ESSAYS ON CONSERVATION ADOPTION AND DISCRETE CHOICE MODELING

by

SHENG GONG

B.S., University of Bedfordshire & China Agricultural University, 2007
M.S., University of Colorado Denver, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

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Manhattan, Kansas

2016

Abstract

This dissertation examines advances in applied discrete choice econometrics in applied settings and conservation practice adoptions by Kansas farmers. The research contributes to the literature by examining the use of discrete choice models to more deeply examine adoption of conservation practices and the choice of crop rotations in Kansas. In addition, a method for examining the proper functional specification of logistic regression models is explored.

The first essay aims to examine landscape, climatic, socio-economic and farm factors affecting choice of crop rotations by farm managers in dryland cropping systems. A particular emphasis is place on the role, insurance products (such as RA-CRC (Revenue Assurance/Crop Revenue Coverage) and ACRE (Average Crop Revenue Election)), as well as marketing options, and characteristics of farming operations. This paper models the joint adoption of crop rotations using a multinomial modeling framework which is used to estimate the probabilities of adopting different crop rotations. The data used for this paper was obtained from a mail survey in 2011 examining Kansas farmers' land use decisions and consisted of an eight-page survey with 46 questions, leading to more than 400 distinct variables.

The purpose of the second essay is to examine and analyze the adoption of conservation practices, no-till, cover crops and use of crediting of nutrients from manure, by Kansas farmers from both a joint and conditional perspective. This study develops a modeling framework that can analyze conditional adoption and examine farmers' joint and conditional adoption decisions. Estimates calculated from the model will allow for an assessment of the linkages between the adoption of different conservation practices, as well as the socio-economic factors that affect the likelihood of adopting conservation practices given other conservation practices have already been adopted on-farm.

The third essay aims to develop a robust test to examine the functional form of predictor/ index function in the logistic regression models as misspecified models can lead to biased and inconsistent estimates, and consequently inappropriate inferences. An Orthogonal Polynomial RESET test is developed to assess proper functional form for different functional form assumptions of the predictor/ index function, as well as provide guidance on the use of the test in applied logistic regression modeling. Monte Carlo Simulations are used to assess the viability of the test and compare it to similar tests found in the literature.

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Chapter 1 - Factors Affecting Crop Rotation on Dryland in KS

1.1 Introduction

Farm operators use crop rotations to provide economic and environmental benefits to their crop production systems including balancing soil fertility, enhancing carbon storage, preventing disease and pest pressures, improving soil structure, and reducing soil erosion (McSorley and Gallaher, 1994; 1995; Miglierina et al., 2000; Al-Kaisi, 2004;). Every crop has different requirements for the various nutrients it needs. When one crop is planted in a field for a long time period, the crop will use nutrients (e.g. potassium) from the soil (Macy, 1936). However, if another crop is grown on the same field that needs different nutrients (e.g. phosphate), then the field has a chance to replenish its nutrients over time. Thus, soil fertility can be balanced and improved by the use of a crop rotation (Baligar, 2001).

The life cycle of pests and harmful plant bacteria can be broken by crop rotation, as certain pests thrive only on certain crops (Hill, 1987). What's more, crop rotation is important with regards to productivity, it can contribute to improved crop yields for crops in rotations, resulting in potentially higher returns for farm operators (Karlen et al., 2006; Triplett, 2008). Other advantages of crop rotations are: decreased risk under adverse conditions; reductions in peak labor times; and better distributions of labor throughout the year, if planting and harvest times are different (Wall and Thierfelder, 2009). Furthermore, crop rotations are required conservation practice for some conservation programs, e.g. the Conservations Stewardship Program (Bergtold and Molnar, 2010). Rotation of crops is a potentially low cost conservation practice and the foundation for other conservation practices that may enhance the benefits of other conservation practices such as residue management, water management, crop nutrient management, and the use of cover crops (Witt et al., 2000; Shrestha et al., 2002; USDA-NRCS, 2008).

Crop rotation has been widely studied in the literature for its ecological and economic efficiency. Some studies have focused on the effect of crop rotations on soil and weed management, (e.g. Tisdall and Oades, 1980; Campbell and Zentner, 1993; Liebman, Matt and Dyck, 1993; Sartori et al., 2005). Few analyses have studied crop insurance and its role on crop rotation decisions. Crop insurance has been available since the 1930s, but it was not until the 1990s that the U.S. government emphasized the use of crop insurance by offering many new products and enhanced premium subsidization (Haken, 2012). Congress first authorized Federal crop insurance to help agricultural recover from the combined effects of the Great Depression and the Dust Bowl (Segal, 2005). The Federal Crop Insurance Corporation (FCIC) was established by the Federal Crop Insurance Act (FCI Act) in 1938 to provide crop insurance for America farmers. Crop insurance contributes to: loan security for lenders; risk management for producers; flexibility and confidence to market crops (Haken, 2012). Agricultural producers face two important risks: yield risk and price risk. Farm operators can purchase crop insurance to reduce both these risks. Crop insurance protects against low yields due to unavoidable perils and protects adverse fluctuations in market prices. By 2001, 58% of federally insured wheat acres were cover by either Revenue Assurance or Crop Revenue Coverage (Nimon and Mishra, 2001). Revenue Assurance (RA) provides coverage to protect against loss of revenue caused by low prices or low yields or both. Revenue Assurance is available for barley, canola/rapeseed, cotton, corn, rice, soybean, sunflowers, and wheat (USDA, RMA). Crop Revenue Coverage (CRC) offers revenue protection based on price and yield expectations that pay for losses below the guarantee at the higher of an early-season price or the harvest price, if the harvest price option is selected. Crop Revenue Coverage is available for cotton, corn, grain, sorghum, rice, soybeans, and wheat (USDA, RMA). Under Average Crop Revenue Election (ACRE), producers may receive revenue-based payments as an alternative to receiving price-based counter-cyclical (CC) payments in addition to regular crop insurance products. Average Crop Revenue Election is available for wheat, barley, oats, sorghum, corn, cotton, soybeans, canola and peanuts (USDA, FSA).

Chambers (1989), Nelson and Loehman (1987) both stated that if the crop insurance is fair enough and providing full coverage, then a risk-averse farmer will make the same production decisions as a risk-neutral one. As a result, insurance helps farm operators adopt more expensive and riskier crops. Hazell et al. (1986) found that the actuarially fair insurance product with full coverage lead to adopting riskier crops. Wu (1999) mentioned the importance of analyzing adverse selection as differently insured and uninsured farms in cropping patterns would reflect adverse selection. Adverse selection describes a situation that farmers' demand for crop insurance is positively correlated with their risk of crop loss. Thus, it is highly likely that the availability and use of insurance products will directly impact the choice of crops in rotation.

The purpose of this study is to examine landscape, climatic, socio-economic and farm factors affecting choice of crop rotations by farm managers in dryland cropping systems. A particular emphasis is place on the role, insurance products (such as RA-CRC (Revenue Assurance/Crop Revenue Coverage) and ACRE (Average Crop Revenue Election)), as well as marketing options, and characteristics of farming operations. The paper will employs a joint adoption approach of crop rotations using a multinomial modeling framework taking account of the endogeneity of the insurance and crop rotation choice. The framework is used to estimate the probabilities of adopting different crop rotations and impact of different factors. These estimates allow for an assessment of linkages between the adoption of crop insurance, as well as the socio-economic factors that affect the likelihood of adopting different crop rotations.

1.2 Literature Review

Crop choice within rotations has been examined in a number of different studies. Campbell and Zentner (1993) did a crop rotation experiment in southwestern Saskatchewan and found soil organic matter in the well-fertilized fallow-winter cereal-wheat rotation remained the same because of the reduced soil erosion and more efficient use of nitrogen. Hennessey (2006) employed quasi-convex choice functions using a Markov-chain modeling framework to develop price-independent and price-dependent principles related to crop rotation. Seo and Mendelsohn (2008) examined crop choice adoption using a multinomial model in a joint framework to analyze Southern American farmers' adaptation to climate change. Livingston et al. (2012) conducted a study examining crop choice and fertilizer applications using stochastic dynamic optimization. They parameterized a baseline model for a representative acre in Iowa and found crop rotations, regardless of prices, were extremely close to optimal. Du et al. (2012) used Markov chain models in a Bayesian framework to analyze how inputs affected crop yield skewness, which became more negative when the crop rotation was switched from corn-corn to corn-soybean, as corn yield skewness decreased with the increase in low levels of nitrogen use. More negative skewness would suggest larger indemnity payouts and extent of crop insurance subsidy costs.

A limited number of studies have examined the effect of crop insurance. Wu (1999) analyzed how crop insurance affected crop mix and chemical use in Central Nebraska. He found that crop insurance would shift land from hay and pasture to corn, and crop insurance lead to an increase in chemical use. Sherrick et al. (2004) employed a two-stage estimation procedure to analyze how farmers' crop insurance decisions were influenced by risk perceptions, competing risk management options as well as structural and demographic differences. However, there are few studies that examine the effect of crop insurance on crop rotations. This study aims to examine how crop rotation is affected by the use of insurance products, as well as marketing options, and characteristics of the farming operations. Stinner and House (1989) emphasized that famers must use a system approach by collecting all the interrelated factors together when addressing conservation needs. Pannell et al. (2006) reviewed a large number of these factors including farm demographics, farm characteristics, cultural barriers, social networks, farmer personalities, risk perceptions, economic well-being, land tenure and other socio-economic factors that may drive conservation practice adoption, including crop rotations and crop choices.

1.3 Data

The data used for this paper was obtained from a mail survey in 2011 examining Kansas farmers' land use decisions. The survey contained questions about how farmers make land-use decision on a wide array of topics. The survey asked respondents to address their goals in farming; participation in conservation programs; use of irrigation; willingness to grow biofuel crops; views related to price, yield, and weather risk; use of insurance and marketing options; and characteristics of the farming operations. The survey consisted of an eight-page survey with 46 questions, leading to more than 400 distinct variables in the survey dataset.

The survey targeted Kansas farmers with 50 or more acres of arable land and over $10,000 in gross farm annual income in 2010 to leave out hobby farmers and part-time producers. Names and addresses were obtained for approximately 23,000 farms meeting these criteria from FarmMarketID (a marketing technology company, www.FarmMarketID.com). A random sample of 10,000 farmers was drawn from the FarmMarketID data, and then sent to respondents following the approach suggested by Dillman (2007). A cover letter explaining the purpose of the survey, the composition of the research team, how the survey results would be used, and how individual survey responses would be safeguard was included.

A total of 2,317 surveys with usable data were received out of the 10,000 sent, while 684 were undeliverable or non-applicable (e.g. farmer was deceased or retired), resulting in a response rate of approximately 25 percent. Due to missing data (either from questions not answered or entry of an implausible value), 1,716 survey were used for the analysis in this study.

To complement the survey data, our analysis also draws upon data on soil characteristics at the county level from the Soil Survey Geographic (SSURGO) database (Soil Survey Staff, USDA-NRCS, 2010). Soils data used in this study include the kw-factor that examines soil erosion potential. County level averages for each soil variable were obtained for all 105 counties across the state of Kansas by taking spatially weighted averages across soil polygons using the percent of area of arable land represented by each soil polygon as the weighting factor. Soil variable values where then assigned to each respondent as the spatially weighted average of the associated county level averages or values using the percentage of their land operated in a given county as the weighting factor (Caldas et al., 2013).

Summary statistics for explanatory (independent) variables derived from the survey, as well as the soil variable are provided in Table 1. Forty- one percent of survey respondents used Average Crop Revenue Election (ACRE) in 2010 while sixty-three percent of survey respondents chose Revenue Assurance and/or Crop Revenue Coverage. Less than half of survey respondents described themselves as being a risk avoider. Fifty-three percent of survey respondents had a member of the household working off the farm, which was treated as "employment" in Dr. D'Souza's adoption model (D'Souza et al., 1993). In general, off-farm income can subsidize farm income in tough times and allow for additional investment opportunities on the farm. With such a “supplement”, farmers may be encouraged to undertake riskier crop rotations, influencing their adoption behavior.

Bergtold and Molnar (2010) used a polychotomous-choice selectivity model to examine the factors affecting the adoption of different conservation practices by small and limited resource farmers in the Southeast. Based on what they found, the result indicated farm characteristics (e.g. size of farm operation, participation in Environmental Quality Incentives Program, raise livestock and rent acres) and farmer demographics and characteristics (e.g. college) affected conservation practice adoption. Other farmer demographics and characteristics (e.g. risk type, families employed off farm, experience and gender) will also play an important role on practice adoption decisions (Feder, 1980; D’Souza et al., 1993). Cooper and Keim (1996) and Cooper (2003) illustrated farmers were encourage to adopt environmentally sound management practices with the use of incentive government payment. To examine how crop rotations are affected by the use of insurance products, this study includes such characteristics of farming operations, farmer demographics and characteristics, landscape attributes, as well as marketing options and government payment.

Summary statistics were compared to statistics in the 2007 Agricultural Census (USDA-NASS, 2007). Survey respondents have been farming on average 36 years, while the 2007 Agricultural Census (USDA-NASS, 2007) indicates the number of years that farmers have been farming their present farm is 26. This difference may be caused by the nature of designed questions. The survey asked total years farming, but the agricultural census asked the number of years working on their present farms. It shows that survey respondents do not only work on their family farm but also other farms and off-farm. Means from 2007 Agricultural Census data (USDA-NASS, 2007) were computed at the state level for all farms with more than 50 acres of agricultural production. The average farm size reported from census is 863.01 acres while the average farm size of survey respondents is 1196.27 acres. Farms with more than 50 acres of crop land production and $ 10,000 in gross farm sales were surveyed, which eliminated a significant number of farms in Kansas. Finally, the 2007 Agricultural Census (USDA-NASS, 2007) indicates that 11 percent of farmers in Kansas are female. In contrast, only 5 percent of the survey respondents are female. This may be due to the fact that female farm operators may run smaller farms on average.

There were 13 crop rotation choices determined for dryland production in the survey as showed in Table 2. We did not model all possible rotations, but used crop rotations commonly identified by farm managers. Four of the rotations (continuous corn, continuous sorghum, corn-sorghum and continuous soybean) were dropped, because they did not have sufficient observations to adequately estimate relationships. Table 2 indicates 17.78% of participants used a corn-soybeans-wheat rotation. The second largest group of participants used a wheat-sorghum-fallow rotation. In contrast, a rotation of sorghum-soybean was only adopted by 2.66% of the respondents.

1.4. Model

Let δ_m, $m = 0, 1, \ldots, M$, be a specific crop rotation, where δ_m is a (r x 1) vector of indicator variables (Y_r) equal to 1 if the r^{th} rotation is used. Under the assumption of utility maximization, a farmer i derives utility from choosing crop rotation m with a given set of attributes /factors X_i that maximizes utility u_{mi}. A utility framework was chosen because farmers may not be strictly motivated by factors related to profit maximization (Robinson et al., 1984;

Skaggs et al., 1994). Crop decisions may be a function of factors that impact both expected profit and other motives, which impacts a farmer's utility (Chouinard et al., 2008). These factors may include farmer perceptions; age and other demographics; and employment (Barry and Baker, 1977; Skaggs et al., 1994).

The observed choice of rotation can be represented by a random utility model:

$$u_{mi} = V_m\{E\,[R(X_i)];\; Z_i;\; \beta_m\} + \varepsilon_{mi}, \qquad (1)$$

where V_m is the deterministic component of utility, *E[R]* is the deterministic component of expected profit, X_i is a set of individual specific explanatory variables affecting profit on practices, Z_i is a set of other variables that do not affect profit on practices, β_m is a vector of parameters specific to bundle *m*, and ε_{im} is the random or unobserved component of utility (Louviere et al., 2000). It is assumed that V_m is linear in X_i and Z_i. A farmer will choose crop rotation *m* if:

$$u_{mi} = max(u_{1i}, \dots, u_{mi}, \dots, u_{Mi}) \qquad (2)$$

If the residuals, ε_{mi}, *m = 0,1, …, M* are independently distributed with extreme value distribution (type 1), then the probability of a farmer choosing δ_m can be written as:

$$\pi_m = \Pr(T = m) = \frac{\exp(V_m\,[E\,(R(X_i));Z_i;\,\beta_m)}{\sum_{s=1}^{M}\exp(V_s\,[E\,(R(X_i));\,Z_i;\,\beta_s)} \qquad (3)$$

where *T* is a polychotomous index equal to *m* if crop rotation *m* is chosen.

Following the methods in Bergtold and Molnar (2010) and Wu and Babcock (1998), a polychotomous-choice selectivity model of adoption is used following a multinomial logistic regression model. The adoption of these rotations is influenced by a number of explanatory factors, including experience, farm sales, farm size, land tenure, participation in conservation programs, farmer perceptions, different types of insurances, and a number of demographic variables.

As suggested by Wu (1999) and Hazell et al. (1986), the use of crop insurance products may impact the choice of crop, and in turn rotation, suggesting that the use of crop insurance products is endogenous. To correct for this, we assume that the use of crop insurance (an observed binary decision) is function of a number of explanatory factory, including: raising livestock, being risk averse, working off-farm, farm experience, land tenure arrangements, farm size, receipt of government payments, college, gender, farm sales, and use of marketing contracts (Wu, 1999). In addition, we incorporate the use of instruments for identification purpose and provide a strong instrumented regressor in the primary regression model. We utilize the variable "Assets" as an instrument as it is likely correlate with the use of insurance products (e.g. presence of debt increases the need for insurance products to be able to pay off the debt in years with low returns) (Sherrick et al., 2004), but independent of the choice of crop rotation.

That is:

$$I_i^* = \alpha' W_i + u_i,\ I_i = \begin{cases} 1, if\ insurance\ is\ purchased \\ 0, otherwise \end{cases}, \quad (4)$$

where I is the observed choice of using insurance products, $W_i$is a set of explanatory variables impacting the choice of purchasing insurance, and u_i is an IID error term distribution extreme value type 1. The model represented by equation (4) can be estimated as a standard logistic regression model. Following Dalton et al. (2011), the predicted use of crop insurance products, $\hat{I}$, is used as an instrumental variables in the multinomial model to control for endogeneity between use of crop insurance and choice of crop rotation.

In this study, it is expected that use of insurance products can play a significant role in the decision-making process and further, we expect farm operators are encouraged by the application of insurance products.

Farm and famer characteristics should impact the choice of adoption as indicated by the literature reviews. In addition, government payment and market contract should also motivate farm operators as they make management decisions to maximize their profits.

It is difficult to interpret the meaning of coefficients in the multinomial logistic model. The marginal effects of explanatory variables on the probability of choosing or adopting a crop provide a measure to assess the impact of specific explanatory factors. The marginal effects provide both a sign and magnitude for the marginal change of an explanatory variable on the probability of adoption. The marginal effects can be expressed as (Greene, 2012):

$$\frac{\partial \pi_m}{\partial X_k} = \pi_m[\beta_m - \sum_{s=0}^{M} \pi_s \beta_s] \qquad (5)$$

It should be noted that the sign of the marginal effects may not follow the sign of β_m for $m = 0,1,\ldots,M$. Standard errors for all marginal effects are estimated using the delta method (Greene, 2012).

1.5. Results and Discussion

For this study, the multinomial model is estimated using NLOGIT 4.0 for all nine crop rotations with sorghum and soybean as the base. MATLAB is then used to estimate associated asymptotic standard errors. The McFadden Pseudo R-square for the regression is equal to 0.051 for the instrumental insurance regression examining insurance use and 0.119 for the multinomial crop rotation model. Marginal effects of the explanatory variables are of more interest than coefficient estimates, especially for the multinomial model, given they examine the change in probability of choosing a crop rotation given a one unit or incremental change in the explanatory variables being examined. Parameter estimates, fit statistics, marginal effects and associated asymptotic statistics for the instrumental insurance regression are presented in Table 3.

Parameter estimates, fit statistics, marginal effects and associated asymptotic statistics for the crop rotation multinomial model are presented in Tables 4 and 5.

1.5.1 Crop Insurance Product Usage

Farm size, government payment, farm operation sales and farmers' assets financed with debt increased the probability of purchasing crop insurance. With more acres rented, larger farm size and more gross values in crop production, farm operators are more likely to seek and require crop insurance to protect their investment and income for the enterprise. Wu (1999) mentions that farmers treat agricultural crop insurance as a mechanism to protect future farm income as government commodity programs have been downsized. Thus, as farms increase in size and diversity, insurance helps to protect against larger risks from operating on more land and more crops. Farms that are more leveraged are more likely to require insurance to help reduce risk (Sherrick et al, 2004). Raising livestock, off-farm employment, farm experience and land rented decrease the likelihood of purchasing crop insurance. Farm operations are more heavily invested in livestock may use cropping operations as a major source of feed, reducing the need for crop insurance. Describing yourself as a risk-avoider, having a college degree, being a male farm operator and decisions influenced by market contract did not play a significant role in determining the likelihood of purchasing crop insurance. Sherrick et al. (2004) found that larger farm size and more land rented increased the probability of purchasing crop insurance by farmers in Illinois, Indiana and Iowa. In addition, they also found risk perceptions, risk management scores and more highly leveraged farms increased the likelihood of using crop insurance, but nothing to do with raising livestock. Interestingly, they stated that farmers preferred revenue insurance to yield insurance when they have a larger farm size.

1.5.2 Crop Rotation Choice

Examining the marginal effects of different explanatory factors on the choice of crop rotations shows that different factors impact different crop rotation decisions.

Sorghum-Soybean (R-S): Describing yourself as a risk-avoider and government payment increased the likelihood of adopting a sorghum-soybean rotation by 4.6% and 0.1%, respectively. Being a male farm operator, participation in EQIP and/ or CSP, receiving government payment from no tillage and higher risk of soil erosion decreased the likelihood of adopting a sorghum-soybean rotation. The purchase of crop insurance did not affect the likelihood of choosing a sorghum-soybean rotation.

Corn-Soybean (C-S): Being a male farm operator, farm operation sales, receiving government payment from no-tillage and higher risk of soil erosion increased the likelihood of using a corn-soybean rotation. Farm size, government payment and possibility of extremely dry periods reduced the probability of choosing corn-soybean rotation. Given the water requirements for corn production, the possibility of a drought decreased the likelihood of using this rotation by 5.8% at a one percent level of significance. Given that much of corn and soybeans is grown using no tillage and corn is a heavy residue crop (Canales, 2016), farmers' wanting to reduce soil erosion would likely choose this type of rotation to protect the soil. Given the strong agricultural markets in the year of the survey, farmers seeking government agricultural payments via crop production would not likely have adopted this or similar crop rotations.

Corn-Soybeans-Wheat (C-S-W): Participation in EQIP and/ or CSP, receiving government payment from no-tillage and higher risk of soil erosion increased the likelihood of adopting corn-soybean-wheat rotation. Government payment reduced the likelihood of adopting this rotation by 0.4% at a 5 percent level of significance. Similar to the adoption of corn-soybean, farmers seeking government agricultural payments via cop production would not likely have adopted this crop rotation.

Continuous Wheat (W-W): Describing yourself as a risk-avoider and use of market contract increased the likelihood of adopting a continuous wheat rotation by 5.0% and 4.0%, respectively. Farm experience, farm operation sales, participation in EQIP and/ or CSP, receiving government payment from no-tillage, higher risk of soil erosion and possibility of extremely dry periods lowered the probability of choosing continuous wheat rotation. Much of the wheat in Kansas is managed using some form of tillage operation (Canales, 2016). Thus farmers who practice no-tillage and/or have more degraded lands are less likely to grow rotations with wheat. Risk averse farmers may decide to grow this rotation (or wheat-fallow) out of familiarity and the certainty it provides based on historical experience.

Wheat-Fallow (W-F): Describing yourself as a risk-avoider and government payment increased the likelihood of adopting a wheat-fallow rotation by 4.6% and 0.1%, respectively. Being a male farm operator, participation in EQIP and/ or CSP, receiving government payment from no-tillage and higher risk of soil erosion reduced the likelihood of using a wheat-fallow rotation.

Wheat-Sorghum-Fallow (W-R-F): Farm size, government payment, receiving government payment from no-tillage and possibility of extremely dry periods increased the likelihood of choosing a wheat-sorghum-fallow rotation. Sorghum is a drought-resistant crop. Thus, periods of dryer weather would likely increase the use of dryland rotations with this crop, by 4.1% in this study. Use of market contract, farm operation sales and higher risk of soil erosion lowered the likelihood of adopting wheat-sorghum-fallow rotation. Again, wheat is usually managed using some form of tillage operation. On the other hand, sorghum and corn are managed predominately with no-tillage. That is, tillage practices tend to be crop specific (Canales, 2016).

Wheat-Corn-Fallow (W-C-F): Government payment and receiving government payment from no-tillage increased the likelihood of adopting wheat-corn-fallow rotation by 0.1% and 4.5%, respectively. Higher risk of soil erosion lowered the likelihood of adopting wheat-corn-fallow by 21.7% at a one percent level of significance.

Wheat-Soybean (W-S): A Higher risk of soil erosion increased the likelihood of adopting a wheat-soybean rotation by 26.2%, while having a college degree decreased the probability of choosing this rotation by 2.9%.

Wheat-Soybean-Sorghum (W-S-R): Having a college degree, receiving government payment from no-tillage and possibility of extremely dry periods increased the likelihood of adopting wheat-soybean-sorghum by 1.9%, 2.3% and 3.0%, respectively.

Farmers with more years of experience may not be willing to adopt an unfamiliar risky crop rotation (Pannell et al., 2006). In this study, similarly, farmers with more farm experience were 0.2% less likely to adopt continuous wheat rotation. Landscape variables (KW Factor) and no-tillage variable were significant for many crop rotations. These two factors are likely to partially drive the choice of crop mix. It is important to note the risk aversion defines farmers' tendency to avoid risks in their decision-making and empirical evidences show that farmers vary in their personal degree of risk aversion (Marra et al., 2003; Pannell et al., 2006). In this study, risk-averse farmers are more willing to adopt sorghum-soybean, continuous wheat and wheat-fallow rotations. We expect risk aversion factor has impact on choices of every rotation, but its power may be dampened by use of insurance products (e.g. ACRE, RA_CRC).

1.6. Conclusion

To understand factors affecting choices on crop rotations, a multinomial logit model was developed to examine how choice of crop rotations would be affected by the use of various insurance products, which include Revenue Assurance/Crop Revenue Coverage and Average Crop Revenue Election, as well as marketing options and characteristics of the farming operations. The multinomial framework was then used to estimate the marginal effects of these different factors on the probability of choosing different crop rotations. As found in this study, the presence of insurance had no direct impact on the choice of selected crop rotation in this paper. This may due to the fact of high crop prices during the time the survey was conducted, potentially reduced the effect of insurance on crop rotation choice. In addition, all the crops investigated were primary commodity crops that have insurance available, which may lessen the impact of crop insurance on choice of crop rotation. On the other hand, it may be that use of crop insurance is crop specific as found in studies examined in the literature review and not impacted by rotation of crops. This could be due to the fact that crop insurance can be purchased annually and requires a history of using the crop on-farm (i.e. that you have historical yields).

Wu (1999) indicates that crop rotations are usually treated as a means of risk management to help mitigate risk. Farmers that use crop rotations may be more risk averse (Fuglie and Bosch, 1995) and more likely to purchase crop insurance (Wu, 1999). Finding here would suggest that risk aversion does impact choice of crop rotation, but famers who identified themselves as a risk avoider were just as likely to purchase crop insurance as other farmers surveyed. It is not clear from the results in this study that crop insurance has an appreciably significant impact on choice of crop rotation, but in fact the choice of purchasing crop insurance may be impacted by choice of crop in rotation, as suggested by Wu (1999). This is an area for future study.

The estimated marginal effects from both crop rotation and crop insurance usage provide statistical information that may help identify and distinguish how farm and farmer characteristics, government payment and market options, and especially insurance products, affect the choice of crop rotations in dryland cropping systems. This study shows the increasing probabilities of using crop insurance as farm size, government payment, farm operation sales and farmers' assets financed with debt went up. But, in contrast, raising livestock, off-farm employment, farm experience and land rented decreased the likelihood of purchasing crop insurance.

Crop insurance has been playing an increasingly significant role as an instrument of the agricultural policy and agricultural conservation practices. Federal crop insurance programs may require conservation components, which may include crop rotations.

Findings from this study suggest that purchase of crop insurance does not significantly drive the choice of crop rotations. If more conservation oriented crop rotation is a goal of federal programs, then mandating them for purchase of deferral crop insurance products may not be an effective policy tool, which may translate to other conservation practices too. It may be that use of deferral conservation programs (e.g. EQIP) and promotion of conservation practices (e.g. no tillage) may be a better route for promoting crop rotation practices that will help to reach federal conservation goals.

A number of limitations in this study do exist though. Farmer's assets financed with debt could be a potentially weak instrumental variable and other potential instruments need to be explored. Farmers' insurance decision was specified as a dichotomous choice and the data does not include information on coverage level or for what crop insurance was purchased. A more well-defined crop insurance variable that is crop specific that possibly includes coverage levels could lead to more insightful findings in the future. The choice of tillage practice may be endogenous with choice of crop rotation, but this was not modeled here (as choice of tillage was based on receipt of an incentive payment) and should be explored more in the future. An unexpected result that necessitates deeper exploration is why being a risk avoider was insignificant in the insurance regression, when this would be expected to be significantly positive. Furthermore, the study could go deeper by exploring specific hypotheses rather than a more correlation based analysis. For future research, the joint probabilities of adopting two or more crops can be studied and developed to capture the dependence between adopting different crop choices based on various insurance products. Moreover, the framework could be built expanded to examine the sequential adoption of crops over time and the impact of various insurance products.

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Table 1.1. Definition of Variables (*N* = 1716)

Variables	Mean	Standard Deviation	Definition
			Landscape Variables
KW Factor	0.30	0.10	Spatially weighted average K-W factor in the counties farmers operate
			Climatic Variables
Possibility Dry period	0.31	0.46	Planting decisions by the farm operator are influenced by the possibility of extremely dry periods in 2010 (1= yes, 0 =no)
			Farmer Characteristics
Experience	35.85	15.04	Number of years the operator has been farming
College	0.34	0.47	Farm operator has earned a college degree (1 = yes, 0 = no)
Gender	0.95	0.23	Gender of farm operator (1 = male, 0 = female)
Off-Farm Employ	0.53	0.50	Farmers or their immediate families employed off the farm (1 = yes, 0 = no)
Risk Avoider	0.40	0.49	Farmer describes themselves as a risk avoider (1 = yes, 0 = no)
			Farm Characteristics
Insurance	0.67	0.47	Use and purchase of ACRE or RA-CRC crop insurance product (1 = yes, 0 = no)
Farm Size	1166.41	6699.15	Total cropland acres operated in 2010
Livestock	0.52	0.50	Cattle and/or hogs raised on farmers' operation in 2010 (1 = yes, 0 = no)
Gross Value	284161.30	415483.90	Total value of sales from farm operations ($)
Market Contract	0.22	0.41	Farmers' planting decisions are influenced by marketing contracts (1 = yes, 0 = no)
Rent Acres	0.43	0.37	Percent of total acres rented
Government Payment	5.61	8.14	Percent of the total gross value of sales from the operation in 2010 was from government payments
Variability Crop Prices	0.33	0.47	Planting decisions were influenced by changes in crop prices in 2010
EQIP and CSP	0.12	0.32	Farmer participates in Environmental Quality Incentives Program (EQIP) and/or Conservation Security/Stewardship Program (CSP) in 2010 (1 = yes, 0 = no)
Assets	17.80	22.47	Percentage of a farmer’s assets from the operation financed with debt in 2010
No Tillage	0.69	0.46	Receive any government conservation payments for no-tillage/conservation tillage (1=yes,0=no)

Standard deviations are provided for continuous variables, but not for binary variables, as they are function of the mean. Thus, the standard deviation of all binary variables is calculated as:√(p(1-p)), where p is the mean of the binary variable.

Table 1.2. Summary of Crop Rotations

Crop Rotations		Corn	Sorghum	Soybean	Wheat	Percentage of Obs.
C-C	continuous corn	X	-	-	-	0.52%
C-S	corn-soybeans	X	-	X	-	14.69%
C-S-W	corn-soybeans-wheat	X	-	X	X	17.78%
R-R	continuous sorghum	X	X	-	-	0.62%
R-S	sorghum-soybean	-	X	X	-	2.66%
W-W	continuous wheat	-	-	-	X	9.65%
W-F	wheat-fallow	-	-	-	X	11.70%
W-R-F	wheat-sorghum-fallow	-	X	-	X	17.21%
W-C-F	wheat-corn-fallow	X	-	-	X	6.28%
C-R	corn-sorghum	X	X	-	-	0.10%
W-S	wheat-soybean	-	-	X	X	10.32%
W-S-R	wheat-soybean-sorghum	-	X	X	X	4.56%
S-S	continuous soybean	-	-	X	-	1.09%
N/A	all the other rotations left	-	-	-	-	2.82%

Table 1.3. Parameter Estimates, Fit Statistics and Marginal Effects for the Insurance Adoption Model

insurance	Coefficient	Marginal Effects
Livestock	-0.857***	-0.182***
	(0.111)	(0.023)
Risk Avoider	-0.015	-0.003
	(0.109)	(0.023)
Off-Farm Employ	-0.197*	-0.043*
	(0.115)	(0.025)
Experience	-0.010***	-0.002***
	(0.004)	(0.001)
Rent Acres	-1.932e-4**	-4.170e-5**
	(0.000)	(0.000)
Farm Size	1.857e-4**	4.010e-5**
	(0.000)	(0.000)
Government Payment	0.011**	0.002**
	(0.005)	(0.001)
College	-0.090	-0.019
	(0.114)	(0.025)
Gender	-0.331	-0.067
	(0.288)	(0.055)
Market Contract	0.148	0.031
	(0.136)	(0.028)
Gross Value	5.830e-7***	1.260e-7***
	(0.000)	(0.000)
Assets	0.005**	0.001**
	(0.003)	(0.001)
Constant	1.617***	N/A
	(0.348)	N/A
Fit Statistics		
Log Likelihood		-1031.606
Likelihood Ratio Test Statistic		110.050
McFaddden Psuedo R2		0.051
Number of Observations		1716

1. Asympotic standard errors are presented in parentheses;
2. *, **, *** indicate statistical significance at 10%, 5% and 1% level, respectively.

Table 1.4. Parameter Estimates and Fit Statistics for the Multinomial Logit Model of Crop Rotations

Variables	Crop Rotations							
	C-S	C-S-W	W-W	W-F	W-R-F	W-C-F	W-S	W-S-R
Insurance	7.300**	6.992**	4.700	9.587***	9.447***	10.805**	3.172	9.895**
	(3.581)	(3.377)	(4.227)	(3.793)	(3.423)	(4.390)	(4.068)	(4.953)
Livestock	1.016	0.893	0.496	0.978	1.333**	0.936	-0.005	1.174
	(0.665)	(0.620)	(0.785)	(0.692)	(0.627)	(0.769)	(0.758)	(0.907)
Risk Avoider	0.306	0.260	1.042***	0.942***	0.508***	0.510*	0.330	0.147
	(0.207)	(0.197)	(0.224)	(0.215)	(0.197)	(0.267)	(0.218)	(0.288)
Off-Farm Employ	0.536**	0.229	0.209	0.422	0.379	0.201	0.209	0.691**
	(0.252)	(0.237)	(0.281)	(0.262)	(0.238)	(0.305)	(0.273)	(0.343)
Experience	0.026**	0.021**	-0.002	0.026**	0.019*	0.026**	0.016	0.018
	(0.011)	(0.010)	(0.013)	(0.011)	(0.010)	(0.013)	(0.012)	(0.015)
Rent Acres	0.001***	0.001***	0.001***	6.034e-4***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm Size	-0.001***	-4.964e-4***	3.566e-4	-2.097e-4	-1.661e-4	-2.133e-4	-0.001***	-4.737e-4*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Government Payment	-0.138***	-0.089***	-0.037***	-0.034***	-0.034***	-0.034**	-0.056***	-0.084***
	(0.022)	(0.017)	(0.013)	(0.010)	(0.010)	(0.014)	(0.017)	(0.026)
College	-0.129	-0.173	0.085	0.135	-0.014	0.146	-0.348	0.374
	(0.224)	(0.212)	(0.246)	(0.235)	(0.212)	(0.275)	(0.245)	(0.302)
Gender	1.711**	0.678	1.653**	-0.359	0.249	1.148	0.333	0.733
	(0.702)	(0.508)	(0.813)	(0.446)	(0.463)	(0.818)	(0.551)	(0.733)
Market Contract	-0.334	-0.296	0.311	0.134	-0.517*	-0.141	-0.237	-0.437
	(0.294)	(0.273)	(0.319)	(0.298)	(0.280)	(0.347)	(0.318)	(0.396)
Gross Value	4.840e-7	1.140e-8	-1.540e-6**	-6.660e-7	-1.270e-6**	-2.370e-7	-2.290e-8	-1.180e-6
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EQIP and CSP	-0.125	0.058	-0.979**	-0.798**	-0.181	-0.421	-0.398	-0.451
	(0.292)	(0.266)	(0.422)	(0.369)	(0.276)	(0.369)	(0.337)	(0.435)
No Tillage	0.936***	1.310***	-0.248	-0.362	0.979***	1.534***	0.533**	1.223***
	(0.216)	(0.214)	(0.229)	(0.222)	(0.210)	(0.343)	(0.223)	(0.332)
KW Factor	9.704***	5.144***	-1.399	-5.706***	-5.183***	-3.792***	4.344**	0.321
	(2.215)	(1.562)	(1.138)	(0.950)	(0.906)	(1.162)	(1.731)	(1.616)
Variability Crop Prices	0.152	0.249	-0.055	-0.039	0.102	0.033	0.106	-0.179
	(0.224)	(0.211)	(0.252)	(0.242)	(0.216)	(0.287)	(0.240)	(0.313)
Possibility Dry Period	-0.560**	-0.126	-0.404	0.109	0.233	-0.115	-0.141	0.599**
	(0.239)	(0.216)	(0.261)	(0.238)	(0.213)	(0.289)	(0.246)	(0.293)
Constant	-10.918***	-8.356***	-4.779	-6.265*	-6.954**	-10.888***	-4.472	-10.360**
	(3.267)	(2.984)	(3.710)	(3.252)	(2.954)	(3.807)	(3.574)	(4.342)

Fit Statistics	
Log likelihood	-3212.503
Likelihood Ratio Test Statistic	867.610
McFaddden Psuedo R2	0.119
Number of Observations	1716

Note: CS-corn-soybean, CSW-corn-soybean-wheat, WW-continuous wheat, WF-wheat-fallow, WRF-wheat-sorghum-fallow, WCF-wheat-corn-fallow, WS-wheat-soybean, WSR-wheat-soybean-sorghum. Asymptotic standard errors are presented in parentheses. *, **, *** indicate statistical significance at 10%, 5% and 1% level, respectively.

Table 1.5. Marginal Effects for the Multinomial Logit Model of Crop Rotation

Variables	Crop Rotations								
	R-S	C-S	C-S-W	W-W	W-F	W-R-F	W-C-F	W-S	W-S-R
Insurance	0.296	0.132	0.077	-0.135	0.296	0.379	0.204	-0.302	0.145
	(0.253)	(0.287)	(0.307)	(0.261)	(0.253)	(0.299)	(0.186)	(0.280)	(0.182)
Livestock	0.021	0.037	0.021	-0.019	0.021	0.080	0.005	-0.071	0.018
	(0.046)	(0.053)	(0.056)	(0.049)	(0.046)	(0.054)	(0.032)	(0.052)	(0.033)
Risk Avoider	0.046***	-0.010	-0.021	0.050***	0.046***	0.007	0.004	-0.008	-0.012
	(0.014)	(0.017)	(0.018)	(0.014)	(0.014)	(0.017)	(0.011)	(0.014)	(0.011)
Off-Farm Employ	0.013	0.031	-0.013	-0.007	0.013	0.011	-0.006	-0.009	0.017
	(0.017)	(0.020)	(0.022)	(0.017)	(0.017)	(0.021)	(0.013)	(0.018)	(0.013)
Experience	0.001	0.001	0.001	-0.002*	0.001	3.482e-4	4.634e-4	-7.060e-5	5.090e-5
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Rent Acres	-1.690e-5	3.160e-5	3.340e-6	2.270e-5	-1.690e-5	1.350e-5	5.060e-6	3.040e-5	1.030e-5
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm Size	1.250e-5	-6.940e-5***	-5.640e-6	2.830e-6	1.250e-5	2.950e-5**	9.140e-6	-2.660e-5	-2.220e-6
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Government Payment	0.001**	-0.009***	-0.004**	0.001	0.001*	0.003***	0.001**	0.001	-0.001
	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
College	0.014	-0.008	-0.019	0.010	0.014	-2.480e-4	0.009	-0.029*	0.019*
	(0.016)	(0.019)	(0.020)	(0.015)	(0.016)	(0.019)	(0.012)	(0.017)	(0.011)
Gender	-0.088***	0.130*	-0.007	0.089	-0.088***	-0.048	0.031	-0.035	0.003
	(0.029)	(0.068)	(0.054)	(0.057)	(0.029)	(0.044)	(0.039)	(0.040)	(0.028)
Market Contract	0.029	-0.017	-0.013	0.040**	0.029	-0.050**	0.005	-0.005	-0.010
	(0.020)	(0.024)	(0.025)	(0.019)	(0.020)	(0.025)	(0.014)	(0.022)	(0.014)
Gross Value	-1.110e-8	1.030e-7***	5.290e-8	-9.210e-8*	-1.110e-8	-1.170e-7***	1.410e-8	3.140e-8	-3.510e-8
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EQIP and CSP	-0.045*	0.016	0.050**	-0.055*	-0.045*	0.021	-0.008	-0.012	-0.008
	(0.027)	(0.024)	(0.025)	(0.029)	(0.027)	(0.025)	(0.016)	(0.024)	(0.017)
No Tillage	-0.089***	0.028*	0.093***	-0.067***	-0.089***	0.052***	0.045***	-0.012	0.023*
	(0.014)	(0.018)	(0.021)	(0.014)	(0.014)	(0.019)	(0.016)	(0.015)	(0.012)
KW Factor	-0.512***	0.993***	0.528***	-0.163***	-0.512***	-0.762***	-0.217***	0.262**	-0.038
	(0.055)	(0.221)	(0.176)	(0.065)	(0.055)	(0.073)	(0.045)	(0.132)	(0.057)
Variability Crop Prices	-0.009	0.008	0.026	-0.010	-0.009	0.006	-0.002	0.002	-0.012
	(0.016)	(0.018)	(0.019)	(0.015)	(0.016)	(0.019)	(0.012)	(0.016)	(0.012)
Possibility Dry Period	0.015	-0.058***	-0.003	-0.028*	0.015	0.041**	-0.004	-0.003	0.030***
	(0.016)	(0.020)	(0.020)	(0.016)	(0.016)	(0.018)	(0.012)	(0.017)	(0.011)

Note: RS-sorghum-soybean, CS-corn-soybean, CSW-corn-soybean-wheat, WW-continuous wheat, WF-wheat-fallow, WRF-wheat-sorghum-fallow, WCF-wheat-corn-fallow, WS-wheat-soybean, WSR-wheat-soybean-sorghum. Asymptotic standard errors are presented in parentheses. *, **, *** indicate statistical significance at 10%, 5% and 1% level, respectively.

Appendix A.1. Survey Letter

a survey of
FARMERS' LAND USE
in Kansas

February 24, 2011

Dear Kansas Agricultural Producer:

These days are both an exciting and uncertain time for U.S. agriculture. Changes to energy and agricultural policy – some enacted, others proposed – are already affecting markets and input costs for common commodities and may even create new markets for once little-known crops like switchgrass. And, as always, farmers face changing and unpredictable price and weather conditions that make crop production a risky business.

How will all these changes shape the cropping decisions of farmers like you? This is one of the key questions in a major agricultural land-use study at Kansas State University and the University of Kansas. Through support from the National Science Foundation and the Kansas Transportation Research Institute, researchers from the two universities are working together to learn more about the decisions that Kansas farmers make.

You have been selected to participate in this study by completing the enclosed land-use survey. The survey asks you about your motivations in farming, the crops you grew in 2010, the risks you face in farming, the way that weather conditions affect your cropping choices, and your views on a number of agricultural policies.

We request that you complete this survey, which will take about 25 minutes of your time, and mail it back using the enclosed prepaid envelope no later than Tuesday, **March 8, 2011**. Your survey responses are very important. **Based on statewide responses to this survey, we will be able to inform policy makers, the energy industry, and the public about the impacts of changing conditions on farmers in Kansas**.

Your responses and commentary will be kept anonymous and results will only be released in summarized form in a way that protects your privacy. We know that your time is valuable and we greatly appreciate your help. If you have any questions about the survey or how the responses will be handled, please contact Dr. Russell Graves, Research Associate, Department of Agricultural Economics, Kansas State University, at 785-532-1957 or at rgraves@ksu.edu.

For more information about the joint land-use study at Kansas State University and the University of Kansas, please visit the following website:

http://www.ipsr.ku.edu/CEP/FLUD2.html

Sincerely yours,

Jeffrey M. Peterson
Associate Professor of Agricultural Economics
Kansas State University
KANSAS STATE UNIVERSITY

Dietrich H. Earnhart
Professor of Economics
University of Kansas
KU THE UNIVERSITY OF KANSAS

Appendix B.1. Survey Questionnaire

A Survey of Farmers' Land Use in Kansas

YOUR GOALS IN FARMING

1. Please rate your agreement with each of the following statements about **why you farm**.

I farm...		*strongly disagree*	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
1a.	...to earn a profit..	☐	☐	☐	☐	☐	☐
1b.	...to enjoy the rural lifestyle................................	☐	☐	☐	☐	☐	☐
1c.	...to leave something to my children (e.g. land)..	☐	☐	☐	☐	☐	☐
1d.	...because I'm financially unable to quit............	☐	☐	☐	☐	☐	☐
1e.	...because it is a hobby or retirement activity.....	☐	☐	☐	☐	☐	☐

2. Please rate your agreement with each of the following statements about **your year-to-year cropping decisions**.

I manage my cropland...		*strongly disagree*	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
2a.	...to maximize my profits....................................	☐	☐	☐	☐	☐	☐
2b.	...to minimize my expenses................................	☐	☐	☐	☐	☐	☐
2c.	...to limit my risk of low returns or losses..........	☐	☐	☐	☐	☐	☐
2d.	...to protect water quality....................................	☐	☐	☐	☐	☐	☐
2e.	...to protect soil/land quality..............................	☐	☐	☐	☐	☐	☐

YOUR OPERATED CROPLAND IN 2010

3. Enter below the names of the counties in which you operated cropland in 2010 and the number of acres of each type.

County name	Owned cropland		Rented cropland	
	Irrigated acres	Non-irrigated acres	Irrigated acres	Non-irrigated acres

4. If you rented land in 2010, please answer questions **4a-4e**. (*If not, continue to question 5.*)

4a. If you cash rented **irrigated** land, what was your average annual rental payment? $______/acre

4b. If you cash rented **non-irrigated** land, what was your average annual rental payment? $______/acre

4c. What percentage of your total rented acreage was rented on a **crop-share basis**? ______%

4d. If you rented land on a **crop-share basis**, what percentage of the crop did you receive? ______%

4e. For the cropland you rented in 2010, in what year did your **longest-running rental agreement** begin?
__ __ __ __ year [example: 2 0 0 5]

5. Enter below your estimate of the average market value (for permanent sale) of each type of cropland you operated in 2010.

	Owned cropland		Rented cropland	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Estimated market value ($/acre)				

1

YOUR PLANTING DECISIONS IN 2010

6. Please enter below the requested information for your **crops in 2010**.

Crop	Did not grow this crop	Acres planted	Acres harvested	Average yield per harvested acre	Average water applied (if irrigated)	Did you harvest or graze the residue from this crop?	What percentage of this crop went to feeding your livestock?
Corn: irrigated	□			bu.	in.	□ Yes □ No	%
Corn: non-irrigated	□			bu.		□ Yes □ No	%
Sorghum (milo): irrigated	□			bu.	in.	□ Yes □ No	%
Sorghum (milo): non-irrigated	□			bu.		□ Yes □ No	%
Soybeans: irrigated	□			bu.	in.	□ Yes □ No	%
Soybeans: non-irrigated	□			bu.		□ Yes □ No	%
Wheat: irrigated	□			bu.	in.	□ Yes □ No	%
Wheat: non-irrigated	□			bu.		□ Yes □ No	%
Alfalfa*	□			tons	in.	□ Yes □ No	%
Double crop (*specify*): ____________					in.	□ Yes □ No	%
Other (*specify*): ____________					in.	□ Yes □ No	%
Other (*specify*): ____________					in.	□ Yes □ No	%

**For alfalfa or other forage crops, report yield as the combined production per acre from all cuttings harvested in 2010.*

7. Which of the following best describes your most prevalent crop rotation on your **irrigated cropland**?
(If you do not irrigate any land, continue to question 8. Mark only one box.)

□ continuous corn □ corn-soybean □ corn-soybean-wheat □ continuous sorghum
□ sorghum-soybean □ continuous wheat □ alfalfa-corn □ continuous alfalfa
□ other *(specify)*:____

8. Which of the following best describes your most prevalent crop rotation on your **non-irrigated cropland**?
(If you have only irrigated land, continue to question 9. Mark only one box.)

□ continuous corn □ corn-soybean □ corn-soybean-wheat □ continuous sorghum
□ sorghum-soybean □ continuous wheat □ wheat-fallow □ wheat-sorghum-fallow
□ wheat-corn-fallow □ other (*specify*):____

9. Approximately when did you decide how many acres to plant to each crop **for the 2010 crop year**?

□ August-October 2009 □ November-December 2009 □ January-February 2010 □ March-April 2010
□ other (*specify*):____

10. Did any of your planted acreage **in the 2010 crop year** represent a break in your planned crop rotation?
□ yes □ no

2

11. When making your planting decisions for the 2010 crop year, many factors may or may not have influenced your decisions. Please rate your agreement with each of the following statements about which factors influenced your 2010 planting decisions.

My 2010 planting decisions were influenced by...		*strongly disagree*	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
11a.	...my planned crop rotation....................................	□	□	□	□	□	□
11b.	...anticipated average crop prices............................	□	□	□	□	□	□
11c.	...anticipated variability in crop prices....................	□	□	□	□	□	□
11d.	...weed pressure...	□	□	□	□	□	□
11e.	...a disease or pest infestation..................................	□	□	□	□	□	□
11f.	...marketing contracts..	□	□	□	□	□	□
11g.	...availability of crop insurance...............................	□	□	□	□	□	□
11h.	...winter/spring soil moisture conditions.................	□	□	□	□	□	□
11i.	...anticipated average temperatures.........................	□	□	□	□	□	□
11j.	...anticipated variability in temperatures.................	□	□	□	□	□	□
11k.	...the possibility of extremely hot periods...............	□	□	□	□	□	□
11l.	...the possibility of extremely cool periods.............	□	□	□	□	□	□
11m.	...the possibility of extremely dry periods...............	□	□	□	□	□	□
11n.	...the possibility of extremely wet periods..............	□	□	□	□	□	□
11o.	...anticipated total rainfall (for the season).............	□	□	□	□	□	□

BIOENERGY AND BIOFUELS

12. Approximately what percentage of your 2010 grain production did you contract directly with a biofuels plant? *(Mark one box in each row.)*

	did not grow	*none*	*1%-25%*	*26%-50%*	*51%-75%*	*76%-100%*	*don't know*
Corn	□	□	□	□	□	□	□
Sorghum	□	□	□	□	□	□	□
Soybeans	□	□	□	□	□	□	□

13. In the future there may be a market for cellulosic materials, such as corn stover or switchgrass, to produce ethanol. Would you consider producing any of the following kinds of cellulosic feedstocks on your farm?

I would consider producing...		*strongly disagree*	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
13a.	...crop residues such as corn stover...........................	□	□	□	□	□	□
13b.	...a perennial bioenergy crop such as switchgrass......	□	□	□	□	□	□
13c.	...an annual bioenergy crop such as forage sorghum..	□	□	□	□	□	□

IRRIGATION IN 2010

(If you did not operate any irrigated cropland in 2010, skip to question 18.)

14. How many cropland acres were irrigated from **groundwater in 2010**? _____ *(If none, continue to question 15.)*

14a. Among your wells, what was the range in the pumping rate? _____ to _____ gallons per minute.

14b. Among your wells, what was the range in depth to water (***before 2010 pumping***)? _____ to _____ feet.

14c. If your groundwater-irrigated cropland is in one or more Groundwater Management Districts (GMDs), please indicate which district(s). *(Mark all that apply.)*

□ Western Kansas GMD No. 1 (Scott City)
□ Equus Beds GMD No. 2 (Halstead)
□ Southwest Kansas GMD No. 3 (Garden City)
□ Northwest Kansas GMD No. 4 (Colby)
□ Big Bend GMD No. 5 (Stafford)
□ other (*specify*): ___________________________

3

15. How many cropland acres were irrigated from **surface water in 2010**? _____ *(If none, continue to question 16.)*

15a. What source(s) of surface water did you use in 2010? *(Mark all that apply.)*

□ reservoir □ naturally flowing river □ on-farm pond □ wastewater lagoon

15b. If your surface water-irrigated cropland is in one or more surface water management districts, please indicate which district(s):____

16. What was your most prevalent energy source to pump and deliver irrigation water in 2010? *(Mark one.)*

□ electricity □ natural gas □ LP gas, propane, or butane
□ diesel fuel □ gasoline or gasohol □ solar or other renewable

17. For each irrigated crop below, indicate the number of acres irrigated by each type of irrigation system in 2010.

Irrigated Crop	**Did not grow or did not irrigate this crop**	Flood (all methods)	Center Pivot Sprinkler (high pressure)	Center Pivot with drop nozzles (low pressure)	Subsurface drip	Other (*specify for each crop*)
Corn	□					
Sorghum (milo)	□					
Soybeans	□					
Wheat	□					
Alfalfa	□					
Other (*specify*):						
Other (*specify*):						

CONSERVATION ON YOUR FARM

18. From which government conservation programs, if any, did you receive payments **in 2010**? *(Mark all that apply.)*

□ Environmental Quality Incentives Program (EQIP)
□ Conservation Reserve Program (CRP)
□ I did not receive conservation payments in 2010
□ Conservation Security/Stewardship Program (CSP)
□ State of Kansas Conservation Programs
□ other (*specify*): ______________________________

19. If you received **CRP payments in 2009 or 2010**, please answer **19a-19d**. *(If not, continue to question 20.)*

19a. How many acres of land did you have enrolled in CRP in 2010? ______ acres

19b. What was the average rental rate for your CRP acreage in 2010? $______/acre

19c. If you had CRP contracts that expired in 2009, what did you do with most of that CRP acreage in 2010? *(Mark one box corresponding to the most prevalent use in 2010.)*

□ reenrolled it under a new contract
□ converted it to crop production
□ utilized it for hay
□ left it idle
□ utilized it for grazing
□ other (*specify*): _________________________________

19d. Please rate your agreement with the following statement:

	strongly disagree	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
If I could do so without penalty I would consider producing a bioenergy crop on my CRP land.........	□	□	□	□	□	□

4

20. Please indicate the in-field conservation practices used in 2010 for each of the crops below, whether or not you received government conservation payments for the practices. *(Mark all that apply in each row.)*

		In-Field Conservation Practices						
Crop	**Did not grow this crop**	No-till/ conservation tillage	Cover crops	Use of a legume crop in crop rotation	Credit nutrients from manure	Terraces	Buffer or Field Strips	Other
Corn: irrigated	□	□	□	□	□	□	□	□
Corn: non-irrigated	□	□	□	□	□	□	□	□
Sorghum (milo): irrigated	□	□	□	□	□	□	□	□
Sorghum (milo): non-irrigated	□	□	□	□	□	□	□	□
Soybeans: irrigated	□	□	□	□	□	□	□	□
Soybeans: non-irrigated	□	□	□	□	□	□	□	□
Wheat: irrigated	□	□	□	□	□	□	□	□
Wheat: non-irrigated	□	□	□	□	□	□	□	□
Did you receive incentives or cost-share for this practice?		□ Yes □ No	□ Yes □ No	□ Yes □ No	□ Yes □ No	□ Yes □ No	□ Yes □ No	□ Yes □ No

RISK

21. When you made your planting decisions for the 2010 crop year, what was your perception of the amount of **yield risk** (due to uncertain growing conditions) you faced for each of the following crops? ***(Please answer for each crop**, even if you did not grow it.)*

	very low	*low*	*moderate*	*high*	*very high*	*don't know*
Corn..................................	□	□	□	□	□	□
Sorghum (milo).................	□	□	□	□	□	□
Soybeans...........................	□	□	□	□	□	□
Wheat................................	□	□	□	□	□	□

22. When you made your planting decisions for the 2010 crop year, what was your perception of the amount of **price risk** (based upon cash sales) you faced for each of the following crops? ***(Please answer for each crop**, even if you did not grow it.)*

	very low	*low*	*moderate*	*high*	*very high*	*don't know*
Corn..................................	□	□	□	□	□	□
Sorghum (milo).................	□	□	□	□	□	□
Soybeans...........................	□	□	□	□	□	□
Wheat................................	□	□	□	□	□	□

23. Please rate your agreement with each statement below regarding your decisions about which crops to plant.

	strongly disagree	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
23a. I avoid planting crops with very uncertain income......	□	□	□	□	□	□
23b. I would be described as a risk avoider........................	□	□	□	□	□	□
23c. In my planting decisions, I prefer "playing it safe".....	□	□	□	□	□	□
23d. In choosing which crops to plant, I am willing to take some risks to obtain higher income on average....	□	□	□	□	□	□

24. Please indicate which methods you used (or will use) to market your 2010 crops. *(Mark all that apply in each row.)*

	cash sales	*forward contracts*	*futures/options*	*other: ___________*
Corn	□	□	□	□
Sorghum (milo)	□	□	□	□
Soybeans	□	□	□	□
Wheat	□	□	□	□

25. Please indicate the types of crop insurance products that you used **in 2010** for each of the crops listed below. *(Mark all that apply in each row.)*

Crop	**did not grow this crop**	APH	RA and/or CRC	GRIP	GRP	ACRE	SURE	Private hail	Other	**I grew but did not insure this crop**
Corn	□	□	□	□	□	□	□	□	□	□
Sorghum	□	□	□	□	□	□	□	□	□	□
Soybeans	□	□	□	□	□	□	□	□	□	□
Wheat	□	□	□	□	□	□	□	□	□	□
Alfalfa	□	□	□	□	□	□	□	□	□	□
Other (*specify*):	□	□	□	□	□	□	□	□	□	□
Other (*specify*):	□	□	□	□	□	□	□	□	□	□

Product Definitions: APH = Actual Production History; RA = Revenue Assurance; CRC = Crop Revenue Coverage; GRIP = Group Risk Income Protection; GRP = Group Risk Plan; ACRE = Acreage Crop Revenue Election; SURE = Supplemental Revenue Assistance Program

YOUR POLICY VIEWS

26. Please rate your agreement with each statement below.

		strongly disagree	*disagree*	*neutral*	*agree*	*strongly agree*	*don't know*
26a.	U.S. biofuel policy has made grain prices less stable...	□	□	□	□	□	□
26b.	U.S. biofuel policy has caused unnecessary increases in global food prices..	□	□	□	□	□	□
26c.	The government's biofuel policies are only helping corn farmers and ethanol companies...........................	□	□	□	□	□	□
26d.	U.S. biofuel production is necessary to reduce our dependence upon foreign oil.......................................	□	□	□	□	□	□
26e.	Climate change is a scam invented by bureaucrats and scientists...	□	□	□	□	□	□
26f.	Environmental legislation is often unfair to farmers....	□	□	□	□	□	□
26g.	Farmers should farm only as much land as they can personally care for..	□	□	□	□	□	□
26h.	Farmland should be farmed so as to protect the long-term capacity of the land even if this means lower production and profits..	□	□	□	□	□	□
26i.	Farmers should use primarily natural fertilizers and production methods such as manure, crop rotation, compost, and biological pest control...........................	□	□	□	□	□	□
26j.	High energy use makes U.S. agriculture vulnerable and should be greatly reduced.....................................	□	□	□	□	□	□

27. Generally speaking, do you consider yourself a Republican, a Democrat, or an Independent? *(Mark one.)*

□ Republican □ Democrat □ Independent □ other □ don't know □ prefer not to answer

28. How would you describe your political beliefs from the choices below? (*Mark one.*)

□ very liberal □ liberal □ moderate □ conservative □ very conservative
□ don't know □ prefer not to answer

ABOUT YOU AND YOUR OPERATION

29. Which of the following best describes the ownership structure of your operation in 2010? *(Mark one.)*

□ family or individual operation (excludes partnerships and corporations) □ incorporated under state law
□ partnership operation (includes family partnerships) □ other:___________________

30. Approximately what percentage of your operation's assets are financed with debt? *(Mark one.)*

□ 0% □ 1-5% □ 6-10% □ 11-15% □ 16-20%
□ 21-30% □ 31-50% □ 51-70% □ 71-90% □ greater than 90%

31. What percentage of the total gross value of sales from your operation **in 2010** was from:

31a. Cash grain production (e.g., wheat, corn, soybeans, etc.)?........................... _____%

31b. Hay and forage production (e.g., alfalfa, brome, etc.)?................................ _____%

31c. Livestock production (or livestock products)?... _____%

31d. Vegetables, fruits, or specialty crops?.. _____%

31e. Government payments?.. _____%

31f. Services or other?... _____%

32. Which of the following **types of livestock** did you raise on your operation in 2010? *(Mark all that apply.)*
□ beef cattle □ dairy cattle □ hogs □ horses
□ sheep □ poultry □ none □ other (*specify*): ___________________

33. Including sales of crops, livestock, poultry, miscellaneous agricultural products, and government agricultural payments **in 2010**, which category represents the yearly total gross value of sales from your operation? *(Mark one.)*

□ less than $25,000 □ $25,000 to $49,999 □ $50,000 to $99,999
□ $100,000 to $149,999 □ $150,000 to $199,999 □ $200,000 to $249,999
□ $250,000 to $299,999 □ $300,000 to $349,999 □ $350,000 to $399,999
□ $400,000 to $449,999 □ $450,000 to $499,999 □ $500,000 to $599,999
□ $600,000 to $699,999 □ $700,000 to $799,999 □ $800,000 to $899,999
□ $900,000 to $999,999 □ $1,000,000 to $1,249,999 □ $1,250,000 to $1,499,999
□ $1,500,000 to $1,749,999 □ $1,750,000 to $1,999,999 □ $2,000,000 and over

34. Based on this total gross value of sales, which category represents your operation's net cash farm income in 2010? *(Mark one.)*

My operation earned a **loss** of:
□ less than $4,999 □ $5,000 to $9,999 □ $10,000 to $24,999
□ $25,000 to $49,999 □ $50,000 to $99,999 □ $100,000 or more

My operation earned a **profit** of:
□ less than $4,999 □ $5,000 to $9,999 □ $10,000 to $24,999
□ $25,000 to $49,999 □ $50,000 to $99,999 □ $100,000 to $149,999
□ $150,000 to $199,999 □ $200,000 to $249,999 □ $250,000 to $299,999
□ $300,000 to $349,999 □ $350,000 to $399,999 □ $400,000 to $449,999
□ $450,000 to $499,999 □ $500,000 to $549,999 □ $550,000 to $599,999
□ $600,000 to $649,999 □ $650,000 to $699,999 □ $700,000 and over

35. Are you a hired manager for this operation? □ yes □ no

36. How many people live in your household? ______ people

37. Are you or any member of your immediate family that is living with you employed off the farm? □ yes □ no

38. What was your total household income in 2010? Include net income from farming, wage or salary income from all sources, social security, and investment income.

□ less than $20,000 □ $20,000 to $39,999 □ $40,000 to $59,999 □ $60,000 to $79,999
□ $80,000 to $99,999 □ $100,000 to $119,999 □ $120,000 to $149,999 □ $150,000 or more

39. In 2010, approximately what percent of your total household income came from the profits from your 2010 farming operation? *(Round to the nearest 10%.)*

□ 10% □ 20% □ 30% □ 40% □ 50% □ 60% □ 70% □ 80% □ 90% □ 100%

40. In what year did you begin farming? __ __ __ __ year [example: 1 9 7 5]

41. What is your age? ______ years

42. What is your gender? □ male □ female

43. What is your race? (*Mark one or more.*)

□ American Indian □ Asian or Pacific Islander □ Black or African American □ White

44. Are you of Spanish, Hispanic, or Latino origin or background, regardless of race? □ yes □ no

45. What is the **highest** level of formal education you have completed? (*Mark one.*)

□ some high school or less □ high school or GED equivalency □ trade school
□ some college □ bachelor's degree or equivalent □ graduate or professional degree

46. Are you married? □ yes □ no

THANK YOU for completing this survey.

Please write any additional comments in the space below.

Chapter 2 - Assessing the Joint and Conditional Adoption of Soil Conservation Practices of Kansas Farm Managers

2.1. Introduction

Conservation systems are able to improve both direct and indirect ecosystem services (Reicosky, 2008). Direct services are improved by farmers' working on agricultural lands, such as providing food and feedstock supplies. Indirect services are enhanced by using conservation systems in existing production systems, which can help to enhance life-fulfilling services (e.g. existence value and scientific discovery), stabilizing services (e.g. partial stabilization of climate and moderation of weather extremes), and preservation of options (e.g. maintenance of ecological components and systems needed for the future) (Chee, 2004). Tilman et al. (2002) found that agricultural systems that do not enhance indirect ecosystem services can degrade soil quality, result in higher soil erosion rates, and potentially require increased input use (e.g. fertilization, irrigation and energy) to offset declining soil productivity. In contrast, well managed agricultural systems that enhance indirect ecosystem services through conservation can help to reduce soil erosion and improve soil quality, as well as improve crop yield and lower crop yield variability (Hanson et al., 2007; Reicosky, 2008).

Agricultural conservation systems consist of a myriad of conservation practices, including conservation tillage, dynamic crop rotations, cover crops, use of legumes in rotation, use of manure, precision agriculture, integrated pest management, and conservation nutrient management practices. The applied economics literature has studied a large number of factors affecting the adoption of these conservation practices. Many studies have examined the adoption of single practices (e.g. Helms et al., 1987; Fuglie and Bosch, 1995; Hamido and Kpomblekou-A, 2009), while only a few others have examined the joint adoption of a set of conservation practices or bundles (e.g. Wu and Babcock, 1998; Bergtold and Molnar, 2010). A limited number of studies have examined the step-wise or sequential adoption of conservation practices (e.g. Byerlee and Polanco, 1986; Leather and Smale, 1991).

Farmers can benefit from the mix and intensity of conservation practices adopted. Conservation practices affect the entire production system on-farm, and their interactions within the production system have an impact on soil and water conservations. Pierce (1985) founded that conservation tillage affected almost the whole crop production system, including crop rotations, planting, equipment performance and so on. As a result, in order to take advantage of conservation practices, farmers must be able to make decisions taking into account the interrelated nature of conservation practices and other agricultural practices. In addition, farmers need to identify the set of local resource concerns (e.g. soil condition, water condition, air condition, plants or animals) and the corresponding set of conservation practices (e.g. time, location and adoption) for a properly and well-developed conservation plan. Stinner and House (1989) emphasize that famers must use a system approach by collecting all the interrelated factors together when addressing conservation needs. The social and economic factors that affect the adoption of conservation practices should also be taken into account with conservation plans. Pannell et al. (2006) reviewed a large number of these factors, including farm demographics, farm characteristics, cultural barriers, social networks, farmers' personalities, risk perceptions, economic well-being, land tenure and other socio-economic factors that drive conservation practice adoption.

The purpose of this study is to examine and analyze the adoption of conservation practices by farmers in Kansas from both a joint and conditional perspective. The study examines farmers' joint and conditional decision to adopt alternative conservation bundles and the socio-economic and farm factors affecting adoption of individual and bundles of conservation practices. To the authors' knowledge the examination of the joint and conditional adoption using cross-sectional data as explored in this paper has not been examined in the agricultural economics literature to date. Thus, the paper provides a novel contribution to the methodology of examining adoption of new technologies. The conservation practices considered here will be the use of conservation tillage, cover crops and crediting of nutrients from manure.

The joint adoption (adopting multiple conservation practices during specified time period) of a bundle or system of conservation practices is modeled using a multinomial logistic framework under a random utility approach. The model is then used to estimate conditional probabilities of adopting conservation practices given the adoption of other practices. These estimates will allow for an assessment of the linkages between the adoption of different conservation practices, as well as the socio-economic factors that affect the likelihood of adopting such conservation practices given other conservation practices have already been adopted (e.g. examine potential step-wise adoption). Farmers may improve on-farm performance of conservation cropping systems through increasing the efficiency of the conservation practices adopted, as well as reducing risk and uncertainty given the useful and valuable background information with past choices. To the authors' knowledge, this approach has not been thoroughly explored in the applied economics literature.

2.2. Background

2.2.1 Cross-Sectional Methods Used in the Adoption Literature

Many studies examine the adoption of single practices. Gould et al. (1989) used a single probit equation and two-limit tobit model to examine factors influencing producers' level of awareness of soil erosion; and found that farmers who worked off-farm had a lower probability of adopting conservation tillage because of a lack of information or commitment to the farm operation. Fuglie and Bosch (1995) employed a simultaneous equation model to study the impact of soil nitrogen testing and illustrated that lower farm sales showed a lower probability to adopt soil nitrogen tests. Uri (1997) used a two-stage decision model to estimate corn produced in the United States in 1987 with Farm Costs and Returns Survey (FCRS) and found that cash grain enterprises preferred to choosing conservation tillage than other types of farms. Soule et al. (2000) used a logistic adoption model with data from 941 U.S. corn producers to study how land tenure affected conservation practice adoption and found that types of lease arrangement would influence the adoption of conservation tillage.

Others have examined the joint adoption of a set of conservation practices. Wu and Babcock (1998) applied a polychotomous-choice model to the choice of alternative management practices, conservation tillage, rotation and soil N testing, on cropland and stated that farmers were more likely to perform conservation practices when they had a conservation plan, but not for small and limited-resource famers. Bergtold and Molnar (2010) used a polychotomous-choice selectivity model to examine factors affecting the adoption of conservation tillage, soil testing and crop rotations by small and limited resource farmers in the southeastern U.S. They found that these farmers had limited adoption of the selected practices and that farmers adopted practices individually rather in bundles. In addition, they found these adoption patterns would affect the eligibility of small and limited-resource farmers' eligibility for the Conservation Security Program (CSP).

Studies have examined the step-wise or sequential adoption of conservation practices. Byerlee and Polanco (1986) found that farmers preferred to adopt practices with the highest returns the earliest and also showed that conservation system adoption is a dynamic and ongoing process. Leather and Smale (1991) pointed out that the simultaneous adoption of bundles of conservation practices would be the most profitable long-term approach, but step-wise adoption might be the least cost option. Khanna (2001) used a bivariate probit model to analyze the sequential decision to adopt soil testing followed by variable rate technology to study the effect of adoption on nitrogen productivity.

This study builds on this literature by considering a methodological framework to expand on the methods examining the adoption of conservation practices (and technologies) using cross-sectional data. A multinomial modeling framework under a random utility approach is used to model the joint adoption of conservation practices. The framework is then used to estimate conditional probabilities of adopting conservation practices from the joint adoption model, which has not been thoroughly explored in the applied economics literature. To model this, we focus on the adoption of three conservation practices by crop farmers in Kansas: no tillage, cover crops and credit nutrients from manure as a fertilizer source.

2.2.2 Conservation Practices

No-Till: No-tillage (no-till), also called zero tillage or direct drilling, is a method used to plant or grow crops or pasture from year to year without influencing the soil through tillage (USDA-NRCS, 2013). No-tillage is planting crops into untilled soil by opening a proper slot with sufficient width and depth to obtain seed coverage (Derpsch and Friedrich, 2009). No-tillage is an agricultural technique that is used to eliminate soil erosion by increasing water and organic matter retention, as well as cycling of nutrients in the soil. Another significant benefit of no-tillage is improvement in soil biological fertility, which makes soil more resilient (USDA-NRCS, 2013). Lal (1976) mentioned that no-tillage results in higher organic matter content and higher concentrations of nitrate-nitrogen under several crop rotations (e.g. maize-cowpeas and soybeans-soybeans), while runoff and erosion losses from use of no-tillage were minimal. Seta et al. (1993) conducted a study evaluating the effects of conventional tillage, chisel-plow tillage and no-tillage on the quality of runoff water near Lexington, KY. They found that no-tillage had the lowest mean runoff tare, total runoff volume, mean sediment concentration and total soil losses. Moreover, NO^{-}_3, NH^{+}_3, and PO^{3-}_4 in the runoff water from no-tillage were higher than the other two practices examined. Tillage practices can have an impact on farm income, commodity production, and markets. There was a large increase in no-till adoption in the U.S. from 38.9 million acres in 1994 to 62.4 million acres by 2004 (Horowitz et al., 2010).

Cover crops: Cover crops are crops planted primarily to manage soil fertility, soil quality, water, weeds and biodiversity in an agroecosystem (Lu et al., 2000). Cover crops are defined as crops grown specifically for covering ground to avoid or eliminate soil erosion and loss of plant nutrients through leaching and runoff (Pieters and McKee, 1938). Elwell and Stocking (1976) presented evidence showing that percent vegetal cover was the primary element determining erosion hazard from crops and grassland in Rhodesia. Everts et al. (2002) found that hairy vetch and hairy vetch and rye cover crop mixtures increased fruit harvest numbers when compared to crop production on bare ground. In addition, cover crops may help to break disease cycles and reduce populations of bacterial and fungal diseases. Cover crops can also contribute to increasing availability of nitrogen to succeeding crops, improve soil structure and water infiltration, reduce surface soil temperature and water evaporation, and increase soil productivity (Frye et al., 1988) Singer et al. (2011) employed a root zone water quality model to analyze the effect of cover crop on nitrogen load in tile drainage in Iowa, and they found that the winter annual cover crop could reduce annual N loads to tile drains by approximately 20% in either 2-year or 3-year maize-soybean and maize-maize-soybean rotation.

Credit nutrients from manure (Manure Practice): Manure can be obtained from dairy, swine, chicken, turkey, and poultry and so on. Nutrients from the manure can be used to replace fertilizer, as well as for crop year and rotation. Manure is used as fertilizer on agricultural lands to contribute to the fertility of the soil by adding organic matter and nutrients that are trapped by bacteria in the soil. Green manure has been barely used recently as its high cost and uncertain yearly performance. However, Westcott and Mikkelsen (1988) found leguminous green manure crops can provide one third to a half of the N required for high-yielding rice varieties. Fronning et al. (2008) conducted a field experiment under a corn-soybean rotation with complete corn stover removal and found use of manure raised soil C level in the 0 to 5 and 0 to 25 cm soil profile and total soil organic C in the 0 to 25 cm profile by 25%. The frequency of chicken manure rates altered vegetative growth characteristics of apple trees significantly (Kakehzadeh et al., 2014). Manure was also found to significantly increase growth and yield parameters, as well as the final yields of vegetable maize (Amos et al., 2013). As a conservation practice, the use of manure should reduce the use of commercial fertilizers on-farm. That is, the nutrients obtained from the manure should be credited and use of commercial fertilizer reduced accordingly.

2.3. Data

The data used for this paper was obtained from a mail survey in 2011 examining Kansas farmers' land use decisions. The survey contained questions about how farmers make their land-use decision on a wide array of topics. The survey asked respondents to address their goals in farming; participation in conservation programs; use of irrigation; willingness to grow biofuel crops; perceptions related to price, yield, and weather risk; usage of insurance and marketing options; and characteristics of the farming operations. A primary goal of the survey was to assess the effects of alternative conservation practice and crop choices on farmers' land-use decisions in Kansas. The survey consisted of an eight-page survey with 46 questions, leading to more than 400 distinct variables in the survey dataset.

The survey targeted Kansas farmers with 50 or more acres of arable land and over $10,000 in gross farm annual income in 2010 to leave out lobby farmers and part-time producers. Names and addresses were obtained for approximately 23,000 farms meeting these criteria from a private vendor, FarmMarketID (a marketing technology company, www.FarmMarketID.com). For the full mailing of the survey, a random sample of 10,000 farmers was drawn from the FarmMarketID database, and then sent to respondents following the approach suggested by Dillman (2007) in late February 2011. A cover letter explaining the purpose of the survey, the composition of the research team, how the survey results would be utilized, and how we would safeguard individual survey responses was included, as well.

A total of 2317 surveys with usable data were received out of the 10,000 sent, while 684 were returned as undeliverable or where non-applicable (e.g. farmer was deceased or retired), resulting in a response rate of approximately 25 percent. Due to missing data (either from questions not answered or entry of an implausible value), 2163 survey were usable for the analysis in this study.

To complement the survey data, our analysis also draws upon public available data on soil characteristics at the county level. Soils data were obtained from the Soil Survey Geographic (SSURGO) database (Soil Survey Staff, USDA-NRCS, 2010). Soils data used in this study included the kw-factor, which examines soil erosion potential; available water content for each soil polygon or unique area of arable land within a county (defined as land under land capability classes 1 to 6); and the standard deviation of slope – as a proxy of the variability of the terrain used for agriculture. County level averages for each soil variable were obtained for all 105 counties across the state of Kansas by taking spatially weighted averages across soil polygons using the percent of area of arable land represented by each soil polygon as the weighting factor.

Palmer Z, index was used as a weather variable, measures short term drought on a monthly basis and is more suitable for agricultural purpose (NOAA-NCDC, 2012; Karl 1986). Both the mean and standard deviation over a 10-year period for each county in Kansas were calculated. Soil variables and Palmer Z variables values where then assigned to each respondent as the spatially weighted average of the associated county level averages or values using the percentage of their land operated in a given county as the weighting factor (Caldas et al., 2013).

Summary statistics for explanatory (independent) variables derived from the survey, as well as the soil and weather variables are shown in Table 1. The table contains five categories of variables that are considered in the joint adoption model examined: landscape attributes, farm characteristics, farmer demographics and characteristics, region and weather. Fifty-two percent of survey respondent raised either cattle or hog or both on farmers' operation in 2010. And twelve percent of farmers in the survey enrolled in Environmental Quality Incentives Program (EQIP) and/or Conservation Security/Stewardship Program (CSP), while less than half of survey respondents described themselves as being a risk-avoider. Fifty-three percent of survey respondents had a member of the household working off the farm, which was treated as "employment" following D'Souza et al., 1993. In general, off-farm income can subsidize a proportion of any loss in farm income. With those "supplements", farmers may be encouraged to undertake riskier crop rotations and to adopt additional conservation practices. Thirty-four percent of farm operators in the survey had earned a college or higher degree and the average of cropland operated in 2010 was approximately 1150 acres.

Survey summary statistics were compared with those in the 2007 Agricultural Census (USDA-NASS, 2007) for Kansas to examine the representativeness of the sample. Survey respondents have been farming on average 36 years, while the 2007 Agricultural Census (USDA-NASS, 2007) indicates the number of years that farmers have been working on their present farm is about 26 years. This difference may be due to the nature of the designed questions. The survey asked total years farming, but the agricultural census asked the number of years working on their present farms. Table 1 shows that survey respondents do not only work on their family farm, but also other farms and off-farm. Farms with more than 50 acres of crop land production and $ 10,000 in gross farm sales were surveyed, which eliminated a significant number of farms in Kansas. The 2007 Agricultural Census (USDA-NASS, 2007) indicates that 11 percent of farmers in Kansas are female. In contrast, only 5 percent of the survey respondents are female. Moreover, survey respondents operate cropland at the average of 1150.41 acres rather than 863.01 acres from the 2007 Agricultural Census (USDA-NASS, 2007). Finally, 47% of farmers receive income off the farm is shown from the 2007 Agricultural Census (USDA-NASS, 2007), while 53% of farmers earn income off the farm in 2010. Thus, there are approximately 33% and 13% increase in total acres and off-farm employment within four years period, respectively.

In this study, we model the joint and conditional adoption of conservation practice bundles. The conservation bundles are made up of up to three conservation practices used by the farmers surveyed in Kansas: no-till, cover crops and use of crediting of nutrients from manure. Those three conservation practices can form a total of eight conservation practice bundles that are listed in Table 2 with associated respondent adoption as a percentage. We refer to these bundles as conservation (management) plans in the paper. More than half (52.17%) of survey respondents adopted the no-till only plan (N), while 33.41% of survey respondents adopted none of the conservation practice bundles listed in Table 2. These conservation practice bundles (management plans) serve as the dependent variable for the joint adoption model considered next.

2.4. Methodology

2.4.1 Theoretical Foundations

A significant purpose of the thesis is to develop a methodology for assessing the conditional adoption of alternative farm practices, which requires the use of a joint adoption framework. Suppose a farmer can choose from adopting *r* possible practices on the farm. These practices can form $M = 2^r$ conservation bundles or conservation management plans. Let δ_m, m = 0, 1, …, M, be a specific bundle, where δ_m is a (R x 1) vector of indicator variables, Y_r, $r = 1, \ldots, R$, equal to 1 if the r^{th} practice is part of bundle *m*. Under the assumption of utility maximization, a farmer *i* derives utility from choosing bundle *m* with a given set of attributes /factors X_i that maximizes his or her utility u_{mi}. The utility for adopting bundle *m* can be represented as:

$$u_{mi} = U\{E\ [R(X_i)];\ Z_i;\ \beta_m\} \qquad (1)$$

where $E[R\ (X_i)]$ is expected profit from adopting the given bundle of conservation practices, X_i is a set of individual specific explanatory variables affecting the profit for bundle *m*, Z_i is a set of other variables that impact the utility for bundle *m*, β_m is a vector of parameters specific to the utility received for adoption bundle *m*. Farmers' decisions on adoption of conservation practices are often influenced and motivated by other factors rather than profit related factors under a utility framework (Skaggs et al., 1994). Thus, it is necessary to distinguish and separate those profit related variables and nonprofit but utility related variables, including farming experience, education and employment (Ervin and Ervin, 1982; D'Souza et al., 1993); age and other demographics (Skaggs et al., 1994). A farmer will adopt bundle *m* if:

$$u_{mi} = max(u_{1i}, \dots, u_{mi}, \dots, u_{Mi}). \qquad (2)$$

2.4.2 Empirical Model

A researcher only observes the choice of bundle adopted. So the theoretical model represented by equations (1) and (2) can be viewed in a random utility framework. That is:

$$u_{mi} = V_m\{E\ [R(X_i)];\ Z_i;\ \beta_m\} + \varepsilon_{mi}$$

where V_m is the determinist component of utility and ε_{mi} is the random or unobserved component of utility (Louviere et al., 2000).

If the residuals, ε_{mi}, *m = 0,1, ..., M* are independently distributed with extreme value distribution (type 1), then the probability of a farmer choosing bundle *m*, δ_m, can be written as:

$$\pi_m = \Pr(I = m) = \frac{\exp(V_m\ [E\ (R(X_i));Z_i;\ \beta_m)}{\sum_{S=1}^{M} \exp(V_s\ [E\ (R(X_i));\ Z_i;\ \beta_s)} \qquad (3)$$

(where *I* is a polychotomous index equal to *m* if bundle *m* is chosen.) Thus, following the methods in Bergtold and Molnar (2010) and Wu and Babcock (1998), a polychotomous-choice selectivity model of adoption is employed in this study. A modified multinomial logistic regression model is used to examine the joint adoption of conservation practices by Kansas farmers. The adoption of these practices is conditional on a number of explanatory factors, including experience, farm sales, land tenure, participation in conservation programs, farmer perceptions, use of insurance, and a number of demographic variables.

For those farm characteristics, it is expected that farm size and rental percentage could have a positive effect on conservation practices. With larger farm size and more rent space, farmers are encouraged to plant and adopt more crops and management plans. Farmers participating in EQIP and/or CSP can obtain more information and gain more experience to increase the probability of adopting conservation practices. Compared with risk-averse farmers, risk-preference or risk-loving ones may choose higher return crops or conservation practices regardless time and region constrain.

For farmer demographics and characteristics, we expect farmers' operation experience, off-farm employment, insured crop insurance and farmers' education level could increase the likelihood of adopting conservation practices. The influence of risk type and gender of farmer will depend on the specific type of conservation practice.

The weather, region and landscape attributes will affect adopting conservation practices differently with various management plans.

With the limited number of observation for conservation management plan bundles CM and NCM listed in Table 2, it is assumed that P (I = CM) = 0, and P (I = NCM) = 0 (i.e. the probability of adopting these bundles is equal to zero, and where I is a ploychotomous index equal to m if bundle m is chosen), such that they will have no direct effect on the estimation of the model. Given the limited number of observations, the effects of the explanatory variables on the adoption of these management plans cannot be reliably identified. Thus, there are six conservation practices used. These assumptions are used in the calculation of other estimated statistics and then leave 2163 degree of freedom for the estimation of the model examining conservation practice adoption.

2.4.3 Unconditional, Conditional and Bivariate Marginal Effects

Following equation (3) a multinomial logistic model is used to estimate the joint adoption of bundles of conservation practices. The model estimates the probability of adopting a bundle given a set of explanatory factors, but allows one to estimate the marginal probability of adopting a single practice; and conditional probability of adopting a practice given other practice adoption. Marginal effects can be derived for all of these types of probabilities.

It is difficult to interpret the meaning of coefficients in the multinomial logistic model. The marginal effects of explanatory variables on the probability of adopting a bundle of practices provide a measure to assess the impact of specific explanatory factors. The marginal effects provide both a sign and magnitude for the marginal change in an explanatory variable on the probability of adoption. These marginal effects can be expressed as (Greene, 2012):

$$\frac{\partial \pi_m}{\partial x_k} = \pi_m\left[\beta_m - \sum_{s=0}^{M} \pi_s \beta_s\right] \qquad (4)$$

It should be noted that the sign of the marginal effects may not follow the sign of β_m for $m = 0,1,\ldots,M$.

Wu and Babcock (1998) emphasize that the unconditional marginal probability of adopting a practice or single element of a conservation bundle sequence may be of interest. The marginal probability of adopting a single practice can be derived from the joint modeling framework as:

$$P_s = \sum_{m\epsilon\{\delta_m:\, Y_s=1\}} \pi_m \qquad (5)$$

where s is the index for the single practice of interest and Y_S is an indicator variable equal to 1 when practice s is included in bundle m. The associated marginal effects for the marginal probabilities can be expressed as (Wu and Babcock, 1998):

$$\frac{\partial P_s}{\partial x_k} = \sum_{m\epsilon\{\delta_m:\, Y_s=1\}} \frac{\partial \pi_m}{\partial x_k} \qquad (6)$$

Joint probabilities of adopting two or more practices can be derived, as well. For example, the probability that a farmer jointly adopts two conservation practices is:

$$P_{rs} = \sum_{m\epsilon\{\delta_m:\, Y_r=1, Y_s=1\}} \pi_{m,} \qquad (7)$$

which is useful when examining conditional adoption between practices. The associated marginal effect for the bivariate probability given by equation (7) is:

$$\frac{\partial P_{rs}}{\partial X_k} = \sum_{m\epsilon\{\delta_m:\, Y_r=1, Y_s=1\}} \frac{\partial \pi_m}{\partial X_k} \qquad (8)$$

The joint adoption or multinomial model estimated allows for the estimation of conditional probabilities. For example, one can estimate the adoption of cover crops, given no-tillage has been adopted. This may assist in examining what factors affect farmers' choices to intensify conservation efforts on-farm to help develop outreach strategies and incentive mechanisms. Using this framework, the adoption of practice *s* given practice *r* has already been adopted can be represented as:

$$\mathrm{P}_{\mathrm{s|r}} = \frac{\mathrm{P}_{\mathrm{sr}}}{\mathrm{P}_{\mathrm{r}}} \qquad (9)$$

where the marginal and bivariate probabilities are given by equation (5) and (7). Of particular interest is the estimation of marginal effect of the explanatory variables for the conditional probabilities assessed. These can be obtained by differentiating the conditional probability with respect to an explanatory variable of interest (k):

$$\frac{\partial P_{s|r}}{\partial X_k} = \frac{\frac{\partial P_{sr}}{\partial X_k} * P_r - P_{sr} * \frac{\partial P_r}{\partial X_k}}{P_r^2} \qquad (10)$$

where the associated marginal effects for the marginal and bivariate probabilities are given by equations (6) and (8). It should be emphasized that all the marginal effects estimated can be done using the joint probabilities and marginal effects estimated using the joint multinomial logistic model given by equations by (3) and (4). That is, the joint framework inherently captures the dependencies between adopting different practices.

To test for the significance of marginal effect, asymptotic estimates of the standard errors are required. Given the complexity of some of the equations of the marginal effects above, the method of Krinsky and Robb (1986) is utilized to estimate the asymptotic standard errors for the calculation of asymptotic z-statistics (see Greene 2012, as well). All marginal effects were calculated as partial averages.

2.5. Result and Discussion

For this study, the empirical joint multinomial model is estimated using NLOGIT 4.0. MATLAB is then used to estimate marginal effects and associated asymptotic standard errors. Parameter estimates for the model are provided in appendix A. The model was estimated with 2163 observation. The McFadden Pseudo R-square for the regression model is equal to 0.0823. Marginal effects of the explanatory variables are of more interest than coefficient estimates which are not readily interpretable in the multinomial logistic model (Greene, 2012). Marginal effects and associated asymptotic statistics from the multinomial model for the adoption of different conservation bundles are estimated and presented in Table 3.

There may exist potential complementarities or substitutability between practices and it is of interest to examine unconditional marginal probabilities, bivariate probabilities and conditional probabilities. Estimated marginal effects of the explanatory variables for the probability of adopting each conservation plan and practice under both unconditional and conditional perspectives, along with the associated asymptotic standard errors are shown in Table 4.

2.5.1 Conservation Practice Bundle (Management Plan) Adoption

Examining the marginal effects of different explanatory factors on the adoption of conservation practice bundles shows that different factors impact different conservation practice bundles/management plans.

No-Tillage Only (N): Available water content, farm size, percent of land rented, participation in EQIP and/or CSP, off-farm employment, having crop insurance, gender, having a college degree, and living in eastern Kansas increased the likelihood of only adopting this management plan. Higher risk of erosion and raising livestock decreased the likelihood of only adopting this conservation practice bundle. Risk of erosion is likely to increase the use of conservation practices that will decrease the potential for erosion, helping to maintain soil productivity. Off-farm employment and having a college degree increased the probability of only adopting no-tillage by 6.9% and 6.6% at a one percent level of significance, respectively. Off-farm employment can subsidize a proportion of the potential loss in farm income to encourage Kansas farmers to adopt no-tillage. In addition, adoption of no-tillage may reduce labor requirements on-time, freeing up time for additional off-farm employment or allowing farm size and revenue to increase. In contrast, raising cattle and/or hogs lowered the probability of only adopting no-tillage by 7.0%. Enrollment in a conservation program increased the likelihood of adoption by 8.1%, emphasizing the impact of financial incentives on adoption.

Cover Crops Only (C): Land characteristics, such as higher risk of soil erosion and greater variability in field slopes increased the likelihood of only adopting cover crops. Higher available water content in the soil, renting more acres, residing in eastern Kansas, and a greater chance of drought decreased the likelihood of only adopting this management plan. Living in eastern Kansas decreased the probability of only adopting cover crops by 1.5% at a one percent level of significance. Higher available water content and renting more land decreased the likelihood of choosing only cover crops by 27.3% and 0.9% at 5% significant level, respectively. Cover crops may use available water content, reducing its availability for the following cash crop, and farmers may be less likely to plant riskier conservation practices, like cover crops, on rental land.

Credit Nutrients from Manure Only (M): Few factors considered impacted the adoption of this management plan. The only statistically significant factors were having a college degree and the raising of livestock on farm. Survey respondents were 1.7% more likely to only adopt the crediting of manure as they raised cattle and/ or hogs. Fuglie and Bosch (1995) mentioned that raising livestock could provide guidance on managing manure application for both farming land and pastures. Thus, raising cattle and/ or hogs significantly increased the use of manure but has no significant or little effect on the probability of adopting cover crops which is associated with soil and weeds management.

No-Tillage and Cover Crops (NC): Renting more acres and participating in the EQIP or CSP increased the likelihood of adopting this management plan. Describing yourself as a risk-avoider, being male and residing in eastern KS decreased the likelihood of adopting this management plan.

No-Tillage and Credit Nutrients from Manure (NM): Farm size, renting more acres, participating in EQIP and CSP, raising livestock, and residing in either eastern or western Kansas increased the likelihood of adopting this management plan. Being a male operator reduced the likelihood of adopting this plan.

For the joint adoption of NC and NM, residence in Eastern Kansas lowered the likelihood of joint adopting no-tillage and cover crops (NC) by 1.8%, but significantly increased the probability of jointly choosing no-tillage and use of manure (NM) by 2.6%. Renting more land and participating in EQIP and/ or CSP both raised the probability of jointly adopting no-tillage and cover crops (NC), and no-tillage and use of manure (NM). In contrast, being a male operator reduced the likelihood of jointly adopting either no-tillage and cover crops (NC) or no-tillage and use of manure (NM).

No Practices (None): Higher erosion potential and farm size contribute to potentially adopting no conservation practice bundle. It could be that marginal lands with high erosion potential are more likely to be retired (e.g. put in the Conservation Reserve Program or similar program) by a farmer or landowner rather than remain in production. Higher available water content in the soil, higher percentage of rented acres, participating in EQIP or CSP, farm experience, being employed off farm, having crop insurance, being male, having a college degree and living in eastern Kansas all reduced the likelihood that no conservation practice bundle would be adopted. The possibility of taking advantage of a conservation program's benefits and having crop insurance that may help to alleviate potential risks of adoption both have the ability of reducing the costs of adoption, increasing the adoption of some type of bundle of conservation practices. In addition, education, maintaining productive soils, and protecting rented lands all are factors that seem to motivate farmers to act on conservation and not take the "none" option.

2.5.2 Unconditional Adoption of No Tillage, Cover Crops and Manure Application

The unconditional probability of adopting a practice is approximately 59% for no-tillage (N); 8.1% for cover crops (C); and 9.2 % for crediting of nutrients from manure (M), respectively. These probability results are quite different from what has been mentioned in Table 3 which eliminates the internal and external influences among those conservation plans and practices. For the single adoption of a practice, many marginal effects of the explanatory variables are significant at the 10% level or above.

Unconditional Adoption of No-Tillage: Higher erosion potential, farm size, farm experience, raising livestock, and a greater chance of drought increased the likelihood of adopting this management plan. Higher available water content, percent of land rented, participating in EQIP and/ or CSP, being employed off farm, being a male operator, having a college degree, residing in eastern Kansas, and greater variability of drought decreased the likelihood of adopting this management plan. Many of the signs follow those for the management bundles described above. Of interest is that, no tillage is more likely to be adopted to maintain soil productivity, to reduce erosion and protect soil water content. While education reduced the likelihood of adoption, it may be that farmers are becoming more experienced with conservation tillage practices and realize that different tillage practices may be needed in different cropping systems.

Unconditional Adoption of Cover Crops: Available water content, farm size, percent of land rented, percent of irrigated land, participating in EQIP and/ or CSP, being employed off farm, having crop insurance, being a male operator, having a college degree, residing in eastern Kansas increased the likelihood of adopting this management plan. The land characteristic, higher risk of soil erosion is the only factor that decreased the likelihood of adopting this management plan. Having a college degree raised the probability of adopting cover crops by 7.4% at a one percent level of significance. It seems that availability of water, in the soil or via irrigation, increases the likelihood of adoption by a considerable amount, potentially due to the lower risk for the following cash crop.

Unconditional Adoption of Crediting Nutrients from Manure: Participating in EQIP and/ or CSP is the only element that increased the likelihood of adopting this conservation practice. Available water content, describing yourself as a risk-avoider, being a male operator, and residing in eastern Kansas decreased the likelihood of adopting this practice. Again, program incentives are likely to increase adoption of conservation practices, while riskier practices (as perceived by the farmer) are less likely to be adopted.

Education seems to decrease the likelihood of adopting no-tillage, but increase the probability of choosing cover crops significantly. Participating in EQIP and/or CSP significantly affects all three unconditional practice adoptions. Particularly, participating in EQIP and/or CSP increases the probability of adopting cover crops and use of manure by 5.9% and 4.1%, respectively, but decreases the probability of adopting no-tillage by 11.5%, which may be due to current programmatic focuses. Thus, education and conservation programs are still important tools for promoting adoption. While most studies focus on the adoption of a single practice, this may ignore potential complementarities or substitutability (i.e. dependencies) between practices, but the joint framework will implicitly take account of this.

2.5.3 Unconditional Simultaneous Adoption of Two Conservation Practices

The joint adoption framework allows one to examine the simultaneous adoption or bundles of practices which can help to assess factors that affect the intensity of adoption on-farm, though, the joint adoption framework does not pick up the potential sequential nature of adoption or piece-meal approach. Not many of the factors considered impact the joint adoption of two conservation practices. Having a college degree and raising livestock increase the likelihood of adopting no-tillage and cover crops, and greater variability in field slopes decreases the likelihood of choosing this management plan by 0.7%. Percent of land rented and participating in EQIP and/or CSP significantly raise the likelihood of adopting no-tillage and use of manure by 2.2% and 2.5%, respectively, and being a risk avoider and a male operator will lower the likelihood of choosing this management plan. These estimates provide guidance on the adoption of bundles of practices, which may be of interest for policymakers' wanting to intensify practices on working agricultural lands.

2.5.4 Conditional Adoption of Conservation Practices

In this study, we proposed using the joint adoption framework to look at the conditional probabilities of adopting conservation practices. This knowledge may help to find out what it would take to get people to increase the size of their bundles of practices or adopt additional practices, based on complementarities with other conservation practices. The conditional probabilities were chosen based on the adoption patterns found in the survey. For example, it would be less likely that cover crops would be adopted as a conservation practice prior to the adoption of no-tillage. Silage farmers Jeffrey and Penny Stevens, participating in the SARE (Sustainable Agriculture Research and Education)-funded project in New England states, illustrated that they had always adopted winter cover crops after no-tillage, which could lower the fuel costs and help to replace some fertilizer inputs (USDA—SARE, 2013). In addition, it may make more management sense to adopt no-tillage prior to the adoption of cover crops, given cover crops increases the amount of residue on the soul surface and increases management intensity significantly. From this study, the estimated conditional probability of adopting cover crops given no-till has been adopted is 6.4%, while the conditional probability of crediting nutrients from manure as a fertilizer given no-till has been adopted is 11.1%.

Based on the analysis of this study, we find that farmers who have already adopted no-tillage are more likely to adopt cover crops if they have a college degree and/or raising livestock. For example, farmers with a college degree are 9.1% more likely to adopt cover crops given no-tillage adopted. Farm size, percent of land rented, and participating in EQIP and/or CSP increase the likelihood of adopting use of manure given no-tillage adopted. Particularly, farmers raising cattle and/or hogs are 6.2% more likely to choose the crediting of nutrients from manure given no-tillage adopted. In contrast, survey respondents are 2.8% less likely to choose the manure conservation practice given no-tillage adopted is they are risk avoiders. Again, these estimates may be useful for policy-maker interested in getting farmers who already have adopted given conservation to intensify their conservation efforts by adopting additional practices.

2.6. Conclusion

Conservation practices significantly affect the whole production system on-farm, as well as soil and water conservation. In order to provide useful guidance and inference, we conducted this study to examine and analyze the adoption of conservation practices by Kansas farmers from both a joint and conditional viewpoint, and the socio-economic and farm factors affecting the adoption. We first model the joint adoption of conservation practices with a multinomial modeling framework and then utilize this framework to estimate conditional probabilities of adopting conservation practices given the adoption of other practices. This provides a novel contribution to the adoption literature on how to examine adoption conditionally using cross-sectional data.

The joint adoption framework is employed to develop a methodology for assessing the conditional adoption of alternative farm practices. A modified multinomial logistic regression model is then used to examine the joint adoption of conservation practices by Kansas farmers, while the adoption of these practices is conditional on a number of explanatory factors. As coefficient estimates are not readily interpretable in the multinomial logistic model, marginal effect is necessary and essential to be estimated for this study. The marginal effects are derived from the associated probabilities which are built under the random utility model. Conservation practice adoption is not only complex and multifaceted, but also a dynamic learning process being filled with knowledge collecting, information evaluating, decisions making and goals reaching. Farmers need to take into account the interrelated nature of conservation practices and other agricultural practices, as well as the social and economic factors that affect the adoption of conservation practices.

Conservation practice adoption is a long learning process (Ghadim and Pannell 1999). Land operators need to balance the benefit brought from conservation practice adoption, as well as the cost of collecting, integrating and evaluating new information for a better decision making. Also, farmers' self-learning ability is required for the innovation to their own situation (Ghadim and Pannell 1999). Results of this study show that both experience and education play an important role in promoting adoption of new practices and conservation intensification. Extension agents should spend time and resource to provide useful and reasonable guidance for farmers and land owners about conservation practices and think about the role of participatory research approaches. In addition, more effective and adoptable conservation practices should continue to be promoted using conservation programs and financial incentives to promote adoption, intensification and replace undesirable practices. Study results emphasize the strong ability of these programs and incentives to promote adoption of single practices, bundles of practices and conservation intensification.

There may be existing potential endogeneity with no-tillage, EQIP and CSP, which were not modeled here, but should be considered in the future. Insurance variables are not included in the model, but may impact choice of tillage and should be included in future studies. Furthermore, specific hypotheses should be explored rather than correlations among various explanatory variables. A significant avenue for future research revolves around the fact that this study was done using cross-sectional data. While the study provides a methodology for providing a deeper analysis of the data, a panel dataset over multiple periods of time would provide a much richer analysis and is an area for future research.

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Table 2.1. Definition of Explanatory Variables and Summary Statistics (N = 2163)

	Variables	Mean	Standard Deviation	Definition
Landscape Attributes	KW Factor	0.30	0.10	Spatially weighted average K-W factor in the counties farmers operate
	Available Water Content	0.16	0.06	Spatially weighted average of available water content in the counties farmers operate
	Std Slope	3.78	1.58	Standard deviation of slope within the counties farmers operate
Farm Characteristics	Farm Size	1150.41	6524.27	Total cropland acres operated in 2010
	Rental Percentage	0.41	0.37	Percent of farm acres rented
	Irrigation Percent	0.05	0.21	Percent of crop land irrigated
	Livestock	0.52	0.50	Cattle and/or hogs raised on farmers' operation in 2010 (1 = yes, 0 = no)
	EQIP and CSP	0.12	0.32	Farmer participates in Environmental Quality Incentives Program (EQIP) and/or Conservation Security/Stewardship Program (CSP) in 2010 (1 = yes, 0 = no)
Farmer Demographics and Characteristics	Experience	35.85	15.04	Number of years the operator has been farming
	Risk Avoider	0.40	0.49	Farmer describes themselves as a risk avoider (1 = yes, 0 = no)
	Off-Farm Employ	0.53	0.50	Farmers or their immediate families employed off the farm (1 = yes, 0 = no)
	Crop Insurance	0.68	0.47	Farmer does not use insurance (1= yes, 0 = no)
	Gender	0.95	0.23	Gender of farm operator (1 = male, 0 = female)
	College	0.34	0.47	Farm operator has earned a college degree (1 = yes, 0 = no)
Region	West	0.23	0.42	Agricultural reporting district 10, 20 or 30 (1 = west, 0 = other area)
	East	0.32	0.47	Agricultural reporting district 70, 80 or 90 (1 = east, 0 = other area)
Weather	Average PZ	0.52	0.11	Mean Palmer Z Drought over past 10 years
	Std PZ	2.04	0.13	Standard deviation of the Palmer Z Drought over past 10 years

The standard deviation of all binary variables is calculated as: $\sqrt{p(1-p)}$, where p is the mean of the binary variable.

Table 2.2. Conservation Plans Adopting Crops Using No-Till, Cover Crops and Manure

In-Field Conservation Practices				
Management Plan	No-Till (N)	Cover Crops (C)	Credit Nutrients from Manure (M)	Percent of Respondents Using Plan
N	X	–	–	52.27
C	–	X	–	1.68
M	–	–	X	1.90
NC	X	X	–	4.19
NM	X	–	X	5.48
CM	–	X	X	0.09
NCM	X	X	X	0.99
NONE	–	–	–	33.41

Table 2.3. Marginal Effects for the Adoption of Different Conservation Practices/Bundles

Variables	NONE	No-Till	Cover Crops	Manure Practice	No-Till and Cover Crops	No-Till and Manure Practice
KW Factor	1.112***	-1.387***	0.119*	-0.039	-0.029	0.225
	(0.418)	(0.449)	(0.061)	(0.056)	(0.161)	(0.195)
Available Water Content	-2.264***	2.787***	-0.273**	0.046	0.131	-0.427
	(0.762)	(0.817)	(0.121)	(0.100)	(0.290)	(0.353)
Std Slope	0.007	-0.001	0.002*	-0.002	-0.003	-0.002
	(0.007)	(0.008)	(0.001)	(0.001)	(0.003)	(0.003)
Farm Size	0.000***	0.000***	0.000	0.000	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rental Percentage	-0.137***	0.100***	-0.009**	-0.005	0.022**	0.029**
	(0.030)	(0.031)	(0.004)	(0.004)	(0.010)	(0.013)
Irrigation Percent	-0.049	0.094	-0.035	0.004	-0.055	0.041
	(0.067)	(0.074)	(0.022)	(0.007)	(0.040)	(0.028)
EQIP and CSP	-0.124***	0.081**	0.003	-0.007	0.026***	0.021*
	(0.038)	(0.037)	(0.004)	(0.006)	(0.010)	(0.013)
Experience	-0.000***	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Risk Avoider	0.013	0.014	-0.002	0.003	-0.016**	-0.013
	(0.021)	(0.022)	(0.003)	(0.003)	(0.008)	(0.010)
Off-Farm Employ	-0.078***	0.069***	-0.004	-0.001	0.009	0.004
	(0.021)	(0.022)	(0.003)	(0.003)	(0.008)	(0.010)
Crop Insurance	-0.022	0.044*	-0.003	-0.001	-0.004	-0.014
	(0.023)	(0.024)	(0.003)	(0.003)	(0.008)	(0.010)
Gender	-0.090*	0.164***	-0.006	0.005	-0.028*	-0.045**
	(0.046)	(0.052)	(0.005)	(0.008)	(0.015)	(0.018)
College	-0.080***	0.066***	-0.005	0.005*	0.002	0.011
	(0.023)	(0.024)	(0.003)	(0.003)	(0.008)	(0.010)
Livestock	0.018	-0.070***	-0.002	0.017***	-0.000	0.037***
	(0.021)	(0.023)	(0.003)	(0.005)	(0.009)	(0.010)
West	-0.010	-0.003	-0.005	0.001	-0.011	0.029**
	(0.031)	(0.032)	(0.004)	(0.004)	(0.011)	(0.013)
East	-0.061**	0.070**	-0.015***	-0.001	-0.018*	0.026**
	(0.027)	(0.028)	(0.005)	(0.003)	(0.010)	(0.012)
Average PZ	0.121	-0.167	-0.035**	0.022	0.034	0.024
	(0.115)	(0.123)	(0.016)	(0.017)	(0.047)	(0.050)
Std PZ	-0.079	0.188	0.008	-0.017	-0.051	-0.049
	(0.108)	(0.115)	(0.015)	(0.013)	(0.043)	(0.052)

1. Standard errors are presented in parentheses;
2. ***, **, * indicate statistical significance at 1%, 5% and 10% level, respectively.

Table 2.4. Estimated Marginal Effects for the Unconditional and Conditional Adoption of No-Till, Cover Crops and Manure

Variables	Unconditional Practice Adoption			Unconditional Adoption of Two Practices		Conditional Adoption	
	No-Till	Cover Crops	Crediting Nutrients from Manure	No-Till and Cover Crops	No-Till and Manure Practice	Cover Crops Given No-Till Adopted	Manure Practice Given No-Till Adopted
KW Factor	0.728*	-1.550***	0.427	-0.141	-0.044	-0.350	-0.179
	(0.449)	(0.451)	(0.299)	(0.197)	(0.160)	(0.427)	(0.278)
Available Water Content	-1.407*	3.043***	-0.900*	0.185	0.161	0.505	0.480
	(0.816)	(0.820)	(0.575)	(0.348)	(0.293)	(0.752)	(0.507)
Std Slope	-0.005	-0.006	0.002	-0.007*	-0.003	-0.013	-0.004
	(0.008)	(0.008)	(0.004)	(0.004)	(0.003)	(0.009)	(0.005)
Farm Size	0.000***	0.000***	0.000	0.000	0.000	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rental Percentage	-0.102***	0.100***	-0.012	-0.015	0.022***	-0.018	0.054***
	(0.033)	(0.033)	(0.023)	(0.016)	(0.008)	(0.033)	(0.016)
Irrigation Percentage	-0.028	0.1467*	-0.184	0.015	-0.047	0.032	-0.078
	(0.090)	(0.091)	(0.123)	(0.025)	(0.043)	(0.065)	(0.071)
EQIP and CSP	-0.115***	0.059*	0.041**	-0.020	0.025**	-0.025	0.062***
	(0.038)	(0.037)	(0.019)	(0.021)	(0.011)	(0.043)	(0.019)
Experience	0.002**	-0.001	0.000	0.000	0.000	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
Risk Avoider	0.007	0.018	-0.022*	0.010	-0.015*	0.019	-0.028*
	(0.022)	(0.022)	(0.013)	(0.009)	(0.009)	(0.020)	(0.015)
Off_Farm Employ	-0.045**	0.057**	-0.006	-0.004	0.008	-0.002	0.022
	(0.023)	(0.023)	(0.014)	(0.010)	(0.009)	(0.019)	(0.015)
Crop Insurance	-0.020	0.042*	-0.017	-0.004	-0.003	-0.005	-0.003
	(0.024)	(0.024)	(0.013)	(0.009)	(0.008)	(0.020)	(0.014)
Gender	-0.108**	0.173***	-0.043*	0.015	-0.024*	0.041	-0.027
	(0.052)	(0.053)	(0.023)	(0.029)	(0.015)	(0.059)	(0.026)
College	-0.048**	0.074***	-0.016	0.016*	0.002	0.037*	0.011

(continued)

	(0.024)	(0.024)	(0.015)	(0.010)	(0.008)	(0.023)	(0.014)
Livestock	0.063***	-0.034	-0.012	0.050***	-0.002	0.091**	-0.014
	(0.024)	(0.024)	(0.013)	(0.017)	(0.008)	(0.040)	(0.014)
West	-0.019	0.003	-0.021	0.002	-0.010	0.007	-0.013
	(0.033)	(0.032)	(0.018)	(0.014)	(0.012)	(0.028)	(0.020)
East	-0.064**	0.082***	-0.064***	-0.001	-0.015	0.004	-0.016
	(0.029)	(0.029)	(0.022)	(0.012)	(0.011)	(0.027)	(0.018)
Average PZ	0.256**	-0.090	-0.094	0.065	0.031	0.097	0.011
	(0.123)	(0.124)	(0.079)	(0.062)	(0.049)	(0.135)	(0.084)
Std PZ	-0.205*	0.153	0.011	-0.050	-0.046	-0.075	-0.048
	(0.114)	(0.114)	(0.073)	(0.047)	(0.045)	(0.098)	(0.077)

1. Standard errors are presented in parentheses;
2. ***, **, * indicates statistical significance at 1%, 5% and 10% level, respectively.

Appendix A.2. Parameter Estimates for the Multinomial Logistic Model of Conservation Practices

Variables	No-Till	Cover Crops	Crediting Nutrients from Manure	No-Till and Cover Crops	No-Till and Manure Practice
Constant	-1.985**	-1.099	-1.588	-0.490	-1.491
	(0.925)	(3.952)	(2.962)	(2.318)	(1.937)
KW Factor	-6.000***	12.913	-8.605	-4.475	0.597
	(2.047)	(8.235)	(7.087)	(4.877)	(4.127)
Available Water	12.150***	-30.703*	13.223	11.133	-0.636
Content	(3.727)	(15.666)	(12.698)	(8.867)	(7.470)
Std Slope	-0.026	0.211*	-0.302**	-0.102	-0.069
	(0.035)	(0.114)	(0.137)	(0.090)	(0.072)
Farm Size	0.000***	0.000	-0.000	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Rental	0.618***	-0.755	-0.223	1.075***	0.991***
Percentage Risk avoider	(0.143)	(0.547)	(0.485)	(0.324)	(0.284)
Irrigation	0.318	-4.685	0.673	-1.386	0.930
Percentage	(0.321)	(3.334)	(0.922)	(1.195)	(0.606)
EQIP and CSP	0.545***	0.869	-0.460	1.130***	0.801***
	(0.183)	(0.575)	(0.751)	(0.312)	(0.290)
Experience	0.001***	0.000	0.004	0.004	0.000
	(0.000)	(0.001)	(0.004)	(0.003)	(0.000)
Risk	-0.019	-0.246	0.367	-0.494**	-0.289
Avoider	(0.102)	(0.363)	(0.329)	(0.245)	(0.211)
Off_Farm	0.373***	(-0.276)	0.120	0.521**	0.341*
Employ	(0.102)	(0.367)	(0.334)	(0.239)	0.204
Crop	0.146	-0.384	-0.077	-0.040	-0.191
Insurance	(0.110)	(0.376)	(0.337)	(0.250)	(0.216)
Gender	0.572**	-0.4967	0.864	-0.487	-0.561
	(0.233)	(0.625)	(1.040)	(0.444)	(0.383)
College	0.374***	-0.477	0.920***	0.328	0.466**
	(0.110)	(0.444)	(0.334)	(0.240)	(0.212)
Livestock	-0.177*	-0.362	2.081***	-0.067	0.641***
	(0.104)	(0.363)	(0.497)	(0.240)	(0.221)
West	0.029	-0.688	0.117	-0.273	0.574**
	(0.151)	(0.519)	(0.485)	(0.350)	(0.293)
East	0.317**	-1.945***	0.073	-0.321	0.692***
	(0.130)	(0.641)	(0.434)	(0.306)	(0.264)
Average PZ	-0.680	-5.256**	2.343	0.569	0.062
	(0.563)	(2.191)	(2.191)	(1.434)	(1.060)
Std PZ	0.577	1.392	-1.898	-1.188	-0.674
	(0.525)	(2.102)	(1.679)	(1.298)	(1.099)

1. Standard errors are presented in parentheses;
2. ***, **, * indicate statistical significant at 1%, 5% and 10% level, respectively.

Chapter 3 - Testing for Functional Form Misspecification in the Logistic Regression Model: RESET and OPRESET Tests

3.1. Introduction

Model misspecification problems in regression models, such as the logistic regression model, can be caused by omitted variables, unmodelled dependence and heterogeneity, and incorrect functional form. In logistic regression models, the functional form refers to the functional relationship between the dependent binary variables and set of regressors or explanatory variables (Press and Wilson, 1978). Bierens (1982, 1984) developed consistent model misspecification tests to assess functional forms of regression models, however the null distribution of the test statistics involved was intractable. Bierens (1987) and Bierens and Hartog (1988) developed a tractable null distribution, but the consistency of the tests relied on randomization of test parameters. Later, Bierens (1990) showed that any conditional moment test of functional form for nonlinear regression model would be converted into a chi-square test. McGuirk et al. (1993) employed a comprehensive set of individual and joint misspecification tests that could help identify misspecification sources, including functional forms. Bergtold et al. (2010) developed a probabilistic reduction approach to check Bernoulli regression models with binary dependent variables for misspecification problems.

The function specification of logistic regression model depends on the choice of transformation (e.g. logistic cdf) and predictor (or index) function (Bergtold et al., 2010). Bergtold et al. (2010) show that the functional form assumption is tired up with the proper choice of predictor function and the choice of the logistic cumulative density function (cdf) for the transformation function arises naturally. Kay and Little (1987) illustrate that the probabilistic structure of the explanatory variables can be used to specify the function form of the index function, but it can be increasingly difficult in cases with many explanatory variables. Functional misspecification of the index function can result in biased and inconsistent estimates which can bring wrong inference.

Thus, it is essential to have a probative functional form test that can pick up potential misspecification in the model to help assess if the logistic regression model is statistically adequate. Given that the predictor function is usually assumed to be linear in the parameters and the explanatory variables, a RESET-type test may be used to test for functional specification. Bergtold et al. (2010) proposed this approach in testing for functional specification of their empirical example in their paper.

Ramsey (1969) derived distributions of classical linear least-square residuals and then derived procedures to test for the specification errors. Ramsey (1969) suggested the RESET (Regression Equation Specification Error Test) test, which tests linearity in the linear regression model. The RESET test seeks to uncover nonlinearities in the functional form. The RESET is ideal test for functional form with high power over a wide variety of alterative hypotheses, which uses 2nd and higher order of the models' fitted vales of the dependent variables. For the test proposed by Betdtold et al. (2010), linearity or the functional form of the predictor is tested using the fitted predictor values. A potential problem with the use of regular polynomials of the fitted predictor (or dependent variables in the RESET test) is that the set of polynomials may lead to collinearity problems during estimation (Shacham and Brauner, 1997). A potential solution to this problem is the use of orthogonal polynomials, which may provide a more robust method for assessing a wider variety of functional forms. Orthogonal polynomials can span the space of square integrable functions, which would likely include many of the functional forms of interest to econometric modelers (Kreyszig, 1978).

The purpose of this study is to develop a robust test based on the classic RESET test using orthogonal polynomials to assess the linearity (in the variables) of the predictor or index function of the logistic regression model. Specifically, the paper will develop a misspecification test, the OPRESET or Orthogonal Polynomial RESET, built upon the RESET, to test the functional specification of logistic regression models; assess the properties of the test for different functional form assumptions of the predictor/index function by conducting a simulation experiment; and provide guidance on the use of the OPRESET test in applied regression model development.

3.2. Methods

3.2.1 Logistic Regression Model

Let Y_i be a Bernoulli random variable with unconditional mean $p = \mathbf{P}(Y_i = 1)$, giving a variance equal to $p\ (1 - p)$. Then, let $\mathbf{X}_i$ be a $(K \times 1)$ vector of explanatory variables. The conditional probability of Y_i given $\mathbf{X}_i$ is: $\mathbf{P}(Y_i = 1|\mathbf{X}_i) = [1 + exp\{-\eta(\boldsymbol{X_i}; \boldsymbol{\beta})\}]^{-1}$, where $\eta(\boldsymbol{X_i}; \boldsymbol{\beta})$ is the predictor or index function. This can be represented as:

$$Y_i = [1 + exp\{-\eta(\boldsymbol{X_i}; \boldsymbol{\beta})\}]^{-1} + u_i, \tag{1}$$

where u_i is a zero mean IID random error term. The functional form of $\eta(\boldsymbol{X_i}; \boldsymbol{\beta})$ is usually chosen to be linear in the explanatory variables, parameters or both, but is dependent upon the distributional properties of the explanatory variables (Bergtold et al. 2010; Kay and Little 1987). For example, Kay and Little (1987) show that if the set of explanatory variables conditional on the dependent variable is multivariate normal, then, in general, the predictor will be quadratic in the explanatory variables.

The most commonly used estimator for logistic regression model is the maximum likelihood estimator (MLE). The log-likelihood function used to estimate the logistic regression model is:

$$L(\boldsymbol{\beta}; Y_i, \mathbf{X}_i) = \sum_i Y_i \ln\big(F(\mathbf{X}_i; \boldsymbol{\beta})\big) + (1 - Y_i)\ln\big(1 - F(\mathbf{X}_i; \boldsymbol{\beta})\big), \qquad (2)$$

where $F(\mathbf{X}_i; \boldsymbol{\beta}) = [1 + exp\{-\eta(\mathbf{X}_i; \boldsymbol{\beta})\}]^{-1}$. To find the estimates of $\boldsymbol{\beta}$, the log-likelihood function given by equation (2) is maximized given the data.

3.2.2 RESET Test

The Ramsey Regression Equation Specification Error Test (RESET) test is a general specification test for the linear regression model (Ramsey, 1969). More specifically, it tests whether non-linear combinations of the fitted values (i.e. predicted dependent variable) help to explain the response variable, indicating potential nonlinearities that are not being modeled. In addition, the RESET test can be regarded as a test of general misspecification (Ramsey, 1969).

Ramsey (1969) developed the RESET (Regression Equation Specification Error Test) to test the statistical specification of the linear regression model. The hypotheses being tested is:

$$H_0: E(Y_t/X_t = x_t) = x_t\beta \quad \text{vs.} \quad H_1: E(Y_t/X_t = x_t) = h(x_t)$$

where $h(x_t)$ is some non-linear function of x_t (Spanos, 1986). The RESET testing procedure can be summarized as follows (Ramanathan, 1998):

1) Estimate the general model by OLS and save the predicted values, $\widehat{Y}_t$.

2) Generate the variables $\widehat{Y}_t^{\,2}$,$\widehat{Y}_t^{\,3}$,$\widehat{Y}_t^{\,4}$, etc. and add them to the model in step (1) and re-estimate.

3) Use an F-test to assess the statistical significance of the estimated coefficients for the polynomials of the fitted values in step (2).

For example, assume a modeler estimates $Y = \alpha_1 + \alpha_2 X_1 + \alpha_3 X_2 + \varepsilon$ and the true regression is nonlinear. The modeler can test for this by first estimating the model to obtain $\hat{Y} = \widehat{\alpha_1} + \widehat{\alpha_2}\, X_1 + \widehat{\alpha_3}\, X_2$. Then, the modeler will calculate $\hat{Y}^2$ and put it in the original regression to obtain: $Y = \alpha_1 + \alpha_2 X_1 + \alpha_3 X_2 + \beta \hat{Y}^2 + \varepsilon$. The square of $\hat{Y}$obtained from second regression depends both on the squares of X_1 and X_2 and on their cross–product $X_1 X_2$. The RESET test amounts then to testing the significance of the estimated β. Rejection of the null hypothesis merely indicates that the equation has been misspecified. As in general misspecification test, the null hypothesis should not be taken to be the true model.

As noted in the introduction, the traditional RESET test uses regular polynomials, which may result in near-multicollinearity among the polynomials of the fitted values, problems during estimation problems, and biased inference. A potential solution to this problem is the use of orthogonal polynomials, which do not suffer from this problem (Shacham and Brauner, 1997).

However, it is necessary to examine orthogonal polynomials, which provides a more robust method for assessing the functional form. When higher order polynomials are to be used to approximate highly nonlinear functions, use of orthogonal polynomials may provide a more robust approach.

3.2.3 Orthogonal Polynomial RESET Test (OPRESET)

The types of orthogonal polynomial used will depend on the domain of the function. If the domain is from negative infinity to positive infinity, the Hermite polynomials are one option that can be used. If the domain is non-negative, then Laguerre polynomials are appropriate, and Legendre or Jacobi polynomials are appropriate if the domain is from zero to one (Kreyszig, 1978). The focus here will be on Hermite polynomials, but other orthogonal polynomials can be utilized.

The general formula for a Hermite polynomial is given by (Kreyszig, 1978):

$$H_n(t) = (-1)^n e^{t^2} \frac{d^n}{dt^n}(e^{-t^2}),\ n = 1,\ 2,\ \ldots. \qquad (3)$$

A better alternative formulation, is using the orthonormal sequence of Hermite polynomials that spans the space of square integrable functions (i.e. $L_2(-\infty,+\infty)$). This sequence is given by:

$$e_n(x) = \frac{1}{\left(2^n n! \sqrt{\pi}\right)^{1/2}} e^{-\left(x^2/2\right)} H_n(x),\ n = 0,\ 1,\ 2,\ \ldots, \qquad (4)$$

where the Hermite polynomial takes the following expanded form:

$$H_n(x) = n! \sum_{j=0}^{N} (-1)^j \frac{2^{n-2j}}{j!(n-2j)!} x^{n-2j}\ , \qquad (5)$$

where $N = n/2$ if n is even and $N = (n-1)/2$ if n is odd (Kreyszig, 1978). Explicit expressions for the first five Hermite polynomials are (Spiegel and Liu, 1999):

$H_0(x) = 1,$

$H_1(x) = 2x\,,$

$H_2(x) = 4x^2 - 2\,,$

$H_3(W) = 8x^3 - 12x$, and

$H_4(W) = 16x^4 - 48x^2 + 12\,.$

Figure 3 depicts the first three orthogonal polynomials $e_n(x)$ for $n = 0, 1, 2, 3, 4$ using equation (4). Any element in the space of square integrable functions, $L_2(-\infty,+\infty)$, which includes the predictor functions of interest, can be uniquely determined by a linear combination of the elements of the orthonormal sequence given by equation (5) (Kreyszig, 1978). Thus, by choosing a tolerable approximation error, a modeler then can essentially approximate the true predictor using a finite number of elements of the orthonormal sequence given by equation (5).

The use of these polynomials can produce a much larger ‘neighborhood’ in which to probe for model misspecifications than traditional polynomials.

We suggest using the orthogonal (Hermite) polynomials in place of the original polynomials in conducting functional form tests for the predictor or index function of the logistic regression model. As done in Bergtold et al. (2010), a modified RESET test can be used to test for the functional form of the predictor. They suggested using the regular polynomials of the fitted predictor function: $\hat{\eta} = \eta\left(\mathbf{X}_i; \widehat{\boldsymbol{\beta}}\right)$ to test for nonlinearity by specifying an encompassing function:

$$\eta(\mathbf{X}_i; \boldsymbol{\beta}) = \beta_0 + \beta_1' x + \gamma_1 \hat{\eta}^2 + \gamma_2 \hat{\eta}^3 (+\gamma_3 \hat{\eta}^4 + \gamma_4 \hat{\eta}^5) \quad (6)$$

Then, test the significance of the estimated parameter vector $\boldsymbol{\gamma}$ to assess if the predictor is misspecified. We advocate extending the robustness of this approach using orthogonal polynomials, specifically Hermite polynomials, to assess the functional form of the predictor function. This amounts to replacing the regular RESET terms using the fitted predictor values in equation (6) with:

$$\gamma_1 * \mathrm{H}(\hat{\eta})^2 + \gamma_2 * \mathrm{H}(\hat{\eta})^3 + \gamma_3 * \mathrm{H}(\hat{\eta})^4 + \gamma_4 * \mathrm{H}(\hat{\eta})^5 + \ldots, \quad (7)$$

which can be extended to as many terms as are needed. The modeler would then test the following hypotheses:

H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = 0$ vs H_1: $\gamma_i = 0$ for at least one $I = 1,2,3,4,\ldots$

A standard likelihood-ratio test can be employed for the purpose of testing these hypotheses. The test takes the form:

$$LR = -2\,(LnL_0 - Ln\,L_1) \sim x^2$$

where $L_0$is the likelihood function from the estimated (restricted) model and L_1 is the likelihood function from the model including the RESET terms (unrestricted model) (Greene, 2012).

Another potential advantage of the RESET and OPRESET tests are that they require only a limited number of degrees of freedom to be conducted, potentially providing a more robust test in models with small samples.

3.2.4 Simulation Experiment

A simulation was conducted to assess the OPRESET test compared to the RESET proposed by Bergtold et al. (2010) to determine their power in detecting potential functional misspecification of the predictor (or index) function. Data for the Monte Carlo Simulations was simulated using a two-step procedure following Bergtold et al. (2010) using the inverse conditional distribution of the explanatory variable(s) on the dependent variable. First, a random sample of the dependent variable (Y_i) is generated of size N. Using the dependent variable as a conditioning variable, the explanatory variables are randomly generated using the specified inverse conditional distribution(s). With multiple explanatory variables, a multivariate inverse conditional distribution was employed. To make the data generation more tractable, these distributions can be decomposed into products of conditional distributions, allowing one conditional random sample (realization) of size N of the multivariate distribution to be generated in a sequential manner. The advantage of this data generation approach is that it allows for a purely statistical method to generate the data and provides exact formulas for the parameters, β, that can be derived as functions of the parameters of the inverse conditional distributions (Bergtold et al. 2010, Scrucca and Weisberg, 2004).

To assess the power of the OPRESET and RESET type tests, four different cases are examined. The models for each case are provided in Table 1. The cases vary by functional form, type of explanatory variables, and level of multicollinearity. For each case, it was assumed the estimated logistic regression model had a predictor function linear in the explanatory variables and parameters, as is usually found in the applied literature. The OPRESET and RESET tests were then used to assess if they could detect that this model was misspecified and arose from the underlying true model as specified in Table 1.

Using the models in Table 1, Monte Carlo simulations were conducted for differing sample sizes of *N = 50; 100; 250; 500; 1000; 2500*; and *5000* to examine effects as sample size is increased. Each Monte Carlo simulation was conducted using 1,000 replications. We conduct OPRESET tests up to order 5 (i.e. with up to 5^{th} degree orthogonal polynomial expansion of the fitted predictor) and RESET tests up to order 3 (i.e. with up to a 3^{rd} degree polynomial expansion of the fitted predictor). The null hypotheses for each of the tests are assumed to be rejected when the p-value for the likelihood ratio test statistic is less than 0.10, as suggested by Spanos (1999). Data generation, simulation and model estimation were all carried out in MATLAB.

3.3. Results

Simulation results are reported in Table 2. Following McGuirk et al. (1993) we report the percentage of times the test rejects that the model is properly specified (i.e. correctly determines the model is misspecified) in 1000 replications, assuming a nominal test size of 5%. The results show the probative power of the misspecification test as sample sizes increase. That is, how often the null hypothesis is correctly rejected.

Overall, in small samples (less than 250 to 500 observation), simulation for both the RESET and OPRESET show that these misspecification tests have low power in detecting potential misspecification of the predictor function. This occurs more often in the cases with explanatory variables (covariates) that are non-normal and/or in the presence of near-multicollinearity between the explanatory variables (covariates). When there are less than 500 observations, it seems that the proposed test do not have enough probative power to provide conclusive results.

The RESET test based on the approach suggested in Bergtold et al. (2010) does a relatively uniform job at detecting misspecification of the models, as sample size increases. The RESET based seems to do a better job at detecting misspecification when the predictor functions is quadratic or includes just simple interaction terms between the explanatory variables (with no transformations of the explanatory variables). RESET test provides a strong probative test for detecting potential missing interaction terms in the predictor function of the logistic regression model. In other cases, the probative power of the test seems to decline. In addition, the probative power of the tests seems to increase with the inclusion of higher order polynomials.

The OPRESET test, performed better on the more nonlinear case 2, compared to the RESET test. This is likely due to the fact that the orthogonal polynomials can provide a better approximation to the underlying true model without the numerical collinearity problems that may arise when using regular polynomials. As with the RESET test, the probative power of the OPRESET test increases as higher order Hermite polynomials are included. Given that only Hermite polynomials were examined here, it may be the case that other orthogonal polynomials may provide more probative power. Compared to RESET, OPRESET test provides a better test for predicting linear predictors that incorporate transformations and (more nonlinear) interaction of the explanatory variables (or covariates).

3.4. Conclusion

The purpose of this paper was to propose and examine a misspecification test for the specification of the predictor (index) function of the logistic regression model. A RESET type test following that proposed by Ramsey (1969) and Bergtold et al. (2010) using orthogonal polynomials was proposed and the probative power of the test at detecting model misspecification was assed and compared to a more conventional RESET type test via simulation.

The RESET and OPRESET test do provide some probative power in detecting potential model misspecifications when sample sizes are larger (500+). The RESET test provides a stronger probative test for detecting potential missing simple interaction terms (e.g. squared terms or direct interactions between non-transformed explanatory variables) in the predictor function of the logistic regression model, while the OPRESET test provides a better test for predicting linear predictors that incorporate more nonlinear transformations of the explanatory variables (e.g. log) and nonlinear interactions of the explanatory variables. Both tests exhibited low power in small sample sizes, especially below 250 observations. Future research should look at examining additional functional forms to assess the probative power of these misspecification tests and other tests, such as the Lagrange Multiplier and Wald tests, to assess if they provide a better platform for misspecification testing.

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Table 3.1. Misspecification Test Results by Functional Form

Case	Description	Cutoff	Functional Form of the Predictor
1	Logistic regression model with quadratic predictor function of 5 normal covariates	0.50	$\eta(X_i;\beta) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$ $+\beta_4 X_4 + \beta_5 X_5 + \beta_{11} X_1^2 + \beta_{12} X_1 X_2$ $+\beta_{13} X_1 X_3 + \beta_{14} X_1 X_4 + \beta_{15} X_1 X_5 + \beta_{22} X_2^2$ $+\beta_{23} X_2 X_3 + \beta_{24} X_2 X_4 + \beta_{25} X_2 X_5 + \beta_{33} X_3^2$ $+\beta_{34} X_3 X_4 + \beta_{35} X_3 X_5 + \beta_{44} X_4^2 + \beta_{45} X_4 X_5$ $+\beta_{55} X_5^2$
2	Logistic regression model with a nonlinear predictor function of 2 covariates distributed Bernoulli and Gamma	0.50	$\eta(X_i;\beta) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 \ln(X_2) +$ $\beta_4 X_1 X_2 + \beta_5 X_1 \ln(X_2)$
3	Logistic regression model with quadratic predictor function of 2 normal covariates with correlation between the two covariates of 0.75	0.60	$\eta(X_i;\beta) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_1^2 +$ $\beta_4 X_1 X_2 + \beta_5 X_2^2$
4	Logistic regression model with a nonlinear predictor function of 2 covariates distributed Bernoulli and Exponential	0.50	$\eta(X_i;\beta) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_1 X_2$

Table 3.2. Monte Carlo Simulation Results by Functional Form

Individual Misspecification Tests With 1000 Runs: Percentage of Times Reject H_0: assumption valid $\alpha = 0.05$

Case	1							2						
N	*50*	*100*	*250*	*500*	*1000*	*2500*	*5000*	*50*	*100*	*250*	*500*	*1000*	*2500*	*5000*
Ramsey (2)	17.8	30.7	58.7	86.1	98.7	100.0	100.0	9.2	13.5	18.7	30.3	38.8	57.3	73.7
Ramsey (3)	17.8	25.5	51.9	79.5	97.9	100.0	100.0	17.3	17.8	18.8	25.3	32.2	60.1	90.0
OPReset (2)	8.6	17.6	42.3	73.6	96.7	100.0	100.0	6.4	13.9	38.1	71.3	95.1	100.0	100.0
OPReset (3)	10.2	14.8	37.9	66.5	95.9	100.0	100.0	11.7	16.7	40.6	72.5	95.3	100.0	100.0
OPReset (4)	13.7	16.4	34.9	61.2	93.8	100.0	100.0	16.3	18.8	37.5	69.7	94.6	100.0	100.0
OPReset (5)	16.8	19.3	36.2	60.1	93.5	100.0	100.0	18.6	20.4	37.1	67.4	94.3	100.0	100.0

Individual Misspecification Tests With 1000 Runs: Percentage of Times Reject H_0: assumption valid $\alpha = 0.05$ *(Continued)*

Case	3							4						
N	*50*	*100*	*250*	*500*	*1000*	*2500*	*5000*	*50*	*100*	*250*	*500*	*1000*	*2500*	*5000*
Ramsey (2)	22.3	29.1	53.1	79.1	97.0	100.0	100.0	14.4	15.3	23.5	32.3	49.2	82.0	97.8
Ramsey (3)	23.8	24.5	45.6	72.1	93.5	100.0	100.0	22.3	18.0	22.2	29.2	43.3	75.8	95.3
OPReset (2)	9.4	11.9	30.5	59.5	88.9	99.6	100.0	5.1	7.9	6.3	9.1	14.1	30.3	52.7
OPReset (3)	11.0	12.9	31.7	58.2	88.1	99.8	100.0	8.7	9.9	7.9	10.0	13.4	29.6	52.7
OPReset (4)	15.9	16.7	31.0	55.5	84.4	99.8	100.0	11.0	11.7	12.2	14.5	22.4	49.5	82.2
OPReset (5)	18.6	17.2	28.4	52.9	82.1	99.7	100.0	15.3	13.6	12.3	14.9	22.7	51.6	82.6

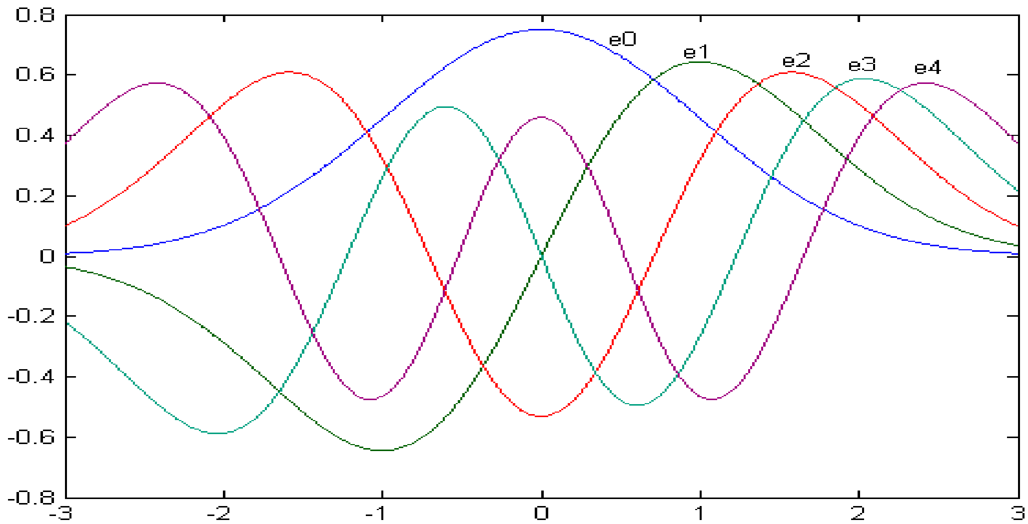

Figure 3.3. Functions $e_n(x)$ for n = *0, 1, 2, 3, 4* involving Hermite Polynomials