wu and Adams (2002), they first estimated eight sets of crop choice/acreage response models for the Corn Belt at field, county, state, and region level, using both NRI and NASS data; then compared their goodness-of-fit measures. Based on their results, micro model was inferior to the region model in predicting aggregate crop acreage, while performed better than the region model when estimating the elasticity for a particular variable. Another reason prevent us from using field-level data is the limited availability of such data. Most of the previous studies using site-specific data utilize the NRI data, such as Wu and Segerson (1995), Wu *et al.*

(1996), Claassen and Tegene (1999), and Tanaka and Wu (2004). However, the newest statistical reliable NRI data is for the year 1997, when working land conservation programs were put into practice for only one year.

Therefore, county level data on expected economic returns from the production of alternative crops or program participation, conservation policy variables and various land characteristics will be used in this study to estimate the shares of cropland devoted to various crops and land retirement program in the Midwest, in a fractional logit model, which was first proposed by Papke and Wooldridge (1996). The model developed in this section extends the original binary fractional logit modeling approach to accommodate multiple fractions as dependent variables, so called multinomial fractional logit (MFL) model. Quasi-maximum likelihood method is used to get more efficient estimates.[9]

4.1 Multinomial Fractional Logit Model with Aggregate Land Use Data

As summarized in Wu and Segerson (1995), there are basically two methods to estimate the share equations for acreage allocation among alternative crops. One starts from the restricted profit function. First assume a specific functional form for the cost or restricted profit function, usually translog or normalized quadratic, and then a closed-form solution to the acreage allocation problem can be derived, so do the share equations (e.g., Weaver 1983; Guyomard, *et al.* 1996; Lansink 1999; Arnade and Kelch 2007). The other assumes specific functional forms, usually logistic, for the share equations directly. See, for example, Tyrrell and Mount (1982), Wu and Segerson (1995), Miller and

[9] Papke and Wooldridge (1996) compared the QML and GLM approaches, and suggested the QML approach required fewer assumptions on the conditional variances of dependent variables.

Plantinga (1999), and Tanaka and Wu (2004). Although this method can not provide implications to the underlying profit function as the first method does, it ensures that the predicted shares are always between zero and one and sum to one. “Although critics argue that the logistic transformation is ad hoc, the practical advantages seem to outweigh the conceptual shortcomings.”[10] Because this study concentrates on the share change under various policies, we use the second approach to formulate the MFL model.

Fractional logit model and quasi-maximum likelihood method were first proposed by Papke and Wooldridge (1996) to analyze the participation rate for 401(K) plans, and then employed in the travel behavior research, such as Sivakumar and Bhat (2002). The convenient modeling methodology and estimation method are particular designed to analyze fractional dependent variables, such as shares. There are several desirable properties of this model to other commonly used models in the literature such as simultaneous equation system or logistic transformation. First, it assumes no particular conditional distribution of the dependent variable, so that avoid possible distributional failure or functional form misspecifications. Second, it ensures the estimated shares are between zero and one. Third, it needs no special treatment of zeros in the dependent variable. That is particular useful in this study where about 5 percent of the dependent variable is zero. [11] In addition, the quasi-maximum likelihood estimator (QMLE) is relatively easy to compute, and it is consistent and efficient no matter the characteristics (continuous or discrete) and distribution of the dependent variable, as long as the

[10] Miller and Plantinga (1999)

[11] Because the logarithm of zero is undefined, zeros in the value of dependent variable must be treated in a logistic specification. One may drop the zero values, assign an arbitrarily small value to the zeros, or use a limited dependent variable estimator such as the Tobit model, depending on the amount of zeros in the dependent variable.

transformation of likelihood function is in the linear exponential family (LEF). The multinomial log-likelihood function, which is a member of the LEF, guarantees the consistency and efficiency of the QMLE in this study. There are also limitations of the model, such as over-dispersion in the variance of the estimators, which will be addressed later.

Following Papke and Wooldridge (1996), suppose land owners in county $i\left(i=1,2,\ldots I\right)$ at year t need to allocate their land to J crops or enroll in CRP according to the rules developed by the analytical model in the previous section. Let s_{ijt} ($j=1,\cdots,J+1$) denote the observed shares of agricultural land allocated to crop j ($j=2,\cdots,J$), enrolled in CRP ($j=J+1$), or planted to all the other crops/fallows ($j=1$) in county i at year t, then $0\le s_{ijt}\le 1$, and $\sum_{j=1}^{J+1} s_{ijt}=1$. Now assume $E\left(s_{ijt}\left|X_{it}\right.\right)=G\left(\beta,X_{it}\right)$, where X_{it} is a vector of explanatory variables, $\beta=\left(\beta_j\left|_{j=1,\cdots J,CRP}\right.\right)$ is a matrix of parameters to be estimated, and $G\left(\cdot\right)$ is a known function satisfying $0<G\left(z\right)<1$ for all $z\in R$ to ensure the predicted value of $s_{ijt}\in\left[0,1\right]$. Usually, multinomial logit function is selected to form $G\left(\cdot\right)$ in the literature. Hence, we have:

$$E\left(s_{ijt}\left|X_{it}\right.\right)=G\left(\beta,X_{it}\right)=\frac{\exp\left(\beta_j' X_{it}\right)}{\sum_{j=1}^{J+1}\exp\left(\beta_j' X_{it}\right)} \qquad (*)$$

Then a quasi-likelihood method is applied to estimate β, where the multinomial log-likelihood function is given by:

$$L(\beta) \equiv \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} s_{ijt} \log\left(\frac{\exp\left(\beta_j' X_{it}\right)}{\sum_{j=1}^{J+1}\exp\left(\beta_j' X_{it}\right)}\right) \qquad (**)$$

(**) is easy to maximize because of the multinomial logit specification and it is a member of the linear exponential family (LEF), so that the QMLE is statistically consistent and asymptotically normally distributed, provided (*) holds, regardless of the distribution of s_{ijt} conditional on X_{it}. However, over-dispersion in the variance of the estimators may arise if the assumption of the variance structure of the multinomial logit QMLE fails, especially where unobserved group effects exist, which is common is panel data.[12] To correct for the possible heteroscedasticity, robust standard errors is employed. A valid estimate of the asymptotic variance of a QMLE can be expressed as $A^{-1}\hat{B}A^{-1}$, and the robust standard errors then are obtained as the square roots of the diagonal elements of it, where A^{-1} is the negative inverse of the estimated Hessian matrix and $\hat{B}$ is the outer product of the estimated first derivative of the log-likelihood function (Papke and Wooldridge, 1996).

By assuming multinomial logit function, the estimated acreage elasticities with respect to the explanatory variables have nice forms: $\hat{\varepsilon}_{ijk} = \frac{\partial \hat{s}_{ij}}{\partial x_{ik}} \frac{x_{ik}}{\hat{s}_{ij}} = x_{ik}\left(\hat{\beta}_{kj} - \sum_{j=2}^{J+1}\hat{s}_{ij}\hat{\beta}_{kj}\right)$, $j = 2, \cdots, J+1$, where $\hat{\varepsilon}_{ijk}$ is the estimated acreage elasticity of crop *j* for county i with

[12] The multinomial logit QMLE assumes $Var\left(s_{ijt} \mid X_{it}\right) = \sigma^2 G\left(\beta, X_{it}\right)\left[1 - G\left(\beta, X_{it}\right)\right]$ for some $\sigma^2 > 0$. See a detailed discussion of this problem in Papke and Wooldridge (1996).

respect to independent variable x_k; $\hat{s}_{ij}$ is the estimated share of land allocated to crop *j* in county i; $\hat{\beta}_{kj}$ is the estimated coefficient for variable x_k.

4.2 Study Region and Data Description

The study region consists of nine Midwest states: Illinois, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin.[13] The Midwest is the major agricultural production region in the U.S. According to the 2008 data, it produced 75 percent of corn, 67 percent of soybeans, and 47 percent of wheat of the whole nation. About half of the commodity and conservation payments in the U.S. were received by the Midwest. Corn, soybeans, wheat and hay occupied more than 90 percent of harvested acres in six of the nine states, except Kansas, North Dakota and Wisconsin in 2008.[14] The percentage of cropland enrolled in CRP varied from four percent in Illinois to eleven percent in North Dakota as of 2008.

Given these facts, we divide the cropland use into six categories: corn, soybeans, wheat, hay, CRP, and "other crops". The "other crops" category is used as the baseline category in the estimation and it includes all cropland not used in the other five

[13] The Midwest usually refers to 12 states: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Ohio, Nebraska, North Dakota, South Dakota and Wisconsin. Indiana, Michigan and Ohio are excluded from this study because CRP enrollment only accounts for a small portion of the agricultural land use in these states --- the total enrollment acres are less than 0.3 million and four percent of total cropland for each state. In the rest of the article, the term "Midwest" refers to only the nine states.

[14] The other major crop in Kansas is Sorghum, and the five crops together occupied more than 98 percent of total harvested acres in Kansas as of 2008. The crops growing in North Dakota are much more diversified than those in the other eight states. The four major crops account for about 76 percent of harvested cropland as of 2008. The other major crops in North Dakota are barley, canola, and sunflower seeds, total of which account for about 15 percent of harvested acres in 2008. In Wisconsin, the four major crops occupied about 85 percent of all harvested acreage, and the other 11 percent were used for silage corn in 2008.

categories.[15] The time span of this study is 11 years from 1996 to 2006. There are 791 counties and one independent city in the study area, seven of which are excluded from the study because agricultural activities account for only a neglected part of the county economy.[16] Thus the number of dependent variable used in the study is 51,810.

The shares of cropland devoted to the first five categories in the 785 Midwest counties are calculated as the ratio of the harvested acreage of the four crops and acreage enrolled in CRP to total cropland in each county/year. The residual is the share of "other crops". Total cropland data are taken from Census of Agriculture. Since Census of Agriculture is conducted every five years, 1992, 1997, 2002 and 2007 Census data are used in the study. The total cropland acreage in any given year is defined as the maximum value of cropland acreage reported in the adjacent two censuses.[17] County level annual harvested acreage for the four crops is taken from USDA's National Agricultural Statistics Service (NASS), and the cumulative CRP enrollment data are obtained from FSA.

The independent variables consist of three types: revenue and policy variables, social characteristics of counties, and dummy variables representing physical

[15] Oats used to be a major crop in the Midwest before 1990. However, the cropping acreage for oats keeps decreasing in the recent years. In 2008, oats only accounted for less than one percent of harvested cropland in Midwest states except for Wisconsin, where 2.4 percent of harvested cropland was devoted to oats. Hence, oats acreage is included in the "other crops" category.

[16] The six counties excluded from the study are Cook, Lake, Ramsey, and St. Louis in Minnesota, Grant in Nebraska and Menominee in Wisconsin; the independent city excluded from the study is St. Louise City. Most of Cook County and Menominee County are Indian Reservation. Less than one percent of land is used for agricultural purpose in Lake and St. Louis Counties. More than 90 percent of Grant County is permanent pasture and rangeland. Ramsey County and St. Louise City are most metropolitan area.

[17] For instance, cropland acreage in 1996 is the maximum value of cropland acreage reported in 1992 and 1997 census. This method may overestimate the share of "other crops" though.

characteristics of soil. The descriptive statistics of dependent and independent variables are listed in Table 4.1. The rest of this section describes how these data are collected and transformed to be used in the estimation process.

4.2.1 Revenue and Policy Data

The expected revenue of crop j in county i at year t can be expressed as $E\left(R_{ijt}\right)=E\left(p_{ijt}\right)E\left(y_{ijt}\right)$, where $E\left(p_{ijt}\right)$ and $E\left(y_{ijt}\right)$ are expected price and yield respectively. Here the correlation between price and yield is omitted for computation ease[18]. Previous research has found that farmers combined information on previous prices, futures prices, government target price or loan rate to form price expectation. Because this study focuses on the impact of government programs on crop acreage allocation, we use a relatively simple method to formulate the expected price. The expected prices are calculated as the weighted average of the higher of the market prices and loan rates in the past three years based on the assumption of adaptive expectations.[19][20] The weights used are 0.5, 0.33 and 0.17 for the three years respectively, following Chavas and Holt (1990). Five-year Olympic average is employed to calculate expected yield.[21]

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[18] The correlations between expected price and expected yield are -0.18 for corn, 0.01 for soybeans, -0.5 for wheat, and 0.36 for hay based on the sample data.

[19] Because hay is not a program crop, there is no loan rate for hay. So weighted average of the market prices are used for all years.

[20] Many studies before 2000s used lagged market prices to form expected crop prices given adaptive expectations, for instance, Chavas et al. (1983), Chavas and Holt (1990), Wu and Segerson (1995). Nowadays, rational expectations are more widely used, such as Orazem and Miranowski (1994), Goodwin et al. (2004), Tanaka and Wu (2004). Because historical futures prices are not available for the purpose of this study, I used adaptive expectations instead. As pointed out in Chavas et al. (1983), futures prices and lagged market prices are highly correlated and reflect similar market information, so use either one of them makes little empirical difference.

[21] Five-year Olympic average is an average during the previous 5-year period, dropping the highest and lowest values. This method can reduce the impact of unusual yields in some years (for example, very low yield due to severe weather) on the expected yield, thus results in more smooth yield expectation than simple or weighted average. I also tried to estimate expected yield by a trend model, as used in Chavas and Holt (1990). However, since the data is relatively short in time, the estimation result is significantly inferior to the current method.

Table 4.1 Descriptive Statistics of Dependent and Independent Variables

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
	Dependent Variables				
CORN	Share of Total Cropland Planting to Corn (percentage)	0.2398	0.1817	0	0.8169
SOYBEANS	Share of Total Cropland Planting to Soybeans (percentage)	0.2214	0.167	0	0.6305
WHEAT	Share of Total Cropland Planting to Wheat (percentage)	0.0951	0.1345	0	0.8547
HAY	Share of Total Cropland Planting to Hay (percentage)	0.1511	0.1427	0	0.9403
OTHER	Share of Total Cropland Planting to Other Crops (percentage)	0.2256	0.1786	0	0.88
CRP	Share of Total Cropland Enrolled in CRP (percentage)	0.067	0.0668	0	0.3415
	Independent Variables				
Price and Policy Variables					
RCORN	Expected Revenue for Corn ($/acre)	253.2145	73.1846	45.5911	614.792
RSOY	Expected Revenue for Soybeans ($/acre)	206.4915	53.8611	45.4682	359.1317
RWHEAT	Expected Revenue for Wheat ($/acre)	127.1344	27.0827	54.7239	222.242
WAGE	Annual Average Weekly Wage Rate ($/week)	404.9956	90.636	126	970
FERTILIZER	Price Paid by Farmers for Fertilizer, index number (1990-92=100)	127.9091	22.0733	105	176
PCOMMO	Total Commodity Payment Received by Farmers ($1,000,000)	7.3499	9.582	0	235
RCRP	Average CRP Rental Rate for Newly Signed Contracts ($/acre)	62.3536	37.3614	0	187.717
LAGCRP	Average CRP Rental Rate for All Active Contracts ($/acre)	59.4123	29.2492	0	163.377
EQIP	Total EQIP Payments ($1,000)	45.3209	81.6612	-7.9048	1304.1
RRSOY	Expected Relative Revenue for Soybeans to Corn (RSOY/RCORN)	0.8302	0.1281	0.2815	1.7146

Table 4.1 (continued)

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
RRWHEAT	Expected Relative Revenue for Wheat to Corn (RWHEAT/RCORN)	0.5305	0.1466	0.1928	1.9454
RRCRP	Expected Relative Revenue for New CRP Contracts to Corn (RCRP/RCORN)	0.253	0.1291	0	0.6484
RRLAGCRP	Expected Relative Revenue for All Active CRP Contracts to Corn (RLAGCRP /RCORN)	0.2351	0.0961	0	0.6151
<u>County and Soil Characteristics Variables</u>					
RUCC03	2003 Rural-urban Continuum Code	6.1745	2.5633	1	9
MLRA1	A Dummy Variable for Major Land Resource Area (MLRA) 102a	0.028	0.1651	0	1
MLRA2	A Dummy Variable for MLRA 102c	0.0293	0.1687	0	1
MLRA3	A Dummy Variable for MLRA 103	0.0611	0.2396	0	1
MLRA4	A Dummy Variable for MLRA 104	0.0255	0.1576	0	1
MLRA5	A Dummy Variable for MLRA 105	0.0357	0.1855	0	1
MLRA6	A Dummy Variable for MLRA 106	0.0268	0.1614	0	1
MLRA7	A Dummy Variable for MLRA 107a	0.0076	0.0871	0	1
MLRA8	A Dummy Variable for MLRA 107b	0.0318	0.1756	0	1
MLRA9	A Dummy Variable for MLRA 108a	0.0191	0.1369	0	1
MLRA10	A Dummy Variable for MLRA 108b	0.0153	0.1227	0	1
MLRA11	A Dummy Variable for MLRA 108c	0.0178	0.1324	0	1
MLRA12	A Dummy Variable for MLRA 108d	0.0127	0.1122	0	1
MLRA13	A Dummy Variable for MLRA 109	0.0408	0.1978	0	1
MLRA14	A Dummy Variable for MLRA 110	0.0166	0.1276	0	1
MLRA15	A Dummy Variable for MLRA 112	0.0318	0.1756	0	1

Table 4.1 (continued)

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
MLRA16	A Dummy Variable for MLRA 113	0.0357	0.1855	0	1
MLRA17	A Dummy Variable for MLRA 114b	0.0115	0.1065	0	1
MLRA18	A Dummy Variable for MLRA 115b	0.0153	0.1227	0	1
MLRA19	A Dummy Variable for MLRA 115c	0.0344	0.1823	0	1
MLRA20	A Dummy Variable for MLRA 116a	0.051	0.2199	0	1
MLRA21	A Dummy Variable for MLRA 116b	0.0089	0.094	0	1
MLRA22	A Dummy Variable for MLRA 120a	0.0076	0.0871	0	1
MLRA23	A Dummy Variable for MLRA 131a	0.0089	0.094	0	1
MLRA24	A Dummy Variable for MLRA 53b	0.0217	0.1456	0	1
MLRA25	A Dummy Variable for MLRA 53c	0.0076	0.0871	0	1
MLRA26	A Dummy Variable for MLRA 54	0.0242	0.1537	0	1
MLRA27	A Dummy Variable for MLRA 55a	0.0102	0.1004	0	1
MLRA28	A Dummy Variable for MLRA 55b	0.0191	0.1369	0	1
MLRA29	A Dummy Variable for MLRA 55c	0.0191	0.1369	0	1
MLRA30	A Dummy Variable for MLRA 56	0.0204	0.1413	0	1
MLRA31	A Dummy Variable for MLRA 57	0.0166	0.1276	0	1
MLRA32	A Dummy Variable for MLRA 63a	0.0115	0.1065	0	1
MLRA33	A Dummy Variable for MLRA 64	0.0153	0.1227	0	1
MLRA34	A Dummy Variable for MLRA 65	0.0242	0.1537	0	1
MLRA35	A Dummy Variable for MLRA 71	0.0115	0.1065	0	1
MLRA36	A Dummy Variable for MLRA 72	0.0395	0.1948	0	1
MLRA37	A Dummy Variable for MLRA 73	0.0369	0.1886	0	1

Table 4.1 (continued)

Variable	Definition	Mean	Standard Deviation	Minimum	Maximum
MLRA38	A Dummy Variable for MLRA 74	0.0115	0.1065	0	1
MLRA39	A Dummy Variable for MLRA 75	0.0217	0.1456	0	1
MLRA40	A Dummy Variable for MLRA 76	0.014	0.1175	0	1
MLRA41	A Dummy Variable for MLRA 79	0.0127	0.1122	0	1
MLRA42	A Dummy Variable for MLRA 90a	0.0268	0.1614	0	1
MLRA43	A Dummy Variable for MLRA 90b	0.0127	0.1122	0	1
MLRA44	A Dummy Variable for MLRA 95a	0.014	0.1175	0	1
MLRA45	A Dummy Variable for MLRA 95b	0.028	0.1651	0	1

Market prices and loan rates for corn, soybeans, and wheat are not published at county level for the whole study period, so I estimate them based on state-level marketing year average (MYA) prices, national loan rates and posted county price (PCP).[22] All crop prices are deflated by the Index of Prices Paid by Farmers for Commodities and Services, Interest, Taxes, and Wage Rates (PPITW). The index is obtained from USDA-NASS, with “1996 = 1”. County level crop yields data are obtained from USDA-NASS. Due to data limitation, the expected revenue of hay is omitted in the model.[23]

Labor and fertilizer are included in the study as input variables to control the effect of production cost on the acreage allocation. To represent labor and fertilizer cost, annual county wage rate and national indexes of price paid for fertilizer are used. Annual average weekly wage rate at county level are obtained from Quarterly Census of Employment & Wages (QCEW) published by Bureau of Labor Statistics and deflated by PPITW. Indexes of price paid for fertilizer are obtained from annual summary of Agriculture Prices published by USDA-NASS.

CRP rental rate is assumed to directly affect the acreage/share enrolled in the program. Due to the “sticky” property of CRP enrollment, i.e. enrolled land can not come back to production within the 10-15 year contract period, rental payment for current year contracts can only explain a limited part of CRP share. To better understand the

[22] Please refer to Appendix C for more information about the construction of county level prices/loan rates.

[23] Because hay is not a program crop, the method used to capture county variation of state-level MYA prices does not apply to hay. Hay prices fluctuate a lot among counties even in the same state due to the lack of price support program and high reliance on location factors, which affect the storage and transportation cost. According to 2005 Iowa data, the maximum value of county hay price is $106/ton, while the minimum is only $43/ton. Hence, using state-level MYA price for hay is not appropriate in the model. Tanaka and Wu (2004) also found the revenue for hay does not significantly affect a farmer’s crop choice decision in the upper Mississippi River basin.

determinants of CRP share, average rental rate for current year CRP contracts and average rental rate for all active contracts are included in the study as explanatory variables. This latter variable contains information on all past enrollment decision and is positively related to current CRP share. CRP enrollment acreage and average rental rate data are obtained from USDA-FSA. One potential problem of the FSA data is that no rental rate is reported, if there is no new enrollment in CRP for a given county/year. To correct this, I use the average rental rate of all adjacent counties in that particular year as an approximation.[24]

The impact of EQIP on crop acreage allocation and CRP participation is also examined in this study. As analyzed in the previous section, the introduction of EQIP may alter the relative returns of various crops and CRP participation by affecting crop tillage practices. As a result, the allocation of cropland to various crops and CRP may change. To capture the impact of EQIP, county total EQIP payment is included as independent variable in the model.[25] EQIP payment data come from two sources. 1996-2004 data are obtained from the Environmental Working Group (EWG) Farm Subsidy

[24] Seven counties (Cook and DuPage in IL, Ashland, Douglas, Iron, Oneida, and Vilas in WI) do not have CRP acreage since the program was put into practice in 1986. It is more likely factors other than rental rate, such as eligibility, prevent cropland in these counties from enrolling into the program. Hence, zero is assigned to the rental rate in these counties for the whole study period.

[25] Here is an example about how EQIP payment may affect acreage allocation. Assume corn, soybeans and wheat producers may receive EQIP subsidies to employ conservation tillage, while hay producers not. Then the relative returns of the three crops to hay and CRP increase, which will lead to less acreage allocated to hay and CRP. However, total EQIP payment is less effective in affecting acreage allocation compared with crop specific payment data, which is not available for the purpose of this study.

Database.[26] And 2005-2007 data are calculated based on information provided by USDA-NRCS.

Besides county loan rate, commodity program payment is also included in the model to capture the impact of commodity program on crop acreage allocation. County total commodity program payment data are also obtained from EWG Farm Subsidy Database. All original farm program payment data are in current value dollar and are deflated by PPITW with "1996 = 100" before using.

4.2.2 County Location and Soil Characteristics Data

Previous research has found urbanization and proximity to urban areas also affects the crop mix and acreage allocation. As pointed out in Livanis *et al.* (2006) and Nehring *et al.* (2006), urban farms could get higher returns by planting high-valued crops such as fruits, vegetables, nursery, and greenhouse crops. Therefore, acreage allocated to field crops tends to be low in those farms. The impact of urbanization on CRP is twofold. On one hand, the opportunity cost of agricultural production is higher in farms/counties close to urban areas, since farmland in those areas is more likely to be converted to residential use than land in their more rural counterparts. Hence, land in counties under higher urban pressure is less likely to enroll in CRP given the same rental rate as in more rural counties. On the other hand, land owners living in urban area value the environmental benefits provided by CRP more than their rural counterparts. Hence, they may participate in the

[26] The EWG county total EQIP payment data are summed according to recipients' residence, not farm residence. Since crop/CRP shares are based on farm/land residence in this study, problem may arise when the physical/mailing addresses of program participants (landowners or tenants) are not in the same county as their farms. Therefore, the EWG data should be used with caution.

program even if the rental rate is lower than returns from crop production, considering the environmental amenities provided by the enrolled land.

To capture the net effect of urbanization on cropland allocation, we include a discrete variable, Rural-urban Continuum Code (RUCC) developed by USDA-ERS, as an explanatory variable in the study. The county specific RUCC has nine values, where 1 indicates the county is in a metro area with 1 million population or more and 9 indicates the county is completely rural, has less than 2,500 urban population, and not adjacent to a metro area.[27] RUCC is updated every 10 years, 2003 data is used for the whole study period.[28]

To control the soil differences across the study region, we use dummy variables to identify the Major Land Resource Area (MLRA) into which a county fits, following Orazem and Miranowski (1994).[29] The Midwest contains ten Land Resource Regions and 76 Major Land Resource Areas. MLRAs with five or fewer counties in the study region are combined with other MLRAs, so there are totally 45 dummy variables used. The smallest MLRA classification includes six counties while the largest includes 48 after the combination. Since the geoclimatic characteristics did not change much over the study period, we use the same value for each county during the entire time span. For counties

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[27] For a detailed introduction about RUCC, refer to http://www.ers.usda.gov/Data/PopulationInteractionZones/iscussion.htm.

[28] The code was redefined in 2003 which makes 1993 codes not compatible. So I did not combine information on both versions and stick on the 2003 version.

[29] MLRAs are geoclimatic regions with similar soils, climates, and agronomic characteristics. Physical characteristics used to define the MLRAs include elevation, topography, climate, soil type, and potential natural vegetation. The differences in geoclimatic regions may affect acreage allocation through the cost of soil preparation.

located in more than one MLRA, the one whose share is the largest is assigned to the county. The MLRA data are obtained from the USDA-NRCS website.[30]

[30] http://www.cei.psu.edu/mlra.

CHAPTER 5. ESTIMATION RESULTS AND POLICY SIMULATION

In this section, two MFL models are estimated and compared in Stata. The first model (model I) uses actual revenue of various crops/CRP. Since the expected revenue for soybeans is highly correlated with the expected revenue for corn, it is dropped from the model. Such setup is consistent with the model used in Tanaka1 and Wu (2004). The estimates of coefficients are reported in Table 5.1 and 5.3. “Other crops” is used as the base use of cropland in the estimation and the other five uses are determined by their profits relative to the base alternative. Unlike linear regression, the interpretation of estimated coefficients in the MFL model is not straight forward. Thus, elasticities are usually used in the literature. The estimates of elasticities are reported in Table 5.2 and 5.3. They are calculated at the mean values of independent variables, where discrete and dummy variables are treated as continuous. Robust standard errors are reported in the parentheses in Table 5.1 - 5.3. The model fits the data reasonably well overall: eighty-four percent of parameters are statistically significant at 1% level, and less than ten percent are not statistically significant at 10% level.[31]

[31] One limitation of the model is that it underestimates the standard errors of estimators due to unobserved group effects across counties and years, which is common in panel data. Given the definition of statistically significance, smaller standard errors lead to inflated number of significant parameters. The potential econometric issues will be discussed later.

Table 5.1 Estimated Coefficients from Multinomial Fractional Logit Model I: Non-dummy Variables

ML fit of fractional multinomial logit		Number of obs	8635
		Wald chi2 (285)	144522
Log pseudolikelihood	-11884	Prob > chi2	0.0000

Variable	Corn	Soybeans	Wheat	Hay	CRP
Intercept	-3.9039***	-3.9039***	-5.1329***	-0.1945*	-4.8307***
	(0.1646)	(0.1646)	(0.1469)	(0.1099)	(0.1678)
RCORN	0.0044***	0.0030***	-0.0012***	-0.0005***	0.0015***
	(0.0002)	(0.0003)	(0.0002)	(0.0002)	(0.0002)
RWHEAT	0.0009	0.0008	0.0078***	-0.0001	-0.0042***
	(0.0006)	(0.0006)	(0.0005)	(0.0005)	(0.0006)
RCRP	0.0054***	0.0061***	-0.0015***	0.0024***	0.0019***
	(0.0004)	(0.0004)	(0.0005)	(0.0003)	(0.0004)
LAGCRP	0.0239***	0.0211***	0.0099***	0.0015***	0.0162***
	(0.0009)	(0.0009)	(0.0010)	(0.0005)	(0.0009)
PCOMMO	0.0125***	0.0097***	0.0037***	-0.0188***	-0.0067***
	(0.0018)	(0.0018)	(0.0010)	(0.0020)	(0.0016)
EQIP	0.0002*	0.00004	-0.0001	-0.0002**	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
WAGE	0.0007***	0.0009***	0.0007***	-0.0004***	-0.0009***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
FERTILIZER	0.0066***	0.0061***	0.0010*	0.0013***	0.0071***
	(0.0005)	(0.0005)	(0.0005)	(0.0004)	(0.0005)
RUCC03	0.0057	0.0053	0.0345***	-0.0180***	0.0455***
	(0.0044)	(0.0046)	(0.0051)	(0.0033)	(0.0054)

Notes: “Other crops” is the base category in estimating the multinomial fractional logit model.

The robust standard errors are listed in parentheses.

***: statistical significant at 1% level

**: statistical significant at 5% level

*: statistical significant at 10% level

Table 5.2 Estimated Elasticities from Multinomial Fractional Logit Model I: Non-dummy Variables

Variable	Corn	Soybeans	Wheat	Hay	CRP
RCORN	0.6843***	0.3441***	-0.7370***	-0.5510***	-0.0600
	(0.0339)	(0.0344)	(0.0469)	(0.0371)	(0.0509)
RWHEAT	0.0587	0.0515	0.9354***	-0.0623	-0.5858***
	(0.0389)	(0.0400)	(0.0664)	(0.0448)	(0.0639)
RCRP	0.1490***	0.1927***	-0.2839***	-0.0431***	-0.0720***
	(0.0112)	(0.0123)	(0.0277)	(0.0142)	(0.0189)
LAGCRP	0.6972***	0.5271***	-0.1374***	-0.6331***	0.2398***
	(0.0239)	(0.0262)	(0.0467)	(0.0285)	(0.0384)
PCOMMO	0.0792***	0.0585***	0.0150***	-0.1505***	-0.0616***
	(0.0072)	(0.0068)	(0.0060)	(0.0121)	(0.0110)
EQIP	0.0102***	0.0006	-0.0067	-0.0107***	-0.0047
	(0.0029)	(0.0030)	(0.0057)	(0.0036)	(0.0049)
WAGE	0.1872***	0.2482***	0.1641***	-0.2526***	-0.4661***
	(0.0270)	(0.0284)	(0.0428)	(0.0348)	(0.0504)
FERTILIZER	0.3721***	0.3078***	-0.3458***	-0.3054***	0.4366***
	(0.0316)	(0.0332)	(0.0602)	(0.0405)	(0.0509)
RUCC03	0.0059	0.0037	0.1836***	-0.1404***	0.2516***
	(0.0134)	(0.0142)	(0.0280)	(0.0159)	(0.0263)

Notes: The robust standard errors are listed in parentheses.

***: statistical significant at 1% level

**: statistical significant at 5% level

*: statistical significant at 10% level

Table 5.3 Estimated Coefficients and Elasticities from Multinomial Fractional Logit Model I: Dummy Variables

Variable	Corn		Soybeans		Wheat		Hay		CRP	
	Coefficient	**Elasticity**	**Coefficient**	**Elasticity**	**Coefficient**	**Elasticity**	**Coefficient**	**Elasticity**	**Coefficient**	**Elasticity**
MLRA1	0.9618***	-0.0039***	1.7917***	0.0193***	3.2786***	0.0610***	0.5374***	-0.0158***	3.3619***	0.0634***
	(0.0989)	(0.0011)	(0.1311)	(0.0021)	(0.1230)	(0.0025)	(0.0912)	(0.0022)	(0.1316)	(0.0027)
MLRA2	0.9045***	0.0041***	1.3884***	0.0183***	0.0297	-0.0215***	0.4246***	-0.0100***	2.4512***	0.0494***
	(0.1075)	(0.0012)	(0.1374)	(0.0022)	(0.1691)	(0.0039)	(0.1027)	(0.0024)	(0.1497)	(0.0031)
MLRA3	0.2955***	-0.0073***	1.0108***	0.0364***	0.5003***	0.0052	-0.2088**	-0.0381***	1.9116***	0.0915***
	(0.1008)	(0.0025)	(0.1334)	(0.0047)	(0.1381)	(0.0065)	(0.0885)	(0.0050)	(0.1344)	(0.0061)
MLRA4	0.2807***	-0.0022**	0.8632***	0.0126***	-1.8918***	-0.0576***	0.2067**	-0.0041**	2.3239***	0.0498***
	(0.1079)	(0.0011)	(0.1415)	(0.0021)	(0.1541)	(0.0032)	(0.0937)	(0.0021)	(0.1363)	(0.0026)
MLRA5	-0.6386***	-0.0181***	-0.6399***	-0.0181***	-1.3007***	-0.0417***	0.3042***	0.0156***	2.1773***	0.0824***
	(0.0877)	(0.0013)	(0.1252)	(0.0027)	(0.1168)	(0.0033)	(0.0771)	(0.0027)	(0.1205)	(0.0033)
MLRA6	0.0606	-0.0124***	0.8966***	0.0100***	2.3263***	0.0482***	0.1545*	-0.0099***	2.5135***	0.0532***
	(0.1010)	(0.0012)	(0.1299)	(0.0020)	(0.1141)	(0.0024)	(0.0907)	(0.0022)	(0.1293)	(0.0026)
MLRA7	0.2055*	0.0003	0.9852***	0.0062***	-2.8460***	-0.0231***	-0.3157***	-0.0037***	1.3844***	0.0093***
	(0.1255)	(0.0004)	(0.1556)	(0.0006)	(0.3089)	(0.0022)	(0.1195)	(0.0007)	(0.1708)	(0.0009)
MLRA8	0.1853*	-0.0061***	0.9213***	0.0174***	0.7638***	0.0124***	-0.2390***	-0.0196***	1.8958***	0.0484***
	(0.1041)	(0.0014)	(0.1341)	(0.0024)	(0.1486)	(0.0039)	(0.0837)	(0.0026)	(0.1334)	(0.0031)
MLRA9	0.3124**	-0.0018*	1.0647***	0.0126***	1.2356***	0.0158***	-0.4447***	-0.0163***	1.6625***	0.0240***
	(0.1283)	(0.0010)	(0.1571)	(0.0016)	(0.1504)	(0.0021)	(0.1133)	(0.0016)	(0.1554)	(0.0021)
MLRA10	0.0044	-0.0033***	0.5649***	0.0053***	0.7300***	0.0078***	-0.3657***	-0.0089***	1.6652***	0.0221***
	(0.1278)	(0.0008)	(0.1573)	(0.0013)	(0.1650)	(0.0018)	(0.1217)	(0.0014)	(0.1499)	(0.0016)
MLRA11	-0.0881	-0.0072***	0.5615***	0.0044***	-0.5846***	-0.0161***	0.1767*	-0.0025*	2.9098***	0.0462***
	(0.1143)	(0.0008)	(0.1441)	(0.0014)	(0.1785)	(0.0024)	(0.1003)	(0.0014)	(0.1453)	(0.0018)
MLRA12	-0.1304	-0.0048***	0.5767***	0.0042***	-1.1146***	-0.0174***	0.0345	-0.0027***	2.7518***	0.0319***
	(0.0931)	(0.0005)	(0.1265)	(0.0009)	(0.1613)	(0.0017)	(0.0827)	(0.0010)	(0.1270)	(0.0012)
MLRA13	-0.5222***	-0.0365***	0.6288***	0.0104***	1.1452***	0.0315***	0.4576***	0.0035	3.2249***	0.1163***
	(0.0904)	(0.0016)	(0.1257)	(0.0030)	(0.1286)	(0.0041)	(0.0759)	(0.0031)	(0.1189)	(0.0037)

Table 5.3 (continued)

Variable	Corn		Soybeans		Wheat		Hay		CRP	
	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity
MLRA14	0.5193***	-0.0003	1.2433***	0.0117***	2.1756***	0.0271***	-0.5789***	-0.0185***	1.9129***	0.0228***
	(0.1326)	(0.0011)	(0.1546)	(0.0015)	(0.1631)	(0.0023)	(0.1041)	(0.0016)	(0.1530)	(0.0020)
MLRA15	-0.8011***	-0.0351***	0.8383***	0.0171***	2.8631***	0.0816***	0.3394***	0.0012	1.8710***	0.0500***
	(0.0929)	(0.0013)	(0.1232)	(0.0023)	(0.1151)	(0.0027)	(0.0780)	(0.0024)	(0.1235)	(0.0031)
MLRA16	0.7732***	-0.0077***	1.7711***	0.0279***	3.2831***	0.0819***	0.2204**	-0.0274***	3.2141***	0.0794***
	(0.1114)	(0.0016)	(0.1380)	(0.0027)	(0.1336)	(0.0033)	(0.0925)	(0.0029)	(0.1386)	(0.0035)
MLRA17	0.9753***	-0.0013**	1.9198***	0.0095***	4.1160***	0.0347***	0.2585	-0.0096***	2.9461***	0.0212***
	(0.1631)	(0.0006)	(0.1837)	(0.0009)	(0.1897)	(0.0012)	(0.1704)	(0.0011)	(0.1777)	(0.0012)
MLRA18	-0.9877***	-0.0153***	0.2550*	0.0037***	2.1530***	0.0327***	-0.0936	-0.0017	1.6125***	0.0244***
	(0.1100)	(0.0007)	(0.1398)	(0.0012)	(0.1414)	(0.0015)	(0.0817)	(0.0013)	(0.1290)	(0.0015)
MLRA19	0.3131***	-0.0105***	1.0240***	0.0139***	2.2647***	0.0566***	0.1118	-0.0174***	2.7151***	0.0721***
	(0.0997)	(0.0014)	(0.1313)	(0.0026)	(0.1242)	(0.0032)	(0.0889)	(0.0026)	(0.1357)	(0.0034)
MLRA20	-2.8880***	-0.0864***	-1.7653***	-0.0292***	-0.2828**	0.0463***	-0.1755***	0.0518***	-0.9314***	0.0133***
	(0.1007)	(0.0023)	(0.1342)	(0.0040)	(0.1282)	(0.0046)	(0.0712)	(0.0041)	(0.1348)	(0.0051)
MLRA21	-3.0652***	-0.0189***	-1.3826***	-0.0039***	1.2177***	0.0193***	0.0427	0.0088***	0.4708***	0.0126***
	(0.1735)	(0.0008)	(0.1870)	(0.0009)	(0.1849)	(0.0010)	(0.0760)	(0.0009)	(0.1557)	(0.0010)
MLRA22	-0.5122***	-0.0066***	0.7156***	0.0028***	1.5394***	0.0091***	0.2141**	-0.0011	3.0098***	0.0203***
	(0.1236)	(0.0004)	(0.1493)	(0.0006)	(0.1822)	(0.0010)	(0.1042)	(0.0007)	(0.1431)	(0.0008)
MLRA23	-1.3549***	-0.0077***	0.3476**	0.0075***	2.5975***	0.0275***	-2.1379***	-0.0147***	0.0300	0.0046***
	(0.1817)	(0.0007)	(0.1801)	(0.0008)	(0.1698)	(0.0009)	(0.1743)	(0.0011)	(0.2362)	(0.0015)
MLRA24	-1.1717***	-0.0262***	-0.2885*	-0.0071***	3.7209***	0.0797***	-0.0446	-0.0018	2.8847***	0.0616***
	(0.1433)	(0.0016)	(0.1733)	(0.0023)	(0.1059)	(0.0021)	(0.0938)	(0.0019)	(0.1213)	(0.0023)
MLRA25	-0.3182***	-0.0032***	-0.4398***	-0.0041***	3.3194***	0.0246***	-0.1952*	-0.0022***	1.8224***	0.0132***
	(0.1131)	(0.0004)	(0.1612)	(0.0008)	(0.1338)	(0.0009)	(0.1105)	(0.0007)	(0.1333)	(0.0008)
MLRA26	-2.6981***	-0.0378***	-4.3614***	-0.0781***	3.6254***	0.1152***	0.2885***	0.0344***	2.6022***	0.0904***
	(0.1098)	(0.0014)	(0.1832)	(0.0031)	(0.1123)	(0.0022)	(0.0897)	(0.0021)	(0.1262)	(0.0025)

Table 5.3 (continued)

Variable	Corn		Soybeans		Wheat		Hay		CRP	
	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity
MLRA27	-3.5966***	-0.0241***	-2.1917***	-0.0098***	3.2817***	0.0460***	-1.2940***	-0.0007	2.1401***	0.0343***
	(0.2302)	(0.0014)	(0.2214)	(0.0015)	(0.1111)	(0.0013)	(0.1395)	(0.0015)	(0.1298)	(0.0013)
MLRA28	-0.8405***	-0.0177***	0.3974***	0.0060***	3.3321***	0.0620***	-0.9630***	-0.0200***	2.7745***	0.0514***
	(0.1222)	(0.0011)	(0.1439)	(0.0016)	(0.1057)	(0.0017)	(0.0879)	(0.0015)	(0.1241)	(0.0019)
MLRA29	0.7014***	-0.0001	1.2267***	0.0100***	2.3343***	0.0311***	0.2141***	-0.0094***	1.8033***	0.0210***
	(0.0973)	(0.0008)	(0.1300)	(0.0015)	(0.1258)	(0.0019)	(0.0821)	(0.0014)	(0.1290)	(0.0019)
MLRA30	-1.2747***	-0.0250***	0.4942***	0.0111***	3.4813***	0.0720***	-1.2875***	-0.0252***	2.7577***	0.0572***
	(0.1323)	(0.0016)	(0.1368)	(0.0016)	(0.1091)	(0.0017)	(0.0946)	(0.0018)	(0.1300)	(0.0022)
MLRA31	-0.7934***	-0.0128***	-0.4452***	-0.0070***	1.7788***	0.0298***	0.2985***	0.0053***	1.7228***	0.0289***
	(0.1142)	(0.0012)	(0.1532)	(0.0016)	(0.1600)	(0.0022)	(0.0795)	(0.0014)	(0.1342)	(0.0017)
MLRA32	-0.8693***	-0.0081***	-1.7066***	-0.0177***	2.9986***	0.0362***	0.4218***	0.0067***	2.4451***	0.0299***
	(0.1389)	(0.0008)	(0.2040)	(0.0016)	(0.1362)	(0.0015)	(0.1087)	(0.0011)	(0.1438)	(0.0016)
MLRA33	-1.3129***	-0.0057***	-3.8513***	-0.0445***	2.3980***	0.0510***	-0.2198**	0.0110***	1.1121***	0.0314***
	(0.1358)	(0.0015)	(0.2031)	(0.0024)	(0.1183)	(0.0015)	(0.0900)	(0.0014)	(0.1429)	(0.0018)
MLRA34	-0.5367***	-0.0112***	-1.3230***	-0.0303***	1.5671***	0.0397***	0.8708***	0.0228***	1.4770***	0.0375***
	(0.0976)	(0.0011)	(0.1488)	(0.0024)	(0.1604)	(0.0036)	(0.0844)	(0.0021)	(0.1286)	(0.0024)
MLRA35	0.7549***	0.0034***	0.1723	-0.0033***	1.0444***	0.0067***	0.5636***	0.0012	1.2758***	0.0093***
	(0.1172)	(0.0006)	(0.1531)	(0.0010)	(0.1335)	(0.0012)	(0.0970)	(0.0009)	(0.1514)	(0.0013)
MLRA36	-1.1347***	-0.0095***	-3.0734***	-0.0860***	3.2428***	0.1634***	-1.9089***	-0.0401***	2.1026***	0.1184***
	(0.0970)	(0.0018)	(0.1344)	(0.0034)	(0.1047)	(0.0033)	(0.0845)	(0.0032)	(0.1239)	(0.0040)
MLRA37	-1.3819***	-0.0279***	-1.8292***	-0.0444***	3.3247***	0.1460***	-1.3399***	-0.0264***	1.9007***	0.0934***
	(0.1091)	(0.0021)	(0.1397)	(0.0032)	(0.1041)	(0.0031)	(0.0766)	(0.0030)	(0.1196)	(0.0038)
MLRA38	-2.1294***	-0.0199***	-0.5583***	-0.0019**	3.8934***	0.0491***	-0.4784***	-0.0010	1.9234***	0.0265***
	(0.1227)	(0.0008)	(0.1397)	(0.0009)	(0.1066)	(0.0010)	(0.0807)	(0.0010)	(0.1251)	(0.0012)
MLRA39	0.4676***	0.0016	0.6331***	0.0051***	2.7997***	0.0521***	-0.5081***	-0.0196***	1.3128***	0.0199***
	(0.1001)	(0.0010)	(0.1304)	(0.0017)	(0.1232)	(0.0022)	(0.0862)	(0.0017)	(0.1333)	(0.0023)

Table 5.3 (continued)

Variable	Corn		Soybeans		Wheat		Hay		CRP	
	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity
MLRA40	-1.6230***	-0.0200***	-0.0802	0.0016	2.6811***	0.0403***	0.0214	0.0030***	1.2546***	0.0203***
	(0.1131)	(0.0008)	(0.1258)	(0.0010)	(0.1180)	(0.0014)	(0.0800)	(0.0011)	(0.1262)	(0.0014)
MLRA41	-1.4354***	-0.0144***	-1.1076***	-0.0102***	4.3332***	0.0591***	-0.6938***	-0.0050***	2.3950***	0.0344***
	(0.1265)	(0.0010)	(0.1334)	(0.0011)	(0.1113)	(0.0012)	(0.0862)	(0.0012)	(0.1303)	(0.0013)
MLRA42	-0.9100***	-0.0120***	-1.2648***	-0.0215***	-0.0751	0.0103***	0.2782***	0.0198***	-0.2621	0.0053
	(0.0950)	(0.0011)	(0.1389)	(0.0023)	(0.1323)	(0.0031)	(0.0784)	(0.0022)	(0.1711)	(0.0037)
MLRA43	-0.4729***	-0.0038***	-0.3962***	-0.0028***	-0.7036***	-0.0067***	-0.1926***	-0.0002	1.0966***	0.0162***
	(0.0980)	(0.0005)	(0.1389)	(0.0011)	(0.1363)	(0.0013)	(0.0743)	(0.0010)	(0.1779)	(0.0019)
MLRA44	-0.9267***	-0.0081***	-0.9614***	-0.0086***	0.8474***	0.0168***	-0.4204***	-0.0010	1.3486***	0.0238***
	(0.0903)	(0.0006)	(0.1277)	(0.0011)	(0.1191)	(0.0014)	(0.0754)	(0.0011)	(0.1246)	(0.0014)
MLRA45	-0.6338***	-0.0123***	-0.4455***	-0.0070***	0.6699***	0.0243***	-0.5421***	-0.0097***	1.3893***	0.0444***
	(0.0921)	(0.0011)	(0.1286)	(0.0021)	(0.1205)	(0.0025)	(0.0840)	(0.0021)	(0.1311)	(0.0028)

Notes: The robust standard errors are listed in parentheses.

***: statistical significant at 1% level

**: statistical significant at 5% level

*: statistical significant at 10% level

The second model (model II) uses relative revenue to corn as explanatory variables, which is the only difference between the two models. By using relative revenues, the information contained in soybeans revenue is also incorporated in the model. Table 5.4 presents the estimates of coefficients and elasticities associated with the non-dummy variables. Robust standard errors are reported in the parentheses too. Like model I, the relative revenue model fits the data pretty well overall: eighty-seven percent of parameters are statistically significant at 1% level, and less than eight percent are not statistically significant at 10% level.[31] In the rest of the section, potential econometric issues are discussed first, and then estimation results from model I are analyzed and compared with those from model II.

5.1 Econometric Issues

Two econometric issues are common for panel data: heteroscedasticity and serial correlation. The potential heteroscedasticity among counties is addressed by employing robust standard errors. However, the potential serial correlation is not corrected in the model. It does not affect the consistency of the QMLE, but the standard errors are underestimated with the existence of serial correlation, and statistical inference based on the estimation results may be less reliable.

Table 5.4 Estimated Coefficients and Elasticities from Multinomial Fractional Logit Model II: Non-Dummy Variables

Variable	Corn		Soybeans		Wheat		Hay		CRP	
	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity	Coefficient	Elasticity
Intercept	-0.3928***		-1.2986***		-3.9806***		-0.4193***		-3.9072***	
	(0.1645)		(0.1841)		(0.1529)		(0.1172)		(0.1726)	
RRSOY	-0.7134***	-0.3017***	-0.6007***	-0.2081***	-0.9949***	-0.5354***	0.2706***	0.5152***	-0.6622***	-0.2592***
	(0.1144)	(0.0536)	(0.1131)	(0.0529)	(0.0799)	(0.0614)	(0.0783)	(0.0538)	(0.0972)	(0.0737)
RRWHEAT	-3.0499***	-0.9049***	-2.4377***	-0.5801***	0.7440***	1.1079***	-0.3195***	0.5437***	-1.1106***	0.1240***
	(0.1324)	(0.0383)	(0.1289)	(0.0366)	(0.0830)	(0.0430)	(0.0948)	(0.0394)	(0.1075)	(0.0488)
RRCRP	0.4389***	0.0353***	0.8299***	0.1342***	-0.7519***	-0.2659***	0.4586***	0.0403***	-0.1810	-0.1215***
	(0.1175)	(0.0146)	(0.1162)	(0.0144)	(0.1170)	(0.0259)	(0.0833)	(0.0161)	(0.1184)	(0.0225)
RRLAG-CRP	4.7744***	0.5093***	4.2509***	0.3862***	2.8600***	0.0592	0.3658***	-0.5273***	5.0184***	0.5667***
	(0.2040)	(0.0239)	(0.2077)	(0.0243)	(0.2259)	(0.0446)	(0.1206)	(0.0276)	(0.2122)	(0.0388)
PCOMMO	0.0155***	0.0933***	0.0120***	0.0678***	0.0054***	0.0195***	-0.0203***	-0.1696***	-0.0055***	-0.0605***
	(0.0020)	(0.0081)	(0.0020)	(0.0075)	(0.0011)	(0.0063)	(0.0021)	(0.0132)	(0.0017)	(0.0114)
EQIP	-0.0002	-0.0005	-0.0002*	-0.0046	-0.0002*	-0.0044	-0.0002**	-0.0031	-0.0001	-0.0002
	(0.0002)	(0.0035)	(0.0002)	(0.0033)	(0.0001)	(0.0054)	(0.0001)	(0.0036)	(0.0001)	(0.0047)
WAGE	0.0004***	0.1130***	0.0006***	0.1865***	0.0004***	0.1420***	-0.0003***	-0.1757***	-0.0010***	-0.4374***
	(0.0002)	(0.0309)	(0.0002)	(0.0308)	(0.0001)	(0.0428)	(0.0001)	(0.0362)	(0.0002)	(0.0511)
FERTI-LIZER	0.0089***	0.5404***	0.0081***	0.4384***	0.0005	-0.5260***	0.0018***	-0.3692***	0.0069***	0.2901***
	(0.0006)	(0.0365)	(0.0006)	(0.0366)	(0.0006)	(0.0602)	(0.0004)	(0.0418)	(0.0006)	(0.0538)
RUCC03	-0.0196***	-0.0786***	-0.0160***	-0.0568***	0.0252***	0.1980***	-0.0188***	-0.0737***	0.0403***	0.2909***
	(0.0049)	(0.0152)	(0.0049)	(0.0149)	(0.0051)	(0.0276)	(0.0034)	(0.0168)	(0.0054)	(0.0264)

Notes: The robust standard errors are listed in parentheses. ***, **, and *: statistical significant at 1%, 5%, and 10% level respectively.

Because the commonly used tests for serial correlation in linear models do not work for the MFL model, I use some graphical method to examine how serious is serial correlation in the error terms. Since the error structures in the five equations are similar, I use corn equation as a representative in the rest of the analysis. The slope of the time series graph of residuals (Figure 5.1) is slightly positive, which indicates serial correlation exist, but to a small extent. The scatter plot of residuals versus their lags (Figure 5.2) has a clear positive slope, about 0.1, which indicates serial correlation to some extent. Alternatively, serial correlation may also be examined by fitting the MFL model and relax the independence assumption across years. The estimated values of parameters are the same, while the standard errors are slightly greater, which implies positive correlation within years. Therefore, one may conclude that serial correlation exists in the error terms to some extent when pooling the county data.

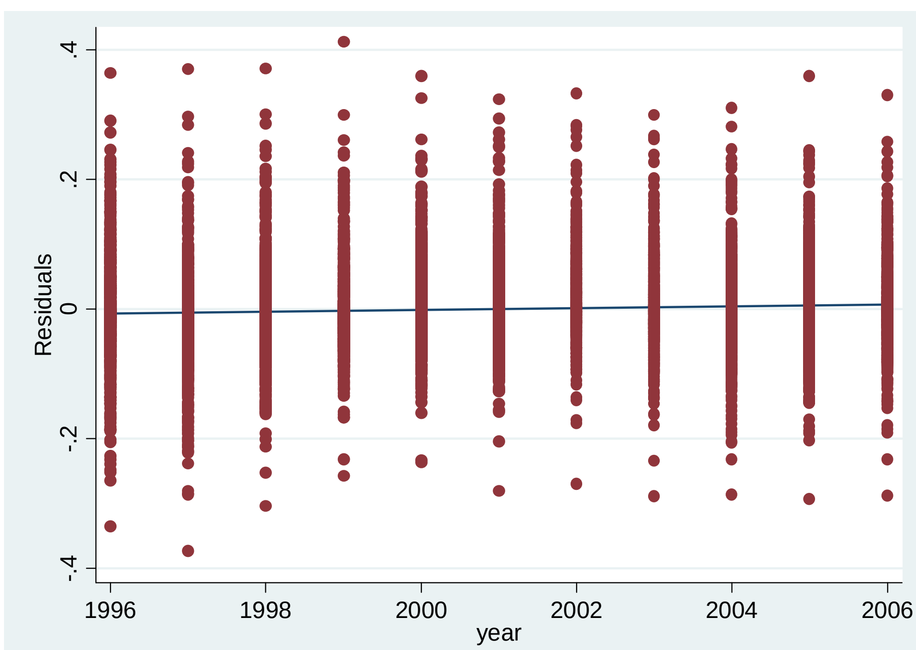

Figure 5.1 Residuals across Time for Corn Equation

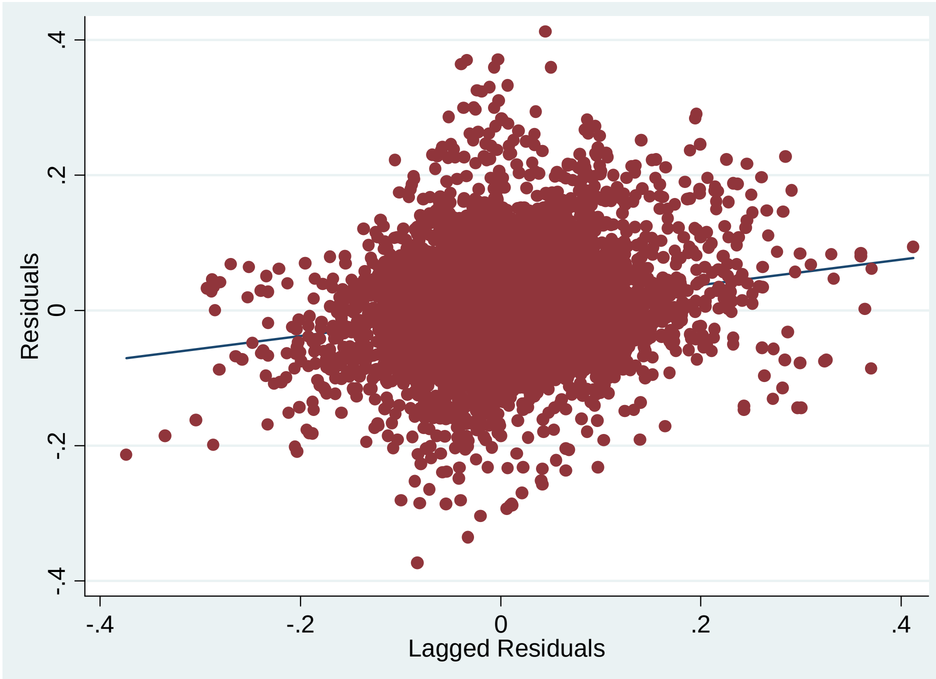

Figure 5.2 Residuals verse Their Lagged Values for Corn Equation

However, the patterns of residuals vary a lot among individual counties. I randomly pick six Iowa counties and six Kansas counties for illustration purpose. Figure 5.3 contains the scatter plots of residuals versus their lags in the six Iowa counties. 19001-19011 represent county FIPs. The correlation is positive in counties 19003, 19005 and 19011, while negative in counties 19001 and 19009. There is no clear pattern in county 19007. Figure 5.4 contains the scatter plots of residuals versus their lags in the six Kansas counties. There exists strong positive correlation among the error terms in five of the six counties, except county 20001, where there is no clear pattern.

There will be less significant estimators when serial correlation is treated in the estimation, due to the increase in standard errors. One way to correct for serial correlation is the cluster bootstrapping method as used in Blass et al. (2010). Over 1000 replications in the bootstrapping may generate reliable standard errors. Due to computer resource constraints, it is not done in the current study.

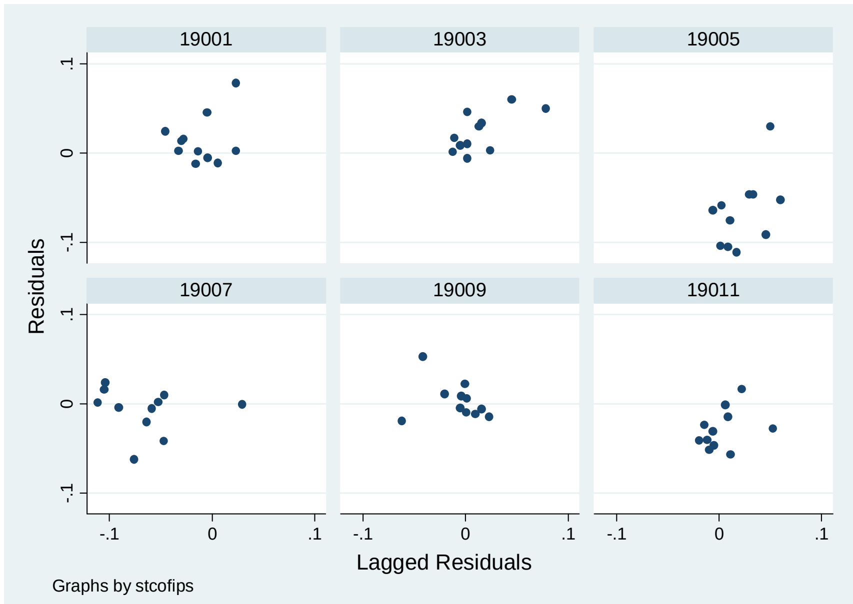

Figure 5.3 Residuals verse Their Lagged Values for Corn Equation in Six Iowa Counties

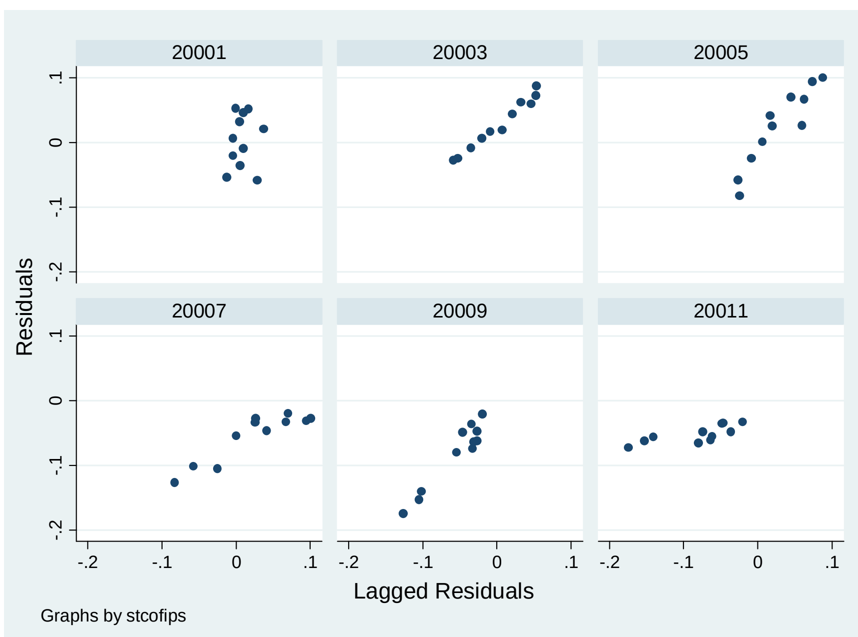

Figure 5.4 Residuals verse Their Lagged Values for the Corn Equation in Six Kansas Counties

5.2 Estimation Results

5.2.1 Revenues

The expected revenue for corn is statistically significant at 1% level in all five equations of model I. The corresponding elasticities all have the expected signs, although it is not significant at 10% level in CRP equation. With 10% increase in the expected revenue for corn, corn and soybeans shares increase by 6.9% and 3.5% respectively, while wheat and hay shares decrease by 7.4% and 5.5% respectively. The expected relative revenue of soybeans to corn (RRSOY) and corresponding elasticities are statistically significant at 1% level in all five equations of model II. Unlike expected, the elasticity of soybeans share with respect to RRSOY is negative. It can be partly explained by the widely used corn-soybeans rotation in the study region, as pointed out in Orazem and Miranowski (1994).

The expected revenue for wheat is statistically significant at 1% level only in wheat and CRP equations of model I. Wheat share increases by 9.4% and CRP share decrease by 5.9% with ten percent increase in the expected revenue for wheat. These results are consistent with the fact that crop acreage is inelastic to revenue changes. There are more statistically significant estimates associated with wheat revenue in model II. The estimated elasticities with respect to the expected relative revenue of wheat to corn (RRWEHAT) and corresponding elasticities are significant in all five equations of model II. They have expected signs in corn and wheat equations. Wheat share increases by 11% while corn share decrease by 9% with ten percent increase in RRWHEAT.

One would expect a negative relationship between crop revenue and CRP enrollment given fixed program rental rate. The estimation results from model I support this argument. CRP share decreases by 5.9% with ten percent increase in expected wheat revenue, and 0.6% with ten percent increase in expected corn revenue, although the elasticity is not statistically significant for expected corn revenue.

5.2.2 Policy Variables

The impacts of conservation policies on crop acreage allocation are directly measured in both models. Higher CRP rental rate should be associated with greater CRP share in any given year as suggested by the profit maximization model. However, the estimation results from both models do not support this statement, although all the estimated elasticities with respect to current year CRP rental rate and expected relative revenue of CRP to corn for current year contract (RRCRP) are statistically significant at 1% level. The estimation result from model I suggests that an increase in current year CRP rental rate will lead to increasing corn and soybeans shares, while decreasing shares of the other two crops and CRP. The estimation result from model II suggests that an increase in RRCRP will lead to increasing corn, soybeans and hay shares, while decreasing shares of wheat and CRP. Several reasons may lead to such unanticipated negative relationship between current year CRP rental rate and CRP share.[32]

First of all, CRP is a long-term program, in the sense that common CRP contracts range from 10 to 15 years. Therefore, land owners can not adjust enrollment acreage as

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[32] Goodwin et. al. (2004) also got negative relationship between CRP rental rate and CRP acreage in a study of crop insurance in Corn Belt and Northern Plain.

frequent as other crop acreage and current year enrollment only accounts for a small proportion of current year CRP share, which suggests cumulative CRP enrollment acreage is not only responsive to current year rental rate, but also relies on past enrollment history. Hence, average rental rate of all active contracts is also included in the model as an explanatory variable to control the past enrollment. The estimated elasticity with respect to the lagged rental rate is positive (0.24) and greater than the absolute value of the elasticity with respect to current year rental rate (0.07), given the estimated coefficients from model I.[33] Similar results are obtained from model II.

The second reason is the scheme of CRP enrollment, which is bidding rather than offering system. A bidding system indicates that not all land owners who are willing to enroll in the program at a given rental rate can be approved. For instance, the average acceptance rate of CRP bids in Kansas is 67% between 1997 and 2006. In other words, the partial equilibrium assumption of crop prices/returns is violated for CRP rental rate, which is endogenously determined by the supply and demand of CRP land in each county.[34] Hence, in some cases, increasing program rental rate may lead to less acreage being accepted in the program. Thirdly, some sign-ups are for re-enrollment only, which means a piece of land can not enroll in the program even though the rental rate is higher than the profit from crop production, if it is not currently enrolled in the program and the contract is about to expire.

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[33] The elasticity with respect to current year rental rate is -0.05 and significant at 1% level in a model without lagged rental rate.

[34] In counties where supply is greater than demand, the current year rental rate is the maximum rental rate preset by FSA. Otherwise, the current year rental rate depends on both supply and demand side factors and may be less than the maximum rental rate.

Finally, land owners may not rely solely on the relative profitability of CRP and crop production when making the enrollment decision. In high CRP enrollment area, some land owners enroll in the program simply because they want to quit agricultural production and receive long term stable retirement income, even when CRP rental payment is less than farming profit, according to various ERS reports. In summary, current year rental rate plays only a limited role in determining CRP share and average rental rate for all active contracts explain more.

Next examine the impact of EQIP. Total EQIP payment does not perform as well as CRP rental rate in the estimation. In model I, the estimated coefficients associated with total EQIP payment are significant at 1% level only in corn and hay equations and the estimated elasticities are very close to zero (range between -0.01 and 0.01), which indicate total EQIP payment exert very little influence on crop acreage allocation. In model II, the estimated coefficients associated with total EQIP payment are significant at 5% level in hay equation and 10% level in soybeans and wheat equations, while none of the estimated elasticities is significant even at 10% level. The results are reasonable since total EQIP payment contains little information on the distribution of EQIP funds among various crops, which is supposed to affect the acreage allocation directly. Given the estimated elasticities from model I, corn share increases by 0.1% while hay share decreases by 0.1% with ten percent increase in total EQIP payment, which suggests corn lands may receive more EQIP funds than hay lands.

The estimation results do not provide evidence that EQIP negatively affect CRP enrollment in the Midwest.[35] Although negative, the estimated coefficient and elasticity of CRP share with respect to total EQIP payment are not statistically significant even at 10% level in both models, which implies EQIP has little or no impact on CRP enrollment in the study region. This is not surprising since the share of land enrolled in CRP does not depend much on the current profitability of CRP relative to other crops, through which EQIP is assumed to affect CRP participation, as discussed above. Furthermore, there is no clear evidence that the introduction of EQIP increases profit of some particular crops.

Two variables are used to represent commodity program: total commodity payment and commodity loan rate. The influence of total commodity payment on crop or CRP shares can be directly measured in the model. It is statistically significant at 1% in all five equations with expected signs in both models: it is positively related with corn, soybeans and wheat (program crops) shares and negatively related with hay (non-program crop) and CRP shares. Although can not be directly measured, the impact of loan rates on crop or CRP share may be estimated indirectly through the impact of expected (relative) revenues in model I. For instance, the 2005 loan rate and MYA price for corn were \$2.02 and \$2.09 respectively in Adams County, Illinois. Thus, 3 percent increase of the 2005 loan rate has no effect on the 2006 expected revenue of corn, while 10 percent increase leads to an increase of 4.7 percent of the expected corn revenue in 2006. Given the estimated elasticities, the shares of cropland allocated to corn and soybeans in Adams County will increase by 1.17 and 0.6 percent respectively (3.23% and 1.65% increases),

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[35] This study only considers the demand side of government conservation programs. On the supply side, these two programs do compete for government funds.

while the shares for wheat and hay will decrease by 0.15 and 0.24 percent respectively (3.48% and 2.60% decreases) in 2006, assuming the expected yield in 2006 remains the same. In general, there exists some substitution effect between commodity and land retirement program. Higher commodity program payment will lead to lower CRP participation rate by increasing the expected return from crop production.

5.2.3 Input Prices

Input costs are also assumed to be important determinants of crop acreage allocation in the study region. One would expect that land shifts from crops using the input more intensively to crops using it less intensively, when the price of a specific input increases. And increased input prices also result in less profit from crop production, so more land are expected to enroll in CRP. The two models do not generate much difference in the sign and magnitude of those elasticities. The estimated elasticities of labor and fertilizer costs are statistically significant at 1% level in all five equations of both models. For instance, 10 percent increase in the price of fertilizer will result in 3.7%, 3.1% and 4.4% increase in corn, soybeans and CRP shares, while 3.4% and 3.0% decrease in wheat and hay shares, based on the results from model I. That is consistent with the fact that wheat and hay are crops using fertilizer more intensive than corn and soybeans in the study region.[36] The elasticity of hay shares with respect to wage rate is

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[36] Corn is a traditional fertilizer intensive crop compared with wheat. A close look of USDA-ERS Commodity Costs and Returns Data reveals that fertilizer (including commercial fertilizers, soil conditioners, and manure) cost accounts for 39 and 33 percent of total operating cost for the production of corn and wheat respectively between 1975 and 1995 nationally. However, the shares change to 32 and 33 respectively between 1998 and 2006, which indicates the evolution of cropping practice lead to less fertilizer use in corn production. More specifically, corn production involves less intensive use of fertilizer (30% of total variable cost) while wheat production

negative and significant (-0.25 from model I and -0.18 from model II) since hay is the most labor intensive crop.

5.2.4 County Location and Soil Characteristics

Urbanization variable RUCC is found to have a positive relationship with CRP enrollment. The estimated elasticity is 0.25 from model I and 0.29 from model II. That is to say, CRP enrollment rate tends to be higher in more remote counties and lower in counties with high urban influence. The negative relationship between urbanization and CRP participation implies land owners in urban counties expect more return from their land, thus require higher rental rate from the program even considering the environmental benefits provided by CRP land. Additionally, land in counties with high urban influence is usually easy to be rent out in case land owners do not want to farm by themselves. The results are consistent with the findings in Parks and Schorr (1997). RUCC is significant in all five equations of model II. The estimated elasticities are positive and relatively large in wheat and CRP equations, while negative and relatively small in the other three equations, which implies urbanization has little impact on the distribution of corn, soybeans and hay acreage in the study region.

Soil characteristics perform pretty well in both models. About 86 percent of the estimated coefficients associated with the dummy variables representing MLRA are

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involves more intensive use of fertilizer (43% of total variable cost) in the study region compared with national average between 1998 and 2006. The reason may partly rely on the fact that the land in Midwest is more suitable for corn than wheat. The average shares of cropland planting to corn and wheat are 24% and 10% respectively. National or regional cost data for hay production is not available. However, based on the “Estimated Costs of Crop Production in Iowa”, an annual report published by Iowa State University Extension Service, about 37% to 49% of total variable costs attribute to fertilizer in alfalfa hay production between 2000 and 2006 in Iowa.

statistically significant at 1% level and more than 90 percent are statistically significant at 10% level in both models. This indicates large differences existed in the cropping patterns among different MLRAs. For instance, the estimated elasticities for MLRA-102C are positive with respect to corn and soybeans, and negative with respect to wheat and hay, which indicates the soil properties favor the cultivation of corn and soybeans in this area. That is also supported by the data: more than half of the cropland is allocated to corn and soybeans in 500 out of the 528 county-year combinations in this area, while the highest sum of shares of wheat and hay is only 15%. In comparison, the estimated elasticities for MLRA-73 are positive with respect to wheat, and negative with respect to all the other three crops, which implies land in this area is more suitable for wheat: wheat share is greater than the total share of the other three crops in 80% of counties in this area.

5.3 Simulated Policy Scenario

The estimated models provide a method to measure quantitatively the impacts of commodity and conservation programs on crop acreage allocation. Six policy changes are simulated in model I: increasing corn and wheat loan rate by 50 and 100 percent and increasing commodity payment and EQIP payment by 50 percent. The simulation is conducted as follows. First, the estimated coefficients from model I are used to predict the crop and CRP shares in 2007. Second, the predicted shares are used to calculate cropping acreage for the four crops and active CRP acreage in 2007. The resulting acreage is then used as the baseline, with which the changes in cropping acreage are calculated given the policy changes. Assume expected yield, total cropland acreage and other independent variables remain at the 2007 level in the simulation.

The simulation results are summarized in Table 5.5. The second and third columns are the actual and predicted harvested acreage of the four crops and cumulative CRP enrollment in 2007, respectively. The fourth column gives the difference in percentage of predicted and actual acreage. The model performs better in predicting acreage of corn, soybeans, and hay than acreage of wheat and CRP. The predicted acreage is 18% and 11% more than the actual acreage for CRP and soybeans respectively, while 15%, 12% and 3% less for wheat, corn and hay respectively. The rest of the columns present the acreage and percentage changes for crop/CRP under various policy scenarios.

First consider corn and wheat loan rates. 50% increase in 2006 corn loan rate has little impact on the acreage allocation in 2007 of the study region: corn, soybeans and CRP acreage slightly increase while wheat and hay acreage slightly decrease. [37] Doubling 2006 corn loan rate leads to about 7 and 1 percent increase in corn and soybeans acreage respectively, while 0.6 to 6 percent decreases in the acreage of the other two crops and CRP in 2007. Such results are not surprising since corn loan rate is relatively low compared with MYA price since 2006. For instance, average corn MYA price is about 1.6 times as average corn loan rate in 2006, and 2.2 times in 2007. Given the way expected revenue is constructed, 50% increase in 2006 corn loan rate barely changes the expected corn revenue in 2007, so does crops and CRP acreage.

The influence of wheat loan rate on acreage allocation is greater, since it is closer to MYA price of wheat in 2006. Wheat and CRP acreage are affected most, while the

[37] Since current year loan rates information is not available when land owners make the acreage allocation decision (usually in Feb), the changes in loan rate considered in this study are for 2006. A similar simulation was done assuming 2007 loan rates are available when land owners make their acreage allocation decision. In this case, the expected price becomes to max (2007 expected price, 2007 loan rate). The results are of no big difference between the two methods.

impacts on the acreage of the other three crops are small. 50% increase in wheat loan rate results in 0.25, 0.2 and 0.7 percent increases in corn, soybeans and wheat acreage, while 0.1 and 1.7 percent decreases in hay and CRP acreage respectively. Doubling wheat loan rate leads to about 11 percent increase in wheat acreage and 10 percent decrease in CRP acreage. The changes of the cropping acreage of the other three crops are less than 2 percent each. In summary, loan rates are effective in determining crop mix as long as they are not far below the market prices. Wheat acreage is more responsive to its loan rate than corn acreage in 2007 of the study region, which is consistent with the fact that the market price of corn is rising rapidly in recent years and far above the loan rate.

The impacts of total commodity program payment are examined in the third column. Program crops, corn, soybeans and wheat acreage increase by 0.9, 0.4 and 0.4 percent respectively with 50% increase in total commodity program payment. Non-program crop hay and CRP acreage are reduced by 2 and 1.3 percent respectively. The result implies crop acreage is unresponsive to total commodity program payment and crop specific payment may serve better in understanding acreage allocation.

The changes in crop shares are very small when total EQIP payment increases by 50%. Corn acreage increases by 1.2 percent, while the reduction of acreage for the other three crops and CRP varies from 0.5 to 1.7 percent. EQIP payment only affects acreage allocation marginally. Hay acreage decreases most with increase in EQIP payment, which supports the previous finding that hay lands may receive less EQIP subsidy. CRP enrollment rate slightly drops with higher EQIP payment (0.5 percent decrease with 50 percent increase in EQIP payment). That is natural since the estimation result suggests no clear relationship between the two programs.

Table 5.5 Simulation Results for the Midwest

				Commodity Program Changes					
				50% Increase in Corn Loan Rate		Double Corn Loan Rates		50% Increase in Wheat Loan Rates	
Crop	Actual Acres	Baseline Acres	% Diff.	Acreage Change	% Change	Acreage Change	% Change	Acreage Change	% Change
Corn	61057367	53677924	-12.09	8033	0.015	3791285	7.06	135519	0.25
Soybeans	42005378	46557639	10.84	1299	0.003	478602	1.03	83990	0.18
Wheat	26056785	22027978	-15.46	-5322	-0.024	-1424118	-6.47	163867	0.74
Hay	22127610	21480163	-2.93	-1895	-0.009	-1364284	-6.35	-25871	-0.12
CRP	16635860	19757512	18.76	490	0.002	-109111	-0.55	-326927	-1.65
Other	29626348	34008143	14.79	-2604	-0.008	-1372374	-4.04	-30578	-0.09

	Commodity Program Changes				Conservation Program Changes	
	Double Wheat Loan Rates		50% Increase in Commodity Program Payment		50% Increase in EQIP Payment	
Crop	Acreage Change	% Change	Acreage Change	% Change	Acreage Change	% Change
Corn	385263	0.72	481849	0.9	644084	1.2
Soybeans	167579	0.36	193733	0.42	-98343	-0.21
Wheat	2338359	10.62	91918	0.42	-133088	-0.6
Hay	-313839	-1.46	-451530	-2.1	-367007	-1.71
CRP	-1998775	-10.12	-249094	-1.26	-104165	-0.53
Other	-578587	-1.7	-66876	-0.2	58520	0.17

CHAPTER 6. CONCLUDING REMARKS

A multinomial fractional logit model is developed in this article to examine the impacts of CRP, loan rates, commodity program and EQIP payment on agricultural land use and crop acreage allocation in the Midwest region of the United States, given various revenues from crop production, input prices, and county physical attributes. Nine states and eleven years county level panel data are employed to estimate the acreage allocation among corn, soybeans, wheat, hay, and CRP participation simultaneously. The estimation results are generally consistent with previous research and agriculture fact in the study region.

Revenues from corn and wheat production are strongly positively related with the acreage allocated to them and negatively related with the acreage of other crops and CRP. As expected, an increase in the price of material inputs such as fertilizer will lead to lower share of the crop which uses that input most intensively and higher share of CRP. Significant differences in the cropping and CRP enrollment patterns are found among different MLRAs. Total commodity program payment received in a county is found to be positively related with program crop acreage and negatively related with non-program crop and CRP acreage. The influence of commodity loan rates is examined indirectly through expected crop revenues. They are found to be effective in determining crop mix and CRP acreage as long as not far below the market prices in the corresponding year. Not surprisingly, commodity loan rates may adversely affect CRP enrollment by substantially increasing the revenues from crop production. Such adverse effect is only trivial when the market prices of crops are high.

The estimation results suggest that expected revenues from crop production have significant, negative impacts on CRP enrollment, while current year CRP rental rate plays only a limited role. There are several reasons. First is the timing scheme of the program. Not surprisingly, the average rental rate for all active contracts is positively related with the share of land enrolled in CRP since the program contract lasts 10-15 years. Second, the bidding system during the program enrollment excludes some lands offered at a given rental rate. Finally, the stable returns provided by the program make the actual enrollment decision diverge from pure profit maximization. As anticipated, urban influence is found to affect CRP enrollment negatively. That is to say, fewer acres will be enrolled in the program in counties with high urban influence, i.e. in or adjacent to urban areas.

No statistical evidence is found that EQIP has an adverse impact on CRP participation, as implied by the theoretical model. Furthermore, the estimated coefficients suggest that the crop acreage allocation and decision of CRP enrollment are affected by total EQIP payment only marginally. Corn acreage increases most while hay acreage decreases most with increasing EQIP payment. The model also sheds some light on how CRP participation changes with increased returns from agricultural production. This study contributes to literature by providing a way to estimate CRP enrollment and multiple crop acreage allocation simultaneously with aggregate data.

Some limitations of the analysis are noted, total EQIP payment does not contain enough information on the cropping history of land participating in EQIP and practice specified payments of the program, which is crucial to analyze the influence of the program on acreage allocation. Like total EQIP payment, total commodity program payment does not explain much of the acreage allocation due to the lack of crop-specific program payment information. The overall accuracy of the estimates and the explanatory power of the empirical model may be improved if more detailed government program data were available. Finally, bootstrapping method may yield more reliable estimates of standard errors if time and resources permitted.

APPENDIX. THE ESTIMATION OF COUNTY-LEVEL PRICES/LOAN RATES

Because county-level market prices/ loan rates for corn, soybeans, and wheat are not available for the whole study period, I estimate them based on state-level marketing year average (MYA) prices, national loan rates and posted county price (PCP), which is assumed to contain information on the market price variance among counties in the same state. Calculated by USDA-FSA for the marketing loan repayment and loan deficiency payment (LDP) provisions, PCP reflects changes in prices in major terminal grain markets, corrected for the cost of transporting grain from the county to the terminal. I assume the ratio of county to state MYA prices for a crop in a given county is stable over the entire study period and can be mimicked by the ratio of PCP to state average PCP, i.e. $\frac{MYAP_{ijst}}{MYAP_{ist}} \approx \frac{PCP_{ijst}}{PCP_{ist}} = \alpha_{ijs}$, where α_{ijs} is a constant, $MYAP_{ist}$ and $MYAP_{ijst}$ are the MYA prices for crop i at year t in state s and county j of state s respectively, and

$PCP_{ist} = \frac{\sum_{j=1}^{J_S} PCP_{ijst}}{J_S}$, J_S is the number of counties in state s. Hence, $MYAP_{ijst}$ can be estimated as $\alpha_{ijs} MYAP_{ist}$. Since PCP data are only available for year 2004-2007, α_{ijs} is calculated as $0.25 \sum_{t=2004}^{2007} \frac{PCP_{ijst}}{PCP_{ist}}$. For county loan rates, only 2003-2007 data are available, therefore, 1996-2002 data are estimated as $LR_{ijst} = 0.2 LR_{it} \sum_{k=2003}^{2007} \frac{LR_{ijsk}}{LR_{ik}}$, where LR_{ijst} is the loan rate for crop i at year t in county j of state s and LR_{it} is the national loan rate for crop i at year t, $t = 1996, \cdots, 2002$. 2004-2007 PCP data are taken from USDA-FSA, 1996-2007 state MYA price data are taken from USDA-NASS, and county and national loan rates are obtained from USDA-FSA and various USDA agricultural statistical reports. Although the assumption of constant relationship between county and state/nation level data is relatively strong, it is partly supported by the 2003-2005 Iowa data. And this rough estimation can provide some insight on identifying the county variation of crop prices and loan rates given state/nation level data.

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