

PRODUCER OPPORTUNISM AND ENVIRONMENTAL IMPACTS OF CROP
INSURANCE AND FERTILIZER DECISIONS

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation of
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Chair

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Abstract

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This dissertation empirically examines crop insurance effects on producers and the environment as well as environmental effects of nitrogen use. It follows the journal article style and includes three self-contained chapters.

In the first paper I analyze whether opportunistic behavior in crop insurance can arise due to asymmetric information between producers and the Federal Crop Insurance Corporation. Producers who insure fields using transitional yields based on county average yields or who select options such as buy-up coverage or revenue insurance may increase their return from crop insurance. Using field-level crop insurance contract data for several crops in five growing regions, I find evidence that producers can profit from using buy-up coverage, revenue insurance, and transitional yields and that the level of producer opportunism is crop specific but not necessarily land-quality specific and is greater due to premium subsidization.

In the second article I characterize the extensive-margin (land allocation) environmental effects of crop insurance and crop insurance contracts between regions using four environmental indicators. Crop insurance participation may affect a producer's acreage decision or how much of each crop to plant. Planting decisions affect the environment because the production of

different crops requires different input levels. Our results indicate that adverse environmental impacts from crop insurance are evident in only two of the four regions analyzed and in only two of the four environmental indicators. Crop insurance is related to adverse wind erosion and total nitrogen loss in North Dakota and wind erosion in Eastern Colorado.

The objective of the third article is to identify terrain attributes where unaccounted nitrogen is likely to occur and the economic impact on producers from a reduction in applied nitrogen. Understanding the environmental sensitivity from agricultural production helps to identify market conditions and technology that policymakers can use to design policies to minimize the economic cost of reducing environmental degradation. Results indicate that spatial econometric methods increase statistical efficiency in parameter estimation over standard econometric estimation. Statistically significant impacts of available nitrogen on yield are observed by terrain attribute and unaccounted nitrogen. Results indicate that the adoption of variable rate fertilizer application technology is not economic with our selection of landscape positions at our experimental site.

Dedication

To my parents and Dr. Lia Nogueira

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT	iv
CHAPTER	
1. INTRODUCTION	1
2. INFORMATION AND OPPORTUNISTIC BEHAVIOR IN FEDERAL CROP INSURANCE PROGRAMS	6
Introduction.....	6
Insurance Characteristics	9
Insurance Decisions and Opportunistic Behavior.....	11
Model, Data, and Analysis.....	15
Results.....	20
Conclusions.....	24
References.....	27
Tables	30
3. CROP INSURANCE, LAND ALLOCATION, AND THE ENVIRONMENT	39
Introduction.....	39
Crop Insurance and Acreage Allocations	43
Acreage Allocations and the Environment	44
Method of Analysis.....	48
Data	53

Results.....	55
Environmental Impacts.....	57
Conclusions.....	60
References.....	63
Tables	65
4. ECONOMIC EFFECTS ON PRODUCERS FROM REDUCING NITROGEN	
POLLUTION IN WHEAT PRODUCTION.....	71
Introduction.....	71
Unaccounted Nitrogen	75
Hypotheses.....	76
Method of Analysis.....	78
Experiment Description – Source of Data	83
Results	84
Conclusions.....	91
References.....	94
Tables	96
APPENDIX A: Computer code for Chapter 2	102
APPENDIX B: Computer code for Chapter 3	152
APPENDIX C: Computer code for Chapter 4	172

LIST OF TABLES

Table	Page
2.1 Variable Description	30
2.2 Buy-up Coverage and Revenue Insurance Parameter Estimates with Social Return as the Dependent Variable	31
2.3 Buy-up Coverage and Revenue Insurance Parameter Estimates with Producer Return as the Dependent Variable	33
2.4 T-yield Paramter Estimates with Social Return as the Dependent Variable.....	35
2.5 T-yield Paramter Estimstes with Producer Return as the Dependent Variable	36
2.6 Estimated Amount of Buy-up Coverage and Revenue Insurance Producer Opportunism due to Subsidy.....	37
2.7 Estimated Amount of T-yield Producer Opportunism due to Subsidy	38
3.1 Description of Insurance Programs.....	65
3.2 Parameter Estimates for General Insurance Damage, Equation(1)	66
3.3 Parameter Estimates for Insurance Contract Damage, Equation(5)	67
3.4 Effects of Revenue vs. Yield Insurance and High vs Low Coverage Level on Acreage Share	68
3.5 Enviromental Effects from Crop Insurance and Contracts.....	69
3.6 Average Enviromental Outcome from Crop Insurance	70
3.7 Parameter Estimates of Producer Premium on Acreage Shares, Equation (6)	70
3.8 Percent Change in Producer Premium Required to Offset Negative Enviromental Outcomes.....	70
4.1 Tests of Spatial Autocorrelation Form, Hypotheses 1-2.....	96
4.2 Estimated Coefficients from Equation (3) Including Higher Elevation in the Spatial Weights Matrix	97
4.3 Tests of Terrain attribute Effect on Response to Available Nitrogen.....	98

4.4	Comparative Statics of Available Nitrogen at Terrain attributes.....	99
4.5	Per Acre Impact of Price Ratios on a Maximum Reduction in Applied Nitrogen.....	100
4.6	Per Acre Economic Impact from Restricting Applied Nitrogen.....	101

CHAPTER ONE

INTRODUCTION

This dissertation empirically examines crop insurance effects on producers and the environment as well as environmental and economic effects of nitrogen fertilizer use. The second chapter examines producer opportunism from crop insurance participation. The third chapter examines the relationship between crop insurance and the environment. The fourth and final chapter examines the economic effects on producers from limiting nitrogen fertilizer use.

Chapter 2, “Information and Opportunistic Behavior in Federal Crop Insurance Programs”, provides an analysis of opportunistic behavior in crop insurance. Producer opportunism results in larger indemnities being paid to producers, which in turn increases taxpayer outlays. Reducing producer opportunistic behavior creates a more efficient risk management program that limits the ability of producers to extract profits, rather than just lower risk, from participating. Producer insurance decisions such as buy-up coverage and revenue insurance can potentially increase producer return from crop insurance. Additionally, producers without proven yields, who insure fields by using transitional yields based on the county average, can potentially increase their indemnity when their expected yield falls sufficiently below the county average yield.

I examine producer opportunism in crop insurance using field-level data in five different growing regions. Field-level data allows us to better estimate the extent of producer opportunistic behavior specific to crop insurance contract decisions. Analyzing growing regions

with greater within-county land resource heterogeneity allows me to identify whether soil and climate variability increases producer opportunism from the use of buy-up coverage, revenue insurance or transitional yields. I estimate an equation for each region analyzed that characterizes the variables on which return is hypothesized to depend.

The results provide policy makers information concerning whether producers are using asymmetric information to increase their return from crop insurance and whether the extent of producer opportunism increases in regions with greater within-county land resource heterogeneity. Results indicate that buy-up coverage, revenue insurance, and transitional yields can each potentially increase producer return. However, producer opportunism in regions with greater within-county land resource heterogeneity is not different from that in regions with less within-county land resource heterogeneity.

Chapter 3, “Crop Insurance, Land Allocation, and the Environment,” provides an analysis of government crop insurance policies and their effect on the environment. It tests hypotheses to determine whether crop insurance and crop insurance contracts have had an impact on producers’ acreage allocation decisions. If an impact is found, the effect of changes in acreage allocations on various environmental factors is estimated. While previous literature has identified that crop insurance can negatively affect the environment, it is possible that the negative environmental impacts are due to a small number of specific crop insurance contract decisions, such as insurance type or selected coverage level and particular characteristics of the region where the crop is grown. Results from this research have important implications for policy makers by identifying environmental consequences from crop insurance and identifying regions that are most environmentally affected by crop insurance.

The relationship between crop insurance and the environment is an important topic. This chapter expands the literature by using producer-level crop insurance contract and performance data to address the impact on acreage allocation. Previous literature has relied on potentially biased aggregate county level data to estimate impacts on acreage allocations. Effects on the environment are determined using four different environmental indicators; wind erosion, soil erosion, nitrogen loss, and the change in total organic carbon. The change in producer premium required to achieve neutral environmental impact is analyzed. Producer premium represents the tool policy makers can use to offset potential negative environmental impacts.

Results indicate statistically significant acreage allocation impacts of crop insurance in all states, but with allocation impacts in two of the four states being economically trivial. Only in North Dakota and Eastern Colorado were some negative environmental effects of crop insurance found. In North Dakota wind erosion and total nitrogen loss were found to be adversely impacted by crop insurance. In Eastern Colorado only wind erosion was found to be adversely impacted by crop insurance. No evidence was found of negative environmental impacts on either soil erosion or total soil organic carbon. Further, the only insurance contract that had negative environmental impacts was yield insurance with low coverage level. No effect was found of producer paid insurance premium on acreage shares, which implies that producers make acreage allocation decisions independently of insurance premium.

Chapter 4, “Economic Effects on Producers from Reducing Nitrogen Pollution in Wheat Production,” provides an analysis of whether an innovative spatial weights matrix that accounts for elevation results in greater statistical efficiency in parameter estimation; whether the effect of nitrogen supply on yield, protein, and unaccounted nitrogen depends on terrain attribute; and whether there is an economic effect on producers from restricting applied nitrogen. Agricultural

producers traditionally apply nitrogen fertilizer on fields for increased output and typically apply at a uniform rate. Applying nitrogen at a uniform rate on fields with different nitrogen needs may result in pollution from over-application to some parts and limit profit from under-application to others. Consequently, determining the variables that affect potential nitrogen pollution and estimating the cost of reducing nitrogen pollution represents an important contribution to reducing adverse environmental impacts from agricultural production.

Site-specific management has been a topic analyzed by economists because of its ability to increase producer profit by applying inputs at different rates across fields to locations where they are needed, thereby reducing over and under-application of inputs. Additionally, site-specific management may reduce nitrogen pollution. Determining the true level of nitrogen pollution is difficult due to complex soil processes. To circumvent this problem we measure the amount of nitrogen that has the highest probability of becoming pollution, and call it unaccounted nitrogen. After reviewing previous literature it appears that no one has examined whether the effects of nitrogen supply on yield, protein, and unaccounted nitrogen vary with terrain attribute.

With agronomic data, observations usually come from experimental plots in close approximation to each other, which brings the validity of the independence-between-observations assumption into question. We test whether including elevation in the spatial weights matrix results in greater statistical efficiency in parameter estimation. Identifying terrain attributes that lead to high levels of unaccounted nitrogen and estimating the economic cost to producers from reducing applied nitrogen can help design policy that decreases nitrogen pollution at lowest cost to producers. Using a constrained profit-maximization model based on

regression parameter estimates, I determine how profit is impacted when the amount of unaccounted for nitrogen is constrained.

Results indicate that including a spatial weight matrix that includes points higher in elevation provided greater statistical efficiency in parameter estimation over standard econometric estimation. Including points lower in elevation in the spatial weights matrix did not further increase statistical efficiency. These results suggest that spatial econometric methods provide better model fit and consequently more precise economic recommendations. Using the spatial model, I found that yield response to available nitrogen was greater with the cosine of aspect, i.e., north or south rather than east or west facing, and that unaccounted nitrogen response to available nitrogen was greater on flat slopes than on steeper slopes. When restricting unaccounted nitrogen to reduce adverse environmental impact, adoption of variable rate fertilizer application technology did not increase profit over uniform rate technology using the landscape positions I developed on the experimental site.

CHAPTER TWO
INFORMATION AND OPPORTUNISTIC BEHAVIOR IN FEDERAL CROP
INSURANCE PROGRAMS

Introduction

Production of agricultural commodities involves many types of risk. Agricultural producers may purchase crop insurance in order to reduce yield and/or revenue risk. Prior to 1994, the crop insurance program experienced very low participation as the program offered insurance for a relatively small number of products and coverage levels, and offered little premium subsidization. Through the Agricultural Reform Act of 1994 and the Agricultural Risk Protection Act (ARPA) of 2000, Congress attempted to entice producer participation in crop insurance by increasing premium subsidies. Policymakers argued that the increased participation due to premium subsidies would eliminate *ad hoc* disaster payments or emergency aid (Ker 2001). Participation in crop insurance has increased. In 1998 more than 180 million acres of farmland was insured under the program, more than three times the acreage insured in 1988 (USDA-RMA Bulletin). The participation incentives created from the higher subsidy levels, however, may also increase the likelihood of opportunistic behavior. Producer opportunism results in larger indemnities being paid to producers, which in turn increases taxpayer outlays. Reducing producer opportunistic behavior creates a more efficient risk management program that limits the ability of producers to extract profits from participating.

Asymmetric information between producers and the Federal Crop Insurance Corporation (FCIC) may allow producers to engage in opportunistic behavior.¹ Producer insurance decisions

¹ Asymmetric information exists when one party in a transaction has more (or better) information than the other party.

such as buy-up coverage and revenue insurance can potentially increase producer return from crop insurance when producers have a better understanding of crop yield risk on their farms than the FCIC.² Producers without proven yields, who insure fields by using the prescribed alternative, transitional yields (T-yields) based on the county average yield, can potentially increase their indemnity when their expected yield falls sufficiently below the county average yield. In this article we examine whether evidence of producer opportunism exists in field-level crop insurance data from the use of buy-up coverage, revenue insurance, and T-yields.

Asymmetric information can result in producer opportunism through both adverse selection and moral hazard. Adverse selection occurs when “hidden information” exists and moral hazard occurs if producers take “hidden action” (Arrow 1985). Generally, we label opportunistic behavior as adverse selection if the producer uses asymmetric information to their advantage in making the insurance decision and moral hazard if the producer changes behavior because they have insurance. It is often difficult to distinguish empirically between adverse selection and moral hazard (Quiggin, Karagiannis, and Stanton 1993), and we do not specifically identify type of asymmetric information. Instead, we examine whether evidence exists that asymmetric information increases producers’ return from crop insurance.

Several authors address the impact of asymmetric information on the use of crop insurance. Roberts, Key, and O’Donoghue (2006) find evidence of moral hazard in yields of insured wheat and soybean farms in Texas. Smith and Goodwin (1996) show that adopters of crop insurance exhibit moral hazard behavior by using fewer inputs than non-adopters. Their findings counter those of Horowitz and Lichtenberg (1993), who conclude that crop insurance participants use higher rates of inputs than non-participants, suggesting that both fertilizer and

² Buy-up coverage refers to any coverage level above 50 percent.

pesticides may be risk-increasing inputs. Makki and Somwaru (2001) suggest adverse selection exists in both coverage-level and insurance type decisions. High-risk producers more often select revenue insurance contracts and higher coverage levels. Skees and Reed (1986) also identify adverse selection due to asymmetric information in the relationship between the producer's choice of coverage level and expected yields, and in the bias introduced in coverage protection when trends are not used to establish expected yields. Just, Calvin, and Quiggin (1999) find that the subsidy benefits of crop insurance outweigh its risk-aversion incentive largely due to adverse selection.

Our study of producer opportunism in crop insurance adds to the previous literature in three important ways: we address the impact of using T-yields on producer opportunism; we analyze effects from the subsidy on producer opportunism; and we use more detailed, field-level crop insurance and performance data to analyze these effects as well as the impact of purchasing buy-up coverage or revenue insurance. This type of data has only been used previously by Roberts, Key, and O'Donoghue (2006).

Field-level data allows us to better estimate the extent of producer opportunistic behavior specific to crop insurance contract decisions. A unit represents a parcel of land insured independently of other parcels (Edwards, 2003a). Producers can insure a crop by the unit (typically a field) or the entire farm. Heterogeneous farms, i.e., farms that include field units with different average yields, provide better opportunities for opportunistic behavior from the use of buy-up coverage, revenue insurance, and T-yields. In our study, we use unit insurance information whereas other studies have generally used either farm or county-level data.

Since asymmetric information may enable producers to increase their returns, the results from this study could have important implications for policy makers. A positive relationship

between the use of buy-up coverage, revenue insurance, or T-yields and return from crop insurance demonstrates the value to producers of using this asymmetric information. If such opportunistic behavior occurs, some relatively simple re-designing of crop insurance programs could reduce the farmer's ability to use buy-up coverage, revenue insurance, or T-yields to generate extraordinary indemnity payments.

This article proceeds as follows. We first outline how a producer can manipulate the yield guarantee, or the minimum yield that results in an indemnity payment, to allow for producer opportunism possibilities. We then present hypotheses relating producer insurance decisions to opportunistic behavior. A description of our model, data, and analysis follows. We present and interpret findings in the results section. Conclusions and a discussion of implications occur in the final section.

Insurance Characteristics

In this section we outline both the details of crop insurance and how the yield guarantee decisions may allow for producer opportunism. Two primary types of insurance exist – yield and revenue. Yield insurance insures only against low yield. Revenue insurance insures against the combination of yield and price. At the beginning of each crop year, the producer can change insurance type. Return per acre from crop insurance depends on the difference between what a producer receives as an indemnity and pays for the insurance: $R_{hj} = I_{hj} - W_{hj}$, where R_{hj} represents the return, I_{hj} represents the indemnity, and W_{hj} represents the crop insurance premium for field h and crop j .

An indemnity payment for yield insurance, also known as multiple peril crop insurance (MPCI), occurs if the yield guarantee, YG_{hj} , is greater than actual production, AP_{hj} . When this

happens, the FCIC calculates the indemnity as $I_{hj} = [YG_{hj} - AP_{hj}] \times PE_j$, where PE_j represents the price election set by the government.

An indemnity payment for revenue insurance, specifically crop revenue coverage, occurs if the revenue guarantee is greater than actual producer revenue. When this happens, the indemnity equals $I_{hj} = [YG_{hj} * \max(BP_j, HP_j)] - [AP_{hj} * HP_j]$, where BP_j and HP_j represents the base and harvest price, respectively.³ The base price represents the average daily settlement price of a futures contract during a month prior to planting. Harvest price equals the average daily settlement prices of a futures contract during a month when the crop matures. The choice of insurance type may lead to opportunistic behavior if the producer's information allows him/her to predict indemnity payments on the insured field more accurately than the FCIC so that his/her expected profit is increased along with reducing risk.

The yield guarantee for computing indemnity with either type of insurance represents a percentage of a producer's actual production history, APH_{hj} . Establishing APH_{hj} yield requires a minimum of four and a maximum of 10 consecutive years of verifiable yield records for the crop on the insured field. The FCIC calculates the yield guarantee for yield and revenue insurance as $YG_{hj} = CL_j \times APH_{hj}$, where CL_j represents coverage level. The revenue guarantee (RG_{hj}) is calculated as $RG_{hj} = YG_{hj} * \max(BP_j, HP_j)$. The producer selects a coverage level

³ An indemnity for income protection, another form of revenue insurance, is calculated using only the base price, $I_{hj} = [YG_{hj} * BP_j] - [AP_{hj} * HP_j]$. For revenue assurance with the harvest price option, the indemnity is calculated the same as crop revenue coverage; without the harvest price option, the indemnity is calculated the same as income protection. Even when the indemnity is calculated the same, revenue assurance and crop revenue coverage differ in the futures month used to calculate the harvest price. Income protection and revenue assurance can also differ in applicable crops, coverage levels, and unit types. Not all coverage levels and unit types are available for each revenue insurance type (Edwards, 2003b).

specific to each crop. Coverage levels typically range between 50 to 85 percent in 5 percent increments. Producers can adjust coverage levels at the beginning of each crop year.

The transitional yield (T-yield) option permits producers to enroll fields in the crop insurance program that have not previously or have only seldom been in production for a particular crop. T-yields are based on the 10-year county average yield. Without an established actual production history, T-yields create the potential for producer opportunism when their expected yield falls sufficiently below the county average yield. If the producer cannot provide the minimum of four years of actual yields for a field, a T-yield must be substituted for each missing year. Depending on the number of T-yields a producer includes or the type of T-yield, the FCIC discounts the county average yield as much as 35 percent in determining the producer production history. If the farmer's expected yield on the field is sufficiently below the county average yield, the use of T-yields can be due to producer opportunism.

Insurance Decisions and Opportunistic Behavior

In our examination of producer opportunism in crop insurance, we examine three specific hypotheses. We use these hypotheses to determine (1) whether the use of buy-up coverage, revenue insurance, or T-yields signals producer opportunism through financial indicators; (2) whether the presence of a subsidy affects the amount of producer opportunism; and (3) whether producer opportunism from the use of buy-up coverage, revenue insurance, or T-yields is greater in regions with greater within-county land heterogeneity. The specific hypotheses that we test and their justification follow.

Hypothesis 1. Return per acre increases with the use of buy-up coverage, revenue insurance, and T-yields. We assess impacts on both producer return and social return, where we

label producer return as the indemnity less producer premium and social return as the indemnity less total premium (including the federal subsidy).⁴ We hypothesize that the use of buy-up coverage, revenue insurance, and T-yield increases both measures of return. Impacts on producer return directly relate to measuring private producer opportunism while impacts on social return allow the measurement of social consequences. Further, we examine whether the use of additional T-yields has a greater impact on producer return and provides evidence of greater producer opportunism.

Producers can select a unique coverage level for each crop based on perceived production risk and the cost of insurance for that coverage level. Selecting a higher coverage level increases the yield guarantee and increases the probability of receiving an indemnity. Since producers likely have a better idea of production risks associated with a crop grown on a particular field than the FCIC, opportunistic behavior may come from the higher yield guarantee. Opportunistic behavior can occur when high risk producers expect a positive return from selecting high coverage levels, even though higher coverage levels result in higher premium costs. More generally, we expect that a larger percentage of producers would select buy-up coverage levels in regions with higher crop production variability than in regions with lower variability.

Producers can also select insurance type, i.e., yield or revenue, for each crop. Without opportunism, producers select insurance type based upon perceived production risk, price risk, and the cost of the insurance type. Revenue insurance has higher premium costs than MPCCI since revenue insurance protects against a price decrease following planting in addition to low yield whereas MPCCI only insures against low yield. Opportunism with revenue insurance can occur if producers have more accurate information than the FCIC about the likelihood they will incur a yield loss and they also want to insure against a price drop.

⁴ The amount of producer premium is specific to each crop insurance contract.

A producer most likely knows, or has a good idea of, the expected yield for each field s/he farms. If the producer has been producing the insured crop on a field and has verifiable yield records, s/he must provide the yields from the field. However, if the producer did not keep good records or *claims failure to keep good records*, s/he must employ T-yields to obtain insurance. Those with expected yields sufficiently below the county average may not only transfer risk but also increase expected profit from the field by purchasing insurance.

Depending on the number of verifiable yield records and other circumstances, a producer may use one, two, three or four T-yields or special T-yields when purchasing crop insurance.⁵ Special T-yields permit a producer to use 100 percent (or in some cases 110 percent) of the county average yield when computing his/her T-yield. Special T-yields are required if the producer has never participated in the crop insurance program or uses a new practice, type, or variety on additional land that has no production history in that crop. The more transitional yields a producer includes in the APH, the less information s/he provides about true expected yields. Thus, the amount of asymmetric information between the producer and the government increases. The government takes this information into account by discounting county average yield more heavily when using a larger number of T-yields to compute APH.⁶

Hypothesis 2. Subsidization of crop insurance promotes producer opportunism. The government provides premium subsidies to reduce the cost of crop insurance and entice more producers to participate in the program. Thus, subsidization may increase number of producers engaging in opportunistic behavior and the amount of total indemnities paid due to this

⁵ We analyze the six most widely used T-yield options. Although not analyzed in this paper, the RMA offers other T-yield options such as personal transitional yield and T-yield for added insurable acreage by practice, type, or variety.

⁶ The following percentages are used to determine APH when using T-yields: 100 percent of the county average for one T-yield, 90 percent for two T-yields, 80 percent for three T-yields, and 65 percent for four T-yields.

opportunistic behavior. We expect that subsidizing crop insurance increases the extent of producer opportunism because it increases the opportunities for, and the returns to, opportunism.

Hypothesis 3. Producer opportunism due to the use of buy-up coverage, revenue insurance, and T-yields is greater in regions with greater within-county land resource heterogeneity. Soil and climate characteristics vary between geographic locations. We examine whether evidence of producer opportunism from the use of buy-up coverage, revenue insurance, and T-yields increases for regions with greater within-county land resource heterogeneity.

Each county has a unique set of agro-climatic characteristics. Land quality represents a particularly important determinant of land use and yields (Hardie and Parks 1997). The FCIC calculates T-yields based on the county average yield. Regions with highly variable land resources may have greater variability of within county yields. The county average yield may not represent the average yield on many fields in such counties. Producers often have more information about expected yields on fields without verifiable yield records than does the FCIC, which must rely on the county average yield. Since producers also have private information about fields with verifiable yield records, they can use this information in deciding the optimal level of buy-up coverage and insurance type. These information asymmetries between producers and the FCIC may allow producers to profit in the use of buy-up coverage, revenue insurance, and particularly in the use of T-yields, in counties with more heterogeneous within-county resources than in counties with more homogeneous within-county resources. The use of T-yields in locations with heterogeneous within-county resources could provide a yield guarantee well above the field's actual production ability and thereby inflate the yield guarantee to unachievable levels.

Model, Data, and Analysis

We now present the empirical model in which we identify variables, regions, crops, and data used in the analysis and outline the analytical procedures. We expect return (both social return and producer return) to depend on county weather characteristics, growing degree days, county, year, crop, field practice (whether the land was in summer fallow the previous year), insurance decisions (coverage level and insurance type), and number of T-yields used to create the APH. Growing degree days represents the only continuous variable. We include a dummy variable for each county, year, crop, practice, coverage level, insurance type, and T-yields. Each T-yield dummy variable represents one of the six possible ways to use T-yields. The number of dummy variables for county, insurance type, and crop depend on the region. We specify all equations in per-acre terms. Table 1 defines the variables used.

To test our hypotheses, we estimate the following equation for each region:

$$(1) \quad Y = D_{CY}\alpha + D_{YR}\delta + X\beta + TY\gamma + \varepsilon$$

where Y represents the magnitude of return (either social return or producer return) at the field-level; D_{CY} corresponds a matrix of county dummy variables used to capture unobserved heterogeneity in agricultural production; D_{YR} refers to a matrix of year dummy variables; X represents a matrix comprised of a vector of ones, growing degree days, and dummy variables for coverage level, insurance type, crop, and field practice; TY is a matrix of T-yield dummy variables ; α and δ are, respectively, estimated county and year fixed-effects parameters; β and γ are estimated parameters; and ε represents the error term.

The data include observations of crop insurance contract information and corresponding performance records for all insured fields by the FCIC for each of eight years – 1995 through 2002. The data set includes all the information that the FCIC has for each crop insurance

contract: indemnity amount, premium paid by producer, amount of subsidy, crop type, number of acres, field practice, coverage level, insurance type, year, county location of field, and type of APH (actual and/or T-yields).

We analyze five different growing regions, two with relatively homogenous within-county land resources (Iowa and Western Nebraska) and three with more heterogeneous land resources (Oklahoma, North-Central Montana, and Eastern Washington). The five growing regions produce some of the same crops, but the crop mix differs by area. To document some of the differences in degree of heterogeneity, one could consider soil organic matter. Soil organic matter represents an important indicator of soil quality and thus land resources (Pulleman et. al. 2000). Regions such as Oklahoma and North-Central Montana generally have lower amounts of soil organic matter and vary much more across relatively small areas such as counties than regions such as Iowa and Western Nebraska. Eastern Washington has areas with high soil organic matter like Iowa and Western Nebraska but also exhibits high variability within counties like Oklahoma and North-Central Montana.

We analyze the returns to four insurance types: one yield insurance (MPCI) and three types of revenue insurance - crop revenue coverage (crop rev coverage), revenue assurance, and income protection. Each crop and region has a different set of available revenue insurance options. We study the effects of the most popular revenue insurance product, crop rev coverage, for each of five major regions. In addition to crop rev coverage, we analyzed revenue assurance in Oklahoma and Iowa, and income protection in Iowa.⁷ Not analyzed in this paper, but available to producers during the study period, is hail insurance.

⁷ Income protection and revenue assurance are available for many crops in the “other” category, however these revenue options were seldom selected by producers. We report parameter estimates for the primary options selected.

Buy-up coverage, revenue insurance, and T-yields can potentially vary by crop type and field practice. Thus, we differentiate these variables by several crop types: wheat, spring wheat, winter wheat, corn for grain (hereafter referred to as corn), soybeans, and “other crops.” We differentiate by two field practices: summer fallow and continuously cropped.⁸ By aggregating all classes of wheat, the three major crops represent the highest-value insured crops grown in the U.S. The “other crops” category represents other insured crops grown in the specific region.⁹

The constant in the estimated equations represents a producer who grew wheat (soybeans in Iowa) on a continuously-cropped, non-irrigated field in a specific county, who provided all actual yields for the field’s APH in year 2002, and purchased catastrophic coverage or MPCCI insurance with a 50 percent coverage level. Thus, we can directly interpret the effect of buy-up coverage, revenue insurance, and T-yields on the dependent variable by their estimated coefficients.¹⁰

We use STATA 8.0 to perform the estimation. Since all models show evidence of heteroskedasticity, we use White’s variance estimator to obtain robust standard errors. Producers often operate multiple fields. Therefore, we do not assume independent and identically distributed (IID) sampling error across fields for a single producer. We do assume IID sampling error between producers. To account for this sampling error structure, we use a robust cluster

⁸ In regions such as Oklahoma and Nebraska, the RMA does not differentiate between winter or spring wheat varieties like they do in regions such as Montana and Washington. Therefore, the crop type “wheat” includes all types of wheat. The RMA makes no distinction in field practice in Oklahoma or Iowa but they do in Montana and Nebraska. Except for Washington, where we only analyze observations where the RMA did not identify field practice, we differentiate between crop types and field practice where the RMA does.

⁹ There are a large number of other potentially insurable crops in each region (e.g., cotton, sorghum, oats, dry beans, sunflowers, and dry peas), but many had low numbers of observations. We focused on crops with a sufficiently large number of observations.

¹⁰ Catastrophic coverage insures for a 50 percent coverage level and 55 percent of the price election set by the government. MPCCI insurance with 50 percent coverage level insures with either 95 or 100 percent of the price election.

estimator (we cluster on producer) which adjusts the variance for within-cluster correlation (Wooldridge 2002).

Serious multicollinearity often occurs when dummy variables are used to represent a large number of independent variables. Using the variance inflation factor (VIF), we checked for the presence of multicollinearity in the independent variables. The VIF measures how inflated the variance of the estimated regression coefficients are when compared to independent variables not linearly related (Kutner et. al. 2005). A VIF value of 10 or more indicates that multicollinearity may influence the estimates. We dropped the corn new producer T-yield dummy variable from the analysis due to a VIF of 229.

A positive and significant relationship between a coverage level, insurance type, or T-yield and the dependent variable suggests that producer opportunism exists. An insignificant or a significantly negative relationship indicates a lack of producer opportunism. We assess marginal impacts on producer opportunism from using more T-yields and using special T-yields by measuring their differential effects on estimated producer return.

To test whether subsidization of crop insurance promotes producer opportunism, we determine whether buy-up coverage, revenue insurance, or T-yield parameter estimates are significantly greater when the dependent variable is producer return (including the subsidy) than when accounting for the full cost of insurance (social return, not including the subsidy). By comparing results between the social return and producer return equations we calculate the amount of producer opportunism, if any, contributed by the subsidy. We implement this test by selecting each buy-up coverage level, revenue insurance, or T-yield variable for which the estimated parameter supported the hypothesis that producer return increases with the use of buy-up coverage, revenue insurance, or T-yields (i.e., where producer opportunism was found). For

each selected variable, we conduct the test by computing the difference in its parameter estimates between the two models: $\Delta\gamma = \hat{\gamma}_p - \hat{\gamma}_s$, where $\hat{\gamma}_p$ represents the estimated coefficient with producer return as the dependent variable, and $\hat{\gamma}_s$ represents the estimated coefficient on the same variable with social return as the dependent variable. We compute a Wald test to determine whether a significant difference exists. We calculate this test because, if the subsidy had not been available, the producer would have had to pay the total premium to get crop insurance and would have received the social return. This would result in an estimated social producer opportunism effect of $\hat{\gamma}_s$. However, with the subsidy, the producer only paid the producer premium which resulted in the estimated private producer opportunism effect of $\hat{\gamma}_p$. A significant positive difference between $\hat{\gamma}_p$ and $\hat{\gamma}_s$ indicates that the subsidy increased producer opportunism.

To permit an examination of the effects of heterogeneity of land resources, our data sample is limited to non-irrigated agricultural production. We supplement the field-level crop insurance contract data with county-level annual growing degree-day data (Schlenker and Roberts 2006). Along with county fixed effects, growing degree-day data act as control variables for heterogeneity between counties that could come from differences in weather and land quality.

Support for greater producer opportunism in regions with greater within-county land resource heterogeneity occurs if the average of all significant buy-up coverage, revenue insurance or T-yield parameter estimates is greater for regions with greater within-county land resource heterogeneity than for regions with less within-county land resource heterogeneity. We compare evidence by conducting the tests for three crops to the extent relevant in five regions.

Results

We present the results for selection of buy-up coverage (55 percent - 85 percent Coverage level variables) and revenue insurance (crop rev coverage, income protection, and revenue assurance variables) using social return as the dependent variable in Table 2. We found six significantly positive parameter estimates on buy-up coverage for wheat in OK, one for summer-fallow wheat in Western NE, two for summer-fallow winter wheat and one each for continuously-cropped winter and spring wheat in North-Central MT, three for corn in OK, and five for corn in Western NE.¹¹ For other crops, we identified one significantly positive parameter for cotton in OK, one for both summer-fallow and continuously-cropped barley in MT, one for barley in WA, two for millet in NE, and one for canola in IA. We found two significantly positive parameter estimates on revenue insurance variables for wheat in OK, one each for both summer-fallow and continuously-cropped winter wheat and summer-fallow spring wheat in MT, one for spring wheat in WA, one each for corn in NE and IA, and one for soybeans in IA.

Based on social return, evidence of producer opportunism from the selection of buy-up coverage occurs in two of the three major crops (none in soybeans), in all four other crops, and in all five growing regions. Even without the subsidy, there is evidence of producer opportunism from selection of revenue insurance in all three major crops and in all five regions.

Table 3 contains results for selection of buy-up coverage and revenue insurance with producer return as the dependent variable. Producer return and social return provided similar results, with a few additional positive and significant parameters when examining producer return. Both producer return and social return provided evidence of producer opportunism from the selection of buy-up coverage. With the exception of soybeans, both producer return and social return showed evidence of producer opportunism from insurance type.

¹¹ Hereafter we refer to the regions only by their state abbreviation.

As evident from table 3, the value to the producer of producer opportunism varied widely, ranging from \$1 to \$61 dollars per acre for buy-up coverage and from \$1 to \$17 for revenue insurance. For example, corn in OK provided producers an average return of \$61 more per acre if the producer selected a 65 percent coverage level rather than a 50 percent coverage level. The average difference was only \$1 per acre greater for the same coverage level for NE millet producers. Growing corn in IA or wheat in WA provided no evidence of an increase in return from buy-up coverage. One possible explanation for this difference in producer opportunism could be that in OK there exists more opportunity to gain by choice of coverage level because favorable growing conditions don't always exist. Having higher coverage levels of crop insurance in OK results in additional profit for the producer because the additional expected benefit outweighs the additional insurance cost.

We present the results for the impacts of T-yields on social return in Table 4. We found four significantly positive parameter estimates on T-yield variables for wheat in OK, one for summer-fallow wheat in NE, four for summer-fallow and three for continuously-cropped winter wheat and two for summer-fallow spring wheat in MT, one for winter wheat in WA, one each for corn in NE and IA, and two for soybeans in IA. Three significantly positive parameter estimates apply to T-yields in "other crops", two for cotton in OK and one for canola in IA. Thus, we found evidence of producer opportunism on social return in the use of T-yields for all three major crops – wheat, corn, and soybeans, as well as for cotton in OK and canola in IA. All five regions provided evidence of producer opportunism from the use of T-yields in at least one crop.

Table 5 contains results for T-yields with producer return as the dependent variable. Nearly all significant parameters for social return were also significant for producer return. Several additional parameters were positive and significant for producer return. Whether

measured in a social sense or a private sense, these results provide considerable evidence that producers exercise opportunistic behavior in the use of T-yields when securing crop insurance. The value of this producer opportunism ranges between \$1 and \$9 per acre. These findings support the idea that potential exists for producers in each region to profit by using T-yields to participate in the federal crop insurance program or by selecting buy-up coverage or revenue insurance. They lend support to the findings previously noted by Roberts, Key, and O'Donoghue (2006), Makki and Somwaru (2001), Just, Calvin, and Quiggin (1999), Smith and Goodwin (1996), and Skees and Reed (1986) that producers participate in crop insurance partly because of adverse selection and moral hazard possibilities.

We found no consistent evidence supporting the idea that producer return increases with the use of additional T-yields. For most commodities and regions, there were not a sufficient number of significant parameters on T-yields to draw a conclusion or else the evidence was ambiguous. Thus, the county average yield discounts used to create the field's yield guarantee when more than one T-yield is used do not appear to be out of balance with the undiscounted county average when only one T-yield is used.

To test whether the subsidization of crop insurance promotes producer opportunism, we computed Wald test statistics on the difference in relevant parameter estimates in equation (1) for the two dependent variables – social return and producer return. Support for the hypothesis was provided by a significant positive difference in the coefficient value due to subsidization when we found evidence of private producer opportunism. We report the test statistics for buy-up coverage and revenue insurance in table 6. In dollars per acre, the values in the table represent the difference in parameter estimates when producer return and social return are the dependent variables. We found a significant positive difference in 89 percent of the parameter estimate

pairs where we identified producer opportunism for buy-up coverage and in 90 percent of the parameter estimate pairs for revenue insurance. Only 4 percent of buy-up coverage and revenue insurance would be consistent with the converse hypothesis that the subsidy reduces the amount of producer opportunism. Table 7 contains the test statistics for subsidization of crop insurance promoting producer opportunism using T-yields. The Wald statistics indicate a significant positive difference in 52 percent of the parameter estimate pairs where we found producer opportunism. Eleven percent of parameter pairs would have been consistent with the converse hypothesis. Thus, strong evidence suggests that the subsidy increases producer opportunism for buy-up coverage and revenue insurance selection but only modest evidence that the subsidy increases producer opportunism when using T-yields.

The value of producer opportunism due to the subsidy for buy-up coverage ranges from \$0.47 to \$11 per acre. For revenue insurance and T-yields the value of producer opportunism ranges from \$1 to \$2 and from \$0.07 to \$3 per acre, respectively. The differences in subsidy effect on producer opportunism between buy-up coverage, revenue insurance and T-yields may be because the subsidy amount for buy-up coverage changes dramatically between coverage levels but much less for revenue insurance and T-yields.

We also examine whether private producer opportunism due to the use of buy-up coverage, revenue insurance, and T-yields increases in regions with greater within-county land resource heterogeneity. We determine whether the more heterogeneous within-county land resource regions have a higher expected producer return than regions with more homogeneous within-county land resources from selection or use of these options. OK, MT, and WA have greater land heterogeneity than IA and NE. Results reported in tables 3 and 5 provide the parameters used to test this hypothesis. We examine both the percent of parameters on buy-up

coverage, revenue insurance, and T-yields that are significantly positive and their average values. Across all crops, we found 33 percent of the estimated parameters on buy-up coverage significantly positive with an average estimated producer opportunism of \$12.43 in the more heterogeneous regions. These figures compare to 30 percent of parameters with average opportunism of \$17 in the more homogeneous regions. For revenue insurance, 70 percent of the parameters in the heterogeneous regions were significantly positive with average estimated producer opportunism of \$7 compared to 38 percent and \$5 in the homogenous regions. For T-yields, 27 percent of the parameters in the heterogeneous regions were significantly positive with average estimated producer opportunism of \$3 per acre compared to 19 percent and \$2 in the homogeneous regions.

For all options, the percent of significant positive parameters was larger in the more heterogeneous regions than in the more homogeneous regions. Also, for revenue insurance and T-yields, the average estimated producer opportunism was greater in the heterogeneous regions than in the homogeneous regions. However, most differences were not very large. So, while evidence generally supports this hypothesis, results do not provide conclusive support.

Conclusions

We have analyzed an important unintended outcome of the federal crop insurance program, producer opportunism. We examined whether evidence of producer opportunism exists in field-level crop insurance contract data for several crops in five different regions from the use of buy-up coverage, revenue insurance, and transitional yields (T-yields). Reducing producer opportunism creates a more efficient risk management program that limits the ability of

producers to extract profits from participating. Our results are important to policy makers because they identify the characteristics of insurance that lead to producer opportunism.

For buy-up coverage, we found evidence of producer opportunism in wheat and corn in all five regions. Estimated opportunism effects from buy-up coverage ranged from trivial to very large in size, \$1 to \$61 per acre. For buy-up coverage, evidence did not support the hypothesis that more heterogeneous land quality increased producer opportunism. This result suggests that an increase in relative producer premium for higher coverage levels is recommended, regardless of land quality, to decrease the amount of producer opportunism. Increasing producer premium can be accomplished by either reducing the subsidy or increasing total insurance cost.

For insurance type, we found evidence of producer opportunism in wheat, corn, and soybeans and in all five regions. Estimated opportunism effects from insurance type were more moderate in size, from \$1 to \$17 per acre. This result indicates that premium structure for insurance type does not fully incorporate necessary information needed to offset opportunistic behavior. We also found greater evidence of producer opportunism in more heterogeneous land quality regions. Revenue insurance may warrant an increase in relative premiums, with a larger increase in premiums for producers in heterogeneous regions.

For T-yields, all three primary crops as well as all five regions showed evidence of producer opportunism. In many cases, the estimated effects were small, in the \$1 to \$9 per acre range. Further, while we found no consistent evidence that using more T-yields resulted in greater producer opportunism, evidence of producer opportunism was greater in the more heterogeneous regions. To address the effect of land quality on establishing APH the RMA has done the right thing by starting to assign a specific T-yield to areas within a county that have similar land quality.

In general our findings provide support for the hypotheses tested in this study. However, some caution is warranted in interpreting the results. It is possible that some of the evidence of producer opportunism could stem from differences in producer ability. For example, low producer ability can lead to expected yields lower than the county average just as poorer agro-climatic conditions can. If the ability of producers is inversely correlation with use of T-yields, our estimates of producer opportunism in using T-yields would be biased upward. It is also possible that fields that receive frequent indemnity payments are receiving larger expected returns from crop insurance than fields that seldom receive an indemnity. If this is true then increased premium amounts should focus on fields with frequent indemnities.

With such caveats, our results provide four important implications relevant to policymakers. First, we have documented that buy-up coverage, revenue insurance, and the use of T-yields can potentially increase expected income of producers. Second, evidence suggests that producer opportunism exists in all three major crops but the amount of producer opportunism varies between crops. Third, evidence suggests that the subsidization of crop insurance increases the level of producer opportunism possibilities, especially for buy-up coverage and revenue insurance. Fourth, evidence suggests that producer opportunism possibilities from exercising these options in regions with relatively homogeneous soils provide similar results when compared to regions with more heterogeneous soils. Each of these findings implies that crop insurance may be prone to producer opportunism issues. Information from this study provides the FCIC evidence that crop insurance contracts warrant redesign considerations to remove the opportunistic possibilities.

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Tables

Table 1. Variable Description

Variable Name	Variable Definition
Producer Return	(indemnity – producer premium)/ acres insured
Social Return	(indemnity – total premium)/ acres insured
Growing Degree Days	county average number of growing degree days above 20 degrees Celsius.
County	A matrix of dummy variables for each county.
Year	A matrix of dummy variables for each year: 1995 to 2002.
Crop	Dummy variables specific for each crop.
Coverage level	A matrix of dummy variables for each coverage level; between 50% and 85% in 5% increments.
Insurance Type	A matrix of dummy variables for producer selection of: multiple peril crop insurance, crop revenue coverage, revenue assurance, or income protection.
MPCI	Multiple Peril Crop Insurance
Crop Rev Coverage	Crop Revenue Coverage Insurance
Field Practice	A dummy variable if field was cropped the previous year, 0 otherwise.
T-yields	A matrix of dummy variables where column “t” =1 if “t” number of T-yields were used, t = 1, 2, 3, 4, 0 otherwise.
New Producer	A dummy variable if the producer is a new producer.
New practice, type, or variety	A dummy variable if the producer used a new practice, type, or variety on additional land that has no production history in the crop.
OK	Oklahoma
MT	North-Central Montana
WA	Eastern Washington
NE	Western Nebraska
IA	Iowa

Table 2. Buy-up Coverage and Revenue Insurance Parameter Estimates with Social Return as the Dependent Variable ^a

Crop	Coverage Level or Revenue Insurance	Region						
		OK	North-Central Summer fallow	MT Continuously cropped	Eastern WA	Western NE Summer fallow	IA Continuousl y cropped	
Wheat (Soybeans in Iowa)	55% Coverage	0.36	—	—	—	^b	-4.41	0.41
	60% Coverage	3.83*	—	—	—	-2.96	-0.78	-0.72
	65% Coverage	1.77*	—	—	—	-0.55	-1.51	-2.04
	70% Coverage	2.66*	—	—	—	2.41*	-1.85	-2.15
	75% Coverage	3.89*	—	—	—	2.85	-2.24	-2.83
	80% Coverage	7.12*	—	—	—	-0.37	-1.43	-4.02
	85% Coverage	7.14*	—	—	—	16.88	4.20	-3.64
	Crop Rev Coverage	1.89*	—	—	—	1.82	-0.69	1.08
	Income Protection Revenue	—	—	—	—	—	—	2.35*
	Assurance	4.55*	—	—	—	—	—	-1.20
Winter Wheat	55% Coverage	—	-0.61	^b	-0.27	—	—	—
	60% Coverage	—	-10.28	^b	-1.25	—	—	—
	65% Coverage	—	-1.20	-3.48	-1.24	—	—	—
	70% Coverage	—	-1.27	-2.59	-1.48	—	—	—
	75% Coverage	—	5.47*	2.69	-1.56	—	—	—
	80% Coverage	—	18.83*	15.27*	-2.36	—	—	—
	85% Coverage	—	15.75	2.79	-0.79	—	—	—
	Crop Rev Coverage	—	15.40*	7.88*	0.40	—	—	—
Spring Wheat	55% Coverage	—	-3.03	-0.99	-0.58	—	—	—
	60% Coverage	—	-2.96	-1.74	-2.05	—	—	—
	65% Coverage	—	-0.62	0.79	-1.41	—	—	—
	70% Coverage	—	0.46	1.89*	-1.40	—	—	—
	75% Coverage	—	0.71	0.96	-0.86	—	—	—
	80% Coverage	—	3.77	-10.97	-3.28	—	—	—
	85% Coverage	—	15.22	^b	-2.05	—	—	—
	Crop Rev Coverage	—	5.85*	0.47	3.67*	—	—	—
Corn	55% Coverage	^b	—	—	—	9.87	—	-0.92
	60% Coverage	-4.45	—	—	—	9.39	—	-1.39
	65% Coverage	55.43*	—	—	—	5.04*	—	-3.32
	70% Coverage	17.80*	—	—	—	22.15*	—	-4.67
	75% Coverage	44.21*	—	—	—	23.52*	—	-6.29
	80% Coverage	^b	—	—	—	36.10*	—	-9.54
	85% Coverage	^b	—	—	—	40.06*	—	-7.95
	Crop Rev Coverage	-2.73	—	—	—	9.50*	—	^b
	Income Protection Revenue	—	—	—	—	—	—	3.74*
Assurance	^b	—	—	—	—	—	-1.89	
Other	55% Coverage	-2.78	11.44*	9.97	-0.54	-4.93	—	1.24*
	60% Coverage	1.28	-4.53	1.53	-1.57	4.70	—	^b
	65% Coverage	6.63*	-0.74	-0.85	-0.84	0.41	—	-0.66
	70% Coverage	-13.37	-0.42	-0.01	-0.14	6.37*	—	-2.62
	75% Coverage	-10.91	-0.14	-3.60	-0.48	13.21*	—	-2.49
	80% Coverage	—	-5.26	-19.10	3.18*	—	—	—
	85% Coverage	—	^b	23.93*	2.20	—	—	—
	Crop Rev Coverage	-6.59	—	—	—	—	—	—
	Income Protection Revenue	—	—	—	—	—	—	^b
Assurance	^b	—	—	—	—	—	—	
No. of Observ.		90869	55286	44921	47444	18665		

Note: * implies parameter is significant at the 0.05 level.

^a Units are in dollars per acre.

^b Variable was available to producers but dropped due to lack of observations fitting the variables criteria.

Table 3. Buy-up Coverage and Revenue Insurance Parameter Estimates with Producer Return as the Dependent Variable ^a

Crop	Coverage Level or Revenue Insurance	Region							
		OK	North-Central Summer fallow	MT Continuously cropped	Eastern WA	Western NE Summer fallow	IA Continuously cropped		
Wheat (Soybeans in Iowa)	55% Coverage	0.77	—	—	—	^b	-4.32	0.41	
	60% Coverage	4.45*	—	—	—	-3.07	-0.17	-0.67	
	65% Coverage	2.46*	—	—	—	0.05	-0.84	-1.17	
	70% Coverage	4.33*	—	—	—	4.18*	-0.44	-0.84	
	75% Coverage	5.65*	—	—	—	5.77*	-0.05	-0.80	
	80% Coverage	9.21*	—	—	—	2.28	1.35	-1.23	
	85% Coverage	6.92*	—	—	—	25.25*	8.84	-0.55	
	Crop Rev Coverage	2.81*	—	—	—	2.90*	-0.18	0.28	
	Income Protection Revenue Assurance	— — — 5.51*	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —	1.51 — — -0.73
	Winter Wheat	55% Coverage	—	-0.09	^b	-0.31	—	—	—
		60% Coverage	—	-10.05	^b	-0.98	—	—	—
65% Coverage		—	-0.16	-2.36	-0.89	—	—	—	
70% Coverage		—	0.35	-0.78	-0.95	—	—	—	
75% Coverage		—	7.01*	5.54*	-1.00	—	—	—	
80% Coverage		—	—	18.87	—	—	—	—	
85% Coverage		—	22.45*	[*]	-0.93	—	—	—	
Crop Rev Coverage		—	20.82	9.66*	0.82	—	—	—	
Spring Wheat	55% Coverage	—	16.74*	9.30*	1.45*	—	—	—	
	60% Coverage	—	-3.39	-1.03	-0.64	—	—	—	
	65% Coverage	—	-2.49	-1.28	-2.07	—	—	—	
	70% Coverage	—	0.27	1.86*	-1.08	—	—	—	
	75% Coverage	—	1.62*	3.40*	-0.71	—	—	—	
	80% Coverage	—	2.13*	2.62*	-0.18	—	—	—	
	85% Coverage	—	6.44*	-7.13	-1.14	—	—	—	
	Crop Rev Coverage	—	17.32	^b	0.32	—	—	—	
Corn	55% Coverage	^b	6.80*	1.60	5.20*	—	10.88	-1.17	
	60% Coverage	2.72	—	—	—	—	10.95	-1.11	
	65% Coverage	61.04*	—	—	—	—	5.88*	-2.32	
	70% Coverage	25.64*	—	—	—	—	24.63*	-3.06	
	75% Coverage	55.11*	—	—	—	—	27.92*	-3.40	
	80% Coverage	^b	—	—	—	—	44.11*	-4.63	
	85% Coverage	^b	—	—	—	—	48.48*	-2.78	
	Crop Rev Coverage	-1.95	—	—	—	—	10.82*	^b	
	Income Protection Revenue Assurance	— — — ^b	— — — —	— — — —	— — — —	— — — —	— — — —	— — — —	1.99* — — -0.69
	Other	55% Coverage	-1.78	11.24*	10.00	-0.82	—	-4.05	0.94*
60% Coverage		3.34	-4.67	2.05	-1.52	—	4.95*	^b	
65% Coverage		8.34*	0.12	0.10	-0.60	—	0.87*	0.62	
70% Coverage		-7.69	0.82	1.49	0.31	—	7.51*	-1.81	
75% Coverage		0.33	1.35	-2.30	0.18	—	17.45*	-0.75	
80% Coverage		—	-1.72	14.15	3.92*	—	—	—	
85% Coverage		—	^b	27.70	[*]	3.26*	—	—	
Crop Rev		-2.53	—	—	—	—	—	—	

Coverage							
Income							
Protection	—	—	—	—	—		b
Revenue							
Assurance	b	—	—	—	—	—	—

Note: * implies parameter is significant at the 0.05 level.

^a Units are in dollars per acre.

^b Variable was available to producers but dropped due to lack of observations fitting the variables criteria.

Table 4. T-yield Parameter Estimates with Social Return as the Dependent Variable ^a

Crop	Number of or type of T-yield(s)	Region						
		OK	North-Central Summer fallow	MT Continuous ly cropped	Eastern WA	Western NE Summer fallow	IA Continuously cropped	
Wheat	4 T-Yields	-1.08	—	—	—	0.29	-2.10	-0.36
(Soybeans in Iowa)	3 T-Yields	-1.64	—	—	—	-0.10	-3.67	-0.73
	2 T-Yields	0.50*	—	—	—	-1.69	-3.13	-0.26
	1 T-Yield	1.09*	—	—	—	-0.76	-3.36	0.29
	New Producer	5.47*	—	—	—	2.27*	-1.80	1.54*
	New practice, type, or variety	1.89*	—	—	—	-1.09	-2.97	1.15*
Winter Wheat	4 T-Yields	—	1.26*	1.12	-0.48	—	—	—
	3 T-Yields	—	1.26*	3.08*	0.14	—	—	—
	2 T-Yields	—	1.34	1.44	0.34	—	—	—
	1 T-Yield	—	1.38*	-0.74	0.55	—	—	—
	New Producer	—	2.61	4.00*	3.78*	—	—	—
Spring Wheat	New practice, type, or variety	—	5.46*	5.22*	-0.32	—	—	—
	4 T-Yields	—	0.56	-2.60	-0.82	—	—	—
	3 T-Yields	—	0.06	-2.99	-1.25	—	—	—
	2 T-Yields	—	1.24*	-1.18	-1.26	—	—	—
	1 T-Yield	—	-0.62	-0.68	-0.80	—	—	—
Corn	New Producer	—	1.70	0.60	-1.66	—	—	—
	New practice, type, or variety	—	2.46*	-1.06	-1.74	—	—	—
	4 T-Yields	-20.24	—	—	—	—	-2.36	-1.52
	3 T-Yields	-11.37	—	—	—	—	-9.26	0.07
	2 T-Yields	-17.08	—	—	—	—	-13.85	0.21
Other	1 T-Yield	-17.85	—	—	—	—	-11.34	0.43
	New Producer	#	—	—	—	—	-5.32	2.55*
	New practice, type, or variety	-18.47	—	—	—	—	5.49*	0.58
	4 T-Yields	-5.33	0.37	-2.17	-0.54	—	-0.59	-0.23
	3 T-Yields	-5.18	0.46	-1.58	-0.09	—	-2.82	0.02
No. of Observ.	2 T-Yields	-6.41	0.31	-0.49	-0.47	—	-3.46	1.13
	1 T-Yield	-5.52	-1.23	-1.90	0.27	—	-4.58	1.55
	New Producer	3.90*	-0.33	-2.60	-0.58	—	-3.25	2.74*
	New practice, type, or variety	5.99*	-1.78	-2.24	0.69	—	0.43	-1.87
		90869	55286	44921	47444	1866	54	

Note: * implies parameter is significant at the 0.05 level.

implies coefficient not estimated due to high VIF.

^a Units are in dollars per acre.

Table 5. T-yield Parameter Estimates with Producer Return as the Dependent Variable ^a

Crop	Number of or type of T-yield(s)	Region						
		OK	North-Central Summer fallow	MT Continuously cropped	Eastern WA	Western NE Summer fallow	IA Continuously cropped	
Wheat (Soybeans in Iowa)	4 T-Yields	-0.73	—	—	—	0.51	-1.18	-0.08
	3 T-Yields	-1.48	—	—	—	0.04	-3.39	-0.62
	2 T-Yields	0.61*	—	—	—	-1.40	-2.83	-0.23
	1 T-Yield	1.16*	—	—	—	-0.37	-2.76	0.29
	New Producer	5.46*	—	—	—	2.86*	-0.78	1.66*
	New practice, type, or variety	1.83*	—	—	—	-0.45	-2.33	1.02*
Winter Wheat	4 T-Yields	—	1.39*	1.10	-0.35	—	—	—
	3 T-Yields	—	1.43*	2.96*	0.26*	—	—	—
	2 T-Yields	—	1.57	1.94*	0.45	—	—	—
	1 T-Yield	—	1.47*	0.80	0.68	—	—	—
	New Producer	—	2.84	3.84	3.98*	—	—	—
	New practice, type, or variety	—	5.80*	4.81*	-0.01	—	—	—
Spring Wheat	4 T-Yields	—	0.76*	-2.62	-0.63	—	—	—
	3 T-Yields	—	0.23	-2.93	-1.08	—	—	—
	2 T-Yields	—	1.42*	-1.21	-1.22	—	—	—
	1 T-Yield	—	-0.51	-0.59	-0.75	—	—	—
	New Producer	—	1.98	0.94	-1.29	—	—	—
	New practice, type, or variety	—	2.52*	-1.46	-1.40	—	—	—
Corn	4 T-Yields	-20.33	—	—	—	-2.04	—	-1.00
	3 T-Yields	-10.36	—	—	—	-9.39	—	0.41
	2 T-Yields	-17.47	—	—	—	-14.05	—	0.32
	1 T-Yield	-16.00	—	—	—	-11.20	—	0.65*
	New Producer	#	—	—	—	-5.23	—	2.92*
	New practice, type, or variety	-16.51	—	—	—	5.52*	—	0.57
Other	4 T-Yields	-5.67	0.36	-1.94	-0.38	-0.33	—	0.01
	3 T-Yields	-5.15	0.41	-1.43	0.09	-2.56	—	0.16
	2 T-Yields	-6.49	0.24	-0.34	-0.37	-2.89	—	1.37
	1 T-Yield	-5.07	-1.51	-1.89	0.35	-3.72	—	2.11*
	New Producer	5.32*	-0.47	-2.57	-0.42	-3.00	—	2.79*
	New practice, type, or variety	8.85*	-2.17	-2.54	1.16*	0.47	—	-1.79

Note: * implies parameter is significant at the 0.05 level.

implies coefficient not estimated due to high VIF.

^a Units are in dollars per acre.

Table 6. Estimated Amount of Buy-up Coverage and Revenue Insurance Producer Opportunity due to Subsidy ^a

Crop	Coverage Level or Revenue Insurance	Region					
		OK	North-Central Summer fallow	MT Continuously cropped	Eastern WA	Western NE Summer fallow	IA Continuousl y cropped
Wheat (Soybeans in Iowa)	55% Coverage	—	—	—	—	—	—
	60% Coverage	0.62*	—	—	—	—	—
	65% Coverage	0.69*	—	—	—	—	—
	70% Coverage	1.67*	—	—	—	1.77*	—
	75% Coverage	1.76*	—	—	—	2.95*	—
	80% Coverage	2.09*	—	—	—	—	—
	85% Coverage	-0.22	—	—	—	8.37*	—
	Crop Rev Coverage	0.92*	—	—	—	1.08*	—
	Income Protection	—	—	—	—	—	—
Revenue Assurance	0.96*	—	—	—	—	—	
Winter Wheat	55% Coverage	—	—	—	—	—	—
	60% Coverage	—	—	—	—	—	—
	65% Coverage	—	—	—	—	—	—
	70% Coverage	—	—	—	—	—	—
	75% Coverage	—	1.54*	2.85*	—	—	—
	80% Coverage	—	3.62*	3.60*	—	—	—
	85% Coverage	—	—	3.87*	—	—	—
	Crop Rev Coverage	—	1.34*	1.42*	1.05*	—	—
Spring Wheat	55% Coverage	—	—	—	—	—	—
	60% Coverage	—	—	—	—	—	—
	65% Coverage	—	—	1.07*	—	—	—
	70% Coverage	—	1.16*	1.51*	—	—	—
	75% Coverage	—	1.42*	1.66*	—	—	—
	80% Coverage	—	2.66*	—	—	—	—
	85% Coverage	—	—	—	—	—	—
	Crop Rev Coverage	—	0.95*	—	1.53*	—	—
Corn	55% Coverage	—	—	—	—	—	—
	60% Coverage	—	—	—	—	—	—
	65% Coverage	5.61*	—	—	—	0.84*	—
	70% Coverage	7.84*	—	—	—	2.48*	—
	75% Coverage	10.90*	—	—	—	4.40*	—
	80% Coverage	—	—	—	—	8.01*	—
	85% Coverage	—	—	—	—	8.42*	—
	Crop Rev Coverage	—	—	—	—	1.32*	—
	Income Protection	—	—	—	—	—	—
Revenue Assurance	—	—	—	—	—	1.75*	
Other	55% Coverage	—	-0.19	—	—	—	0.30*
	60% Coverage	—	—	—	—	0.25	—
	65% Coverage	1.71*	—	—	—	0.47*	—
	70% Coverage	—	—	—	—	1.14*	—
	75% Coverage	—	—	—	—	4.24*	—
	80% Coverage	—	—	—	0.74*	—	—
	85% Coverage	—	—	3.77*	1.06*	—	—
	Crop Rev Coverage	—	—	—	—	—	—
	Income Protection	—	—	—	—	—	—
Revenue Assurance	—	—	—	—	—	—	

Note: * implies parameter is significant at the 0.05 level.

^a Units are in dollars per acre.

Table 7. Estimated Amount of T-yield Producer Opportunism due to Subsidy ^a

Crop	Number of or type of T-yield(s)	Region					
		OK	North-Central Summer fallow	Central MT Continuousl y cropped	Eastern WA	Western NE Summer fallow	IA Continuous ly cropped
Wheat (Soybeans in Iowa)	4 T-Yields	—	—	—	—	—	—
	3 T-Yields	—	—	—	—	—	—
	2 T-Yields	0.11*	—	—	—	—	—
	1 T-Yield	0.07*	—	—	—	—	—
	New Producer	-0.01	—	—	—	0.59*	0.12*
Winter Wheat	New practice, type, or variety	-0.06	—	—	—	—	-0.13*
	4 T-Yields	—	0.13	—	—	—	—
	3 T-Yields	—	0.17*	-0.12	0.12*	—	—
	2 T-Yields	—	—	0.50*	—	—	—
	1 T-Yield	—	0.09	—	—	—	—
Spring Wheat	New Producer	—	—	—	0.20	—	—
	New practice, type, or variety	—	-2.94*	-0.41	—	—	—
	4 T-Yields	—	-0.20*	—	—	—	—
	3 T-Yields	—	—	—	—	—	—
	2 T-Yields	—	0.18*	—	—	—	—
Corn	1 T-Yield	—	—	—	—	—	0.22*
	New Producer	—	—	—	—	—	0.37*
	New practice, type, or variety	—	0.06	—	—	—	—
	4 T-Yields	—	—	—	—	—	—
	3 T-Yields	—	—	—	—	—	—
Other	2 T-Yields	—	—	—	—	—	—
	1 T-Yield	—	—	—	—	—	0.05*
	New Producer	1.42*	—	—	—	—	0.08
	New practice, type, or variety	2.86*	—	—	0.47*	0.03	—
	4 T-Yields	—	—	—	—	—	—
3 T-Yields	—	—	—	—	—	—	
2 T-Yields	—	—	—	—	—	—	

Note: * implies parameter is significant at the 0.05 level.

^a Units are in dollars per acre.

CHAPTER THREE

CROP INSURANCE, LAND ALLOCATION, AND THE ENVIRONMENT

Introduction

Policymakers, the public, and economists are all concerned about the contributions of agriculture to the worsening condition of the environment. Agricultural pollution from erosion represents the leading cause of water quality impacts on rivers and lakes (National Water Quality Inventory 2000). As soil moves, soil particles carry nutrients and chemicals with it, both reducing soil quality and degrading waterways. While agricultural producers, putative stewards of the land, are the direct agents, their actions are influenced by numerous factors, especially market conditions (e.g., input and output prices) and government policies (e.g., subsidies). Hence, it is important to understand the relationship between market conditions, government policy, and the environment. In this article we focus on government crop insurance policies and their effect on the environment.

In the mid 1990's the federal government strongly encouraged agricultural producers to enlist in federal crop insurance. Farmers responded to these initiatives, and consequently the U.S. government's cost for providing crop insurance increased nominally from \$1.4 billion in 1995 to \$3.6 billion in 2006, an increase of nearly 250 percent (Congressional Research Service, 2007). As a result of increased crop insurance participation, the government may have unknowingly contributed to environmental degradation. While the financial arrangements of insurance may seem removed from environmental impacts, crop insurance participation may affect a producer's acreage decision, i.e., how much of each crop to plant. Planting decisions affect the environment because the production of different crops requires different input levels, so crop insurance could lead to greater negative environmental consequences. For example, corn

is regarded as a high-input crop in the Midwest, requiring higher levels of potentially environmentally damaging inputs like fertilizer and chemicals than soybeans. Therefore, the net environmental impact from the management package used for corn production may be worse than the environmental impact from the management package used for soybean production. Crop insurance could negatively affect the environment by promoting planting of more environmentally-harmful crops in environmentally-sensitive areas.

The objective of this study is to determine whether participation in federal crop insurance has an impact on producers' acreage allocation decisions, and, if so, to estimate the effect of acreage allocations on various environmental factors. In general, policy can affect two kinds of farm decisions – the land use decision at the extensive margin (i.e., the amount of land devoted to a crop) and the output-impacting, enterprise management decisions at the intensive margin (i.e., the amount and organization of other inputs used on the land given the crop choice). We analyze the decision at the extensive margin for two reasons. First, it is likely that crop insurance has more impact on land use decisions than other management decisions; and second, it may be of greater importance in affecting total chemical use and environmental quality than the intensive margin, (Wu and Adams 2001).¹²

In a recent article addressing the acreage effects of crop insurance, Goodwin, Vandever, and Deal (2004) find evidence that increased participation in crop insurance programs results in statistically significant acreage responses. They also find that the acreage response from crop insurance varies by crop type and regions. A small number of articles have addressed the

¹² Note that the dichotomy between extensive and intensive margin is somewhat fictional because ultimately the farm operator chooses a production package, which comprises the intertwined combination of inputs, including land, used for farm production. What is the extensive margin versus the intensive margin is really a matter of how the production problem is framed. In essence, the conventional view that includes extensive and intensive margins assumes that the land choice is made first, and the other management decisions have to do with the intensity with which the land is utilized.

extensive margin impacts of crop insurance on the environment. Wu and Adams (2001) used risk measures as independent variables to estimate acreage response equations and examined the effects of revenue insurance by simulating the effects of changing production risks and expected returns on cropping patterns. Their results provide evidence that revenue insurance alters cropping patterns and are likely to involve environmental consequences. Wu (1999) shows that providing crop insurance in the Central Nebraska Basin shifted land away from hay and pasture to corn, which, in turn increased chemical use at the extensive margin.

If changes in cropping patterns affect environmental impact and if insurance cause's shifts to more intensively managed crops, then counties with higher acreage shifts are likely to have higher levels of environmental damage. While this suggests that crop insurance as a whole can affect the environment, it is possible that the primary negative environmental impacts are due to a small number of specific crop insurance contract decisions, such as insurance type or selected coverage level. Moreover, the nature and extent of damage will likely depend on factors such as risk level, types of crops grown, and location (i.e., climatic and soil conditions).

Our study of the environmental effects of crop insurance contributes to the current literature in three important ways. First, producer-level crop insurance contract information and performance data are used to address the impact on acreage allocation of two producer-selected crop insurance decisions – coverage level and insurance type. Producer-level data allows us to accurately analyze the relationship between crop insurance and acreage allocations. Unlike previous studies, our study does not suffer from potential loss of information by aggregating to county-level or by relying on potentially inaccurate survey responses.

Second, the effects of acreage allocation changes on the environment are estimated using four different environmental indicators: wind erosion, soil erosion, nitrogen loss, and the change

in total organic carbon.¹³ Because wind and soil erosion adversely impact soil quality, health, and productivity as well as environmental quality, it is essential to measure the effects of both causes (USDA-NRCS 2003a, 2003b). Nitrogen loss impacts ecosystems by contaminating streams (or groundwater) while reducing nitrogen available for plant production. Carbon sequestration, i.e., the change of total organic carbon stored in the soil, is important because removing carbon from the atmosphere helps mitigate global warming. Carbon sequestration is one of the most promising ways for reducing the buildup of greenhouse gasses in the atmosphere (Department of Energy 2007).

Third, the change in crop insurance producer premium required to achieve neutral environmental impact is assessed. If we find that crop insurance adversely affects the environment, then producer premium may be a tool that policymakers can use to offset environment damage. Per acre premium amount represents the cost of insurance to producers and is the information producers use to make acreage decisions. Therefore, a change in producer premium should bring about a change in the acreage decision.

We use producer-level crop insurance data to determine the effects of crop insurance on acreage allocation in four separate growing regions. Using the calculated regional changes in acreage allocation, we simulate the effect of an acreage change on the environment using the National Nutrient Loss and Soil Carbon Database (NNLSC) (Potter et al. 2006). The NNLSC was created by the U.S. Department of Agriculture's Natural Resources Conservation Service and the Texas Agricultural Experiment Station's Blackland Research Center. It uses a system of databases and models to increase understanding of environmental impacts, such as levels of sediment and nutrient loss, due to physical processes occurring on U.S. farm fields (NNLSC,

¹³ Nitrogen loss is computed as the sum of nitrate in runoff, nitrate in leachate, nitrate in subsurface lateral flow, organic nitrogen in waterborne sediment, organic nitrogen in windborne sediment, and volatilized nitrogen.

2008). Using the NNLSC, we assess the impact of changes in land management strategies (in our case, crop acreages) on sediment loss from both wind and soil erosion, total nitrogen loss, and change in total organic carbon.

Results from this study have important potential implications for policy. A significant relationship between crop insurance or crop insurance contracts and acreage allocations would suggest that crop insurance or the type of crop insurance contract is associated with acreage allocation. A positive relationship between crop insurance or crop insurance contracts and environmental damage would provide evidence that insurance premium costs do not reflect the full social cost of crop insurance. In addition, we analyze producer-selected crop insurance decisions using a variety of crops from several growing regions to identify the regional sensitivity of crop insurance on the environment. This type of analysis can help policymakers identify regions that are most environmentally affected by crop insurance.

This paper is organized as follows. We first briefly describe crop insurance options and acreage allocations. Then we describe detailed hypotheses that will be tested to achieve the objectives, and follow that section with our method of analysis and data. Findings are presented and interpreted in the results section, followed by conclusions and a discussion of implications of results in the final section.

Crop Insurance and Acreage Allocations

Agricultural producers who enroll in the crop insurance program make decisions about coverage level and insurance type. Producers select a unique buy-up coverage level, typically between 50 and 85 percent of the yield guarantee for each crop based on production risk and the cost of insurance for that buy-up coverage level. Selecting a higher buy-up coverage level increases premium costs, leads to a higher yield guarantee and, therefore, a lower amount of production

risk. With a lower amount of production risk, producers may choose to plant more acres of a risky crop than they would without crop insurance. The increased acreage of the crop could conceivably cause environmental degradation.

Producers can also select insurance type, i.e., yield or revenue, for each crop. We analyze the most widely used insurance plans -- including three revenue-based plans (Crop Revenue Coverage [CRC], Income Protection [IP], Revenue Assurance [RA]), and two yield-based plans (Multiple Peril Crop Insurance [MPCI] and catastrophic insurance [CAT]) and are described in table 1. CRC protects against low yield, low price, or a combination of both; MPCI and CAT insure against low yield. CAT insurance is a special form of MPCI for which the government pays 100 percent of the premium.¹⁴ Producers select insurance type based upon perceived production risk, price risk, and the cost of the insurance type. Selecting an insurance type will depend upon the producer's information about yield and price expectations. Selecting revenue insurance over yield insurance has the potential to provide additional revenue through price protection.

Acreage Allocations and the Environment

In our examination of the impact of crop insurance on acreage allocations and the resulting environmental impact, we build a production model that describes the problem, test whether crop insurance adversely impacts the environment, and then determine whether a change in the premium pricing policy can remedy any damages. The theoretical framework is a multiple-output production model in which there are two sets of outputs, Y (a vector of crop yields) and E (a vector of environmental outputs), and two types of inputs, total land, L (to be allocated to a set of crop activities) and other inputs, X . The inputs and outputs are embedded in the production technology choices from which management decisions are made, represented by the

¹⁴ From this point forward we will refer to yield insurance as MPCI and CAT insurance as CAT.

transformation function: $G(Y, E) = F(L, X)$. Yields are subject to variation which is suppressed in this equation. Among the important characteristics of this technology are that crop yields are affected by the quality and quantity of land allocated to their production. The equation also allows environmental outputs (impacts) to be influenced by the land allocation. Both yields and environmental impacts depend on the package of L and X chosen by the manager.

Management choice is based on maximizing the profit function, $\pi = \pi(P, R, I)$, subject to this technology, where π is profit, P is the vector of output prices, R is the vector of input prices (including land) and I is the net indemnity from crop insurance. Prices and indemnities are stochastic, and their distributions are suppressed in the profit function. However, since this is an insurance model the empirical model will include stochastic prices and yield; and the profit function will be embedded in a utility model that includes a risk aversion component. Based on the literature and economic theory, we postulate and test three hypotheses with this model.

Hypothesis 1 (General Insurance Damage). Crop insurance has specific negative impacts on the environment. Certain crops can be more harmful to the environment because of associated fertilizer and chemical use. Referring to the production technology, it is generally not the crop itself that causes the environmental damage, but the production package which is implemented to produce this crop.

We test the general insurance damage hypothesis using four environmental indicators (wind erosion, soil erosion, total nitrogen loss, and soil organic carbon). Each environmental indicator is tested independently, which results in four independent conclusions.

Both wind and soil erosion cause loss of topsoil, the first and most productive layer of soil, which results in fewer nutrients being available to plants and consequently a decrease in

land productivity. Also, soil erosion causes negative environmental impacts due to its impacts on water as a “non-point” pollution source (Lal, 2001).

Nitrogen loss through waterborne sediment, dissolved in surface water runoff or dissolved in leachate, as well as organic nitrogen can enter streams and results in eutrophication by enriching water with nitrates. Nitrogen loss through volatilization results in reduced nitrogen available for plant production.

Carbon sequestration stores the primary greenhouse gas, carbon dioxide, in the ground or the ocean.¹⁵ Changes in carbon dioxide levels are receiving increasing worldwide attention because of their effect on global climate change. Carbon is sequestered in soils as plant organic matter. Soils contain more carbon than is contained in vegetation and the atmosphere combined which makes soils a major reservoir and sink (i.e., a positive environmental outcome) for carbon (Swift 2001).

Hypothesis 2 (Insurance Type Damage). Revenue insurance and higher buy-up coverage level have larger negative environmental impacts than do MPCCI and low-coverage insurance.

Producer-selected crop insurance options such as revenue insurance and higher buy-up coverage may have greater negative effect on the environment by promoting growth of more environmentally-harmful crops in environmentally-sensitive areas. We test this hypothesis using the same procedure outlined in the general insurance damage hypothesis.

This hypothesis is based on the assumptions that farm operators are risk averse, that insurance is more favorable to riskier crops, and that riskier crops produce greater environmental damage. Presumably, if the different forms of insurance are neutral with respect to risk (fair insurance) and/or the riskiness of the crop is unrelated to its potential for environmental damage, this hypothesis would not be supported.

¹⁵ Due to data limitations, carbon dioxide is the only greenhouse gas we study.

Hypothesis 3. Crop insurance has greater environmental impact in regions with greater within-county land resource heterogeneity. It is possible that the effects of crop insurance on the environment differ systematically between regions that vary in both their agro-climatic heterogeneity and crop mix.¹⁶ Because of the yield risk protection offered by crop insurance, crop insurance participation may lead to larger changes in land use in regions with high land heterogeneity compared to regions with less land heterogeneity. We test the land heterogeneity hypothesis by examining whether larger environmental impacts from crop insurance and crop insurance contracts occur in regions with greater land resource heterogeneity. We examine four growing regions: two relatively homogenous regions, i.e., more uniform land quality characteristics (Iowa and North Dakota in the Midwest), and two more heterogeneous regions (Washington in the Pacific Northwest and Colorado in the Northern Great Plains). The four regions grow some of the same crops, but the mix of crops differs substantially between regions.

We do not have a strong expectation regarding this hypothesis because theory, logic and experience point in competing directions. On the one hand, a small change in a homogenous region could raise the average level of environmental damages caused by the great mass of farmers. On the other hand, more heterogeneous regions have more scope for environmental damage scenarios to play out. Among the latter possibilities are: (a) heterogeneous circumstances allow more “gaming” of the system by farm operators with respect to their acreage allocations, (b) heterogeneous areas may have a higher probability of having environmentally sensitive and nonsensitive land on the same farm, and (c) if insurance is biased to favor riskier crops, then heterogeneous areas will tend to have fatter risk tails and thus more environmental risk.

¹⁶ Weather and soil conditions can influence production decisions. Different production decisions, such as different crops, can result in different levels of risk from agricultural production. These risks can lead producers to select different crop insurance contracts.

Method of Analysis

In order to determine the relationships between crop insurance and the environment, we first estimate producer acreage response equations. We assume that agricultural producers are price takers and act as utility-maximizing firms. We design our model after Coyle's (1992) linear mean-variance model of utility maximization, which incorporates price uncertainty into the utility maximization. We specify utility as $U = E(\pi) - (\alpha/2)V(\pi)$, where $\alpha > 0$ represents the risk aversion measure, E and V are the expectation and variance operators, π is profit defined as $\pi = \bar{p}y - wx$, vectors y and x are output and input levels, vectors p and w correspond to output and input prices, and \bar{p} is the vector of expected prices. Hotelling's lemma yields the output supply equation with regressors that include input prices, expected output prices, variances and covariance's of output prices. The structure of the implied output supply equations guides our specification of acreage share equations, which we estimate for each crop in each region:

$$(1) \quad y_{ik} = \delta_i + \mu_i I_{ik} + \sum_{j=1}^n a_{ij} \bar{p}_j + \sum_{j=1}^n b_{ij} \text{Var}(p_j) + \sum_{j=1}^{n-1} \sum_{l=j+1}^n \eta_{ijl} \text{Cov}(p_j, p_l) + e_{ik}$$

where y_{ik} represents the ratio of crop i ($i=1, \dots, n$) acres to total insured acres on farm k ; I is a binary variable with a value of 1 if crop insurance (other than catastrophic insurance) is purchased, 0 otherwise; \bar{p}_j is expected price of crop j ; $\text{var}(p_j)$ is the variance of price; $\text{cov}(p_j, p_l)$ is the covariance of prices j and l ; δ_i , μ_i , a_{ij} , b_{ij} , and η_{ijl} are parameters to be estimated; e_{ik} is the error term which is assumed to be distributed $N(0, \sigma_{ij}I)$, and σ_{ij} is the covariance of the i^{th} and j^{th} equation disturbance. The constant represents a producer who selected catastrophic coverage. The time subscript t was dropped to reduce notational clutter.

Following Chavas and Holt (1996), we use an adaptive expectations formulation to calculate expected prices and specify variances and covariances of prices. For each crop, expected price at time t is calculated as the average market price plus a drift parameter δ :

$$(2) \quad \bar{p} = E_t(p_t) = \delta + \beta p_{t-1}$$

where E is the expectation operator, p is the price at time t , and δ is the mean of the first difference. We specify the variance of a crop's price as:

$$(3) \quad \text{var}_t(p_t) = 0.50(p_{t-1} - E_{t-2}(p_{t-1}))^2 + 0.33(p_{t-2} - E_{t-3}(p_{t-2}))^2 + 0.17(p_{t-3} - E_{t-4}(p_{t-3}))^2$$

The variance can be interpreted as the sum of squared prediction errors for the previous three years, with declining weights of 0.50, 0.33, and 0.17. Also following their specification, the covariance between prices for crops j and l is:

$$(4) \quad \text{cov}_t(p_j, p_l) = 0.50(p_{j,t-1} - E_{t-2}(p_{j,t-1}))(p_{l,t-1} - E_{t-2}(p_{l,t-1})) + 0.33(p_{j,t-2} - E_{t-3}(p_{j,t-2}))(p_{l,t-2} - E_{t-3}(p_{l,t-2})) + 0.17(p_{j,t-3} - E_{t-4}(p_{j,t-3}))(p_{l,t-3} - E_{t-4}(p_{l,t-3}))$$

The covariance of price uses the same weights as the variance of price.

State-level expected crop prices, variance of crop prices, and covariance of crop prices are normalized by an index of factor prices paid by producers. Normalizing maintains zero homogeneity of the acreage share equations in these variables.¹⁷ Because crops compete for the same land resources, contemporaneous correlation of the error terms is likely across equations. Thus, we estimate equation (1) as a system of acreage equations for each region. One equation is deleted from the system since the dependent variables sum identically to 1 for each producer. Convexity in prices is maintained by the Cholesky factorization. Symmetry among the cross-

¹⁷ Zero homogeneity implies that a proportional increase in all output and input prices and output price variances and covariances does not affect optimal acreage shares.

equation price parameters is maintained at the data means.¹⁸ Iterative nonlinear seemingly unrelated regression (ITSUR) is used to estimate the system and assure invariance of parameter estimates to the equation deleted (“other crops”).¹⁹ A significant relationship between crop insurance and the dependent variable indicates an association between crop insurance and acreage allocation.

To test the general insurance damage hypothesis, we use the estimation results obtained from the acreage equations in equation (1) together with the National Nutrient Loss and Soil Carbon Database (NNLSC), developed by soil scientists, to predict environmental impacts of estimated resource reallocation due to crop insurance. To determine the effect of crop insurance on the environment and to test the general insurance damage hypothesis, we base the NNLSC simulation on the predicted acreage allocation shares with and without crop insurance. The simulation results enable us to estimate whether crop insurance negatively affects the environment, but unfortunately they do not permit us to derive confidence intervals so we are limited to drawing deterministic assessments of the test results. With four environmental indicators, we examine this hypothesis independently for each indicator.

Based on 1997 Natural Resource Inventory data (NRI), Cropping Practice Survey data, and Area Studies data, the NNLSC developed a micro simulation model that was used to create the nutrient loss database (Potter et al. 2006). For this study the 97NRI NNLSC database was used because it is comprised of all cropland situations available in the model. A Unique Resource Unit (URU) was developed from NRI data points, state, crop type, climate type, soil type, irrigation type, and conservation practice. Each URU was treated as a field and on average

¹⁸ Because the symmetry conditions apply to the cross-partial derivatives of the expected utility function, cross-price parameters are identical among output equations. The parameters in the acreage share equations are weighted by the ratio of mean yields, so the symmetry conditions are imposed at the means.

¹⁹ To alleviate high collinearity among variables, we dropped all covariance variables as regressors.

is 12,000 acres in size representing different types of tillage practice, fertilizer application methods, and types of manure applications. Many model runs were conducted for each URU. Each model run provided a data line in the nutrient loss database, resulting in over 1.4 million individual model runs. Results from the NNLSC represent 30 years of simulation results.

The 97NRI NNLSC database file does not contain environmental data on every crop we analyze. When this occurs, we choose the next best crop in the NNLSC database to serve as a proxy. For example, corn was used as a proxy for canola in Eastern Washington. The NNLSC database does not contain environmental information for dry beans and dry peas nor for any other legume in Washington or surrounding states, so we used soybeans in Eastern Colorado as the proxy for both crops. In North Dakota, sorghum served as a proxy for both sunflower and canola and soybeans served as a proxy for dry beans. In Eastern Colorado, soybeans and sorghum served as proxies for dry beans and sunflower, respectively.

For support of the general insurance damage hypothesis, it is necessary that (a) crop insurance significantly affects acreage allocation, and (b) the value from NNLSC for a measure of environmental degradation is higher when crop insurance is used than when it is not. We draw a conclusion with each environmental indicator (for a total of four tests) in each region.

To examine the insurance contract damage hypothesis, we re-specify equation (1) slightly by identifying the specific crop insurance contract and estimate the following equation using the same procedures as noted for equation (1):

$$(5) \quad y_{ik} = \delta_i + \mu_i RHC_{ik} + o_i RLC_i + v_i MHC_{ik} + \pi_i MLC_{ik} + \sum_{j=1}^n a_{ij} \bar{p}_j + \sum_{j=1}^n b_{ij} Var(p_j) + \sum_{j=1}^{n-1} \sum_{l=j+1}^n \eta_{ijl} Cov(p_j, p_l) + e_{ik}$$

where *RHC* is a binary variable taking the value 1 if the producer-selected revenue insurance and high level of buy-up coverage, *RLC* is a binary variable taking the value 1 if the producer-selected revenue insurance and a low level of buy-up coverage, *MHC* is a binary variable taking the value 1 if the producer-selected MPCCI insurance and a high level of buy-up coverage, and *MLC* is a binary variable taking the value 1 if the producer-selected MPCCI insurance and low level of buy-up coverage. The constant represents a producer who selected catastrophic coverage. We determine whether a significant difference exists between the coefficients for revenue and MPCCI insurance and between higher and lower coverage.

For support of the insurance contract damage hypothesis, it is necessary that (a) the effect on acreage allocation is significantly different from high buy-up coverage than from low buy-up coverage and the value from the NNLSC for a measure of environmental degradation is at least five percent higher (which we define as a “large” difference) when high buy-up coverage is selected than when low buy-up coverage is selected, and (b) the effect on acreage allocation is significantly different from revenue insurance than from MPCCI insurance and the value from NNLSC for a measure of environmental degradation is at least five percent higher when revenue insurance is selected than when MPCCI insurance is selected. We compare evidence by examining each environmental indicator (for a total of four tests) in each region.

For support of the land heterogeneity hypothesis, it is necessary that greater environmental impact from crop insurance occur in regions with greater within-county land resource heterogeneity. This will be judged to occur if the average of all significantly different environmental effects is greater for regions with greater within-county land resource heterogeneity than for regions with less within-county land resource heterogeneity. We test this hypothesis using each environmental indicator.

For our final objective, if we determine that crop insurance negatively impacts the environment, we estimate the reduction in payment required for no acreage allocation effect (excluding catastrophic coverage) to achieve a neutral environmental impact. First, we estimate the effect of the Risk Management Agency calculated producer premium (*Prem*) on acreage allocation:

$$(6) \quad y_{ik} = \delta_i + \mu_i \text{Prem}_{ik} + \sum_{j=1}^n a_{ij} \bar{p}_j + \sum_{j=1}^n b_{ij} \text{Var}(p_j) + \sum_{j=1}^{n-1} \sum_{l=j+1}^n \eta_{ijl} \text{Cov}(p_j, p_l) + e_{ik}$$

where μ_i represents estimated parameter from producer paid premium. We define producer premium as the amount paid per acre by each farmer. Therefore, a change in producer premium impacts acreage allocation by μ_i . Using μ_i , we identify the change in producer premium needed to offset acreage allocation changes from crop insurance participation, i.e., to return the acreage allocation to what it is when crop insurance is not used.

Data

We use a rich administrative data set that consists of producer-level crop insurance contracts and acreage allocations for the years 1995–2002. The data set includes information that the Federal Crop Insurance Corporation (FCIC) has for each crop insurance contract: indemnity amount, premium paid by producer, crop type, number of acres in crop, coverage level, insurance type, year, and county location of field. We studied four regions: Iowa, North Dakota, Eastern Colorado, and Eastern Washington. All four regions produce at least three of six primary crops: wheat, corn, soybeans, barley, sunflower, and dry peas. We also include an “other” category that represents additional crops commonly produced in the region.²⁰

²⁰ The “other” category in North Dakota includes canola and dry beans. In Iowa it includes oats. In Eastern Colorado it includes dry beans and barley. In Eastern Washington it includes canola, oats, and dry beans.

For a producer to be included in our analysis, s/he needs to meet two criteria. First, the producer was enrolled in the crop insurance program for at least six of the eight years of the study period. Second, during the study period the producer grew each of the region's primary crops. The latter criterion assures that each producer has the ability to produce each of the region's primary crops.

We do not have acreage allocation data on producers who did not enroll in the crop insurance program. We use a crop insurance contract that best represents the missing population to account for their acreage allocations. Producers who insure using the least expensive crop insurance contract (CAT) have a very low probability of receiving an indemnity because it provides protection only against a catastrophically low yield, so they have nearly the same incentives in selecting acreage allocations as producers without crop insurance. Consequently, we treat acreage allocations under CAT coverage as representing uninsured producers.

With CAT coverage, the government pays 100 percent of the premium and producers pay an administrative fee of 100 dollars for each crop produced in each county. CAT coverage insures against yields below 50 percent of APH at 55 percent of the government set price, thus providing insurance at 27.5 percent of revenue.²¹ In contrast, the next lowest available insurance contract is yield insurance at 50 percent of APH and 100 percent price, providing insurance at 50 percent of revenue. CAT coverage was originally developed for producers who needed to insure because of the mandatory insurance participation rule for producers to participate in government programs. Enacted by the government in 1995, the mandatory participation rule was dropped in 1996 but CAT coverage remains an available crop insurance option.

²¹ The term "revenue" is used here to describe the guarantee in yield insurance since only yield is insured and the government-set price is fixed. This is not to be confused with revenue insurance where both yield and price are insured.

State-level output and input prices are calculated using the data set developed and described in Ball, Hallahan, and Nehring (2004). Output price is the sum of cash price plus government payments per bushel.

Results

The estimated coefficients for the regional systems of acreage share equations with an insurance binary variable, equation (1), are reported in table 2.²² The constant in each equation represents a producer who selected CAT. All own-price parameters are non-negative as constrained by the Cholesky factorization, but less than half are significant at the 5 percent level. In nearly all equations, we found evidence of both substitute and complementary outputs, i.e., at least one cross-price parameter was negative (substitute) and at least one was positive (complement).

In all regions we found statistically significant impacts of crop insurance on acreage allocations. A significantly positive relationship between crop insurance and acreage share was found for corn in Eastern Colorado, for soybeans in Iowa, and for barley in North Dakota and Eastern Washington. A significantly negative relationship between crop insurance and acreage share was found for wheat in North Dakota and corn in Iowa. Results for corn suggest different effects on acreage share depending upon region. This would seem to partially contradict previous research by Wu 1999 who identified statistically significant positive acreage response for corn from crop insurance. In that our results suggest that for corn a positively or negatively significant acreage response from crop insurance depends upon the region. However, this result is not surprising because of the high quality producer level data used in the analysis. While statistically significant impacts of crop insurance were found in all states, they were economically trivial in two. Only in North Dakota and Eastern Colorado did crop insurance

²² Although they were estimated as part of the regional systems, we do not report estimated coefficients for two crops with very small acreage shares. They include sunflower (2.0 percent in Eastern Colorado and 6.2 percent in North Dakota) and dry peas (2.2 percent in Eastern Washington).

impact acreage allocations by more than 5 percent. Among the estimated equations, only wheat and barley acreage shares in North Dakota and corn acreage share in Eastern Colorado were impacted by larger amounts.

Table 3 contains the insurance contract portion of the estimation results for the system of acreage share equations with crop insurance revenue and coverage level as binary variables, equation (5).²³ The effect of crop insurance contracts on acreage shares varied between -22 and +2 percent for wheat, -1 and +9 percent for corn, 0 and +1 percent for soybeans, and +1 and +21 percent for barley. The majority of the insurance contracts had a statistically significant impact on crop acreage allocations in each region. Our results lend support to the findings of Goodwin, Vandever and Deal (2004) that crop insurance participation results in statistically significant acreage responses and that the magnitude of response varies by region.

To test whether a significant difference exists between revenue and yield insurance and between high and low coverage level, we computed Wald test statistics. Results from these tests are reported in table 4. We found a significant difference in Iowa and Eastern Colorado between revenue and yield insurance and in Iowa and North Dakota between high and low coverage levels. These findings support the idea that the effects on acreage allocation are not always the same for different insurance contracts. This result suggests that producers' acreage allocation decisions are not entirely independent of their selection of insurance contract. Producers who select a more expensive crop insurance contract, such as high coverage level, may be more willing to increase their acreage of higher-risk crops (i.e., high return crops that may not consistently grow well). Previous research has identified revenue insurance as altering cropping patterns (e.g., Wu and Adams 2001). However, our results suggest that only in two of the four

²³ Price and variance parameter estimates were similar in parameter values and statistical significance to those in Table 1 so are not reported in this table.

regions did revenue insurance alter cropping patterns, a result that furthers the idea that acreage allocation effects from crop insurance are region specific.

A possible explanation for the difference in the effect of crop insurance contract on acreage shares may be found in the consistency of crop growing conditions. Inconsistent growing conditions along with additional protection offered from more expensive crop insurance contracts may induce insured farmers to allocate more acres to that crop, whereas consistent growing conditions may not induce a change in crop insurance contract and therefore no change in acreage share.

Environmental Impacts

Using the estimated impacts of crop insurance on acreage allocations, we now consider the extensive margin environmental impact from crop insurance. We analyze four different environmental indicators: wind erosion, soil erosion, total nitrogen loss, and change in soil organic carbon. The expected environmental damage caused by each planted acre of a crop was weighted by the crop's share of total acreage in the region. All crops were accounted for, so the sum of acreage shares is equal to 1 in each region. With no formal method to test for statistically significant adverse environmental impacts from crop insurance, we treat a 5 percent increase in the absolute value of an environmental indicator as being a "large" difference. All assessments of large differences are relative to the environmental impact with no crop insurance.

Estimated environmental outcomes from crop insurance contracts are presented in table 5. They represent the contribution of all crops in the region to environmental damage under each of six crop insurance options: none purchased, crop insurance purchased, and each of four insurance contracts purchased. In North Dakota, where we previously found statistically significant and economically nontrivial acreage shifts due to crop insurance, we also found that

crop insurance had a “large” adverse environmental impact in terms of wind erosion and total nitrogen loss. The same was true for wind erosion in Eastern Colorado. In the regions where we found only economically trivial differences in acreage allocation from crop insurance, we found no “large” adverse environmental impact of crop insurance due to extensive margin effects. None of the environmental impacts of crop insurance was large in Iowa or Eastern Washington, and in no region were the organic carbon and soil erosion impacts of crop insurance “large”.

Similar results were found for the specific insurance contract options. Only low coverage yield insurance had any “large” adverse environmental impacts. They were for the same indicators in the same regions as crop insurance had large environmental impacts. With so few large impacts on any of the environmental indicators, there is little evidence to support either the general insurance damage hypothesis or the insurance contract damage hypothesis.

We next examined whether crop insurance had greater adverse environmental impact in regions with greater within-county land resource heterogeneity using results reported in table 5 were used to test this hypothesis. With two significantly different and greater environmental indicators in North Dakota (one of the more homogenous regions) one in Eastern Colorado (one of the more heterogeneous regions), and none in the other homogeneous and the other heterogeneous region, no evidence was found relative to the individual environmental indicators to support the land heterogeneity hypothesis.

We also examined the overall environmental impact of crop insurance in each region and computed the average across regions. Without other strong priors, we weighted the environmental indicators equally. The calculated overall environmental outcomes are reported by region in table 6. We interpret this indicator as a measure of overall environmental health. Although agricultural production had the largest adverse impact on the environment in Iowa, the

effect of crop insurance was to slightly reduce the environmental impact. We found the overall environmental impact of crop insurance to be the worst in North Dakota of all four regions. The environmental impact of crop insurance was negative in both Eastern Washington and Eastern Colorado, but the overall impact was slight in both regions. Thus, the land heterogeneity hypothesis was clearly rejected. The average overall environmental impact across regions was negative, but small enough that we also reject the general insurance damage hypotheses and the insurance contract damage hypothesis

For our final objective, we determine the reduction in payment for crop insurance required for no acreage allocation effect needed to offset negative environmental outcomes from regions where crop insurance negatively affects the environment. Two regions provided evidence of a negative environmental impact from crop insurance – North Dakota and Eastern Colorado. Estimated effects of per-acre producer premium on acreage allocation are presented in table 7. In North Dakota we found that insurance premium, although frequently statistically significant, has very little effect on acreage share.

The estimated reduction in per-acre reduction in payment required for no acreage allocation effect and consequently no negative environmental outcomes are reported in table 8. For North Dakota, they varied from a 5,486 percent decrease for wheat to a 787 percent decrease for sunflowers. For Eastern Colorado the change in per-acre producer premium required to offset negative environmental outcomes varied from a 149 percent decrease for corn to an 8 percent decrease for wheat. In North Dakota the percent decrease in per-acre producer premium to offset negative environmental outcomes results in values that make producer premium zero (i.e., the reductions in producer premium exceed 100 percent), implying that insurance is no longer available to these producers. Results are contradictory to our expectations. These results

suggest that in both North Dakota and Eastern Colorado, acreage share decisions are not dependent on crop insurance premium.

Conclusions

In this article we analyze the extensive-margin (i.e., via land allocation) environmental effects of crop insurance and crop insurance contracts between regions using high quality producer-level crop insurance data with four different environmental indicators. Our results identify regions where the environment is worse off because of crop insurance and the specific environmental characteristics that are most affected.

We find statistically significant acreage allocation impacts of crop insurance in all states, but they are economically trivial in two. Only in North Dakota and Eastern Colorado did crop insurance impact acreage allocations by more than 5 percent. Consequently, important extensive-margin effects of crop insurance were evident only in these two regions. Our results suggest that the effects of crop insurance on acreage allocations are region specific. This highlights the consequences of applying results for the same crop from one region to all regions. However, for regions not analyzed but with similar characteristics as the ones we analyzed similar results are expected.

Because of the limited extensive-margin effects, negative environmental impacts of crop insurance were also noted only in these two regions. Further, the adverse impacts only affected two of four environmental indicators (wind erosion and total nitrogen loss) in North Dakota and one indicator (wind erosion) in Eastern Colorado. This result suggests that negative environmental outcomes from crop insurance participation are specific to individual regions and particular environmental indicators (i.e., environmental dimensions). We found no evidence of widespread adverse extensive-margin impacts from crop insurance participation on either soil

organic carbon or soil erosion rates. However, across all regions, we found a slight negative environmental impact from crop insurance.

Among the specific crop insurance contracts, we only found negative environmental impacts from one insurance contract – yield insurance with low coverage level. This finding implies that the most widely used insurance contract type places a larger environmental cost on society than the other insurance contract types. Thus, yield insurance with low coverage level may appear to warrant an increase in relative premium rates between insurance contracts for producers in heterogeneous regions. However, we found no effect of producer paid insurance premium on acreage shares. Since producers appear to be making acreage allocation decisions independently of insurance premium, then policymakers need to look to different tools than insurance premium if they want to offset the modest, environmentally-adverse acreage allocation effects from crop insurance.

Our findings differ from some previous literature in that they provide slender to insignificant support for any of our three environmental impact hypotheses. There is somewhat greater support for underlying “hypotheses” – that crop insurance will effect land allocation decisions; a result which is consistent with the findings of Wu (1999). While our results on the environmental impacts indicate that, in some regions, crop insurance can negatively affect the environment, usually the impacts are small. In attempting to identify regions that might be more sensitive, we had focused on relatively heterogeneous land resource regions, but even here, we found minor impacts. However, our analysis did not address possible adverse environmental impacts of producer acreage expansion due to crop insurance participation relative to producer acreage expansion without crop insurance (partly because of the data set which included only those with minimum insurance, i.e., CAT. This topic warrants examination in future work on

crop insurance. Moreover, our limited support for the impact of crop insurance on land allocation, and the likelihood of locally important environmental impacts, suggest additional study is warranted in this arena.

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Table 1. Description of Insurance Programs

Policy Type	Description	Risk Protection	Available Coverage Levels ^a
Crop Revenue Coverage (CRC)	Protection is based on revenue (yield * price). Two prices are used – the base price (minimum guaranteed price) and the harvest price. Indemnity is based on loss below the revenue guarantee using the higher price.	Revenue (Yield * Price)	50 to 85 percent in 5 percent increments
Income Protection (IP)	Protection is based on revenue using the base price. Indemnity is based on loss below the revenue guarantee.	Revenue	50 to 75 percent in 5 percent increments
Revenue Assurance (RA)	Protection is based on revenue using the base price, unless the fall harvest price option is selected. Then RA functions like the CRC.	Revenue	65 to 85 percent in 5 percent increments
Multiple Peril Crop Insurance (MPCI)	Protection is based on yield. Insures at 100 percent of a specified price. ^b Indemnity is based on yield loss only.	Yield	50 to 85 percent in 5 percent increments
Catastrophic Coverage (CAT)	Protection is based on yield. Insures at 50 percent of yield at 55 percent of specified price, so it effectively insures 27.5% of guarantee. Indemnity is based on yield loss only. ^b Entire premium is paid by Federal Government. Producer pays \$100 administration fee.	Yield	50 percent

^a Available coverage levels are specific to crop type.

^b Yield-based insurance plans are multiplied by a price established by the Federal Crop Insurance Corporation to represent the dollar value of each bushel.

Table 2. Parameter Estimates for General Insurance Damage, Equation (1)

Crop	Parameter	Region							
		Iowa		North Dakota		Eastern Colorado		Eastern Washington	
Wheat	Insurance	—		-0.118*	(0.0051)	-0.0011	(0.0014)	0.00025	(0.00061)
	P Wheat	—		0.0011	(0.00074)	0.0012	(0.00066)	1.3e-13	(6.5e-10)
	P Corn	—		—		0.0013	(0.00079)	—	
	P Barley	—		-6.3e-4	(0.00046)	—		2.1e-12	(1.0e-8)
	P Sunflower [#]	—		-3.3e-4	(0.00026)	-0.00011	(0.000068)	1.8e-12	(9.2e-9)
	P Other	—		0.061	(0.064)	-0.0044	(0.0025)	-5.9e-12	(2.9e-8)
	V Wheat	—		-0.0043	(0.044)	-0.178*	(0.047)	-0.075	(0.066)
	V Corn	—		—		0.311*	(0.110)	—	
	V Barley	—		0.0041	(0.024)	—		-0.056	(0.124)
	V	—		-143.1	(94.62)	1767.5*	(573.06)	0.0031	(.0050)
	Sunflower [#]	—		—		—		—	
	V Other	—		-1.197*	(0.296)	1.164	(0.747)	-1.311	(1.33)
	Time	—		-0.015*	(0.0035)	0.022*	(0.0080)	0.0014	(0.0037)
	Constant	—		1.072*	(0.072)	0.635*	(0.067)	0.889*	(0.029)
Corn	Insurance	-0.0044*	(0.00021)	—		0.065*	(0.0022)	—	
	P Wheat	—		—		0.0038	(0.0023)	—	
	P Corn	1.3e-12	(6.7e-8)	—		0.0043	(0.0027)	—	
	P Barley [^]	7.6e-12	(0.0000041)	—		—		—	
	P Sunflower	—		—		-0.00037	(0.00022)	—	
	P Other	2.8e-11	(0.0000088)	—		-0.014	(0.0086)	—	
	V Wheat	—		—		0.146*	(0.380)	—	
	V Corn	0.00031	(0.0046)	—		-0.283*	(0.090)	—	
	V Barley [^]	-0.020*	(0.0018)	—		—		—	
	V Sunflower	—		—		1786.3*	(432.420)	—	
	V Other	0.070*	(0.00026)	—		-1.202*	(0.630)	—	
	Time	-0.0022*	(0.00026)	—		0.020*	(0.0065)	—	
Constant	0.583*	(0.0016)	—		0.301*	(0.054)	—		
Barley [^]	Insurance	0.0051*	(0.00018)	0.133*	(0.0024)	—		0.0068*	(0.0094)
	P Wheat	—		-0.0086	(0.00064)	—		2.2e-12	(1.1e-8)
	P Corn	2.90e-12	(1.6e-8)	—		—		—	
	P Barley [^]	0.00081*	0.00040)	0.00053	(0.00071)	—		0.086*	(0.0062)
	P Sunflower [#]	—		-0.0021	(0.00035)	—		-0.031*	(0.0023)
	P Other	-0.0066	(0.0036)	0.048	(0.034)	—		0.179*	(0.013)
	V Wheat	—		-0.062*	(0.022)	—		0.021	(0.055)
	V Corn	-3.2e-4	(0.0050)	—		—		—	
	V Barley [^]	0.020*	(0.0018)	0.0013	(0.013)	—		0.450*	(0.107)
	V	—		-104.9*	(51.06)	—		-0.0086*	(0.0044)
	Sunflower [#]	—		—		—		—	
	V Other	-0.065*	(0.0093)	0.052	(0.154)	—		1.426	(1.164)
	Time	0.0022*	0.000027)	-0.0044*	(0.0018)	—		0.0032	(0.0037)
	Constant	0.419*	(0.0038)	0.039	(0.038)	—		0.017	(0.026)
# Obs		167,220		12,082		17,197		8,969	

Note: Standard errors are shown in parentheses, P is price, V is variance, ^ indicates soybeans in Iowa, and # indicates dry peas in Eastern Washington. Single asterisk (*) implies parameter is significant at the 0.05 level. Although equations were also estimated for sunflower in North Dakota and Eastern Colorado and for dry peas in Eastern Washington, their estimated coefficients are not reported in this table because their acreage shares were so small.

Table 3. Parameter Estimates for Insurance Contract Damage, Equation (5)

Crop	Parameter	Regions			
		Iowa	North Dakota	Eastern Colorado	Eastern Washington
Wheat					
	Revenue and High Coverage Level	—	-0.221* (0.010)	-0.0026 (0.0042)	0.0029* (0.0013)
	Revenue and Low Coverage Level	—	-0.171* (0.0067)	-0.0084* (0.0025)	0.0032* (0.0019)
	Yield and High Coverage Level	—	-0.099* (0.0098)	0.023* (0.0084)	-0.00044 (0.00074)
	Yield and Low Coverage Level	—	-0.109* (0.0051)	0.00025 (0.0016)	0.00018 (0.00083)
Corn					
	Revenue and High Coverage Level	-0.0038* (0.00033)	—	0.089* (0.0050)	—
	Revenue and Low Coverage Level	-0.0030* (0.00036)	—	0.077* (0.0027)	—
	Yield and High Coverage Level	-0.0062* (0.00030)	—	0.086* (0.020)	—
	Yield and Low Coverage Level	-0.0048* (0.00025)	—	0.055* (0.0023)	—
Barley [^]					
	Revenue and High Coverage Level	0.0049* (0.00031)	0.137* (0.014)	—	0.0075 (0.0048)
	Revenue and Low Coverage Level	0.0046* (0.00024)	0.109* (0.0068)	—	0.0080 (0.0069)
	Yield and High Coverage Level	0.0055* (0.00026)	0.205* (0.011)	—	0.0076* (0.0011)
	Yield and Low Coverage Level	0.0052* (0.00021)	0.132* (0.0027)	—	0.0052* (0.0016)

Note: Standard errors are shown in parentheses, ^ indicates soybeans in Iowa, and single asterisk (*) implies parameter is significant at the 0.05 level.

Table 4. Effects of Revenue vs. Yield Insurance and High vs. Low Coverage Level on Acreage Share

Insurance	Region			
	Iowa	North Dakota	Eastern Colorado	Eastern Washington
Revenue Insurance	-0.0053* (0.00069)	-0.029 (0.061)	-.2180* (0.0294)	0.0086 (0.0094)
High Coverage	0.0027* (0.00073)	0.129* (0.062)	0.0030 (0.0280)	0.0018 (0.0084)

Note: Standard errors are shown in parentheses, and single asterisk (*) implies parameter is significant at the 0.05 level.

Table 5. Environmental Effects from Crop Insurance and Contracts

Environmental Indicator	Region	No Insurance	Insurance	Crop Insurance Contract			
				Revenue High Buy-up	Revenue Low Buy-up	Yield High Buy-up	Yield Low Buy-up
Wind Erosion	North Dakota	1.35	1.49*	1.36	1.39	1.36	1.43*
	Iowa	0.50	0.50	0.50	0.50	0.50	0.50
	Eastern Colorado	0.92	0.99*	0.87	0.88	0.92	1.04*
	Eastern Washington	0.035	0.036	0.036	0.036	0.035	0.036
Soil Erosion	North Dakota	0.45	0.45	0.45	0.46	0.45	0.46
	Iowa	2.83	2.83	2.83	2.83	2.83	2.83
	Eastern Colorado	0.21	0.21	0.20	0.20	0.20	0.21
	Eastern Washington	1.37	1.37	1.37	1.37	1.37	1.37
Total Nitrogen Loss	North Dakota	26.59	29.17*	26.76	27.18	26.67	28.14*
	Iowa	51.89	51.79	51.88	51.87	51.87	51.85
	Eastern Colorado	15.64	15.88	16.12	16.21	15.78	15.32
	Eastern Washington	30.37	30.40	30.36	30.36	30.38	30.36
Change in Soil Organic Carbon	North Dakota	-3.03	-3.12	-3.04	-3.06	-3.03	-2.97
	Iowa	-6.38	-6.38	-6.38	-6.38	-6.38	-6.38
	Eastern Colorado	-0.88	-0.86	-0.88	-0.88	-0.88	-0.86
	Eastern Washington	-0.24	-0.24	-0.24	-0.24	-0.24	-0.24

Note: Wind erosion, soil erosion, and change in soil organic carbon values are in tons per acre. Total nitrogen losses are in lbs. per acre. Single asterisk (*) indicates a difference greater than 5

percent from no insurance and larger in absolute value.

Table 6. Average Environmental Outcome from Crop Insurance ^a

Region	Average	
	Insurance	No Insurance
Iowa	15.23	15.25
North Dakota	8.56	7.92
Eastern Washington	8.01	8.00
Eastern Colorado	4.48	4.42
Average	9.07	8.89

^a Calculated as the average of absolute values of individual environmental indicators. Equal weights were placed on all environmental indicators.

Table 7. Parameter Estimates of Producer Premium on Acreage Shares, Equation (6)

Crop	Parameter	Region	
		North Dakota	Eastern Colorado
Wheat	Premium	-0.00069*	-0.0044*
		(0.0001)	(0.0003)
Barley [^]	Premium	0.0011*	0.0029*
		(0.0001)	(0.0003)
Sunflower	Premium	0.0019*	0.020*
		(0.0002)	(0.0004)

Note: Standard errors are shown in parentheses, [^] indicates corn in Eastern Colorado, and single asterisk (*) implies parameter is significant at the 0.05 level.

Table 8. Percent Change in Producer Premium Required to Offset Negative Environmental Outcomes

Crop	Region	
	North Dakota	Eastern Colorado
Wheat	-5,486 [^]	-8
Corn	—	-149 [^]
Barley	-2,302 [^]	—
Sunflower	-787 [^]	-16

Note: Units are in percents, and [^] values imply zero producer premiums.

CHAPTER FOUR
ECONOMIC EFFECTS ON PRODUCERS FROM REDUCING
NITROGEN POLLUTION IN WHEAT PRODUCTION

Introduction

Efficient nitrogen management is critical for the economic production of crops and the long-term protection of environmental quality (Lopez-Bellido *et al.* 2006). Agricultural producers apply nitrogen to increase cereal production. However, removal rates of applied nitrogen in harvested cereal grain are estimated to be only 33 percent (Raun and Johnson 1999). Additionally, losses of available nitrogen supplies are estimated to range from 1 percent to 35 percent (Kumar and Goh 2000). Consequences of inefficient use of nitrogen are lower profits for producers and higher levels of environmental pollution.

Agricultural producers typically apply nitrogen to their fields at a uniform rate. But often, fields are not uniform in their nitrogen requirements. For fields with different intra-field nitrogen needs, a uniform application of nitrogen results in over-application in some areas and under-application in other areas (Fiez, Pan, and Miller, 1995). Under-application limits potential yields and revenue, and hence profit. Over-application can result in pollution because of the excess available nitrogen, impacting ecosystems by contaminating groundwater, streams, lakes, and oceans. Additionally, nitrogen pollution can contribute to global warming through emissions of a greenhouse gas, nitrous oxide. Hence, determination of the field-scale variables that affect potential nitrogen pollution and the resulting cost of reducing nitrogen pollution would be an important contribution to reducing adverse environmental impacts from agricultural production and possibly enhancing agricultural production and profits.

Land qualities influence production; we grow corn in some regions and wheat in others for this reason. However, land qualities may also matter at the field level. When we think of the variability of soil quality, we normally think of soil properties such as organic matter content. However, terrain attributes (i.e., topographic properties) have been used to help explain spatial variability of crop yields (Green and Erskine, 2004). Terrain attributes may be linked to differences in yields through a variety of mechanisms, including both the spatial and topographical features like slope and aspect as well as underlying soil properties through their systematic spatial distribution – e.g., adjoining plots can be expected to have similar soil properties, other things equal, and hilltops often have “thinner” soil than bottom lands. Terrain attributes may also be used to help explain potential nitrogen pollution. This is because applications of nitrogen to landscapes with terrain attributes that promote nitrogen pollution will likely lead to greater amounts of pollution. Therefore, identifying terrain attributes that can lead to greater amounts of nitrogen pollution could be important for reducing nitrogen pollution. From a research standpoint, efficiently decreasing the amount of nitrogen pollution will need to consider both the reduction in producer profit and the increases in “social welfare” caused by limiting applied nitrogen at different terrain attributes.

Site-specific management (precision agriculture) has been proposed as an approach to increase producer profit by applying inputs at the correct time and at different rates (i.e., variable-rate) across fields to locations where they are needed, thereby reducing over and under-application of inputs. By applying inputs as needed, site-specific management or variable-rate technology may reduce nitrogen pollution. Additionally, the economic effect on producers from reducing nitrogen supply by variable-rate technology may be less than the same reduction by uniform application. On the other hand, site specific application will generally require more

intense use of some inputs, and hence is likely to increase production costs. Therefore, the net effect on farm profits depends on which effect is greater, better yield to application ratio versus higher input costs.

Several studies have addressed the impact of spatial stability of yield response to nitrogen. Lambert, Lowenberg-DeBoer, and Malzer (2006) found that spatial variation of crop response to both nitrogen and phosphate is significant. Mamo *et al.* (2003) documented that a uniform application of nitrogen results in over-fertilized areas while other areas are under-fertilized. Fiez, Pan, and Miller (1995) identified terrain attributes where nitrogen fertilizer uptake efficiency was low and nitrogen loss percentages were high, indicating the need to reduce nitrogen losses by lowering applied nitrogen on terrain attributes susceptible to nitrogen loss. Anselin, Bongiovanni, and Lowenberg-DeBoer (2004) found that nitrogen response differs by landscape position and that site-specific application may be profitable. It appears that very little research has focused on whether the effects of available nitrogen on key outputs -- yield, protein, and unaccounted nitrogen -- vary with terrain attribute. Thus, we do not yet have necessary information to judge the resulting economic effect on growers from reducing unaccounted nitrogen through variable-rate technology.

Ideally, for full accounting we would like to measure nitrogen pollution. However, due to complex soil and landscape-scale processes, it is difficult to measure the true level of nitrogen pollution. To circumvent this important problem, we measure the amount of nitrogen that has the highest probability of becoming pollution, and call it unaccounted nitrogen. Unaccounted nitrogen represents the amount of nitrogen that crop production and soil measurements do not account for.

In this article we examine: (a) whether the effect of nitrogen supply on hard red spring wheat (HRSW) yield, protein, and unaccounted nitrogen at a research site in Eastern Washington depends on field-scale terrain attribute, (b) whether an innovative spatial weights matrix that accounts for elevation results in greater statistical efficiency in parameter estimation, and (c) how regulation of applied nitrogen may affect producers profit, comparing uniform and site-specific application methods.

Identifying (field-scale) terrain attributes where unaccounted nitrogen is likely to occur and the economic impact on producers from a reduction in applied nitrogen is important to producers and policy makers. Identifying the terrain attributes that lead to high levels of unaccounted nitrogen and the economic impact on producers from a decrease in applied nitrogen can help design future policy to decrease nitrogen pollution most economically.

Considered independently, plots with the same terrain characteristics can appear at significant distances from each other. For modelers, this is desirable because standard statistical models generally assume independence among observations or data points. However, in agronomic data, observations normally come from the same geographic location and it is likely that land parcels in close proximity share common characteristics, (e.g., soil properties) which brings the validity of the independence assumption into question (Anselin, Bongiovanni, and Lowenberg-DeBoer 2004). Failing to account for valid spatial autocorrelation would result in inefficient parameter estimates that bias the test statistics.

Standard spatial autocorrelation techniques assume a two-dimensional spatial effect (i.e., latitude and longitude). With a non-flat surface, like a hill, this assumption may not be valid. In this study, we incorporate a third axis, elevation, into the spatial weights matrix -- which effectively models the spatial effect as three dimensional. We determine whether including

positions higher in elevation in the spatial weights matrix results in greater statistical efficiency in parameter estimation.

This article proceeds as follows. We first provide a description of how the amount of nitrogen pollution is determined. We present hypotheses relating to whether the impact of including elevation in the spatial weights matrix results in greater statistical efficiency in parameter estimation and the impact of applied nitrogen by terrain attribute on yield, protein, and nitrogen pollution. A description of our model and data follows. We present and interpret findings in the results section. Conclusions and discussion of implications occur in the final section.

Unaccounted nitrogen

To measure unaccounted nitrogen (N_u) requires measurement of nitrogen available to plants, the amount removed in harvested grain, the quantity remaining in the soil after harvest, and the amount of nitrogen that changed from an available to an unavailable form. Soil was sampled in the spring to measure the amount of nitrogen available to the plant (N_{av}). Nitrogen fertilizer was applied to the soil (N_f). During the growing season, nitrogen can change from an organic form, which the plant is unable to use, to an inorganic form (mineralization) which the plant is able to use, and vice-versa (immobilization). We call inorganic nitrogen that results from these processes net nitrogen mineralization (NM). We estimated NM from total soil nitrogen in the top ten centimeters of the soil at a turnover rate of one percent per year. Net mineralization can be either a source of nitrogen or a nitrogen sink. Immobilized nitrogen may be recovered in the future through mineralization and subsequent plant uptake. Nitrogen can be found in the grain (N_g) and in the residue of the crop (N_r). After harvest a second soil sample is taken which measures the amount of nitrogen remaining in the soil (N_h). We can now identify unaccounted

nitrogen by subtracting available nitrogen (i.e., nitrogen in the grain, nitrogen in the residue of the crop, and nitrogen in the fall soil sample) from nitrogen supply (i.e., the sum of the spring soil sample, applied nitrogen, and net mineralization):

$$(1) \quad N_l = N_{av} + N_f + NM - (N_g + N_r + N_h)$$

We compute values for unaccounted nitrogen using equation (1) and use these values in the regression analysis.

Hypotheses

Hypothesis 1. Including a spatial weights matrix that incorporates higher elevation results in greater statistical efficiency in parameter estimation. Nitrogen is thought to typically move down a slope with water and eventually to a stream or river. In hilly terrain, nitrogen may move from a point higher in elevation to a point lower in elevation. Nitrogen deposits at a location in a field can be influenced by locations higher in elevation, thus creating a spatial structure. Not accounting for the spatial structure through spatial econometric methodology can lead to biased variance. Therefore, including elevation in the spatial weights matrix may result in increased model efficiency. To test this hypothesis, we determine whether a larger and significant difference exists between the log-likelihood value for the system of equations that incorporates a spatial weights matrix with points higher in elevation and the log-likelihood value for the system that does not consider a spatial weights matrix.

Hypothesis 2. Including a spatial weights matrix that also incorporates lower elevation does not further increase statistical efficiency in parameter estimation. With the intuitive idea that nitrogen typically moves down a hill, points lower in elevation would not have an effect on points higher in elevation. In this case, adding information into the spatial weights matrix from points lower in elevation would not lead to greater statistical efficiency in parameter estimation.

However, soil and water with opposite signs are attracted to each other. As soil becomes drier, it can attract more water. This relationship can lead to water being “pulled uphill” to drier soil. To test this hypothesis we determine whether a larger and significant difference exists in the log-likelihood value for the system of equations that includes points lower in elevation and the log-likelihood value for the system that only includes points higher in elevation.

Hypothesis 3. Terrain attributes have a statistically significant effect on the yield response to nitrogen supply. Previous research has identified relationships between terrain attributes and grain yields (Kaspar *et al.* 2003). Nitrogen is often applied at a uniform rate across the entire field. Research has shown that, even with uniform fertilizer application, yields within a field can vary considerably from one point to the next (Pan *et al.* 1997). This result is not surprising since just a visual observation of a field can reveal crop density differences across the landscape, and yields typically vary with crop density. Since crop density can vary with terrain characteristics we expect the response of yield to available nitrogen to vary with terrain attributes. We test this hypothesis by determining whether yield response to available nitrogen is dependent on terrain attribute (defined in the methods section). Moreover, by modeling spatial autocorrelation, we can interpret the impact of terrain attributes more clearly. A satisfactory accounting of spatial autocorrelation will help control for some aspects of soil quality (e.g., variations in carbon content).

Hypothesis 4. Terrain attributes have a statistically significant effect on the protein response to nitrogen supply. Agricultural producers of grains may also apply nitrogen to increase or maintain a minimum level of protein. Because yields can vary within a field it is likely that protein will also vary due to terrain attributes. We test this hypothesis by determining whether protein response to available nitrogen is dependent on terrain attribute.

Hypothesis 5. Terrain attributes have a statistically significant effect on the unaccounted nitrogen response to nitrogen supply. If it is possible that both yield and protein of wheat vary within a field, then it is possible that unaccounted nitrogen also varies. We test this hypothesis by determining whether unaccounted nitrogen response to nitrogen supply is dependent on terrain attribute. Identifying within-field locations that result in highest unaccounted nitrogen response to available nitrogen would also identify locations that would achieve the greatest environmental benefit from a reduction in applied nitrogen.

Method of Analysis

The empirical model consists of two related models – a statistical model to test the hypotheses listed above and a constrained optimization simulation model to identify “profit-maximizing” nitrogen application levels and technologies under specified scenarios. We develop the statistical model first.

We are interested in the effect of available nitrogen and terrain attribute on yield, protein, and unaccounted nitrogen. Response equations are derived for each. A spatial model is used to correct for spatial autocorrelation (Anselin 1988). We analyze three terrain attributes – slope, elevation, and aspect (with aspect represented by two variables as noted below).

Contemporaneous correlation may exist among the three equations, given that the dependent variable in each equation is a function of nitrogen. Therefore, the equations are estimated as a seemingly unrelated system (SUR):

$$(2) \quad Y = X\beta + \mu$$

$$\text{where } Y = \begin{bmatrix} \text{Yield} \\ \text{Protein} \\ \text{Unaccounted Nitrogen} \end{bmatrix}, \quad X = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix}, \quad \beta = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix}, \quad \mu = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix}$$

The system of equations is estimated via maximum likelihood (Anselin, 1988). The estimated coefficients from all three equations will be used in the economic analysis.

Each equation is specified as a function of nitrogen supply, geo-referenced location ($j=1, \dots, 705$), year ($t=1, \dots, 6$), previous crop ($i=1, \dots, 6$), terrain attribute ($k=1, \dots, 4$), squared nitrogen supply, and interactions between available nitrogen and terrain attribute:

$$(3) \quad Y_j = \rho Z + \alpha_0 + \sum_{t=1}^5 \alpha_t T + \sum_{i=1}^5 \alpha_{i+5} I + \beta_1 N_j + \beta_2 N_j^2 + \sum_{k=1}^3 \beta_{k+2} K + \sum_{k=1}^4 \beta_{k+5} KN_j + \mu_j$$

where ρ is the spatial lag autoregression coefficient; $Z = (W_1 \bullet W_2) Y_j$; W_1 and W_2 are the spatial weight matrices; \bullet refers to the Hadamard product (element by element multiplication); T is a matrix of year binary variables; I is to a matrix of previous crop binary variables; $N = SS + A + NM$ is the amount of nitrogen supply; K is a matrix of terrain attributes; KN is a matrix of interaction terms (terrain attributes multiplied by available nitrogen); μ is the error term which is assumed to be distributed $N(0, \sigma_{ij} I)$; and σ_{ij} is the covariance of the i^{th} and j^{th} equation disturbance; ρ , $\alpha_1 - \alpha_{10}$, and $\beta_1 - \beta_9$ are all parameters to be estimated.

The Hadamard product of W_1 and W_2 provides a spatial weights matrix of 1.0 divided by the Euclidian distance of points higher in elevation than the reference point. The diagonals in W_1 and W_2 are set to zero and rows are rescaled so they sum to one. This allows for the total effect of all neighbors to be independent of the number of neighbors. The spatial weights matrix W_1 is used to specify the neighbors (defined by elevation) and is composed of zeros and ones.²⁴ A one indicates that the point is higher in elevation than the reference point, zero otherwise. The spatial weights matrix W_2 is composed of values of 1 divided by the Euclidian distance from the

²⁴ To prevent the calculated $\ln(\det((I - \rho * WW)))$ in the log-likelihood from going to infinity, zeros were replaced with 0.001.

reference point. Spatial autocorrelation is expected to exist only between points within the same year and not between points in different years; therefore, between year points are set to zero. Construction of this type of spatial autocorrelation results in a block diagonal spatial weights matrix (i.e., blocks along the main diagonal give within-year distance and off-diagonal blocks are zero).

Equation (3) represents a spatial lag model where the spatial autocorrelation is restricted to the dependent variable (Anselin, Bongiovanni, and Lowenberg-DeBoer 2004, and Anselin 1988). The spatial lag model corrects for non-independent observations and correlated error terms. The constants in each estimated equation represents observations in 2006 with a previous crop of spring peas. GAUSS 8.0 is used to perform the estimation.

For the spatial weights matrix we need to determine the Euclidian distance between all points. Each observation is assigned a unique value for latitude and longitude, (x_n, z_n) . With the first and second observations having values (x_1, z_1) and (x_2, z_2) , respectively, and defining $\Delta z = z_2 - z_1$, we calculate distance in feet, Δd , by:

$$(4) \Delta d = .7498 \arctan\left(\frac{\sqrt{(\cos(x_2) \sin(\Delta z))^2 + (\cos(x_1) \sin(x_2) - \sin(x_1) \cos(x_2) \cos(\Delta z))^2}}{\sin(x_1) \sin(x_2) + \cos(x_1) \cos(x_2) \cos(\Delta z)}\right)$$

Aspect, measured in radians, is an angular variable. To estimate our continuous dependent variables on this angular regressor, we transform the angular variable into its sine and cosine (Mardia, 1976) which creates two aspect variables.

To test the first hypothesis, we calculate a likelihood ratio test statistic to determine whether a larger and significant difference exists between the log-likelihood value for the system of equations that includes a spatial weights matrix with higher elevation and the log-likelihood

value for the system that does not consider any spatial structure. A larger and significant log-likelihood ratio test statistic indicates support for this hypothesis.

For the second hypothesis, that including a spatial weights matrix that also incorporates lower elevation does not further increase statistical efficiency, we compute a J-test statistic because the test is non-nested. Support for this hypothesis is found by failing to reject when the null hypothesis is the spatial weights matrix that includes only higher elevation.²⁵

To determine whether terrain attributes have a statistically significant effect on the yield, protein, or unaccounted nitrogen response equations to available nitrogen, we test the alternate joint hypothesis that the parameter estimates for β_6 , β_7 , β_8 , and β_9 in equation (3) are equal to zero. An independent test is conducted for each equation. Rejecting the alternate hypothesis indicates support for our hypothesis that terrain attribute has a statistically significant effect on yield (hypothesis 3), protein (hypothesis 4), or unaccounted nitrogen (hypothesis 5) response to available nitrogen. If we reject an alternate hypothesis, we then examine which terrain attributes are significantly different.

For our final objective, we employ some of the estimated coefficients from the statistical in an optimization model (described below). The optimization model is used to simulate the economic impact on producers from restricting applied nitrogen. We solve a constrained profit-maximization problem based on the regression parameter estimates. With a constraint on the maximum level of unaccounted nitrogen, we can calculate a shadow price for unaccounted nitrogen, i.e., the affect on profit of a one unit change in the constraint. Different scenarios can be modeled by changing wheat price, nitrogen price, and/or the acceptable amount of

²⁵ The J-test is non-symmetric, i.e., falsification of the null by the alternative does not preclude the alternative from being falsified by the null (Anselin, 1988). While the power of the test can often be improved by conducting the test twice, with the null and alternative hypotheses switching places, it offers no improvement in our case.

unaccounted nitrogen and re-calculating the economic effects on producers from regulating the amount of applied nitrogen.

The optimization model is a linear programming model. The objective function maximizes producer profit subject to an acceptable amount of unaccounted nitrogen. The constrained optimization problem is expressed as:

$$(5) \quad \text{Max}_{K,A} E[\pi] = \sum_k^{15} \text{Share}_k * E \{ pY + [(PR - 14) / 2.5](\text{Prem or Disc})[\bar{Y}_k] - CA \}$$

s.t. $UN \leq U$

where E is the expectations operator; π is profit; Share_k is the acreage share of the k^{th} terrain attribute; P is the price of dark northern spring wheat (HRSW); Y, PR, and MN are predicted values of yield, protein, and unaccounted nitrogen, respectively, from equation (3); Prem and Disc are protein premiums and discounts per bushel; C is the price of nitrogen; A is the amount of applied nitrogen; and U is the maximum acceptable amount of unaccounted nitrogen. Each terrain attribute corresponds to a unique combination of slope, elevation, and aspect. Slope and elevation are each divided into three categories: low, medium, and high. Means and standard deviation are used in creating slope and elevation categories. The mean value represents the medium, the high value is one standard deviation to the right of the mean, and the low value is one standard deviation to the left. For slope low, medium, and high were found to be 3.52, 6.36, and 9.2 percent, respectively. For elevation low, medium, and high were found to be 11.55, 19.94, and 28.33 feet, respectively. Aspect is divided into north and south. This “digitalization” of the continuous data divides the field into fifteen independent terrain attribute zones ($K=15$).²⁶ We incorporate estimated response equations (equation 3) into a profit function conditional on expected grain price, protein price, and nitrogen price (equation 5). Using the software program

²⁶ Three combinations of terrain attributes were not represented in the data. Each had south aspect: low slope and high elevation, high slope and low elevation, and high slope and high elevation.

General Algebraic Modeling System (GAMS) version 2.0.28.0, we identify the nitrogen rate that maximizes expected profit. Keeping all other factors the same we determine the shadow price (i.e., how much profit changes) when the maximum acceptable amount of unaccounted nitrogen, U , increases or decreases by one unit.

Experiment Description – Source of Data

Data for this analysis came from the Washington State University Cook Agronomy Farm (CAF) located north of Pullman, Washington, in a 21 inch rainfall zone located in the rolling Palouse hills. Unlike many nitrogen studies where data come from a small number of experimental plots, our data were obtained by sampling multiple global positioning system (GPS) referenced sites from field experiments, resulting in over 700 individual sites. Each GPS referenced site represents an area 10 meters by 10 meters. Terrain attribute data were determined by data collected at each geo-referenced site. A six-year field experiment was begun in fall 2000. The experiment used a three-year rotation that consisted of hard red winter wheat in year 1, one of six alternative crops in year 2, and HRSW in year 3. The six alternative crops were winter barley, spring barley, winter peas, spring peas, winter canola, and spring canola. The crops were staggered so that all were grown every year and each crop was grown twice on the same land during the six years. Each year HRSW was grown on approximately a 30-acre parcel for a total of 90 acres in the experiment. Each alternative crop was grown on 1/6 of a parcel (approximately five acres). The CAF farm uses no-till, direct-seed technology (i.e., seeds are planted directly into standing stubble), full size machinery, and field-sized plots to represent commercial farming operations.

Average HRSW grain and protein prices were calculated as the average of the harvest month (August) and were obtained from the Agricultural Marketing Service (Hansen 2008).

Current price was determined as the August 2008 delivery to Union Elevator and Warehouse Company in Whitman, County. We obtained recent average nitrogen price from previous Washington State University Extension Bulletins: 2001 to 2004 (Nail et al. 2004), 2005 (Painter 2005), and 2006 (Hinman, Ruchert, and Bragg 2006). Current prices were found by contacting a local fertilizer dealer (Wilbur-Ellis 2008). Variable-rate nitrogen application technology cost was estimated to be \$14.80 dollars per acre (Anselin, Bongiovanni, and Lowenberg-DeBoer 2004).

Results

We begin our discussion with test results for the first two hypotheses. This will lead us to the preferred statistical model. Then we compare and contrast the preferred model to our other possible models. Using the preferred model, we test hypotheses 3-5 and discuss those findings. Finally, we present results from the simulation (from the optimization model).

Recall that the first hypothesis specified that a spatial weights matrix that incorporates higher elevation would result in greater statistical efficiency in parameter estimation. We found a statistically significant improvement (at the 1 percent level) as indicated by the likelihood ratio test statistic reported in table 1. Hence, hypothesis 1 is strongly supported by the statistical test.

The second hypothesis stated that adding lower elevation into the spatial weights matrix would not further increase statistical efficiency. Results of the J-test statistic comparing the model with the lower elevation points added to the model with only the higher elevation points are reported in table 1. The test statistic is insignificant -- even at the 10 percent level. This test statistic indicates failure to reject this hypothesis.

With evidence supporting the use of spatial seemingly unrelated regression econometric methods over ordinary seemingly unrelated regression (SUR) and no evidence supporting

inclusion of points lower in elevation in the spatial structure, we proceed to test hypotheses 3-5 using the model that incorporates only higher elevation points in the spatial matrix.

Parameter estimates from the spatial SUR model (with higher elevation points) are reported in table 2. For each equation, the constant represents spring peas in year 2006. In both the yield and protein equations, estimated coefficients on both nitrogen supply variables (N and N^2) are significant. Thus, both yield and protein levels are dependent on nitrogen supply, and nitrogen exhibits diminishing marginal productivity as reflected in the quadratic relationship. For the unaccounted nitrogen equation, only the coefficient on N was found to be significant, which indicates a linear relationship between applied nitrogen and unaccounted nitrogen for the range of the data.

Most results from the spatial SUR model were similar to those obtained from the SUR model without a spatial weights matrix. The primary differences were a few parameter estimates on the year dummy variables in the unaccounted nitrogen equation. The magnitudes of most estimated parameters were similar in both models. Only one parameter estimate changed signs. However, the most important difference was that the parameter on N^2 in the yield equation was insignificant in the (non-spatial) SUR model which implies constant marginal productivity over the range of the data. Thus, drawing inferences about yield response to nitrogen supply based on test statistics from a (non-spatial) SUR can be seriously misleading, especially outside the data range. Along with the improvement in loglikelihood value, this result is similar to those of Anselin, Bongiovanni, and Lowenberg-DeBoer (2004) who found that incorporating a spatial structure considerably improved their model fit.

A significant parameter on a terrain attribute and N interaction term was found in each equation. This suggests that at least one dimension of terrain attribute significantly affects yield,

protein, and unaccounted nitrogen response to nitrogen supply. However, the significance of individual parameters provides only a partial test, in part because the terrain characteristics are likely to be co-linear. A joint hypothesis test is required to determine whether terrain attributes collectively have a statistically significant effect on yield, protein, or unaccounted nitrogen response to nitrogen supply (hypotheses 3-5). We performed Wald tests for each equation to test whether all terrain attribute parameters, β_6 , β_7 , β_8 , and β_9 , in the relevant equation of (3) are jointly equal to zero. Rejection of this alternate hypothesis would be required to support the original hypothesis.

Wald test statistics for each equation are reported in Table 3. We found statistically significant impacts of interactions between terrain attribute and nitrogen supply on yield and unaccounted nitrogen, so we conclude that hypotheses 3 and 5 are supported. For yield, a statistically significant parameter estimate was found between the interaction of nitrogen supply and the cosine of aspect. For unaccounted nitrogen, we found a statistically significant and negative parameter estimate between the interaction of nitrogen supply and slope. These results indicate variability of yield and unaccounted nitrogen response across terrain attributes. Yield response from nitrogen supply was found to be higher on north and south slopes than on east and west slopes. Unaccounted nitrogen response from nitrogen supply was found to decrease as the slope increases, indicating that flatter areas, possibly near a waterway, release larger amounts of unaccounted nitrogen than areas with greater slope from the same amount of nitrogen supply.

We did not find support by the joint test for hypothesis 4 regarding protein response to nitrogen supply. Thus, the joint hypothesis and individual parameter hypothesis tests rendered different conclusions. As in the yield equation, a statistically significant parameter estimate was found in the protein equation between the interaction of nitrogen supply and the cosine of aspect.

Like yield, protein content was found to be higher on north and south slopes than on east and west slopes from nitrogen supply.

Table 4 presents the comparative statics of response due to the interaction of nitrogen supply and terrain attributes for all three equations. We analyzed three different slopes and elevations – low, average, and high. Average represents the mean value, high and low represent plus and minus one standard deviation from the mean. For aspect we analyzed north and south facing slopes. The fifteen different classes used in this study represent one of many different possible combinations of classes. Determining the correct type and number of classes is difficult both practically and conceptually. Future work will use different methods, such as cluster analysis, to determine analyze the issue of the proper type and number of classes for different analytic and practical purposes.

The yield response to a one-pound increase in nitrogen supply ranged from a low of .065 to a high of .137 bushel increase, depending on terrain attribute. Protein response to a one-pound increase in nitrogen supply ranged from a low of .012 to a high of .017 percent increase, depending on the terrain attribute. The effect of terrain attribute on unaccounted nitrogen response to a one-pound increase in nitrogen supply ranged from a low of .525 to a high of .871 pound increase. Hence, terrain attributes are estimated to have the biggest impact on yield response (varying by more than 100%), which followed by their impact on unaccounted nitrogen response (varying by 66%) and protein response (varying by 42%). For yield and unaccounted nitrogen, north slope terrain increased response to nitrogen supply relative to the south slope. The opposite effect was found for protein. The terrain attribute that resulted in the largest unaccounted nitrogen response (i.e., estimated nitrogen loss) was low slope, high elevation, and north aspect. Since the responses are all positive, these comparative static results also make

clear that, at mean available nitrogen levels, additional nitrogen increases yield, protein, and unaccounted nitrogen at all terrain attributes.

For our final objective, we use the simulation model to examine the impact on producers from restricting applied nitrogen under two different management schemes (application methods) – uniform and variable rate. In order to assess the sensitivity of economic returns, 28 separate scenarios were examined for each application method. They included all combinations of high, average, and low HRSW price, protein price, and nitrogen price, where average represents the mean price observed during the experimental trial period (2001-2006), high and low represents the high and low prices observed during the experimental trial period (2001-2006), respectively. The final scenario was based on current (Summer, 2008) prices.

Table 5 presents some of the results from the simulation model, in particular the impact of price ratios on a maximum reduction of applied nitrogen on unaccounted nitrogen and profit. For both application methods we analyze two different price ratios: the ratio of protein price to nitrogen, i.e., protein price divided by nitrogen cost and crop price divided by nitrogen cost. For both price ratios we analyze two different levels, low and high. Low (high) represents the minimum (maximum) price ratio – the ratio of the output price to the input price. Results indicate that when output prices are low relative to input prices (low price ratios), the effect on both unaccounted nitrogen and producer profit from a maximum reduction in applied nitrogen is substantially less than with high price ratios. This indicates the importance prices have in determining the economic impact on producers of regulating applied nitrogen.

We present results in table 6 for twelve of the scenarios – low, average, and high prices during the study period and current prices with three levels of maximum allowable unaccounted

nitrogen.²⁷ Results were computed on a per-acre basis. For four of the twelve scenarios, no nitrogen was applied since the maximum allowable unaccounted nitrogen was set so low. For four of the remaining eight scenarios, variable rate application used more nitrogen than uniform rate application. Expected producer profit was greater under uniform application than under variable application for these eight scenarios. Differences in unaccounted nitrogen between the application methods for these twelve scenarios varied from -3 pounds per acre with high prices from unconstrained profit maximization to 55 pounds per acre from unconstrained profit maximization and current prices. In one of four scenarios with unconstrained profit maximization, variable rate application reduced unaccounted nitrogen when compared to uniform rate application. With a binding constraint on unaccounted nitrogen, differences in the shadow prices between the application methods for the twelve scenarios varied from \$0.05 per pound with current prices to \$1.10 per pound with high prices.

The cost of variable rate application will determine whether it is more, less or equally profitable compared to the uniform rate. We examine some “break-even” costs to help assess the prospects for profitable variable application management. In table 6 the “Min” column under profit represents the minimum cost of variable rate for it to be as profitable as uniform rate. For example, in unconstrained profit maximization with low prices variable rate could not cost more than an additional \$6.89 per acre for it to be as profitable as uniform rate. As we decrease the maximum allowable amount of misplaced nitrogen the minimum cost for variable rate to be profitable also decreases. That is, as the restrictions on nitrogen become tighter, the net returns to using variable rate management increases.

²⁷ In the interest of space, only results for low, average, high and current prices are reported in the table. An excel file containing the results from all scenarios is available from the author.

Constraining the amount of unaccounted nitrogen reduces profit (as it logically must, if binding). However, the effects differ noticeably between recent, average and current, higher prices. The ratio of current price to the average price is .51, indicating how much higher current price is when compared to average price. For a maximum reduction in unaccounted nitrogen (i.e., no applied nitrogen) under uniform application method with average recent prices, producer profit would be reduced by an estimated \$8.50 per acre and unaccounted nitrogen would decrease by 115 pounds. With current, higher prices, a maximum reduction in unaccounted nitrogen from nitrogen application reduces producer profit trivially (\$0.45 per acre) but is accompanied by a 19 pound decrease in unaccounted nitrogen. Current prices do nearly as much in this regard for the environment as quantity restrictions on nitrogen loss do, and combining them maximizes the environmental benefit at an insignificant additional cost.

With average prices for the uniform application method, the largest possible reduction of unaccounted nitrogen from the unconstrained profit maximizing level is 115 pounds per acre. To accomplish this reduction, no nitrogen would be applied, down from 152 pounds per acre. Thus, for each pound decrease in applied nitrogen, unaccounted nitrogen would be reduced by an average of 0.76 pounds. To reduce unaccounted nitrogen by one pound, 1.31 fewer pounds of nitrogen must be applied. Each pound reduction of unaccounted nitrogen costs producers an average of \$0.07 in profit. For low (high) prices each pound reduction of unaccounted nitrogen costs producers an average of \$0.09 (\$0.53) in profit.

At higher current prices (Summer 2008), the cost to producers would be reduced since producers apply less nitrogen to achieve maximum profit. In fact, with unconstrained profit maximization, current prices reduce the amount of applied nitrogen by 126 pounds and the amount of unaccounted nitrogen by 96 pounds per acre from their unconstrained levels at

average prices. To reduce unaccounted nitrogen the remaining 19 pounds would require a reduction of 25 pounds of applied nitrogen, at a cost of only \$.02 per pound reduction in unaccounted nitrogen.

Conclusions

Using spatial econometric methods, we have analyzed the impact of nitrogen supply fertilizer by terrain attribute on yield, protein, and unaccounted nitrogen. We have also examined some of the potential impacts on producer profit from requirements to reduce unaccounted nitrogen. Understanding the environmental sensitivity from agricultural production helps to identify market conditions and technology that policymakers can use to design policies to minimize the economic cost of reducing environmental degradation. It will ultimately help inform farmers about when it makes sense to start moving towards greater levels of variable rate management.

We found that including a spatial weights matrix that incorporates higher elevations along with slope and aspect (direction of slope) resulted in greater statistical efficiency in parameter estimation over standard econometric estimation. We also found that including lower elevations in the spatial weights matrix did not further increase the statistical efficiency. Spatial econometric methods provided better model fit, thereby improving model accuracy and more importantly, more precise economic recommendations. These results imply that it is the “gravity” based effects of spatial continuity that matter, rather than more general effects – as for example would be the case for migration of water toward dryer areas or for more general local soil fertility conditions.

With the spatial model controlling for some local soil effects, we identified statistically significant impacts of nitrogen supply by terrain attribute on yield and unaccounted nitrogen response. We found that yield response to nitrogen supply was the greatest when aspect cosine

was the largest, i.e., north or south. We also found that unaccounted nitrogen response to nitrogen supply was greater on flat slopes than on steeper slopes. Consequently, to reduce unaccounted nitrogen, greater attention should be paid to nitrogen supply in the flatter areas. In these areas, nitrogen has a higher probability of becoming pollution since the only way to exit the field is into plants, surface or ground water, or the atmosphere – and presumably not by passing the nitrogen to lower elevations.

The economic effect on producer profit from restricting unaccounted nitrogen was examined by simulating 28 scenarios. Twelve scenarios, nine based on low, average, and high prices during the experimental trials and three based on current (2008) prices were reported in the paper. The results of these simulations suggest ways that policymakers might induce producers to reduce unaccounted nitrogen. If required to minimize unaccounted nitrogen, producers would lose between \$8.50 per acre at average 2001-2006 prices and \$96.60 per acre at high 2001-2006 prices but less than \$0.50 per acre at current 2008 prices. Thus, inducement to reduce applied nitrogen and consequently unaccounted nitrogen could be accomplished with trivial cost to the farmer by a standard in 2008 but the same standard could impose substantial costs at some historical prices. So, the financial burden of nitrogen restrictions depends critically on both prices and the level of the restriction. With low price ratios between grain price and nitrogen the economic effect on producers is substantially less than from a high price ratio.

Three terrain attributes, slope, elevation, and aspect, are used to identify differences in yield, protein, and unaccounted nitrogen response to nitrogen supply. These three attributes represent a small number of potential terrain attribute variables in one model. It may be that other terrain attributes variables such as the wetness index and specific catchment area may be important in determining the yield, protein, and unaccounted nitrogen response to nitrogen

supply. Identifying the correct terrain attributes to include in the response equations is a current ongoing analysis.

Without knowing the true amount of nitrogen pollution, unaccounted nitrogen represents the best proxy for nitrogen pollution. Reducing unaccounted nitrogen should have a positive impact on the environment. The benefit to society from a reduction in unaccounted nitrogen is unknown and variable depending on the amount transformed into “local pollution” such as in local groundwater, and global pollution such as the amount of nitrous oxide emissions. However, with a value ranging between \$0.07 and \$0.53 per pound in applied nitrogen to producers (under typical historical prices), policymakers may want to consider a program that compensates producers for reducing applied nitrogen. However, with current high prices for both output and input costs -- \$9.2 per bushel of DNSW and \$0.75 per unit of Nitrogen -- producers have a strong profit motive to limit applied nitrogen and consequently reduce levels of unaccounted nitrogen, thereby creating a healthier environment without government regulation.

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Table 1. Tests of Spatial Autocorrelation Form, Hypotheses 1-2

Statistic	Model		
	No Spatial Weights Matrix	Spatial Weights with Points Higher in Elevation	Spatial Weights with all Points
Log-likelihood value	-20.56	-9.23	-9.22
Likelihood ratio test statistic	—	22.72***	—
J-test statistic	—	—	0.01

Note: Three asterisks (***) indicate significance at the 1 percent level.

Table 2. Estimated Coefficients and Z-Statistics from Equation (3) Including Higher Elevation in the Spatial Weights Matrix

Equation Parameter	Yield		Protein		Unaccounted Nitrogen	
	Parameter	Z-Stat	Parameter	Z-Stat	Parameter	Z-Stat
Rho	0.011	0.02	-0.103	-0.42	-0.650	-2.89
Constant	14.51	0.96	12.848	3.45	-115.349	-2.12
Year 2005	11.64	3.83	-1.368	-2.95	44.895	5.45
Year 2004	24.96	3.35	11.818	-3.81	11.818	4.19
Year 2003	-0.87	-0.63	0.334	1.68	21.196	0.77
Year 2002	18.02	4.02	0.086	0.33	14.908	2.40
Year 2001	23.17	3.51	-2.224	-3.51	50.861	5.45
Spring barley	-0.13	-0.10	-0.546	-2.72	23.535	3.11
Spring canola	2.40	1.60	-0.414	-2.80	4.089	0.64
Winter canola	1.39	1.10	-0.185	-1.04	-0.489	-0.07
Winter pea	1.10	0.77	0.081	0.43	0.143	0.02
Winter barley	-0.27	-0.20	-0.562	-2.86	17.746	2.18
Available nitrogen (N)	0.12	3.53	0.016	3.88	0.745	4.25
N ²	-0.00077	-2.33	-0.00013	-3.06	0.00013	0.75
Cosine (aspect)	-7.98	-3.56	0.633	2.22	-20.809	-1.68
Sin (aspect)	1.60	0.71	-0.479	-1.59	18.924	1.50
Slope	-0.28	-0.48	-0.012	-0.17	8.120	2.67
Elevation	0.33	1.35	0.0048	0.14	-0.808	-0.61
Cosine (aspect)*N	0.026	3.79	-0.0018	-2.15	0.058	1.62
Sine (aspect)*N	-0.0067	-0.90	0.0015	1.59	-0.058	-1.51
Slope*N	.00054	0.32	-0.00075	-0.34	-0.024	-2.57
Elevation*N	-0.0010	-1.28	-0.00071	-0.71	0.0054	1.29

Note: Aspect is in radians. Slope is in percents. Elevation is in feet.

Table 3. Tests of Terrain attribute Effect on Response to Available Nitrogen

Test	Equation		
	Yield	Protein	Unaccounted Nitrogen
Wald Statistic	5.4*	0.04	8.03*

Note: Single asterisk (*) indicates significance at the 10 percent level.

Table 4. Comparative Statics of Available Nitrogen at Terrain attributes

Terrain attribute			Equation		
Slope ^a	Elevation ^b	Aspect	Yield	Protein	Unaccounted Nitrogen
Low (3.52)	Low (11.55)	North	0.134	0.014	0.780
Low	Low	South	0.081	0.017	0.664
Low	Average (19.94)	North	0.126	0.013	0.825
Low	Average	South	0.073	0.017	0.709
Low	High (28.33)	North	0.117	0.012	0.871
Average (6.36)	Low	North	0.134	0.014	0.780
Average	Low	South	0.081	0.017	0.664
Average	Average	North	0.127	0.013	0.756
Average	Average	South	0.075	0.016	0.640
Average	High	North	0.119	0.012	0.801
Average	High	South	0.066	0.016	0.685
High (9.20)	Low	North	0.137	0.013	0.641
High	Average	North	0.129	0.012	0.686
High	Average	South	0.076	0.016	0.570
High	High	North	0.120	0.012	0.732

Note: Low and high represent values one standard deviation to the left and right of the mean, respectively. Average indicates the mean value. ^a Units are in percents. ^b Units are in feet.

Table 5. Per Acre Impact of Price Ratios on a Maximum Reduction in Applied Nitrogen

		Price Ratio			
		protein/nitrogen		yield/nitrogen	
		low	high	low	high
Uniform	Unaccounted Nitrogen	-7.37	-265.17	-57.01	-236.44
	Profit	-0.12	-137.11	-12.73	-82.13
Variable	Unaccounted Nitrogen	-29.27	-257.51	-89.49	-237.60
	Profit	-2.17	-141.97	-15.90	-90.56

Note: Profit is in dollars per acre. Unaccounted Nitrogen is in pounds per acre.

Table 6. Per Acre Economic Impact from Regulating Applied Nitrogen

Prices	Maximum Allowable Unaccounted Nitrogen			Spring Soil Sample			Applied Nitrogen			Profit			Unaccounted Nitrogen			Shadow Price	
	Nitrogen	Mineralized Nitrogen	Nitrogen	Uniform	Variable	Diff	Uniform	Variable	Diff	Min	Uniform	Variable	Diff	Uniform	Variable		
Low	400	50	110	195.3	194.01	-1.29	161.62	153.71	-7.91	6.89	263.67	270.15	6.48	0.00	0.00		
	160	50	110	60.81	58.81	-2.00	155.36	144.32	-11.04	3.76	160.00	160.00	0.00	0.12	0.18		
	114.68	50	110	0.01	0.01	0.00	148.68	133.88	-14.80	0.00	114.68	114.68	0.00	0.17	0.45		
Average	400	50	110	151.62	167.9	16.28	178.77	172.42	-6.35	8.45	229.49	249.38	19.89	0.00	0.00		
	160	50	110	60.81	58.74	-2.07	175.68	165.46	-10.22	4.58	160.00	160.00	0.00	0.09	0.16		
	114.68	50	110	0.01	0.01	0.00	170.25	155.45	-14.80	0.00	114.68	114.68	0.00	0.15	0.51		
High	400	50	110	281.44	279.2	-2.24	230.13	216.8	-13.33	1.47	332.54	329.83	-2.71	0.00	0.00		
	160	50	110	60.81	64.4	3.59	165.79	154.9	-10.89	3.91	160.00	160.00	0.00	0.67	0.66		
	114.68	50	110	0.01	0.01	0.00	133.58	118.78	-14.80	0.00	114.68	114.68	0.00	0.74	1.08		
Current	400	50	110	25.45	94.12	68.67	317.15	312.58	-4.57	10.23	133.53	188.88	55.35	0.00	0.00		
	160	50	110	25.45	58.51	34.06	317.15	311.17	-5.98	8.82	133.53	160.00	26.47	0.00	0.10		
	114.68	50	110	0.01	0.01	0.00	316.70	301.90	-14.80	0.00	114.68	114.68	0.00	0.05	0.88		

Note: Nitrogen units are in pounds per acre; profit and shadow price are in dollars per acre. Low, Average, and High represents study period prices. Current represents summer 2008 prices.

COMPUTER CODE FOR CHAPTER TWO
INFORMATION AND OPPORTUNISTIC BEHAVIOR IN FEDERAL CROP
INSURANCE PROGRAMS

Appendix A

COMPUTER CODE FOR CHAPTER TWO INFORMATION AND OPPORTUNISTIC BEHAVIOR IN FEDERAL CROP INSURANCE PROGRAMS

*Code for year 2002 to merge all four file types. Only code for 2002 is shown, other years are identical in code. To change year to 2001 change type0215a to type0115a in the infile line.

The same logic follows for all file types.

```
options compress=yes;
libname e 'D:\' ;

data e.type0215a;
  %let _EFIERR_ = 0; /* set the ERROR detection macro variable */
  infile 'e:\typ0215a.txt' TRUNCOVER lrecl=554 ;
  format RecType best2. ;
  format ORG $2. ;
  format State best2. ;
  format Company best3. ;
  format PolicyNum best7. ;
  format CropYear best4. ;
  format CropCode best4. ;
  format PlanCd best2. ;
  format County best3. ;
  format UnitNum best5. ;
  format TypeCd $3. ;
  format Practice $3. ;
  format CvrqFlag $1. ;
  format RecordNum best3. ;
  format TYldMapArea $3. ;
  format NCSYld best6.4;
  format AgrmntTyp $2. ;
  format AgrmntNum $8. ;
  format AgrmntProcFlag $2. ;
  format M14RevFlag best2. ;
  format YldIndicator $2. ;
  format TransYld best10.2 ;
  format FSAYld best10.2 ;
  format ApprovYld best10.2 ;
  format PrevApprovYld best10.2 ;
  format Year1 best4. ;
  format Typel $2. ;
  format Annual1 best10.2 ;
  format Acres1 best8.2 ;
  format Rev1 best6. ;
```

```

format Year2 best4. ;
format Type2 $2. ;
format Annual2 best10.2 ;
format Acres2 best8.2 ;
format Rev2 best6. ;
format Year3 best4. ;
format Type3 $2. ;
format Annual3 best10.2 ;
format Acres3 best8.2 ;
format Rev3 best6. ;
format Year4 best4. ;
format Type4 $2. ;
format Annual4 best10.2 ;
format Acres4 best8.2 ;
format Rev4 best6. ;
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format Type5 $2. ;
format Annual5 best10.2 ;
format Acres5 best8.2 ;
format Rev5 best6. ;
format Year6 best4. ;
format Type6 $2. ;
format Annual6 best10.2 ;
format Acres6 best8.2 ;
format Rev6 best6. ;
format Year7 best4. ;
format Type7 $2. ;
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format Acres9 best8.2 ;
format Rev9 best6. ;
format Year10 best4. ;
format Type10 $2. ;
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format Acres10 best8.2 ;
format Rev10 best6. ;
format RateState best2. ;
format RateCounty best3. ;
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format YldLimFlag best2. ;
format Bypass $1. ;
format YrsActualRef best3. ;
format YldINDX best4.1 ;
format Option $16. ;
format RateYld best10.2 ;
format AvgYld best10.2 ;
format PrevLimFlag best2. ;
input

```

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@4 ORG \$2.
@7 State 2.
@10 Company 3.
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@27 CropCode 4.
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@35 County 3.
@39 UnitNum 5.
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@140 Type1 \$2.
@143 Annual1 10.2
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@163 Rev1 6.
@170 Year2 4.
@175 Type2 \$2.
@178 Annual2 10.2
@189 Acres2 8.2
@198 Rev2 6.
@205 Year3 4.
@210 Type3 \$2.
@213 Annual3 10.2
@224 Acres3 8.2
@233 Rev3 6.
@240 Year4 4.
@245 Type4 \$2.
@248 Annual4 10.2
@259 Acres4 8.2
@268 Rev4 6.
@275 Year5 4.
@280 Type5 \$2.
@283 Annual5 10.2
@294 Acres5 8.2
@303 Rev5 6.
@310 Year6 4.
@315 Type6 \$2.
@318 Annual6 10.2
@329 Acres6 8.2
@338 Rev6 6.
@345 Year7 4.
@350 Type7 \$2.

```

    @353 Annual7 10.2
    @364 Acres7 8.2
    @373 Rev7 6.
    @380 Year8 4.
    @385 Type8 $2.
    @388 Annual8 10.2
    @399 Acres8 8.2
    @408 Rev8 6.
    @415 Year9 4.
    @420 Type9 $2.
    @423 Annual9 10.2
    @434 Acres9 8.2
    @443 Rev9 6.
    @450 Year10 4.
    @455 Type10 $2.
    @458 Annual10 10.2
    @469 Acres10 8.2
    @478 Rev10 6.
    @485 RateState 2.
    @488 RateCounty 3.
    @492 FarmSerial $7.
    @500 YldLimFlag 2.
    @503 Bypass $1.
    @505 YrsActualRef 3.
    @509 YldINDX 4.1
    @514 Option $16.
    @531 RateYld 10.2
    @542 AvgYld 10.2
    @553 PrevLimFlag 2.
;
    if _ERROR_ then call symput('_EFIERR_',1); /* set ERROR detection macro
variable */

run;
data e.type0215b;
    %let _EFIERR_ = 0; /* set the ERROR detection macro variable */
    infile 'e:\typ0215b.txt' TRUNCOVER lrecl=554 ;
    format RecType best2. ;
    format ORG $2. ;
    format State best2. ;
    format Company best3. ;
    format PolicyNum best7. ;
    format CropYear best4. ;
    format CropCode best4. ;
    format PlanCd best2. ;
    format County best3. ;
    format UnitNum best5. ;
    format TypeCd $3. ;
    format Practice $3. ;
    format CvrgFlag $1. ;
    format RecordNum best3. ;
    format TYldMapArea $3. ;
    format NCSYld best6.4;
    format AgrmntTyp $2. ;
    format AgrmntNum $8. ;
    format AgrmntProcFlag $2. ;

```

```

format M14RevFlag best2. ;
format YldIndicator $2. ;
format TransYld best10.2 ;
format FSAYld best10.2 ;
format ApprovYld best10.2 ;
format PrevApprovYld best10.2 ;
format Year1 best4. ;
format Type1 $2. ;
format Annual1 best10.2 ;
format Acres1 best8.2 ;
format Rev1 best6. ;
format Year2 best4. ;
format Type2 $2. ;
format Annual2 best10.2 ;
format Acres2 best8.2 ;
format Rev2 best6. ;
format Year3 best4. ;
format Type3 $2. ;
format Annual3 best10.2 ;
format Acres3 best8.2 ;
format Rev3 best6. ;
format Year4 best4. ;
format Type4 $2. ;
format Annual4 best10.2 ;
format Acres4 best8.2 ;
format Rev4 best6. ;
format Year5 best4. ;
format Type5 $2. ;
format Annual5 best10.2 ;
format Acres5 best8.2 ;
format Rev5 best6. ;
format Year6 best4. ;
format Type6 $2. ;
format Annual6 best10.2 ;
format Acres6 best8.2 ;
format Rev6 best6. ;
format Year7 best4. ;
format Type7 $2. ;
format Annual7 best10.2 ;
format Acres7 best8.2 ;
format Rev7 best6. ;
format Year8 best4. ;
format Type8 $2. ;
format Annual8 best10.2 ;
format Acres8 best8.2 ;
format Rev8 best6. ;
format Year9 best4. ;
format Type9 $2. ;
format Annual9 best10.2 ;
format Acres9 best8.2 ;
format Rev9 best6. ;
format Year10 best4. ;
format Type10 $2. ;
format Annual10 best10.2 ;
format Acres10 best8.2 ;
format Rev10 best6. ;
format RateState best2. ;

```

```

format RateCounty best3. ;
format FarmSerial $7. ;
format YldLimFlag best2. ;
format Bypass $1. ;
format YrsActualRef best3. ;
format YldINDX best4.1 ;
format Option $16. ;
format RateYld best10.2 ;
format AvgYld best10.2 ;
format PrevLimFlag best2. ;
input
  @1 RecType 2.
  @4 ORG $2.
  @7 State 2.
  @10 Company 3.
  @14 PolicyNum 7.
  @22 CropYear 4.
  @27 CropCode 4.
  @32 PlanCd 2.
  @35 County 3.
  @39 UnitNum 5.
  @45 TypeCd $3.
  @49 Practice $3.
  @53 CvrgFlag $1.
  @55 RecordNum 3.
  @59 TYldMapArea $3.
  @63 NCSYld 6.4
  @70 AgrmntTyp $2.
  @73 AgrmntNum $8.
  @82 AgrmntProcFlag $2.
  @85 M14RevFlag 2.
  @88 YldIndicator $2.
  @91 TransYld 10.2
  @102 FSAYld 10.2
  @113 ApprovYld 10.2
  @124 PrevApprovYld 10.2
  @135 Year1 4.
  @140 Type1 $2.
  @143 Annual1 10.2
  @154 Acres1 8.2
  @163 Rev1 6.
  @170 Year2 4.
  @175 Type2 $2.
  @178 Annual2 10.2
  @189 Acres2 8.2
  @198 Rev2 6.
  @205 Year3 4.
  @210 Type3 $2.
  @213 Annual3 10.2
  @224 Acres3 8.2
  @233 Rev3 6.
  @240 Year4 4.
  @245 Type4 $2.
  @248 Annual4 10.2
  @259 Acres4 8.2
  @268 Rev4 6.
  @275 Year5 4.

```

```

    @280 Type5 $2.
    @283 Annual5 10.2
    @294 Acres5 8.2
    @303 Rev5 6.
    @310 Year6 4.
    @315 Type6 $2.
    @318 Annual6 10.2
    @329 Acres6 8.2
    @338 Rev6 6.
    @345 Year7 4.
    @350 Type7 $2.
    @353 Annual7 10.2
    @364 Acres7 8.2
    @373 Rev7 6.
    @380 Year8 4.
    @385 Type8 $2.
    @388 Annual8 10.2
    @399 Acres8 8.2
    @408 Rev8 6.
    @415 Year9 4.
    @420 Type9 $2.
    @423 Annual9 10.2
    @434 Acres9 8.2
    @443 Rev9 6.
    @450 Year10 4.
    @455 Type10 $2.
    @458 Annual10 10.2
    @469 Acres10 8.2
    @478 Rev10 6.
    @485 RateState 2.
    @488 RateCounty 3.
    @492 FarmSerial $7.
    @500 YldLimFlag 2.
    @503 Bypass $1.
    @505 YrsActualRef 3.
    @509 YldINDX 4.1
    @514 Option $16.
    @531 RateYld 10.2
    @542 AvgYld 10.2
    @553 PrevLimFlag 2.
;
    if _ERROR_ then call symput('_EFIERR_',1); /* set ERROR detection macro
variable */
run;
data e.type0215;
    set e.type0215a e.type0215b;
run;

data e.type0211;
    %let _EFIERR_ = 0; /* set the ERROR detection macro variable */
    infile 'e:\type0211.txt' TRUNCOVER lrecl=462 ;
    format RecType best2. ;
    format ORG $2. ;
    format State best2. ;
    format Company best3. ;
    format PolicyNum best7. ;
    format CropYear best4. ;

```

```

format CropCode best4. ;
format PlanCd best2. ;
format County best3. ;
format UnitNum best5. ;
format TypeCd $3. ;
format Practice $3. ;
format CvrqFlag $1. ;
format RecordNum best3. ;
    format TYPE15Recordnumber best3. ;
    format Snn best9. ;
    format rateclass $3. ;
    format maparea $3. ;
    format crushdistrict $2. ;
    format referencecropyear best4. ;
    format writtenagreementtype $2. ;
    format writtenagreementnumber best8. ;
    format writtenagreementprocessingflag $2. ;
    format DATEPLANTED best8. ;
    format guaranteedreductionflag $1. ;
    format yield best10.2 ;
    format dollaramountofinsurance best10.2 ;
    format numberoftrees best10. ;
    format coveragelevel best5.4 ;
    format guaranteeperacre best10.2 ;
    format guaranteedreductionfactor best3. ;
    format reportedacres best8. ;
    format totalguarantee best10.2 ;
    format priceelectionamount best8.4 ;
    format contractprice best8.4 ;
    format insuredshare best4.3 ;
    format liability best10. ;
    format priceelectionfactor best5.4 ;
    format yieldconversionfactor best4.3 ;
    format basepremiumprate best12.8 ;
    format preliminarybaserate best8. ;
    format loadedpremiumperacre best8.4 ;
    format unitoption $2. ;
    format commonoptioncodes best20. ;
    format rateclassoption best20. ;
    format experiencefactor best4.3 ;
    format premiumratesurcharge $1. ;
    format unitpremiumadjustment best5.4 ;
    format RAfallharvestpriceoption $1. ;
    format IPcountyaverageyield best8.1 ;
    format rawholefarmdiscount best5.4 ;
    format priceindicator $1. ;
    format totalpremium best10. ;
    format subsidy best10. ;
    format additionalsubsidy best10. ;
    format additionalsubsidyflag $1. ;
    format satatesubsidy best10. ;
    format statesubsidyflag $1. ;
    format producerpremium best10. ;
    format privatepolicy $3. ;
    format intendedacorage $1. ;
    format seedcompany best3. ;
    format rateseed best2. ;

```



```

format ratecounty best3. ;
format farmserialnumber $7. ;
format numberofsections best2. ;
format seedcycle $1. ;
format m14review best2. ;
format ceocoveragelevel best5.4 ;
format efapremiumdiscount best10. ;
format efadiscounthflag $1. ;
format historicalpackout best3.2 ;
format prorotationfactor best3.2 ;
format rateyield best10.2 ;

```

input

```

@1 RecType 2.
@4 ORG $2.
@7 State 2.
@10 Company 3.
@14 PolicyNum 7.
@22 CropYear 4.
@27 CropCode 4.
@32 PlanCd 2.
@35 County 3.
@39 UnitNum 5.
@45 TypeCd $3.
@49 Practice $3.
@53 CvrqFlag $1.
@55 RecordNum 3.
    @59 TYPE15Recordnumber 3.
@63 Snn 9.
@73 rateclass $3.
@77 maparea $3.
@81 crushdistrict $2.
@84 referencecropyear 4.
@02 writtenagreementtype $2.
@92 writtenagreementnumber 8.
@102 writtenagreementprocessingflag $2.
@104 DATEPLANTED 8.
@113 guaranteedreductionflag $1.
@115 yield 10.2
@126 dollaramountofinsurance 10.2
@137 numberoftrees 10.
@148 coveragelevel 5.4
@154 guaranteeperacre 10.2
@165 guaranteedreductionfactor 3.
@169 reportedacres 8.
@178 totalguarantee 10.2
@189 priceelectionamount 8.4
@198 contractprice 8.4
@207 insuredshare 4.3
@212 liability 10.
@223 priceelectionfactor 5.4
@229 yieldconversionfactor 4.3
@234 basepremiumrate 12.8
@247 preliminarybaserate 8.
@256 loadedpremiumperacre 8.4
@265 unitoption $2.
@268 commonoptioncodes 20.

```

```

    @289 rateclassoption 20.
    @310 experiencefactor 4.3
    @315 premiumratesurcharge $1.
    @317 unitpremiumadjustment 5.4
    @323 RAfallharvestpriceoption $1.
    @325 IPcountyaverageyield 8.1
    @334 rawholefarmdiscount 5.4
    @340 priceindicator $1.
    @342 totalpremium 10.
    @253 subsidy 10. /*does not take this number dont know why*/
    @364 additionalsubsidy 10.
    @375 additionalsubsidyflag $1.
    @377 satatesubsidy 10.
    @388 statesubsidyflag $1.
    @390 producerpremium 10.
    @402 privatepolicy $3.
    @405 intendedacorage $1.
    @407 seedcompany 3.
    @411 rateseed 2.
    @414 ratecounty 3.
    @418 farmserialnumber $7.
    @426 numberofsections 2.
    @429 seedcycle $1.
    @431 ml4review 2.
    @434 ceocoveragelevel 5.4
    @440 efapremiumdiscount 10.
    @451 efa discountflag $1.
    @453 historicalpackout 3.2
    @457 prorationfactor 3.2
    @461 rateyield 10.2
;
    if _ERROR_ then call symput('_EFIERR_',1); /* set ERROR detection macro
variable */
run;
data e.type0221;
%let _EFIERR_ = 0; /* set the ERROR detection macro variable */
infile 'e:\type0221.txt' TRUNCOVER lrecl=360;
format RecType best2. ;
format ORG $2. ;
format State best2. ;
format Company best3. ;
format PolicyNum best7. ;
format CropYear best4. ;
format CropCode best4. ;
format PlanCd best2. ;
format County best3. ;
format UnitNum best5. ;
format TypeCd $3. ;
format Practice $3. ;
format CvrgFlag $1. ;
    format Claimnumber best8. ;
format RecordNum best3. ;
    format TYPE11recordnumber best3. ;
    format Snn best9. ;
    format rateclass $3. ;
    format stagecode $2. ;
    format Allpercentreplantpaymentflag $1. ;

```

```

format stageguaranteeperacre best10.2 ;
format determinedacres best8.2 ;
format lossguarantee best10.2 ;
format harvestproduction best10.2 ;
format productiontocount best10.2 ;
format productiontocountrevcrops best10.2 ;
format farmunitdeficiency $11. ; /*could have negatives*/
format insuredshare best4.3 ;
format grppaymentcalculation best4.3 ;
format indemnity $11. ; /*could have negatives*/
format sugarfactor best3. ;
format auditcorrection best1. ;
format primarymonth best2. ;
format secondarymonth best2. ;
format primarycause best2. ;
format primaryprecent best3.2;
format secondarycause best2. ;
format simplifiedclaim $1. ;
format farmserianumber $7. ;
format guaranteedreductionfactor best3. ;
format dollaramountofinsurance best10.2 ;
format liabilityadjustmentfactor best7.6 ;
format contractprice best8.4 ;
format guaranteedreductionflag $1. ;
format yield best10.2 ;
format numberoftrees best11. ;
format coveragelevel best5.4 ;
format priceelectionamount best8.4 ;
format writtenagreementnumber $8. ;
format writtenagreementtype $2. ;
format writtenagreementprocessingflag $2. ;
format valiescrowflag $1. ;
format priceelectionfactor best5.4 ;
format m14reviewflag best2. ;
format ceocoveragelevel best5.4 ;
format ceoindemnityfactor best6.5 ;
format priceindicator $1. ;
format lossadjusterssignaturedate best8. ;
format noticeoflossdate best8. ;
format primarydateofdamage best8. ;
format secondarydateofdamage best8. ;

```

input

```

@1 RecType 2.
@4 ORG $2.
@7 State 2.
@10 Company 3.
@14 PolicyNum 7.
@22 CropYear 4.
@27 CropCode 4.
@32 PlanCd 2.
@35 County 3.
@39 UnitNum 5.
@45 TypeCd $3.
@49 Practice $3.
@53 CvrqFlag $1.

```

```

        @55 Claimnumber 8.
@64 RecordNum 3.
        @68 TYPE11recordnumber 3.
        @72 Snn 9.
        @82 rateclass $3.
        @86 stagecode $2.
        @89 Allpercentreplantpaymentflag $1.
        @91 stageguaranteeperacre 10.2
        @102 determinedacres 8.2
        @111 lossguarantee 10.2
        @122 harvestproduction 10.2
        @133 productiontocount 10.2
        @144 productiontocountrevcrops 10.2
        @155 farmunitdeficiency $10.
        @166 insuredshare 4.3
        @171 grppaymentcalculation 4.3
        @176 indemnity $10.
        @187 sugarfactor 3.
        @191 auditcorrection 1.
        @193 primarymonth 2.
        @196 secondarymonth 2.
        @199 primarycause 2.
        @202 primaryprecent 3.2
        @206 secondarycause 2.
        @209 simplifiedclaim $1.
        @211 farmserianumber $7.
        @219 guaranteedreductionfactor 3.
        @223 dollaramountofinsurance 10.2
        @234 liabilityadjustmentfactor 7.6
        @242 contractprice 8.4
        @251 guaranteedreductionflag $1.
        @253 yield 10.2
        @264 numberoftrees 11.
        @276 coveragelevel 5.4
        @282 priceelectionamount 8.4
        @291 writtenagreementnumber $8.
        @300 writtenagreementtype $2.
        @303 writtenagreementprocessingflag $2.
        @306 valiescrowflag $1.
        @308 priceelectionfactor 5.4
        @314 m14reviewflag 2.
        @317 ceocoveragelevel 5.4
        @323 ceoindemnityfactor 6.5
        @330 priceindicator $1.
        @332 lossadjusterssignaturedate 8.
        @341 noticeoflossdate 8.
        @350 primarydateofdamage 8.
        @359 secondarydateofdamage 8.
;
if _ERROR_ then call symput('_EFIERR_',1); /* set ERROR detection macro
variable */
run;
data e.type0210;
%let _EFIERR_ = 0; /* set the ERROR detection macro variable */
infile 'e:\type0210.txt' TRUNCOVER lrecl=554 ;
format RecType best2. ;
format ORG $2. ;

```

```

format State best2. ;
format Company best3. ;
format PolicyNum best7. ;
format CropYear best4. ;
format recordnumber best3. ;
format branchoffice $2. ;
format idtype best1. ;
format idnumber best9. ;
format entitytype $1. ;
format employee $1. ;
format M14reviewflag best2. ;

input
    @1 RecType 2.
    @4 ORG $2.
    @7 State 2.
    @10 Company 3.
    @14 PolicyNum 7.
    @22 CropYear 4.
        @27 recordnumber best3.
    @31 branchoffice $2.
    @34 idtype best1.
    @36 idnumber best9.
    @46 entitytype $1.
    @48 employee $1.
    @50 M14reviewflag best2.

;
if _ERROR_ then call symput('_EFIERR_',1); /* set ERROR detection macro
variable */
run;

/*INPUT state code below here*/
/*State=19 is really IOWA*/
data e.kstype0211;set e.type0211; if state = 19 then output;;run;
data e.kstype0215;set e.type0215; if state = 19 then output;;run;
data e.kstype0221;set e.type0221; if state = 19 then output;;run;
data e.kstype0210;set e.type0210; if state = 19 then output;;run;

proc sort data= e.kstype0215;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typedc practice approvlyd;
run;
proc sort data= e.kstype0211;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typedc practice yield;
run;
data e.kstype0211; /*corrects units for approved yield*/
    set e.kstype0211;
    approvlyd=yield * 10;
run;
proc sort data= e.kstype0221;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typedc practice ;

```

```

run;
data e.kstype0221;
    set e.kstype0221; drop writtenagreementnumber;
run;
data e.kstype0211;
    set e.kstype0211; drop writtenagreementnumber best;
run;
data e.kstype0211; /*locates double typellentries when merging type 11 and
type 21*/
    set e.kstype0211;
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag=1;
    else flag=0;
run;
data e.kstype0221; /*locates double type21entries when merging type 11 and
type 21*/
    set e.kstype0221;
    l_2policynum= Lag(policynum);
    l_2cropcode= Lag(cropcode);
    l_2plancd= Lag(plancd);
    l_2county= Lag(county);
    l_2unitnum= lag(unitnum);
    l_2typecd= lag(typecd);
    l_2practice= lag(practice);
    if l_2policynum=policynum and l_2cropcode=cropcode
    and l_2unitnum=unitnum and l_2plancd=plancd and l_2county= county
and l_2typecd=typecd
    and l_2practice=practice then flag2=1;
    else flag2=0;
run;
data e.ks02210211;
    merge e.kstype0211 e.kstype0221;
    by ORG state company policynum cropyear cropcode plancd county unitnum
typecd practice ;
run;
data e.ks02210211; /*find duplicate typelland21 observations*/
    set e.ks02210211;
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag1=1;

```

```

                else flag1=0; /*find duplicate typelland21 observations*/
run;
data e.ks02210211; /*find duplicate typelland21 observations*/
    set e.ks02210211;
    l_3policynum= Lag(policynum);
    l_3cropcode= Lag(cropcode);
    l_3plancd= Lag(plancd);
    l_3county= Lag(county);
    l_3unitnum= lag(unitnum);
    l_3typecd= lag(typecd);
    l_3practice= lag(practice);
    if l_3policynum=policynum and l_3cropcode=cropcode
    and l_3unitnum=unitnum and l_3plancd=plancd and l_3county= county
and l_3typecd=typecd
    and l_3practice=practice then flag3=1;
    else flag3=0; /*find duplicate typelland21 observations*/
run;
data e.ks02210211; /*find duplicate typelland21 observations*/
    set e.ks02210211;
    if flag = 0 and flag1 = 1 then delete;
run;
data e.ks02210211; /*find duplicate typelland21 observations*/
    set e.ks02210211;
    if flag2 = 0 and flag3 = 1 then delete;
run;
/*data e.ks02210211;*/
/*    set e.ks02210211;*/
/*    recordnum15 = typel5recordnumber;*/
/*run;*/

proc sort data= e.ks02210211;
    by    ORG state company policynum cropyear cropcode plancd county
unitnum typecd practice approvyld ;
run;

/*data e.ks0215;*/
/*    set e.kstype0215;*/
/*    recordnum15 = recordnum;*/
/*run;*/
data e.kstype0215; /*find duplicate typel5 observations*/
    set e.kstype0215;
    l_annual9=lag(annual9);
    l_annual10=lag(annual10);
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag=1;
    else flag=0;
run;

```

```

data e.ks02210211; /*find duplicate type15 observations*/
    set e.ks02210211;
    l_2policynum= Lag(policynum);
    l_2cropcode= Lag(cropcode);
    l_2plancd= Lag(plancd);
    l_2county= Lag(county);
    l_2unitnum= lag(unitnum);
    l_2typecd= lag(typecd);
    l_2practice= lag(practice);
    if l_2policynum=policynum and l_2cropcode=cropcode
    and l_2unitnum=unitnum and l_2plancd=plancd and l_2county= county
and l_2typecd=typecd
    and l_2practice=practice then flag2=1;
    else flag2=0; /*find duplicate type15 observations*/
run;
proc sort data= e.kstype0215;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typecd practice ;
run;
data e.ksmerged02A;
    merge e.kstype0215 e.ks02210211;
    by ORG state company policynum cropyear cropcode plancd county unitnum
typecd practice ;
run;
data e.ksmerged02A; /*locates double type15entries when merging type 11 and
type 21 to type 15*/
    set e.ksmerged02A;
    l_annual9=lag(annual9);
    l_annual10=lag(annual10);
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag1=1;
    else flag1=0;
run;
data e.ksmerged02A; /*locates double type15entries when merging type 11 and
type 21 to type 15*/
    set e.ksmerged02A;
    l_3policynum= Lag(policynum);
    l_3cropcode= Lag(cropcode);
    l_3plancd= Lag(plancd);
    l_3county= Lag(county);
    l_3unitnum= lag(unitnum);
    l_3typecd= lag(typecd);
    l_3practice= lag(practice);
    if l_3policynum=policynum and l_3cropcode=cropcode
    and l_3unitnum=unitnum and l_3plancd=plancd and l_3county= county
and l_3typecd=typecd
    and l_3practice=practice then flag3=1;

```



```

                else flag3=0;
run;
data e.ksTmerged02A;
    set e.ksmerged02A;
    if flag = 0 and flag1 = 1 then delete;
run;
data e.ksTmerged02A;
    set e.ksTmerged02A;
    if flag2 = 0 and flag3 = 1 then delete;
run;
proc sort data= e.kstype0210;
    by    ORG state company policynum cropyear ;
run;
data e.ksmerged02;
    merge e.kstype0210 e.ksTmerged02A;
    by ORG state company policynum cropyear;
run;
data e.ksmerged02;
    set e.ksmerged02;
    drop tyldmaparea ncsyld agrmnttyp agrmntnum agrmntprocflag
m14revflag yldindicator transyld
                                fsayld prevapprovyld rev1 rev2 rev3 rev4 rev5 rev6
rev7 rev8 rev9 rev10 ratestate
                                ratecounty farmserial yldlimflag bypass yrsactualref
yldindx avgyld prevlimflag
                                snn rateclass maparea crushdistrict referencecropyear
writtenagreementtype
                                writtenagreementprocessingflag guaranteedreductionflag
yield dollaramountofinsurance
                                numberoftrees guaranteeperacre
guaranteedreductionfactor totalguarantee contractprice
                                insuredshare liability priceelectionfactor
yieldconversionfactor basepremiumprate
                                preliminarybaserate loadedpremiumperacre
rateclassoption experiencefactor
                                premiumratesurcharge unitpremiumadjustment
ipcountyaverageyield rawholefarmdiscount
                                priceindicator subsidy additionalsubsidy
additionalsubsidyflag satatesubsidy
                                statesubsidyflag privatepolicy intendedacorage
seedcompany
                                rateseed farmserialnumber numberofsections seedcycle
m14review ceocoveragelevel
                                efapremiumdiscount efadiscountflag historicalpackout
prorationfactor rateyield
                                claimnumber stagecode allpercentreplantpaymentflag
                                grppaymentcalculation sugarfactor auditcorrection
secondarymonth primarypercent secondarycause
                                simplifiedclaim farmserianumber
liabilityadjustmentfactor valiescrowflag m14reviewflag
                                ceoindemnityfactor lossadjusterssignaturedate
noticeoflossdate primarydateofdamage
                                secondarydateofdamage commonoptioncodes;
run;
data e.ksmerged02; /*find duplicate typel5 observations*/
    set e.ksmerged02;
    l_annual9=lag(annual9);

```

```

    l_annual10=lag(annual10);
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag=1;
    else flag=0; /*find duplicate type15 observations*/
run;

data e.iamerged02;
    set e.ksmerged02;
    if flag = 1 then delete;

```

```
run;
```

*After all files for each year are merged we then merge all years using the following code

* This code also merges weather data

```

options compress = yes;
libname d "H:\Dissertation\Crop Insurance Paper\Crop Insurance Paper\C.I.
DATA";

```

```
/*to massage producerpremium, down to -----*/
```

```

data d.try2;
set d.montana;
if cropyear=2000 then delete;
run;
data d.try3;
set d.try2 d.iamerged00;
run;
data d.montana;
set d.try3;
if yield = . then yield = approvyld/10;
run;
/*-----*/
/*START ANALYSIS*/

```

```

data d.montana;
    set d.allregionsmerged02 d.allregionsmerged01 d.allregionsmerged00
d.allregionsmerged99
d.allregionsmerged98 d.allregionsmerged97 d.allregionsmerged96
    d.allregionsmerged95 d.allregionsmerged94;
run;
data d.montana;
    set d.montana;
    drop l_annual9 l_annual10 l_policynum l_cropcode l_plancd l_county
l_unitnum l_typecd

```

```

        l_2practice l_2unitnum l_2policynum l_2cropcode l_2plancd
l_2county      l_2typecd l_2practice l_3unitnum l_3policynum l_3cropcode
               l_3plancd l_3county l_3typecd l_3practice branchoffice idtype
entitytype employee
               covrgflag recordnum;;

run;
proc sort data= d.montana;by idnumber ;run;
data d.montana; /*corrects misspecified years*/
  set d.montana;
  if year1 > 2000 then year1= year1 - 100;
  else year1= year1;
  if year2 > 2000 then year2= year2- 100;
  else year2= year2;
  if year3 > 2000 then year3= year3 - 100;
  else year3=year3;
  if year4 > 2000 then year4= year4 - 100;
  else year4=year4;
  if year5 > 2000 then year5= year5 - 100;
  else year5=year5;
  if year6 > 2000 then year6= year6 - 100;
  else year6=year6;
  if year7 > 2000 then year7= year7 - 100;
  else year7=year7;
  if year8 > 2000 then year8= year8 - 100;
  else year8=year8;
  if year9 > 2000 then year9= year9 - 100;
  else year9=year9;
  if year10 > 2000 then year10= year10 - 100;
  else year10=year10;
  if cropyear = 1901 then cropyear = cropyear + 100;
  if year10 = 1901 then year10 = year10 + 100;

run;

proc means data= d.montana; run;
data d.try;
set d.montana;
if year10 = . then delete;
if dateplanted= . then delete;
if approvyld= 0 then delete;
if cropyear < 1987 then delete;
drop flag;
run;
data d.MTALL;
set d.try;
keep insuredshare reportedacres typecd type6-type10 annual7-annual10 CropCode
County practice policynum CropYear unitnum plancd coveragelevel dateplanted
totalpremium producerpremium lossguarantee indemnity primarymonth
primarycause approvyld idnumber state;
run;

data d.mtall;
set d.mtall;
newindem=1;
newindem=indemnity;
newpractice = 1;
newpractice=practice;

```

```
if newpractice = . then delete;
run;
```

```
data d.mtall;
set d.mtall;
if cropyear = 1989 then cy89 = 1; else cy89=0;
if cropyear = 1990 then cy90 = 1; else cy90=0;
if cropyear = 1991 then cy91 = 1; else cy91=0;
if cropyear = 1992 then cy92 = 1; else cy92=0;
if cropyear = 1993 then cy93 = 1; else cy93=0;
if cropyear = 1994 then cy94 = 1; else cy94=0;
if cropyear = 1995 then cy95 = 1; else cy95=0;
if cropyear = 1996 then cy96 = 1; else cy96=0;
if cropyear = 1997 then cy97 = 1; else cy97=0;
if cropyear = 1998 then cy98 = 1; else cy98=0;
if cropyear = 1999 then cy99 = 1; else cy99=0;
if cropyear = 2000 then cy00 = 1; else cy00=0;
if cropyear = 2001 then cy01 = 1; else cy01=0;
if cropyear = 2002 then cy02 = 1; else cy02=0;
run;
```

```
data d.mtall;
set d.mtall;
if cropcode = 441 then cropcode = 41;
if cropcode = 481 then cropcode = 81;
if cropcode = 11 then c11 = 1; else c11=0;
if cropcode = 16 then c16 = 1; else c16=0;
if cropcode = 41 then c41 = 1; else c41=0;
if cropcode = 43 then c43 = 1; else c43=0;
if cropcode = 81 then c81 = 1; else c81=0;
if cropcode >300 then delete;
run;
```

```
data d.mtall;
set d.mtall;
/*P4 indicates CC, P5 indicates SF*/
if newpractice = 2 then p2 = 1; else p2=0;
if newpractice = 3 then p3 = 1; else p3=0;
if newpractice = 4 then p4 = 1; else p4=0;
if newpractice = 5 then p5 = 1; else p5=0;
if newpractice = 8 then p8 = 1; else p8=0;
if newpractice = 9 then p9 = 1; else p9=0;
if newpractice = 86 then p86 = 1; else p86=0;
if newpractice = 93 then p93 = 1; else p93=0;
if newpractice = 108 then p108 = 1; else p108=0;
if newpractice = 997 then delete;
run;
```

```
/*create dummy variables indicating percentage of coverage level*/
data d.mtall;
set d.mtall;
if coveragelevel = .5 then c5 = 1; else c5=0;
if coveragelevel = .6 then c6 = 1; else c6=0;
if coveragelevel = .65 then c65 = 1; else c65=0;
if coveragelevel = .7 then c7 = 1; else c7=0;
if coveragelevel = .75 then c75 = 1; else c75=0;
if coveragelevel = .8 then c8 = 1; else c8=0;
```

```

if coveragelevel = .85 then c85 = 1; else c85=0;
run;

/*create dummy variables indicating type of crop insurance policy*/
data d.mtall;
set d.mtall;
if plancd = 25 then Plan25 = 1;else plan25=0;
if plancd = 42 then Plan42 = 1;else plan42=0;
if plancd = 44 then Plan44 = 1;else plan44=0;
if plancd = 90 then Plan90 = 1;else plan90=0;

run;

/*create dummy variables indicating primary month of loss*/
data d.mtall;
set d.mtall;
if primarymonth = 1 then pm1 = 1; else pm1=0;
if primarymonth = 2 then pm2 = 1; else pm2=0;
if primarymonth = 3 then pm3 = 1; else pm3=0;
if primarymonth = 4 then pm4 = 1; else pm4=0;
if primarymonth = 5 then pm5 = 1; else pm5=0;
if primarymonth = 6 then pm6 = 1; else pm6=0;
if primarymonth = 7 then pm7 = 1; else pm7=0;
if primarymonth = 8 then pm8 = 1; else pm8=0;
if primarymonth = 9 then pm9 = 1; else pm9=0;
if primarymonth = 10 then pm10 = 1; else pm10=0;
if primarymonth = 11 then pm11 = 1; else pm11=0;
if primarymonth = 12 then pm12 = 1; else pm12=0;

if primarycause = 44 then pc44 = 1; else pc44=0;
if primarycause = 11 then pc11 = 1; else pc11=0;
if primarycause = 81 then pc81 = 1; else pc81=0;
if primarycause = 43 then pc43 = 1; else pc43=0;
if primarycause = 12 then pc12 = 1; else pc12=0;
if primarycause = 13 then pc13 = 1; else pc13=0;
if primarycause = 71 then pc71 = 1; else pc71=0;
if primarycause = 21 then pc21 = 1; else pc21=0;
if primarycause = 61 then pc61 = 1; else pc61=0;

run;

/*create dummy variables indicating crop year*/
data d.mtall;
set d.mtall;
if newindem= . then newindem=0;
if producerpremium= . then delete;

ReturnP1=newindem-producerpremium;
ReturnG1=newindem-totalpremium;
run;

data d.four;
set d.mtall;
if type10='S' and type9='S' and type8='S' and type7='S'
then T4=1;else T4=0;

```

```

if type10='A' and type9='E' and type8='E' and type7='E'
then TE=1;else TE=0;

if type10='A' and type9='X' and type8='X' and type7='X'
then TX=1;else TX=0;

if TE=1 or TX=1
then T3=1;else T3=0;

if type10='A' and type9='A' and type8='N' and type7='N'
then T2=1;else T2=0;

if type10='A' and type9='A' and type8='A' and type7='T'
then T1=1;else T1=0;

if type10='A' and type9='A' and type8='A' and type7='A'
then T0=1;else T0=0;

if type10='I' and type9='I' and type8='I' and type7='I'
then TI=1;else TI=0;

if type10='H' and type9='H' and type8='H' and type7='H'
then TH=1;else TH=0;

if TI or TH=1
then Tnew=1; else Tnew=0;

if type10='T' and type9='T' and type8='T' and type7='T'
then TT=1;else TT=0;

if T4=1 or TE=1 or TX=1 or T3=1 or T2=1 or T1=1 or T0=1 or TI=1 or TH=1 or
Tnew=1 or TT=1
then TTT=1;else TTT=0;
if TTT=0 then delete;

newreportedacres= reportedacres/100;
if newreportedacres=0 then delete;
INDEM=newindem/newreportedacres;
if INDEM= . then INDEM=0;

if INDEM > 0 then FLAGINDEM= 1;
if FLAGINDEM= . then FLAGINDEM=0;

if t4=1 or t3=1 or t2=1 or t1=1 and t0=0 then t=1; else t=0;
if dateplanted=0 then delete;
if coveragelevel <.45 then delete;run;
/*this fixes a problem with multiple vectors with the same information.  c11
etc. is the type of crop grown.*/
data d.four;
set d.four;
drop c11 c16 c41 c81 c11;
if c11 = . then c11=1;
if c16 = . then c16=1;
if c41 = . then c41=1;
if c81 = . then c81=1;

```

```

run;
/*These data steps keep or drop counties from the analysis.*/
data d.Ggdiowa;
set d.Ggdiowa;
county=var1-19000;
run;
/*This data step keeps or drops counties from the analysis.*/
data d.cggdiowa;
set d.ggdiowa;
if county = 33 or county = 41 or county = 47 or county = 79 or county = 91
or county = 93 or county = 95 or county = 13 or county = 15 or county = 21 or
county = 195 or county = 185 or county = 171 or county = 167 or county = 163
or county= 11 or county = 19 or county = 35 or county = 49 or county = 27 or
county = 29 or county = 45 or county = 55 or county = 59 or county = 73 or
county = 1 or county = 67 or county = 187 or county = 25 or county = 85 or
county = 9 then cflag=1;else cflag=0;
if cflag =0 then delete;
drop var471-var638;
run;
data d.Ggdok;
set d.Ggdok;
county=var1-40000;
run;
data d.cggdok;
set d.ggdok;
if county = 001 or county = 005 or county = 009 or county = 025 or county =
039 or county = 043 or county = 045 or county = 053 or county = 077 or county
= 105 or county = 141 or county = 151 then cflag=1;else cflag=0;
if cflag =0 then delete;
drop var471-var638;
run;
data d.Ggdne;
set d.Ggdne;
county=var1-31000;
run;
data d.cggdne;
set d.ggdne;
if county = 009 or county = 017 or county = 031 or county = 033 or county =
045 or county = 047 or county = 069 or county = 085 or county = 087 or county
= 111 or county = 117 or county = 137 or county = 149 or county = 161 or
county = 171 or county= 177 then cflag=1;else cflag=0;
if cflag =0 then delete;
drop var471-var638;
run;
data d.Ggdmt;
set d.Ggdmt;
county=var1-30000;
run;
data d.cggdmt;
set d.ggdmt;
if county = 005 or county = 013 or county = 019 or county = 021 or county =
027 or county = 033 or county = 041 or county = 045 or county = 051 or county
= 055 or county = 069 or county = 071 or county = 073 or county = 083 or
county = 085 or county= 091 or county = 99 or county = 101 or county = 105
then cflag=1;else cflag=0;
if cflag =0 then delete;
drop var471-var638;

```

```

run;
data d.Ggdwa;
set d.Ggdwa;
county=var1-53000;
run;
data d.cggdwa;
set d.ggdwa;
if county = 025 or county = 043 or county = 001 or county = 075 or county =
021 or county = 005 or county = 071 or county = 013 or county = 023 or county
= 063 or county = 003 then cflag=1;else cflag=0;
if cflag =0 then delete;
drop var471-var638;
run;

/*Create State Files*/
data d.ia;
set d.four;
if State = 19 then sflag=1;
if sflag=. then delete;
run;
data d.ok;
set d.four;
if State = 40 then sflag=1;
if sflag=. then delete;
run;

data d.ne;
set d.four;
if State = 31 then sflag=1;
if sflag=. then delete;
run;
data d.mt;
set d.four;
if state = 30 then sflag=1;
if sflag=. then delete;
run;
data d.wa;
set d.four;
if state = 53 then sflag=1;
if sflag=. then delete;
run;

/*This part massages the weather data into a form that can be merged with
d.ia*/
data d.precip1(rename = (year2002= c2002 year2001=c2001 year2000=c2000
year1999=c1999 year1998=c1998 year1997=c1997 year1996=c1996 year1995=c1995
year1994=c1994 year1993=c1993 year1992=c1992 year1991=c1991 year1990=c1990
year1989=c1989));
set d.cggdiowa;
if var2 = 100 then pflag=1;else pflag=0;
if pflag=0 then delete;
run;
proc transpose data=d.precip1 out=new1;
by county;
var c2002-c1989;
run;

```



```

data d.Precip (rename = (coll=Precip));
set new1;
year = _name_;
if year = 'c2002' then cropyear = 2002;
if year = 'c2001' then cropyear = 2001;
if year = 'c2000' then cropyear = 2000;
if year = 'c1999' then cropyear = 1999;
if year = 'c1998' then cropyear = 1998;
if year = 'c1997' then cropyear = 1997;
if year = 'c1996' then cropyear = 1996;
if year = 'c1995' then cropyear = 1995;
if year = 'c1994' then cropyear = 1994;
if year = 'c1993' then cropyear = 1993;
if year = 'c1992' then cropyear = 1992;
if year = 'c1991' then cropyear = 1991;
if year = 'c1990' then cropyear = 1990;
if year = 'c1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd00(rename = (year2002=zerogg2002 year2001=zerogg2001
year2000=zerogg2000 year1999=zerogg1999 year1998=zerogg1998
year1997=zerogg1997 year1996=zerogg1996 year1995=zerogg1995
year1994=zerogg1994 year1993=zerogg1993 year1992=zerogg1992
year1991=zerogg1991 year1990=zerogg1990 year1989=zerogg1989));
set d.cggsdiowa;
if var2 = 0 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd00 out=new2;
by county;
var zerogg2002-zerogg1989;
run;
data d.GGDzero (rename = (coll=GGDzero));
set new2;
year = _name_;
if year = 'zerogg2002' then cropyear = 2002;
if year = 'zerogg2001' then cropyear = 2001;
if year = 'zerogg2000' then cropyear = 2000;
if year = 'zerogg1999' then cropyear = 1999;
if year = 'zerogg1998' then cropyear = 1998;
if year = 'zerogg1997' then cropyear = 1997;
if year = 'zerogg1996' then cropyear = 1996;
if year = 'zerogg1995' then cropyear = 1995;
if year = 'zerogg1994' then cropyear = 1994;
if year = 'zerogg1993' then cropyear = 1993;
if year = 'zerogg1992' then cropyear = 1992;
if year = 'zerogg1991' then cropyear = 1991;
if year = 'zerogg1990' then cropyear = 1990;
if year = 'zerogg1989' then cropyear = 1989;

drop _name_ year;

run;

```

```

data d.ggd10(rename = (year2002=tengg2002 year2001=tengg2001
year2000=tengg2000 year1999=tengg1999 year1998=tengg1998 year1997=tengg1997
year1996=tengg1996 year1995=tengg1995 year1994=tengg1994 year1993=tengg1993
year1992=tengg1992 year1991=tengg1991 year1990=tengg1990
year1989=tengg1989));
set d.cggdiowa;
if var2 = 10 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;

proc transpose data=d.ggd10 out=new3;
by county;
var tengg2002-tengg1989;
run;
data d.GGDten (rename = (coll=GGD10));
set new3;
year = __name__;
if year = 'tengg2002' then cropyear = 2002;
if year = 'tengg2001' then cropyear = 2001;
if year = 'tengg2000' then cropyear = 2000;
if year = 'tengg1999' then cropyear = 1999;
if year = 'tengg1998' then cropyear = 1998;
if year = 'tengg1997' then cropyear = 1997;
if year = 'tengg1996' then cropyear = 1996;
if year = 'tengg1995' then cropyear = 1995;
if year = 'tengg1994' then cropyear = 1994;
if year = 'tengg1993' then cropyear = 1993;
if year = 'tengg1992' then cropyear = 1992;
if year = 'tengg1991' then cropyear = 1991;
if year = 'tengg1990' then cropyear = 1990;
if year = 'tengg1989' then cropyear = 1989;

drop __name__ year;

run;
data d.ggd20(rename = (year2002=twentygg2002 year2001=twentygg2001
year2000=twentygg2000 year1999=twentygg1999 year1998=twentygg1998
year1997=twentygg1997 year1996=twentygg1996 year1995=twentygg1995
year1994=twentygg1994 year1993=twentygg1993 year1992=twentygg1992
year1991=twentygg1991 year1990=twentygg1990 year1989=twentygg1989));
set d.cggdiowa;
if var2 = 20 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd20 out=new4;
by county;
var twentygg2002-twentygg1989;
run;
data d.GGDtwenty (rename = (coll=GGD20));
set new4;
year = __name__;
if year = 'twentygg2002' then cropyear = 2002;
if year = 'twentygg2001' then cropyear = 2001;
if year = 'twentygg2000' then cropyear = 2000;
if year = 'twentygg1999' then cropyear = 1999;
if year = 'twentygg1998' then cropyear = 1998;
if year = 'twentygg1997' then cropyear = 1997;

```

```

if year = 'twentygg1996' then cropyear = 1996;
if year = 'twentygg1995' then cropyear = 1995;
if year = 'twentygg1994' then cropyear = 1994;
if year = 'twentygg1993' then cropyear = 1993;
if year = 'twentygg1992' then cropyear = 1992;
if year = 'twentygg1991' then cropyear = 1991;
if year = 'twentygg1990' then cropyear = 1990;
if year = 'twentygg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd33(rename = (year2002=thirtythreegg2002 year2001=thirtythreegg2001
year2000=thirtythreegg2000 year1999=thirtythreegg1999
year1998=thirtythreegg1998 year1997=thirtythreegg1997
year1996=thirtythreegg1996 year1995=thirtythreegg1995
year1994=thirtythreegg1994 year1993=thirtythreegg1993
year1992=thirtythreegg1992 year1991=thirtythreegg1991
year1990=thirtythreegg1990 year1989=thirtythreegg1989));
set d.cggdiowa;
if var2 = 33 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd33 out=new5;
by county;
var thirtythreegg2002-thirtythreegg1989;
run;
data d.GGDthirty3 (rename = (coll=GGD33));
set new5;
year = _name_;
if year = 'thirtythreegg2002' then cropyear = 2002;
if year = 'thirtythreegg2001' then cropyear = 2001;
if year = 'thirtythreegg2000' then cropyear = 2000;
if year = 'thirtythreegg1999' then cropyear = 1999;
if year = 'thirtythreegg1998' then cropyear = 1998;
if year = 'thirtythreegg1997' then cropyear = 1997;
if year = 'thirtythreegg1996' then cropyear = 1996;
if year = 'thirtythreegg1995' then cropyear = 1995;
if year = 'thirtythreegg1994' then cropyear = 1994;
if year = 'thirtythreegg1993' then cropyear = 1993;
if year = 'thirtythreegg1992' then cropyear = 1992;
if year = 'thirtythreegg1991' then cropyear = 1991;
if year = 'thirtythreegg1990' then cropyear = 1990;
if year = 'thirtythreegg1989' then cropyear = 1989;

drop _name_ year;

run;
proc sort data=d.ia;
by county cropyear;
run;
proc sort data=d.precip;
by county cropyear;
run;
proc sort data=d.ggdzero;
by county cropyear;

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```

run;
proc sort data=d.ggdten;
by county cropyear;
run;
proc sort data=d.ggdtwenty;
by county cropyear;
run;
proc sort data=d.GGDthirty3;
by county cropyear;
run;

/*-----*/
-----*/
/*MERGE DATA HERE*/

data try2;
merge d.ia d.precip d.ggdzero d.ggdten d.ggdtwenty d.ggdthirty3;
by county cropyear;
run;
data d.mergedIA;
set try2;
if ggd10 =. then delete;
if idnumber= . then delete;
if idnumber= 0 then delete;
run;

/*This part massages the weather data into a form that can be merged with
d.ok*/
/*-----OKLAHOMA-----*/
-----*/
data d.precip1OK(rename = (year2002= c2002 year2001=c2001 year2000=c2000
year1999=c1999 year1998=c1998 year1997=c1997 year1996=c1996 year1995=c1995
year1994=c1994 year1993=c1993 year1992=c1992 year1991=c1991 year1990=c1990
year1989=c1989));
set d.cggdOK;
if var2 = 100 then pflag=1;else pflag=0;
if pflag=0 then delete;
run;
proc transpose data=d.precip1OK out=new1;
by county;
var c2002-c1989;
run;
data d.Precip (rename = (coll=Precip));
set new1;
year = _name_;
if year = 'c2002' then cropyear = 2002;
if year = 'c2001' then cropyear = 2001;
if year = 'c2000' then cropyear = 2000;
if year = 'c1999' then cropyear = 1999;
if year = 'c1998' then cropyear = 1998;
if year = 'c1997' then cropyear = 1997;
if year = 'c1996' then cropyear = 1996;
if year = 'c1995' then cropyear = 1995;
if year = 'c1994' then cropyear = 1994;
if year = 'c1993' then cropyear = 1993;
if year = 'c1992' then cropyear = 1992;
if year = 'c1991' then cropyear = 1991;

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if year = 'c1990' then cropyear = 1990;
if year = 'c1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd00(rename = (year2002=zerogg2002 year2001=zerogg2001
year2000=zerogg2000 year1999=zerogg1999 year1998=zerogg1998
year1997=zerogg1997 year1996=zerogg1996 year1995=zerogg1995
year1994=zerogg1994 year1993=zerogg1993 year1992=zerogg1992
year1991=zerogg1991 year1990=zerogg1990 year1989=zerogg1989));
set d.cggdOK;
if var2 = 0 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd00 out=new2;
by county;
var zerogg2002-zerogg1989;
run;
data d.GGDzeroOK (rename = (coll=GGDzero));
set new2;
year = _name_;
if year = 'zerogg2002' then cropyear = 2002;
if year = 'zerogg2001' then cropyear = 2001;
if year = 'zerogg2000' then cropyear = 2000;
if year = 'zerogg1999' then cropyear = 1999;
if year = 'zerogg1998' then cropyear = 1998;
if year = 'zerogg1997' then cropyear = 1997;
if year = 'zerogg1996' then cropyear = 1996;
if year = 'zerogg1995' then cropyear = 1995;
if year = 'zerogg1994' then cropyear = 1994;
if year = 'zerogg1993' then cropyear = 1993;
if year = 'zerogg1992' then cropyear = 1992;
if year = 'zerogg1991' then cropyear = 1991;
if year = 'zerogg1990' then cropyear = 1990;
if year = 'zerogg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd10(rename = (year2002=tengg2002 year2001=tengg2001
year2000=tengg2000 year1999=tengg1999 year1998=tengg1998 year1997=tengg1997
year1996=tengg1996 year1995=tengg1995 year1994=tengg1994 year1993=tengg1993
year1992=tengg1992 year1991=tengg1991 year1990=tengg1990
year1989=tengg1989));
set d.cggdOK;
if var2 = 10 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;

proc transpose data=d.ggd10 out=new3;
by county;
var tengg2002-tengg1989;
run;
data d.GGDtenOK (rename = (coll=GGD10));

```

```

set new3;
year = _name_;
if year = 'tengg2002' then cropyear = 2002;
if year = 'tengg2001' then cropyear = 2001;
if year = 'tengg2000' then cropyear = 2000;
if year = 'tengg1999' then cropyear = 1999;
if year = 'tengg1998' then cropyear = 1998;
if year = 'tengg1997' then cropyear = 1997;
if year = 'tengg1996' then cropyear = 1996;
if year = 'tengg1995' then cropyear = 1995;
if year = 'tengg1994' then cropyear = 1994;
if year = 'tengg1993' then cropyear = 1993;
if year = 'tengg1992' then cropyear = 1992;
if year = 'tengg1991' then cropyear = 1991;
if year = 'tengg1990' then cropyear = 1990;
if year = 'tengg1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd20(rename = (year2002=twentygg2002 year2001=twentygg2001
year2000=twentygg2000 year1999=twentygg1999 year1998=twentygg1998
year1997=twentygg1997 year1996=twentygg1996 year1995=twentygg1995
year1994=twentygg1994 year1993=twentygg1993 year1992=twentygg1992
year1991=twentygg1991 year1990=twentygg1990 year1989=twentygg1989));
set d.cggdOK;
if var2 = 20 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd20 out=new4;
by county;
var twentygg2002-twentygg1989;
run;
data d.GGDtwentyOK (rename = (coll=GGD20));
set new4;
year = _name_;
if year = 'twentygg2002' then cropyear = 2002;
if year = 'twentygg2001' then cropyear = 2001;
if year = 'twentygg2000' then cropyear = 2000;
if year = 'twentygg1999' then cropyear = 1999;
if year = 'twentygg1998' then cropyear = 1998;
if year = 'twentygg1997' then cropyear = 1997;
if year = 'twentygg1996' then cropyear = 1996;
if year = 'twentygg1995' then cropyear = 1995;
if year = 'twentygg1994' then cropyear = 1994;
if year = 'twentygg1993' then cropyear = 1993;
if year = 'twentygg1992' then cropyear = 1992;
if year = 'twentygg1991' then cropyear = 1991;
if year = 'twentygg1990' then cropyear = 1990;
if year = 'twentygg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd33(rename = (year2002=thirtythreegg2002 year2001=thirtythreegg2001
year2000=thirtythreegg2000 year1999=thirtythreegg1999

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year1998=thirtythreegg1998 year1997=thirtythreegg1997
year1996=thirtythreegg1996 year1995=thirtythreegg1995
year1994=thirtythreegg1994 year1993=thirtythreegg1993
year1992=thirtythreegg1992 year1991=thirtythreegg1991
year1990=thirtythreegg1990 year1989=thirtythreegg1989));
set d.cggdOK;
if var2 = 33 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd33 out=new5;
by county;
var thirtythreegg2002-thirtythreegg1989;
run;
data d.GGDthirty30K (rename = (coll=GGD33));
set new5;
year = _name_;
if year = 'thirtythreegg2002' then cropyear = 2002;
if year = 'thirtythreegg2001' then cropyear = 2001;
if year = 'thirtythreegg2000' then cropyear = 2000;
if year = 'thirtythreegg1999' then cropyear = 1999;
if year = 'thirtythreegg1998' then cropyear = 1998;
if year = 'thirtythreegg1997' then cropyear = 1997;
if year = 'thirtythreegg1996' then cropyear = 1996;
if year = 'thirtythreegg1995' then cropyear = 1995;
if year = 'thirtythreegg1994' then cropyear = 1994;
if year = 'thirtythreegg1993' then cropyear = 1993;
if year = 'thirtythreegg1992' then cropyear = 1992;
if year = 'thirtythreegg1991' then cropyear = 1991;
if year = 'thirtythreegg1990' then cropyear = 1990;
if year = 'thirtythreegg1989' then cropyear = 1989;

drop _name_ year;

run;

proc sort data=d.OK;
by county cropyear;
run;
proc sort data=d.precipOK;
by county cropyear;
run;
proc sort data=d.ggdzeroOK;
by county cropyear;
run;
proc sort data=d.ggdtenOK;
by county cropyear;
run;
proc sort data=d.ggdtwentyOK;
by county cropyear;
run;
proc sort data=d.ggdthirty30K;
by county cropyear;
run;
/*-----*/
/*MERGE DATA HERE*/
data try2;

```

```

merge d.OK d.precipOK d.ggdzeroOK d.ggdtenOK d.ggdtwentyOK d.ggdthirty3OK;
by county cropyear;
run;
/*This deletes counties not used in the analysis, to add additional counties
go back up to where counties are listed*/
data d.mergedOK;
set try2;
if ggd10 =. then delete;
if idnumber= . then delete;
if idnumber= 0 then delete;
run;

/*This part massages the weather data into a form that can be merged with
d.NE*/
/*-----NEBRASKA-----*/
-----*/
data d.precip1(rename = (year2002= c2002 year2001=c2001 year2000=c2000
year1999=c1999 year1998=c1998 year1997=c1997 year1996=c1996 year1995=c1995
year1994=c1994 year1993=c1993 year1992=c1992 year1991=c1991 year1990=c1990
year1989=c1989));
set d.cggdNE;
if var2 = 100 then pflag=1;else pflag=0;
if pflag=0 then delete;
run;
proc transpose data=d.precip1 out=new1;
by county;
var c2002-c1989;
run;
data d.PrecipNE (rename = (coll=Precip));
set new1;
year = _name_;
if year = 'c2002' then cropyear = 2002;
if year = 'c2001' then cropyear = 2001;
if year = 'c2000' then cropyear = 2000;
if year = 'c1999' then cropyear = 1999;
if year = 'c1998' then cropyear = 1998;
if year = 'c1997' then cropyear = 1997;
if year = 'c1996' then cropyear = 1996;
if year = 'c1995' then cropyear = 1995;
if year = 'c1994' then cropyear = 1994;
if year = 'c1993' then cropyear = 1993;
if year = 'c1992' then cropyear = 1992;
if year = 'c1991' then cropyear = 1991;
if year = 'c1990' then cropyear = 1990;
if year = 'c1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd00(rename = (year2002=zerogg2002 year2001=zerogg2001
year2000=zerogg2000 year1999=zerogg1999 year1998=zerogg1998
year1997=zerogg1997 year1996=zerogg1996 year1995=zerogg1995
year1994=zerogg1994 year1993=zerogg1993 year1992=zerogg1992
year1991=zerogg1991 year1990=zerogg1990 year1989=zerogg1989));
set d.cggdNE;

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```

if var2 = 0 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd00 out=new2;
by county;
var zerogg2002-zerogg1989;
run;
data d.GGDzeroNE (rename = (coll=GGDzero));
set new2;
year = _name_;
if year = 'zerogg2002' then cropyear = 2002;
if year = 'zerogg2001' then cropyear = 2001;
if year = 'zerogg2000' then cropyear = 2000;
if year = 'zerogg1999' then cropyear = 1999;
if year = 'zerogg1998' then cropyear = 1998;
if year = 'zerogg1997' then cropyear = 1997;
if year = 'zerogg1996' then cropyear = 1996;
if year = 'zerogg1995' then cropyear = 1995;
if year = 'zerogg1994' then cropyear = 1994;
if year = 'zerogg1993' then cropyear = 1993;
if year = 'zerogg1992' then cropyear = 1992;
if year = 'zerogg1991' then cropyear = 1991;
if year = 'zerogg1990' then cropyear = 1990;
if year = 'zerogg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd10(rename = (year2002=tengg2002 year2001=tengg2001
year2000=tengg2000 year1999=tengg1999 year1998=tengg1998 year1997=tengg1997
year1996=tengg1996 year1995=tengg1995 year1994=tengg1994 year1993=tengg1993
year1992=tengg1992 year1991=tengg1991 year1990=tengg1990
year1989=tengg1989));
set d.cggdNE;
if var2 = 10 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;

proc transpose data=d.ggd10 out=new3;
by county;
var tengg2002-tengg1989;
run;
data d.GGDtenNE (rename = (coll=GGD10));
set new3;
year = _name_;
if year = 'tengg2002' then cropyear = 2002;
if year = 'tengg2001' then cropyear = 2001;
if year = 'tengg2000' then cropyear = 2000;
if year = 'tengg1999' then cropyear = 1999;
if year = 'tengg1998' then cropyear = 1998;
if year = 'tengg1997' then cropyear = 1997;
if year = 'tengg1996' then cropyear = 1996;
if year = 'tengg1995' then cropyear = 1995;
if year = 'tengg1994' then cropyear = 1994;
if year = 'tengg1993' then cropyear = 1993;

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if year = 'tengg1992' then cropyear = 1992;
if year = 'tengg1991' then cropyear = 1991;
if year = 'tengg1990' then cropyear = 1990;
if year = 'tengg1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd20(rename = (year2002=twentygg2002 year2001=twentygg2001
year2000=twentygg2000 year1999=twentygg1999 year1998=twentygg1998
year1997=twentygg1997 year1996=twentygg1996 year1995=twentygg1995
year1994=twentygg1994 year1993=twentygg1993 year1992=twentygg1992
year1991=twentygg1991 year1990=twentygg1990 year1989=twentygg1989));
set d.cggdNE;
if var2 = 20 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd20 out=new4;
by county;
var twentygg2002-twentygg1989;
run;
data d.GGDtwentyNE (rename = (col1=GGD20));
set new4;
year = _name_;
if year = 'twentygg2002' then cropyear = 2002;
if year = 'twentygg2001' then cropyear = 2001;
if year = 'twentygg2000' then cropyear = 2000;
if year = 'twentygg1999' then cropyear = 1999;
if year = 'twentygg1998' then cropyear = 1998;
if year = 'twentygg1997' then cropyear = 1997;
if year = 'twentygg1996' then cropyear = 1996;
if year = 'twentygg1995' then cropyear = 1995;
if year = 'twentygg1994' then cropyear = 1994;
if year = 'twentygg1993' then cropyear = 1993;
if year = 'twentygg1992' then cropyear = 1992;
if year = 'twentygg1991' then cropyear = 1991;
if year = 'twentygg1990' then cropyear = 1990;
if year = 'twentygg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd33(rename = (year2002=thirtythreegg2002 year2001=thirtythreegg2001
year2000=thirtythreegg2000 year1999=thirtythreegg1999
year1998=thirtythreegg1998 year1997=thirtythreegg1997
year1996=thirtythreegg1996 year1995=thirtythreegg1995
year1994=thirtythreegg1994 year1993=thirtythreegg1993
year1992=thirtythreegg1992 year1991=thirtythreegg1991
year1990=thirtythreegg1990 year1989=thirtythreegg1989));
set d.cggdNE;
if var2 = 33 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd33 out=new5;
by county;
var thirtythreegg2002-thirtythreegg1989;

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```

run;
data d.GGDthirty3NE (rename = (coll=GGD33));
set new5;
year = _name_;
if year = 'thirtythreeegg2002' then cropyear = 2002;
if year = 'thirtythreeegg2001' then cropyear = 2001;
if year = 'thirtythreeegg2000' then cropyear = 2000;
if year = 'thirtythreeegg1999' then cropyear = 1999;
if year = 'thirtythreeegg1998' then cropyear = 1998;
if year = 'thirtythreeegg1997' then cropyear = 1997;
if year = 'thirtythreeegg1996' then cropyear = 1996;
if year = 'thirtythreeegg1995' then cropyear = 1995;
if year = 'thirtythreeegg1994' then cropyear = 1994;
if year = 'thirtythreeegg1993' then cropyear = 1993;
if year = 'thirtythreeegg1992' then cropyear = 1992;
if year = 'thirtythreeegg1991' then cropyear = 1991;
if year = 'thirtythreeegg1990' then cropyear = 1990;
if year = 'thirtythreeegg1989' then cropyear = 1989;

drop _name_ year;

run;

proc sort data=d.NE;
by county cropyear;
run;
proc sort data=d.precipNE;
by county cropyear;
run;
proc sort data=d.ggdzeroNE;
by county cropyear;
run;
proc sort data=d.ggdtenNE;
by county cropyear;
run;
proc sort data=d.ggdtwentyNE;
by county cropyear;
run;
proc sort data=d.ggdthirty3NE;
by county cropyear;
run;
/*-----*/
/*-----*/
/*MERGE DATA HERE*/
data try2;
merge d.NE d.precipNE d.ggdzeroNE d.ggdtenNE d.ggdtwentyNE d.ggdthirty3NE;
by county cropyear;
run;
/*This deletes counties not used in the analysis, to add additional counties
go back up to where counties are listed*/
data d.mergedNE;
set try2;
if ggd10 =. then delete;
if idnumber= . then delete;
if idnumber= 0 then delete;
run;

```

```

/*This part massages the weather data into a form that can be merged with
d.MT*/
/*-----MONTANA-----
-----*/
data d.precip1(rename = (year2002= c2002 year2001=c2001 year2000=c2000
year1999=c1999 year1998=c1998 year1997=c1997 year1996=c1996 year1995=c1995
year1994=c1994 year1993=c1993 year1992=c1992 year1991=c1991 year1990=c1990
year1989=c1989));
set d.cggdMT;
if var2 = 100 then pflag=1;else pflag=0;
if pflag=0 then delete;
run;
proc transpose data=d.precip1 out=new1;
by county;
var c2002-c1989;
run;
data d.PrecipMT (rename = (coll=Precip));
set new1;
year = _name_;
if year = 'c2002' then cropyear = 2002;
if year = 'c2001' then cropyear = 2001;
if year = 'c2000' then cropyear = 2000;
if year = 'c1999' then cropyear = 1999;
if year = 'c1998' then cropyear = 1998;
if year = 'c1997' then cropyear = 1997;
if year = 'c1996' then cropyear = 1996;
if year = 'c1995' then cropyear = 1995;
if year = 'c1994' then cropyear = 1994;
if year = 'c1993' then cropyear = 1993;
if year = 'c1992' then cropyear = 1992;
if year = 'c1991' then cropyear = 1991;
if year = 'c1990' then cropyear = 1990;
if year = 'c1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd00(rename = (year2002=zerogg2002 year2001=zerogg2001
year2000=zerogg2000 year1999=zerogg1999 year1998=zerogg1998
year1997=zerogg1997 year1996=zerogg1996 year1995=zerogg1995
year1994=zerogg1994 year1993=zerogg1993 year1992=zerogg1992
year1991=zerogg1991 year1990=zerogg1990 year1989=zerogg1989));
set d.cggdMT;
if var2 = 0 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd00 out=new2;
by county;
var zerogg2002-zerogg1989;
run;
data d.GGDzeroMT (rename = (coll=GGDzero));
set new2;
year = _name_;
if year = 'zerogg2002' then cropyear = 2002;
if year = 'zerogg2001' then cropyear = 2001;
if year = 'zerogg2000' then cropyear = 2000;

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```

if year = 'zerogg1999' then cropyear = 1999;
if year = 'zerogg1998' then cropyear = 1998;
if year = 'zerogg1997' then cropyear = 1997;
if year = 'zerogg1996' then cropyear = 1996;
if year = 'zerogg1995' then cropyear = 1995;
if year = 'zerogg1994' then cropyear = 1994;
if year = 'zerogg1993' then cropyear = 1993;
if year = 'zerogg1992' then cropyear = 1992;
if year = 'zerogg1991' then cropyear = 1991;
if year = 'zerogg1990' then cropyear = 1990;
if year = 'zerogg1989' then cropyear = 1989;

```

```
drop _name_ year;
```

```
run;
```

```

data d.ggd10(rename = (year2002=tengg2002 year2001=tengg2001
year2000=tengg2000 year1999=tengg1999 year1998=tengg1998 year1997=tengg1997
year1996=tengg1996 year1995=tengg1995 year1994=tengg1994 year1993=tengg1993
year1992=tengg1992 year1991=tengg1991 year1990=tengg1990
year1989=tengg1989));

```

```
set d.cggdMT;
```

```
if var2 = 10 then gflag=1;else gflag=0;
```

```
if gflag=0 then delete;
```

```
run;
```

```
proc transpose data=d.ggd10 out=new3;
```

```
by county;
```

```
var tengg2002-tengg1989;
```

```
run;
```

```
data d.GGDtenMT (rename = (coll=GGD10));
```

```
set new3;
```

```
year = _name_;
```

```
if year = 'tengg2002' then cropyear = 2002;
```

```
if year = 'tengg2001' then cropyear = 2001;
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if year = 'tengg2000' then cropyear = 2000;
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if year = 'tengg1999' then cropyear = 1999;
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if year = 'tengg1998' then cropyear = 1998;
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if year = 'tengg1997' then cropyear = 1997;
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if year = 'tengg1996' then cropyear = 1996;
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if year = 'tengg1995' then cropyear = 1995;
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if year = 'tengg1994' then cropyear = 1994;
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```
if year = 'tengg1993' then cropyear = 1993;
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```
if year = 'tengg1992' then cropyear = 1992;
```

```
if year = 'tengg1991' then cropyear = 1991;
```

```
if year = 'tengg1990' then cropyear = 1990;
```

```
if year = 'tengg1989' then cropyear = 1989;
```

```
drop _name_ year;
```

```
run;
```

```

data d.ggd20(rename = (year2002=twentygg2002 year2001=twentygg2001
year2000=twentygg2000 year1999=twentygg1999 year1998=twentygg1998
year1997=twentygg1997 year1996=twentygg1996 year1995=twentygg1995
year1994=twentygg1994 year1993=twentygg1993 year1992=twentygg1992
year1991=twentygg1991 year1990=twentygg1990 year1989=twentygg1989));

```

```

set d.cggdMT;
if var2 = 20 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd20 out=new4;
by county;
var twentygg2002-twentygg1989;
run;
data d.GGDtwentyMT (rename = (coll=GGD20));
set new4;
year = _name_;
if year = 'twentygg2002' then cropyear = 2002;
if year = 'twentygg2001' then cropyear = 2001;
if year = 'twentygg2000' then cropyear = 2000;
if year = 'twentygg1999' then cropyear = 1999;
if year = 'twentygg1998' then cropyear = 1998;
if year = 'twentygg1997' then cropyear = 1997;
if year = 'twentygg1996' then cropyear = 1996;
if year = 'twentygg1995' then cropyear = 1995;
if year = 'twentygg1994' then cropyear = 1994;
if year = 'twentygg1993' then cropyear = 1993;
if year = 'twentygg1992' then cropyear = 1992;
if year = 'twentygg1991' then cropyear = 1991;
if year = 'twentygg1990' then cropyear = 1990;
if year = 'twentygg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd33(rename = (year2002=thirtythreegg2002 year2001=thirtythreegg2001
year2000=thirtythreegg2000 year1999=thirtythreegg1999
year1998=thirtythreegg1998 year1997=thirtythreegg1997
year1996=thirtythreegg1996 year1995=thirtythreegg1995
year1994=thirtythreegg1994 year1993=thirtythreegg1993
year1992=thirtythreegg1992 year1991=thirtythreegg1991
year1990=thirtythreegg1990 year1989=thirtythreegg1989));
set d.cggdMT;
if var2 = 33 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd33 out=new5;
by county;
var thirtythreegg2002-thirtythreegg1989;
run;
data d.GGDthirty3MT (rename = (coll=GGD33));
set new5;
year = _name_;
if year = 'thirtythreegg2002' then cropyear = 2002;
if year = 'thirtythreegg2001' then cropyear = 2001;
if year = 'thirtythreegg2000' then cropyear = 2000;
if year = 'thirtythreegg1999' then cropyear = 1999;
if year = 'thirtythreegg1998' then cropyear = 1998;
if year = 'thirtythreegg1997' then cropyear = 1997;
if year = 'thirtythreegg1996' then cropyear = 1996;
if year = 'thirtythreegg1995' then cropyear = 1995;
if year = 'thirtythreegg1994' then cropyear = 1994;

```

```

if year = 'thirtythreeegg1993' then cropyear = 1993;
if year = 'thirtythreeegg1992' then cropyear = 1992;
if year = 'thirtythreeegg1991' then cropyear = 1991;
if year = 'thirtythreeegg1990' then cropyear = 1990;
if year = 'thirtythreeegg1989' then cropyear = 1989;

drop _name_ year;

run;

proc sort data=d.MT;
by county cropyear;
run;
proc sort data=d.precipMT;
by county cropyear;
run;
proc sort data=d.ggdzeroMT;
by county cropyear;
run;
proc sort data=d.ggdtenMT;
by county cropyear;
run;
proc sort data=d.ggdtwentyMT;
by county cropyear;
run;
proc sort data=d.ggdthirty3MT;
by county cropyear;
run;
/*-----*/
-----*/
/*MERGE DATA HERE*/
data try2;
merge d.MT d.precipMT d.ggdzeroMT d.ggdtenMT d.ggdtwentyMT d.ggdthirty3MT;
by county cropyear;
run;
/*This deletes counties not used in the analysis, to add additional counties
go back up to where counties are listed*/
data d.mergedMT;
set try2;
if ggd10 =. then delete;
if idnumber= . then delete;
if idnumber= 0 then delete;
run;

/*This part massages the weather data into a form that can be merged with
d.WA*/
/*-----WASHINGTON-----*/
-----*/
data d.precip1(rename = (year2002= c2002 year2001=c2001 year2000=c2000
year1999=c1999 year1998=c1998 year1997=c1997 year1996=c1996 year1995=c1995
year1994=c1994 year1993=c1993 year1992=c1992 year1991=c1991 year1990=c1990
year1989=c1989));
set d.cggdWA;
if var2 = 100 then pflag=1;else pflag=0;
if pflag=0 then delete;

```

```

run;
proc transpose data=d.precipl out=new1;
by county;
var c2002-c1989;
run;
data d.PrecipWA (rename = (coll=Precip));
set new1;
year = _name_;
if year = 'c2002' then cropyear = 2002;
if year = 'c2001' then cropyear = 2001;
if year = 'c2000' then cropyear = 2000;
if year = 'c1999' then cropyear = 1999;
if year = 'c1998' then cropyear = 1998;
if year = 'c1997' then cropyear = 1997;
if year = 'c1996' then cropyear = 1996;
if year = 'c1995' then cropyear = 1995;
if year = 'c1994' then cropyear = 1994;
if year = 'c1993' then cropyear = 1993;
if year = 'c1992' then cropyear = 1992;
if year = 'c1991' then cropyear = 1991;
if year = 'c1990' then cropyear = 1990;
if year = 'c1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd00(rename = (year2002=zerogg2002 year2001=zerogg2001
year2000=zerogg2000 year1999=zerogg1999 year1998=zerogg1998
year1997=zerogg1997 year1996=zerogg1996 year1995=zerogg1995
year1994=zerogg1994 year1993=zerogg1993 year1992=zerogg1992
year1991=zerogg1991 year1990=zerogg1990 year1989=zerogg1989));
set d.cggdWA;
if var2 = 0 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd00 out=new2;
by county;
var zerogg2002-zerogg1989;
run;
data d.GGDzeroWA (rename = (coll=GGDzero));
set new2;
year = _name_;
if year = 'zerogg2002' then cropyear = 2002;
if year = 'zerogg2001' then cropyear = 2001;
if year = 'zerogg2000' then cropyear = 2000;
if year = 'zerogg1999' then cropyear = 1999;
if year = 'zerogg1998' then cropyear = 1998;
if year = 'zerogg1997' then cropyear = 1997;
if year = 'zerogg1996' then cropyear = 1996;
if year = 'zerogg1995' then cropyear = 1995;
if year = 'zerogg1994' then cropyear = 1994;
if year = 'zerogg1993' then cropyear = 1993;
if year = 'zerogg1992' then cropyear = 1992;
if year = 'zerogg1991' then cropyear = 1991;
if year = 'zerogg1990' then cropyear = 1990;
if year = 'zerogg1989' then cropyear = 1989;

```



```

drop _name_ year;

run;

data d.ggd10(rename = (year2002=tengg2002 year2001=tengg2001
year2000=tengg2000 year1999=tengg1999 year1998=tengg1998 year1997=tengg1997
year1996=tengg1996 year1995=tengg1995 year1994=tengg1994 year1993=tengg1993
year1992=tengg1992 year1991=tengg1991 year1990=tengg1990
year1989=tengg1989));
set d.cggdWA;
if var2 = 10 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;

proc transpose data=d.ggd10 out=new3;
by county;
var tengg2002-tengg1989;
run;
data d.GGDtenWA (rename = (coll=GGD10));
set new3;
year = _name_;
if year = 'tengg2002' then cropyear = 2002;
if year = 'tengg2001' then cropyear = 2001;
if year = 'tengg2000' then cropyear = 2000;
if year = 'tengg1999' then cropyear = 1999;
if year = 'tengg1998' then cropyear = 1998;
if year = 'tengg1997' then cropyear = 1997;
if year = 'tengg1996' then cropyear = 1996;
if year = 'tengg1995' then cropyear = 1995;
if year = 'tengg1994' then cropyear = 1994;
if year = 'tengg1993' then cropyear = 1993;
if year = 'tengg1992' then cropyear = 1992;
if year = 'tengg1991' then cropyear = 1991;
if year = 'tengg1990' then cropyear = 1990;
if year = 'tengg1989' then cropyear = 1989;

drop _name_ year;

run;
data d.ggd20(rename = (year2002=twentygg2002 year2001=twentygg2001
year2000=twentygg2000 year1999=twentygg1999 year1998=twentygg1998
year1997=twentygg1997 year1996=twentygg1996 year1995=twentygg1995
year1994=twentygg1994 year1993=twentygg1993 year1992=twentygg1992
year1991=twentygg1991 year1990=twentygg1990 year1989=twentygg1989));
set d.cggdWA;
if var2 = 20 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd20 out=new4;
by county;
var twentygg2002-twentygg1989;
run;
data d.GGDtwentyWA (rename = (coll=GGD20));
set new4;
year = _name_;
if year = 'twentygg2002' then cropyear = 2002;

```

```

if year = 'twentygg2001' then cropyear = 2001;
if year = 'twentygg2000' then cropyear = 2000;
if year = 'twentygg1999' then cropyear = 1999;
if year = 'twentygg1998' then cropyear = 1998;
if year = 'twentygg1997' then cropyear = 1997;
if year = 'twentygg1996' then cropyear = 1996;
if year = 'twentygg1995' then cropyear = 1995;
if year = 'twentygg1994' then cropyear = 1994;
if year = 'twentygg1993' then cropyear = 1993;
if year = 'twentygg1992' then cropyear = 1992;
if year = 'twentygg1991' then cropyear = 1991;
if year = 'twentygg1990' then cropyear = 1990;
if year = 'twentygg1989' then cropyear = 1989;

drop _name_ year;

run;

data d.ggd33(rename = (year2002=thirtythreegg2002 year2001=thirtythreegg2001
year2000=thirtythreegg2000 year1999=thirtythreegg1999
year1998=thirtythreegg1998 year1997=thirtythreegg1997
year1996=thirtythreegg1996 year1995=thirtythreegg1995
year1994=thirtythreegg1994 year1993=thirtythreegg1993
year1992=thirtythreegg1992 year1991=thirtythreegg1991
year1990=thirtythreegg1990 year1989=thirtythreegg1989));
set d.cggdWA;
if var2 = 33 then gflag=1;else gflag=0;
if gflag=0 then delete;
run;
proc transpose data=d.ggd33 out=new5;
by county;
var thirtythreegg2002-thirtythreegg1989;
run;
data d.GGDthirty3WA (rename = (coll=GGD33));
set new5;
year = _name_;
if year = 'thirtythreegg2002' then cropyear = 2002;
if year = 'thirtythreegg2001' then cropyear = 2001;
if year = 'thirtythreegg2000' then cropyear = 2000;
if year = 'thirtythreegg1999' then cropyear = 1999;
if year = 'thirtythreegg1998' then cropyear = 1998;
if year = 'thirtythreegg1997' then cropyear = 1997;
if year = 'thirtythreegg1996' then cropyear = 1996;
if year = 'thirtythreegg1995' then cropyear = 1995;
if year = 'thirtythreegg1994' then cropyear = 1994;
if year = 'thirtythreegg1993' then cropyear = 1993;
if year = 'thirtythreegg1992' then cropyear = 1992;
if year = 'thirtythreegg1991' then cropyear = 1991;
if year = 'thirtythreegg1990' then cropyear = 1990;
if year = 'thirtythreegg1989' then cropyear = 1989;

drop _name_ year;

run;

proc sort data=d.WA;
by county cropyear;

```

```

run;
proc sort data=d.precipWA;
by county cropyear;
run;
proc sort data=d.ggdzeroWA;
by county cropyear;
run;
proc sort data=d.ggdtenWA;
by county cropyear;
run;
proc sort data=d.ggdtwentyWA;
by county cropyear;
run;
proc sort data=d.ggdthirty3WA;
by county cropyear;
run;
/*-----*/
-----*/
/*MERGE DATA HERE*/
data try2;
merge d.WA d.precipWA d.ggdzeroWA d.ggdtenWA d.ggdtwentyWA d.ggdthirty3WA;
by county cropyear;
run;
/*This deletes counties not used in the analysis, to add additional counties
go back up to where counties are listed*/
data d.mergedWA;
set try2;
if ggd10 =. then delete;
if idnumber= . then delete;
if idnumber= 0 then delete;
run;

data d.all;
set d.mergedWA d.mergedOk d.mergedMT d.mergedNE d.mergedIA;
run;

/*From here I exported the data to STATA*/
/*Export the data using .csv format*/
/*In STATA import the data using "Import ASCII data " remember to search for
.csv files*/
/*Remember to open one of the five states do files and increase memory and
mat size when importing data*/
/*1,260,380 observations*/

/*STOP HERE-----*/
-----*/

*the following code is for stata, it tests the hypotheses
clear
*-----HYPOTHESIS #1 (Producer Return)-----
-----
set memory 9000m
set matsize 500

use "H:\Dissertation\Crop Insurance Paper\Crop Insurance Paper\C.I.
DATA\allregions.dta", clear

```

```

*Generage dummy variables for states
gen IOWA = (state==19)
gen OKLAHOMA = (state==40)
gen NEBRASKA = (state==31)
gen MONTANA = (state==30)
gen WASHINGTON = (state==53)

*this CODE IS FOR IOWA
drop if IOWA ==0
*delete indemnity outliers
drop if indem>400
* drop unesessary variables
drop type6 type7 annual7 type8 annual8 type9 annual9 type10 annual10
dateplanted
drop lossguarantee indemnity flagindem sflag

*Generate dummy variables for additional counties
gen county33 = (county==33)
gen county41 = (county==41)
gen county47 = (county==47)
gen county79 = (county==79)
gen county91 = (county==91)
gen county93 = (county==93)
gen county95 = (county==95)
gen county13 = (county==13)
gen county15 = (county==15)
gen county21 = (county==21)
gen county195 = (county==195)
gen county185 = (county==185)
gen county171 = (county==171)
gen county167 = (county==167)
gen county163 = (county==163)
gen county19 = (county==19)
gen county35 = (county==35)
gen county49 = (county==49)
gen county27 = (county==27)
gen county29 = (county==29)
gen county45 = (county==45)
gen county55 = (county==55)
gen county59 = (county==59)
gen county73 = (county==73)
keep if county==33 | county==41 | county==79 | county==93 | county==95 |
county==13 | county==195 | county==185 | county==171 | county==163 |
county==19 | county==35 | county==49 | county==27| county==29 | county==45 |
county==55 | county==59

drop c16 c41 c43 c81

*stem cropcode

*gen wheat = (cropcode==11)
*gen barley = (cropcode==91)
*gen cotton = (cropcode==21)
*gen Sorghum = (cropcode==51)
gen corn =(cropcode==41)

```

```

*gen scorn = (cropcode==43)
gen soybeans =(cropcode==81)
*gen oats = (cropcode==16)
*gen dbeans = (cropcode==47)
*gen sflower = (cropcode==78)
gen canola = (cropcode==16)
drop if cropcode==11 | cropcode==91 | cropcode==51 | cropcode==42 |
cropcode==33 | cropcode==43

*new, use only for checking farm numbers

gen revI=approvyld/10*newreportedacres*insuredshare

sort policynum idnumber
*keep if insuredshare > .30

keep if corn==1
keep if cropyear==2002
collapse county (sum) revI, by(idnumber)
keep if revI > 5500
sort county idnumber

*CAT coverage code
replace approvyld=approvyld/10 if approvyld >100
gen revI=approvyld*newreportedacres*insuredshare
gen CAT= (coveragelevel==.5)*(producerpremium==0)
sort policynum idnumber

keep if corn==1
keep if cropyear==2002
collapse county (sum) revI (mean) CAT, by(idnumber)

keep if CAT ==1

sort county idnumber
*Done CAT code

count if county==33
count if county==55
count if county==195
count if county==19
count if county==29
count if county==27
count if county==59
count if county==95

*stop new

*to check for only wheat corn soybeans canola observations:
*hist cropcode

*stem plancd
*hist plancd
*this keeps the most used plan codes
keep if plancd==25 | plancd == 90 | plancd==42 | plancd==44

```

```
drop if cropyear==1989 | cropyear==1990 | cropyear==1991 | cropyear==1992 |
cropyear==1993
```

```
*stem practice
*hist practice
* practice ==002 is irrigation
* practice ==003 is non-irrigation
* practice ==004 is continuous cropping
* practice ==005 is summerfallow
keep if practice ==003
```

```
*stem coveragelevel
gen c55 = (coveragelevel>=.54) & (coveragelevel<=.56)
```

```
keep if indem >= 0
```

```
destring typecd, replace force
```

```
*stem typecd
*typecd 15 is durum wheat
keep if typecd==16 | typecd==997
gen type16=(typecd==016)
gen type29=(typecd==029)
gen type997=(typecd==997)
```

```
gen t4cg=(corn==1)*(t4)*(type16)
gen t3cg=(corn==1)*(t3)*(type16)
gen t2cg=(corn==1)*(t2)*(type16)
gen t1cg=(corn==1)*(t1)*(type16)
gen TIcg=(corn==1)*(ti)*(type16)
gen THcg=(corn==1)*(th)*(type16)
gen TTcg=(corn==1)*(tt)*(type16)
```

```
gen t4s=(soybeans==1)*(t4)*(type997)
gen t3s=(soybeans==1)*(t3)*(type997)
gen t2s=(soybeans==1)*(t2)*(type997)
gen t1s=(soybeans==1)*(t1)*(type997)
gen TIs=(soybeans==1)*(ti)*(type997)
gen THs=(soybeans==1)*(th)*(type997)
gen TTs=(soybeans==1)*(tt)*(type997)
```

```
gen t4o=(canola==1)*(t4)
gen t3o=(canola==1)*(t3)
gen t2o=(canola==1)*(t2)
gen t1o=(canola==1)*(t1)
gen TIo=(canola==1)*(ti)
gen THo=(canola==1)*(th)
gen TTo=(canola==1)*(tt)
```

*Generate Crop Coverage Level Dummy Variables

```
gen c55c= (corn==1)*(c55==1)*(type16)
gen c60c= (corn==1)*(c6==1)*(type16)
gen c65c= (corn==1)*(c65==1)*(type16)
gen c70c= (corn==1)*(c7==1)*(type16)
gen c75c= (corn==1)*(c75==1)*(type16)
gen c80c= (corn==1)*(c8==1)*(type16)
gen c85c= (corn==1)*(c85==1)*(type16)
```

```
gen c55s= (soybeans==1)*(c55==1)*(type997)
gen c60s= (soybeans==1)*(c6==1)*(type997)
gen c65s= (soybeans==1)*(c65==1)*(type997)
gen c70s= (soybeans==1)*(c7==1)*(type997)
gen c75s= (soybeans==1)*(c75==1)*(type997)
gen c80s= (soybeans==1)*(c8==1)*(type997)
gen c85s= (soybeans==1)*(c85==1)*(type997)
```

```
gen c55o= (canola==1)*(c55==1)
gen c60o= (canola==1)*(c6==1)
gen c65o= (canola==1)*(c65==1)
gen c70o= (canola==1)*(c7==1)
gen c75o= (canola==1)*(c75==1)
gen c80o= (canola==1)*(c8==1)
gen c85o= (canola==1)*(c85==1)
```

```
gen p42c = (corn==1)*(plan42)*(type16)
gen p44c = (corn==1)*(plan44)*(type16)
gen p25c = (corn==1)*(plan25)*(type16)
```

```
gen p42s = (soybeans==1)*(plan42)*(type997)
gen p44s = (soybeans==1)*(plan44)*(type997)
gen p25s = (soybeans==1)*(plan25)*(type997)
```

```
gen p42o = (canola==1)*(plan42)
gen p44o = (canola==1)*(plan44)
gen p25o = (canola==1)*(plan25)
```

```
gen Preturn=(newindem-producerpremium)/newreportedacres
```

```
reg Preturn cy95 cy96 cy97 cy98 cy99 cy00 cy01 corn t4cg t3cg t2cg t1cg TIcg
TTcg t4s t3s t2s t1s TIs TTs t4o t3o t2o t1o TIo TTo c55c c60c c65c c70c c75c
c80c c85c c55s c60s c65s c70s c75s c80s c85s c55o c60o c65o c70o c75o c80o
c85o p42c p44c p25c p42s p44s p25s p42o p44o p25o plan44 county33 county41
county79 county93 county95 county13 county195 county185 county171 county19
county35 county49 county27 county29 county45 county55 county59 ,
cluster(idnumber)
```

* Dropped ggd20 and Canola due to high VIF.

```

*predict resid, residuals
*predict yhat, xb
*twoway (scatter resid yhat)
*pnorm resid
*swilk resid
*sktest resid
*summarize shiftpreturnds
vif

```

```

gen ind= (newindem)
replace ind=1 if ind >.5

```

```

*-----HYPOTHESIS #1 (Producer Return)-----
-----

```

```

gen Treturn=(newindem-totalpremium)/newreportedacres

```

```

reg Treturn cy95 cy96 cy97 cy98 cy99 cy00 cy01 corn t4cg t3cg t2cg t1cg TIcg
TTcg t4s t3s t2s t1s TIs TTs t4o t3o t2o t1o TIo TTo c55c c60c c65c c70c c75c
c80c c85c c55s c60s c65s c70s c75s c80s c85s c55o c60o c65o c70o c75o c80o
c85o p42c p44c p25c p42s p44s p25s p42o p44o p25o plan44 county33 county41
county79 county93 county95 county13 county195 county185 county171 county19
county35 county49 county27 county29 county45 county55 county59 ,
cluster(idnumber)

```

```

*predict resid, residuals
*predict yhat, xb
*twoway (scatter resid yhat)
*pnorm resid

```

```

vif

```

```

*-----HYPOTHESIS #2 (Subsidy& Coverage Level)-----
-----

```

```

*-----
-----

```

```

gen Pretreturn=(newindem-producerpremium)/newreportedacres

```

```

reg Pretreturn cy95 cy96 cy97 cy98 cy99 cy00 cy01 corn t4cg t3cg t2cg t1cg TIcg
TTcg t4s t3s t2s t1s TIs TTs t4o t3o t2o t1o TIo TTo c55c c60c c65c c70c c75c
c80c c85c c55s c60s c65s c70s c75s c80s c85s c55o c60o c65o c70o c75o c80o
c85o p42c p44c p25c p42s p44s p25s p42o p44o p25o plan44 county33 county41
county79 county93 county95 county13 county195 county185 county171 county19
county35 county49 county27 county29 county45 county55 county59 ,
est store Producer

```

```

gen Treturn=(newindem-totalpremium)/newreportedacres

```



```
reg Treturn cy95 cy96 cy97 cy98 cy99 cy00 cy01 corn t4cg t3cg t2cg t1cg TICg
TTcg t4s t3s t2s t1s TIs TTs t4o t3o t2o t1o TIo TTo c55c c60c c65c c70c c75c
c80c c85c c55s c60s c65s c70s c75s c80s c85s c55o c60o c65o c70o c75o c80o
c85o p42c p44c p25c p42s p44s p25s p42o p44o p25o plan44 county33 county41
county79 county93 county95 county13 county195 county185 county171 county19
county35 county49 county27 county29 county45 county55 county59 ,
est store Total
```

```
suest Total Producer , cluster(idnumber)
```

```
*Wald Tests (T-yields)
```

```
test [Producer_mean]TIs=[Total_mean]TIs,
test [Producer_mean]TTs=[Total_mean]TTs,
```

```
test [Producer_mean]t1cg=[Total_mean]t1cg,
test [Producer_mean]TICg=[Total_mean]TICg,
```

```
test [Producer_mean]t1o=[Total_mean]t1o,
test [Producer_mean]TIO=[Total_mean]TIO,
```

```
*Wald Tests (Coverage Level & Insurance types)
```

```
test [Producer_mean]p42c=[Total_mean]p42c,
test [Producer_mean]p42c=[Total_mean]p42c,
```

```
*Coverage Level Wald Tests
```

```
*Corn
```

```
test [Producer_mean]c55c=[Producer_mean]c60c,
test [Producer_mean]c60c=[Producer_mean]c65c,
test [Producer_mean]c65c=[Producer_mean]c70c,
test [Producer_mean]c70c=[Producer_mean]c75c,
test [Producer_mean]c75c=[Producer_mean]c80c,
test [Producer_mean]c80c=[Producer_mean]c85c,
```

```
*Soybeans
```

```
test [Producer_mean]c55s=[Producer_mean]c60s,
test [Producer_mean]c60s=[Producer_mean]c65s,
test [Producer_mean]c65s=[Producer_mean]c70s,
test [Producer_mean]c70s=[Producer_mean]c75s,
test [Producer_mean]c75s=[Producer_mean]c80s,
test [Producer_mean]c80s=[Producer_mean]c85s,
```

```
*Other
```

```
test [Producer_mean]c55o=[Producer_mean]c60o,
test [Producer_mean]c60o=[Producer_mean]c65o,
test [Producer_mean]c65o=[Producer_mean]c70o,
test [Producer_mean]c70o=[Producer_mean]c75o,
test [Producer_mean]c75o=[Producer_mean]c80o,
test [Producer_mean]c80o=[Producer_mean]c85o,
```

COMPUTER CODE FOR CHAPTER THREE
CROP INSURANCE, LAND ALLOCATION, AND THE ENVIRONMENT

Appendix B

COMPUTER CODE FOR CHAPTER THREE

CROP INSURANCE, LAND ALLOCATION, AND THE ENVIRONMENT

```
/*START HERE for Crop Insurance, Land Allocation, and Environment Paper
Analysis*/
/*INPUT state code below here*/
/* STATE=08 IS COLORADO, STATE=53 IS WASHINGTON, STATE = 38 IS NORTH DAKOTA,
AND STATE=19 IOWA*/
data d.mttype0011;
    set d.type0011;
if state= 08 or state= 53 or state=38 or state=19 then output;
run;
data d.mttype0015;
    set d.type0015;
if state= 08 or state= 53 or state=38 or state=19 then output;
run;
data d.mttype0021;
    set d.type0021;
if state= 08 or state= 53 or state=38 or state=19 then output;
run;
data d.mttype0010;
    set d.type0010;
if state= 08 or state= 53 or state=38 or state=19 then output;
run;
proc sort data= d.mttype0015;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typed practice approvyld;
run;
proc sort data= d.mttype0011;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typed practice yield;
run;
data d.mttype0011;
    set d.mttype0011;
    approvyld=yield * 10;
run;
proc sort data= d.mttype0021;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typed practice ;
run;
data d.mttype0021;
    set d.mttype0021; drop writtenagreementnumber;
run;
data d.mttype0011;
    set d.mttype0011; drop writtenagreementnumber and best;
run;
data d.mttype0011; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mttype0011;
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
```

```

    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
        if l_policynum=policynum and l_cropcode=cropcode
            and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
            and l_practice=practice then flag=1;
        else flag=0; /*find duplicate type15 observations*/
run;
data d.mttype0021; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mttype0021;
    l_2policynum= Lag(policynum);
    l_2cropcode= Lag(cropcode);
    l_2plancd= Lag(plancd);
    l_2county= Lag(county);
    l_2unitnum= lag(unitnum);
    l_2typecd= lag(typecd);
    l_2practice= lag(practice);
        if l_2policynum=policynum and l_2cropcode=cropcode
            and l_2unitnum=unitnum and l_2plancd=plancd and l_2county= county
and l_2typecd=typecd
            and l_2practice=practice then flag2=1;
        else flag2=0; /*find duplicate type15 observations*/
run;
data d.mt00210011;
    merge d.mttype0011 d.mttype0021;
    by ORG state company policynum cropyear cropcode plancd county unitnum
typecd practice ;
run;

data d.mt00210011; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mt00210011;
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
        if l_policynum=policynum and l_cropcode=cropcode
            and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
            and l_practice=practice then flag1=1;
        else flag1=0; /*find duplicate type15 observations*/
run;
data d.mt00210011; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mt00210011;
    l_3policynum= Lag(policynum);
    l_3cropcode= Lag(cropcode);
    l_3plancd= Lag(plancd);
    l_3county= Lag(county);
    l_3unitnum= lag(unitnum);

```

```

        l_3typecd= lag(typecd);
        l_3practice= lag(practice);
            if l_3policynum=policynum and l_3cropcode=cropcode
            and l_3unitnum=unitnum and l_3plancd=plancd and l_3county= county
and l_3typecd=typecd
            and l_3practice=practice then flag3=1;
            else flag3=0; /*find duplicate type15 observations*/
run;
data d.mt00210011;
    set d.mt00210011;
    if flag = 0 and flag1 = 1 then delete;
run;
data d.mt00210011;
    set d.mt00210011;
    if flag2 = 0 and flag3 = 1 then delete;
run;
data d.mt00210011;
    set d.mt00210011;
        recordnum15 = type15recordnumber;
run;

proc sort data= d.mt00210011;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typecd practice approvyld ;
run;

data d.mt0015;
    set d.mttype0015;
        recordnum15 = recordnum;
run;
data d.mt0015;
    set d.mt0015;
        l_annual9=lag(annual9);
        l_annual10=lag(annual10);
        l_policynum= Lag(policynum);
        l_cropcode= Lag(cropcode);
        l_plancd= Lag(plancd);
        l_county= Lag(county);
        l_unitnum= lag(unitnum);
        l_typecd= lag(typecd);
        l_practice= lag(practice);
            if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
            and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
            and l_practice=practice then flag=1;
            else flag=0; /*find duplicate type15 observations*/
run;
data d.mt00210011;
    set d.mt00210011;
        l_2policynum= Lag(policynum);
        l_2cropcode= Lag(cropcode);
        l_2plancd= Lag(plancd);
        l_2county= Lag(county);
        l_2unitnum= lag(unitnum);
        l_2typecd= lag(typecd);
        l_2practice= lag(practice);

```

```

        if l_2policynum=policynum and l_2cropcode=cropcode
        and l_2unitnum=unitnum and l_2plancd=plancd and l_2county= county
and l_2typecd=typecd
        and l_2practice=practice then flag2=1;
        else flag2=0; /*find duplicate type15 observations*/
run;
proc sort data= d.mt0015;
    by ORG state company policynum cropyear cropcode plancd county
unitnum typecd practice ;
run;
data d.mergedmt00A;
    merge d.mt0015 d.mt00210011;
    by ORG state company policynum cropyear cropcode plancd county unitnum
typecd practice ;
run;
data d.mergedmt00A;
    set d.mergedmt00A;
    l_annual9=lag(annual9);
    l_annual10=lag(annual10);
    l_policynum= Lag(policynum);
    l_cropcode= Lag(cropcode);
    l_plancd= Lag(plancd);
    l_county= Lag(county);
    l_unitnum= lag(unitnum);
    l_typecd= lag(typecd);
    l_practice= lag(practice);
    if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
    and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
    and l_practice=practice then flag1=1;
    else flag1=0; /*find duplicate type15 observations*/
run;
data d.mergedmt00A; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mergedmt00A;
    l_3policynum= Lag(policynum);
    l_3cropcode= Lag(cropcode);
    l_3plancd= Lag(plancd);
    l_3county= Lag(county);
    l_3unitnum= lag(unitnum);
    l_3typecd= lag(typecd);
    l_3practice= lag(practice);
    if l_3policynum=policynum and l_3cropcode=cropcode
    and l_3unitnum=unitnum and l_3plancd=plancd and l_3county= county
and l_3typecd=typecd
    and l_3practice=practice then flag3=1;
    else flag3=0; /*find duplicate type15 observations*/
run;
data d.Tamergedmt00A;
    set d.mergedmt00A;
    if flag = 0 and flag1 = 1 then delete;
run;
data d.Tmergedmt00A;
    set d.tamergedmt00A;
    if flag2 = 0 and flag3 = 1 then delete;
run;

```

```

proc sort data= d.mttype0010;
    by   ORG state company policynum cropyear ;
run;
data d.mergedmt00;
    merge d.mttype0010 d.Tmergedmt00A;
    by ORG state company policynum cropyear;
run;
/*data d.Amergedmt00;
    set d.mergedmt00;
        drop tyldmaparea ncsyld agrmnttyp agrmntnum agrmntprocflag
m14revflag yldindicator transyld
        fsayld prevapprovyld rev1 rev2 rev3 rev4 rev5 rev6
rev7 rev8 rev9 rev10 ratestate
        ratecounty farmserial yldlimflag bypass yrsactualref
yldindx avgyld prevlimflag
        snn rateclass maparea crushdistrict referencecropyear
writtenagreementtype
        writtenagreementprocessingflag guaranteedreductionflag
yield dollaramountofinsurance
        numeroftrees guaranteeperacre
guaranteedreductionfactor totalguarantee contractprice
        liability priceelectionfactor yieldconversionfactor
basepremiumprate
        preliminarybaserate loadedpremiumperacre
rateclassoption experiencefactor
        premiumratesurcharge unitpremiumadjustment
ipcountyaverageyield rawholefarmdiscount
        priceindicator subsidy additionalsubsidy
additionalsubsidyflag satatesubsidy
        statesubsidyflag privatepolicy intendedacorage
seedcompany
        rateseed farmserialnumber numberofsections seedcycle
m14review ceocoveragelevel
        efapremiumdiscount efadiscountflag historicalpackout
prorationfactor rateyield
        claimnumber stagecode allpercentreplantpaymentflag
        grppaymentcalulation sugarfactor auditcorrection
secondarymonth primaryprecent secondarycause
        simplifiedclaim farmserianumber
liabilityadjustmentfactor valiescrowflag m14reviewflag
        ceoindemnityfactor lossadjusterssignaturedate
noticeoflossdate primarydateofdamage
        secondarydateofdamage commonoptioncodes;
run;*/
data d.Amergedmt00; /*locates double type15entries when merging type 11 and
type 15*/
    set d.mergedmt00;
        l_annual9=lag(annual9);
        l_annual10=lag(annual10);
        l_policynum= Lag(policynum);
        l_cropcode= Lag(cropcode);
        l_plancd= Lag(plancd);
        l_county= Lag(county);
        l_unitnum= lag(unitnum);
        l_typecd= lag(typecd);
        l_practice= lag(practice);

```

```

        if l_annual9=annual9 and l_annual10=annual10 and
l_policynum=policynum and l_cropcode=cropcode
        and l_unitnum=unitnum and l_plancd=plancd and l_county= county
and l_typecd=typecd
        and l_practice=practice then flag=1;
        else flag=0; /*find duplicate type15 observations*/
run;
data d.allregionsmerged00;
    set d.Amergedmt00;
    if flag = 1 then delete;

run;

```

*The following code breaks the merged code into two separate usable files.

```

options compress=yes;
libname e 'H:\Dissertation\Crop Insurance and Environment\C.I.E. DATA' ;

data e.Allregions;
    set e.allregionsmerged02 e.allregionsmerged01 e.allregionsmerged00
e.allregionsmerged99 e.allregionsmerged98 e.allregionsmerged97
e.allregionsmerged96 e.allregionsmerged95 e.allregionsmerged94;
run;
proc sort data= e.allregions;by idnumber cropyear;run;
data all;
    set e.allregions;
    if policynum < 5 then delete;
    if dateplanted < 1 then delete;
    if dateplanted = . then delete;
run;
data all;
    set all;
newflag=1;
run;
data all1;
set all;
drop branchoffice recordnumber idtype entitytype employee m14reviewflag
cvrgflag recordnum tyldmaparea ncsyld agrmntnum agrmnttyp agrmntprocflag
m14revflag
yldindicator year1 type1 annual1 acres1 rev1 year2 type2 annual2 acres2 rev2
year3 type3 annual3 acres3 rev3 year4 type4 annual4 acres4 rev4
year5 type5 annual5 acres5 rev5 year6 type6 annual6 acres6 rev6 year7 type7
annual7 acres7 rev7 year8 type8 annual8 acres8 rev8
yldlimflag bypass yearsactualref yldindx option rateyld avgyld revlimflag
l_annual9 l_annual10 l_policynum l_cropcode l_plancd l_county l_unitnum
l_typecd l_practice flag type15recordnum snn rateclass maparea crushdistrict
referencecropyear writtenagreementtype writtenagreementprocessingflag
guaranteereductionflag
dollaramountofinsurance ratestate ratecounty farmserial yrsactualref
prevlimflag type15recordnumber writtenagreementtype numberoftrees
guaranteereductionfactor priceelectionfactor yieldconversionfactor
preliminarybaserate loadedpremiumperacre commonoptioncodes rateclassoption
premiumratesurcharge

```



```

unitpremiumadjustment RAfallharvestpriceoption IPcountyaverageyield
rawholefarmdiscount priceindicator additionalssubsidy additionalssubsidyflag
satatesubsidy statesubsidyflag privatepolicy intendedacorage seedcompany
farmserialnumber numberofsections seedcycle m14review efadiscountflag
historicalpackout
prorationfactor rateyield Claimnumber TYPE11recordnumber stagecode
Allpercentreplantpaymentflag stageguaranteeperacre simplifiedclaim
farmserianumber valiescrowflag
ceoindemnityfactor lossadjustersignaturedate noticeoflossdate l_2policynum
l_2cropcode l_2plancl l_2county l_2unitnum l_2typed l_2practice flag2 flag1
l_3policynum l_3cropcode l_3plancl l_3county l_3unitnum l_3typed l_3practice
recordnum15 flag3 ;
run;
proc sort data= all1; by ORG state company idnumber cropyear cropcode plancl
county unitnum typed practice; run;
data e.panelCOND;
set e.panell1;
if state=08 or state=38 then output;
run;

data e.panelWAIA;
set e.panell1;
if state =53 or state=19 then output;
run;

/*STOP HERE-----*/

```

*The following STATA code is for analyzing Colorado, all three other states code are similar.

```

*-----
*-----
*-----

clear

set memory 500m
set matsize 500

*---THIS CODE IDENTIFIES PRODUCERS WHO PARTICIPATED ALL YEARS-----
-----

use "H:\Dissertation\Crop Insurance and Environment\panelcond.dta ", clear
compress
*Generage dummy variables for states
gen COLORADO = (state==8)
gen NORTHDAKOTA = (state==38)
gen WASHINGTON = (state==53)
gen IOWA = (state==19)
drop if cropyear==1994
*this CODE IS FOR COLORADO
drop if COLORADO == 0
drop rectype company approvyld prevapprovyld year9 type9 annual9 acres9 rev9
priceelectionamount subsidy rateseed ceocoveragelevel efapremiumdiscount

```

```

sort state idnumber cropyear crocode plancd county typed practice
gen acres = reportedacres/100
gen nyield = yield
sort idnumber cropyear
gen cropyearlag = cropyear[_n-1]
gen fcropyear = 0
replace fcropyear=1 if cropyearlag==cropyear
drop if fcropyear==1
collapse (sum) cropyear, by (idnumber)
*We need to identify producers who used Add all years 1994 + 1995 + ....=
15988.
*Drop all producers who did not participate 5 of 8 years
*drop if cropyear<=9984
*Drop all producers who did not participate 6 of 8 years
drop if cropyear <=11985
*Drop all producer who did not participate 7 of 8 years
*drop if cropyear <=13986
*so we drop all idnumbers who did not participate all years
*drop if cropyear <=15987
gen cropflag=1
drop cropyear

sort idnumber
save file1, replace

use "H:\Dissertation\Crop Insurance and Environment\panelcond.dta ", clear
compress
*Generate dummy variables for states
gen COLORADO = (state==8)
gen NORTHDAKOTA = (state==38)
gen WASHINGTON = (state==53)
gen IOWA = (state==19)
drop if cropyear==1994
*this CODE IS FOR COLORADO
drop if COLORADO == 0
drop retype company approvyld prevapprovyld year9 type9 annual9 acres9 rev9
priceelectionamount subsidy rateseed ceocoveragelevel efapremiumdiscount
sort state idnumber cropyear crocode plancd county typed practice

sort idnumber
merge idnumber using file1

keep if cropflag== 1

sort state idnumber crocode plancd county typed practice cropyear

destring typed, replace force

*Identify Catastrophic Coverage
replace coveragelevel = .25 if coveragelevel ==.5 & producerpremium == 0

sort idnumber cropyear

*stem crocode

*Identify the other category
*47==drybeans, 91==barley

```

```

gen other=1 if cropcode == 47 | cropcode == 91
replace cropcode = 1 if other ==1

*replace total producer premium with per acre producer premium.
gen acres=reportedacres/100
replace producerpremium = producerpremium/acres
replace indemnity = indemnity/acres

*Save data so it can be used in the next step
save "G:\panelcondlco.dta", replace

*--END SUM EACH FARMS ACRES-----
-----

*--THIS CODE DROPS PRODUCERS WITH A coveragelevel THAT is not possible-----
-----

use "G:\panelcondlco.dta ", clear
compress

sort idnumber
drop _merge
*drop producers who have coveragelevels below .2
by idnumber: gen cov1 = coveragelevel < .2

*drop producers who grew corn silage
by idnumber: gen corn1 = cropcode == 41 & typedc == 26

*drop producers who grew durum wheat
by idnumber :gen dur1 = cropcode == 11 & typedc == 15

gen covcorn = cov1 ==1 | corn1 ==1 | dur1==1

save file, replace

use "G:\panelcondlco.dta ", clear
compress
drop _merge
sort idnumber
merge idnumber using file
drop _merge
*Drop all idnumbers that dont use the specified crop mix in 1995.
sort idnumber

drop if covcorn ==1
*Find ratio of SW to WW acres

gen wwacres = (typedc==11)*(acres)
gen swacres = (typedc==12)*(acres)
gen wheatacres = (typedc==11 | typedc==12)*(acres)
gen sumacres = sum(wheatacres)
gen sumwwacres = sum(wwacres)
gen sumswacres = sum(swacres)

save "G:\panelcond6aco.dta", replace
*---END COD FOR DORPPING PRODUCERS

```

```
*---THIS CODE SUMS EACH FARMS ACRES FOR EACH CROP TYPE (I.E., IT SUMS THE
UNITS)-----
```

```
-----
use "G:\panelcond6aco.dta ", clear
compress
```

```
sort state idnumber cropyear cropcode plancd typecd practice
```

```
collapse (sum) acres (mean) indemnity (mean) producerpremium coveragelevel
plancd, by (state idnumber cropyear cropcode)
```

```
save file, replace
```

```
use "G:\panelcond6aco.dta ", clear
compress
*Generage dummy variables for states
```

```
*this CODE IS FOR COLORADO
```

```
drop if COLORADO == 0
```

```
sort state idnumber cropyear cropcode plancd practice
```

```
collapse (mean) yield, by (state idnumber cropyear cropcode )
```

```
merge state idnumber cropyear cropcode using file
```

```
drop _merge
```

```
*Save data so it can be used in the next step
```

```
save "G:\panelcond2co.dta", replace
```

```
*-END SUM EACH FARMS ACRES-----
```

```
-----
use "G:\panelcond2co.dta ", clear
compress
```

```
sort idnumber
```

```
by idnumber: gen fix = plancd < 24.99
```

```
by idnumber: gen fixa = plancd >25.1 & plancd < 41.99
```

```
by idnumber: gen fixb = plancd >42.1 & plancd < 43.99
```

```
by idnumber: gen fixc = plancd > 44.1 & plancd < 89.99
```

```
by idnumber: gen fix1 = coveragelevel > .265 & coveragelevel < .495
```

```
by idnumber: gen fix2 = coveragelevel > .515 & coveragelevel < .545
```

```
by idnumber: gen fix3 = coveragelevel > .565 & coveragelevel < .595
```

```
by idnumber: gen fix4 = coveragelevel > .615 & coveragelevel < .645
```

```
by idnumber: gen fix5 = coveragelevel > .655 & coveragelevel < .695
```

```
by idnumber: gen fix6 = coveragelevel > .715 & coveragelevel < .745
```

```
by idnumber: gen fix7 = coveragelevel > .765 & coveragelevel < .795
```

```
by idnumber: gen fix8 = coveragelevel > .815 & coveragelevel < .845
```

```
by idnumber: gen fix9 = coveragelevel > .865
```

```
by idnumber: gen fix10 = yield==0
```

```
gen Afix = fix == 1 | fixa==1 | fixb==1 | fixc==1 | fix1==1 | fix2==2 |
```

```
fix3==3 | fix4==1 | fix5==1 | fix6==1 | fix7==1 | fix8==1 | fix9==1 |
```

```
fix10==1
```

```
drop fix fixa fixb fixc fix1 fix2 fix3 fix4 fix5 fix6 fix7 fix8 fix9 fix10
```

```
keep if Afix==1
```

```
save file, replace
```

```
use "G:\panelcond2co.dta ", clear
compress
```

```

sort idnumber
merge idnumber using file
drop _merge

sort idnumber

drop if Afix==1
save "G:\panelcond2aco.dta", replace

*---THIS CODE SUMS  ACRES of EACH FARM for EACH YEAR-----
-----
use "G:\panelcond2aco.dta ", clear
compress

sort state idnumber cropyear

gen nacres = acres
collapse (sum) nacres, by (state idnumber cropyear )

sort state idnumber cropyear
save file, replace

use "G:\panelcond2aco.dta ", clear
compress

sort state idnumber cropyear

merge state idnumber cropyear using file

save "G:\panelcond3co.dta", replace
*--END SUM ACRES OF EACH FARM FOR EACH YEAR-----
-----

*--THIS CODE IDENTIFIES FARMS THAT ATLEAST USED THE FOLLOWING CROPS IN all
years-----

* WHEAT CROPCODE 11

* I will use producers who used these crops plus other crops in the analysis

use "G:\panelcond3co.dta ", clear
compress

sort idnumber

by idnumber: gen allcrop =  cropcode == 11 | cropcode==41
keep if allcrop == 1

drop _merge
save file, replace

use "G:\panelcond3co.dta ", clear
compress

```

```

drop _merge
sort idnumber
merge idnumber using file
drop _merge

sort idnumber

keep if allcrop == 1
drop allcrop
save "G:\panelcond4co.dta", replace
*--END IDENTIFYING FARMS THAT USED THE SPECIFIED CROP MIX-----
-----

*--THIS CODE DROPS PRODUCERS WITH A CROP THAT WAS NOT USED OFTEN-----
-----

use "G:\panelcond4co.dta ", clear
compress

sort idnumber

* every producer who uses a cropcode in crop1 will be kept
by idnumber: gen crop1 = cropcode == 78 | cropcode == 11 | cropcode == 41 |
cropcode==1
keep if crop1 == 0

save file, replace

use "G:\panelcond4co.dta ", clear
compress

sort idnumber
merge idnumber using file
drop _merge
*Drop all idnumbers that dont use the specified crop mix in 1995.
sort idnumber

drop if crop1 ==0
*stem cropcode

save "G:\panelcond5co.dta", replace
*--END CODE FOR DROPPING PRODUCERS WHO USED A CROP THAT WAS NOT USED OFTEN---
-----

*--THIS CODE MERGERS PRICE DATA-----
use "G:\pricesCO.dta", replace
compress

sort cropyear
save file, replace

use "G:\panelcond5co.dta ", clear
compress
sort cropyear

merge cropyear using file

```

```

sort idnumber cropyear

drop _merge

save "G:\panelcond9opipvarco.dta", replace
*--END MERGING CODE OF CROP INSURANCE AND INPUT PRICE INDEX

use "G:\panelcond9opipvarco.dta", replace
compress
drop if state==.

*replace yield == 0 with a really small yield.
replace yield =.1 if yield == 0

gen cat = (coveragelevel==.25)
gen ins = (cat==0)
gen cshare= acres/nacres

*Create total product
gen tayield = nacres*yield

*Normalize all prices by index of factor prices paid
gen npwheat = (ypwheat/nd)/tayield
gen npcorn = (ypcorn/nd)/tayield
gen npsun = (ypsun/nd)/tayield
gen npother = (yptother/nd)/tayield

gen pprem = (producerpremium/nd)/tayield

gen nvwheat = (vwheat/nd)/tayield
gen nvcorn = (vcorn/nd)/tayield
gen nvsun = (vsun/nd)/tayield
gen nvother = (vother/nd)/tayield

*gen nvcornwheat = (cvcornwheat/nd)/tayield
*gen ncvwheatother = (cvwheatother/nd)/tayield
*gen nvcornother = (cvcornother/nd)/tayield
*drop if nvcornother==.

*generate acres and crop type
gen Swheat = (cropcode==11)*(cshare)
gen Scorn = (cropcode==41)*(cshare)
gen Ssun = (cropcode==78)*(cshare)
gen Sother = (cropcode==1)*(cshare)

*generate yield and crop type
gen wheatyield = (cropcode==11)*(yield)
gen cornyield = (cropcode==41)*(yield)
gen sunyield = (cropcode==78)*(yield)
gen otheryield = (cropcode==1)*(yield)

drop if wheatyield >= 200
drop if cornyield >= 600
save "G:\panelcond10opipvarco.dta", replace

*--THIS CODE DROPS PRODUCERS WITHOUT A COMPLETE SHARE FOR EACH YEAR-----
-----

```

```

use "G:\panelcond10opipvarco.dta", clear
compress

sort idnumber

collapse (sum) cshare, by (idnumber)

drop if cshare <6

gen share1 = 1

save file, replace

use "G:\panelcond10opipvarco.dta", clear
compress

sort idnumber
merge idnumber using file
drop _merge
*Drop all idnumber that do not have a share1=1
drop if npwheat == .
drop if share1 ==.
gen time = cropyear - 1994
gen RHC = (coveragelevel >= .74)*(plancd==44 | plancd==25 | plancd==42 )
gen RLC = (coveragelevel <= .74 & coveragelevel >=.47)*(plancd==44 |
plancd==25 | plancd==42 )
gen YHC = (coveragelevel >= .74)*(plancd==90 )
gen YLC = (coveragelevel <= .74 & coveragelevel >=.47)*(plancd==90 )

sum npwheat npcorn npsun npother nvwheat nvcorn nvsun nvother pprem
*use info from sum to normalize variables:
*new var = (var - var min)/(var max- var min)
gen nnpwheat = (npwheat - .000000000851)/(.18436-.000000000851)
gen nnpcorn = (npcorn - .00000000606)/(.1535-.00000000606)
gen nnpsun = (npsun - .000000000243)/(.00714-.000000000243)
gen nnpother = (npother - .00000000176)/(.05183-.00000000176)
gen nnvwheat = (nvwheat - .000000000206)/(.0286485-.000000000206)
gen nnvcorn = (nvcorn - .000000000393)/(.00953-.000000000393)
gen nnvsun = (nvsun - .00000000000128)/(.00000390-.00000000000128)
gen nnvother = (nvother - .0000000000549)/(.00104-.0000000000549)
gen nnpprem = (pprem - 0)/(.1352861)

replace nnpwheat = nnpwheat*1000
replace nnpcorn = nnpcorn*1000
replace nnpsun = nnpsun*1000
replace nnpother = nnpother*1000
replace nnvwheat = nnvwheat*1000
replace nnvcorn = nnvcorn*1000
replace nnvsun = nnvsun*1000
replace nnvother = nnvother*1000
replace nnpprem = nnpprem*1000

save "G:\panelcond10co.dta", replace

```



```
*--END CODE FOR DROPPING PRODUCERS WITHOUT A COMPLETE SHARE FOR EACH YEAR----
```

```
-----  
*identify acres  
gen otheracres = (cropcode==1)*(acres)  
gen wheatacres = (cropcode==11)*(acres)  
gen cornacres = (cropcode==41)*(acres)  
gen sunfloweracres = (cropcode==78)*(acres)  
gen sumotheracres = sum(otheracres)  
gen sumwheatacres = sum(wheatacres)  
gen sumcornacres = sum(cornacres)  
gen sumsunflower = sum(sunflower)  
gen sumacres = sum(acres)
```

```
*--TRANPOSE DATA SO ONE LINE IS A PRODUCER!!!  
use "G:\panelcond10co.dta", replace  
compress
```

```
sort state idnumber cropyear  
keep if cropcode==11  
rename Swheat sharewheat  
rename cropcode wcropcode  
rename yield wyield  
rename coveragelevel wcoveragelevel  
rename plancd wplancd  
rename acres wacres  
rename indemnity windemnity  
rename npprem wpprem  
rename nacres wnacres  
rename ins wins  
rename RHC wRHC  
rename RLC wRLC  
rename YHC wYHC  
rename YLC wYLC
```

```
save file, replace  
use "G:\panelcond10co.dta", replace  
compress
```

```
sort state idnumber cropyear  
merge state idnumber cropyear using file  
save "G:\panelcond10conew.dta", replace
```

```
use "G:\panelcond10conew.dta", replace  
compress  
keep if cropcode==41  
drop _merge  
rename Scorn sharecorn  
rename cropcode ccropcode  
rename yield cyield  
rename coveragelevel ccoveragelevel  
rename plancd cplancd  
rename acres cacres  
rename indemnity cindemnity  
rename npprem cpprem  
rename nacres cnacres  
rename ins cins  
rename RHC cRHC
```

```

rename RLC cRLC
rename YHC cYHC
rename YLC cYLC
keep state idnumber cropyear sharecorn ccropcode cyield ccoveragelevel
cplancd cacres cindemnity cpprem cnacres cins cRHC cRLC cYHC cYLC

sort state idnumber cropyear
save file, replace
use "G:\panelcond10conew.dta", replace
compress

sort state idnumber cropyear
drop _merge
merge state idnumber cropyear using file

save "G:\panelcond10conew1.dta", replace

use "G:\panelcond10conew1.dta", replace
compress
keep if cropcode==1
drop _merge
rename Sother shareother
rename cropcode ocropcode
rename yield oyield
rename coveragelevel ocoveragelevel
rename plancd oplancd
rename acres oacres
rename indemnity oindemnity
rename npprem opprem
rename nacres onacres
rename ins oins
rename RHC oRHC
rename RLC oRLC
rename YHC oYHC
rename YLC oYLC

sort state idnumber cropyear
save file, replace
use "G:\panelcond10conew1.dta", replace
compress

sort state idnumber cropyear
drop _merge
merge state idnumber cropyear using file

save "G:\panelcond10conew1a.dta", replace

use "G:\panelcond10conew1a.dta", replace
compress
keep if cropcode==78
drop _merge
rename Ssun sharesun
rename cropcode scropcode
rename yield syield
rename coveragelevel scoveragelevel
rename plancd splancd
rename acres sacres

```

```

rename indemnity sindemnity
rename npprem spprem
rename nacres snacres
rename ins sins
rename RHC sRHC
rename RLC sRLC
rename YHC sYHC
rename YLC sYLC
keep state idnumber cropyear sharesun scropcode syield scoveragelvl spland
sacres sindemnity spprem snacres sins sRHC sRLC sYHC sYLC

sort state idnumber cropyear
save file, replace
use "G:\panelcond10conew1a.dta", replace
compress
sort state idnumber cropyear cropyear
drop _merge
merge state idnumber cropyear using file
*keep cropcode == 11 observations (all other crop data is included with it!!)
keep if cropcode==11
*if a producers complete allocation went to corn then the other estimated
equation crop must be zero or else
*the observation will be dropped.
replace sharecorn = 0 if sharecorn==.
replace sharesun =0 if sharesun==.
replace cins = 0 if cins==.
replace cRHC = 0 if cRHC==.
replace cRLC = 0 if cRLC==.
replace cYHC = 0 if cYHC==.
replace cYLC = 0 if cYLC==.
replace sins = 0 if sins==.
replace sRHC = 0 if sRHC==.
replace sRLC = 0 if sRLC==.
replace sYHC = 0 if sYHC==.
replace sYLC = 0 if sYLC==.

*Clean up data
drop _merge crop1 vwheat vcorn vsun pwheat pcorn psun nd lpwheat lpcorn lpsun
Swheat Scorn Ssun

save "G:\panelcond10conew2.dta", replace

*****
*****
use "G:\panelcond10conew2.dta", replace
compress
summarize
*transfer to SHAZAM
*****
*****
*FOR PREMIUM *****
use "G:\panelcond10conew2.dta", replace
compress
drop if producerpremium==0
summarize
*transfer to SHAZAM
*****

```

*The following SHAZAM code is for Colordado, insurance only. Insurance contracts break down the insurance dummy variable into four dummy variables

```
par= 200000
READ (G:\dataCO.csv)&
  sharewheat sharecorn sharesun windemnity cindemnity sindemnity &
  wpprem cpprem spprem wRHC cRHC sRHC wRLC cRLC sRLC wYHC cYHC sYHC &
  wYLC cYLC sYLC wins cins sins npwheat npcorn npsun npother &
  nvwheat nvcorn nvsun nvother time
```

sample 1 17197

*Yields, wheat = 13.904 corn 40.427 sunflowers 431.099

nl 3/predict=YHAT ncoef=30 iter = 40000 stepsize=0.0001

```
eq sharewheat = c1 + i1*wins + (b11**2)*npwheat*13.904 &
+ (13.904*b12*b11**2)*npcorn &
+ (13.904*b13*b11**2)*npsun + (b14*b11**2)*npother*13.904&
+ b15*nvwheat + b16*nvcorn + b17*nvsun + b18*nvother + b19*time
```

```
eq sharecorn = c2 + i2*cins + (40.472*b12*b11**2)*npwheat &
+ (b12**2*b11**2+b22**2)*npcorn*40.427 &
+ 40.472*(b12*b13*b11**2 + b23*b22**2)*npsun&
+ (b12*b11**2*b14 + b24*b22**2)*npother*40.427&
+ b25*nvwheat + b26*nvcorn + b27*nvsun + b28*nvother + b29*time
```

```
eq sharesun = c3 + i3*sins + (431.099*b13*b11**2)*npwheat &
+ (b12*b11**2*b13 + b23*b22**2)*npcorn*431.099 &
+(b13**2*b11**2+b23**2*b22**2+b33**2)*npsun*431.099 &
+(b13*b11**2*b14+b23*b22**2*b24+b34*b33**2)*npother*431.099 &
+ b35*nvwheat + b36*nvcorn + b37*nvsun + b38*nvother + b39*time
```

*Starting Values

*own-price = 10, cross price ==-5, variance== -1

```
coef c1 -15 i1 -.5
coef b11 15
coef b12 -5 b13 -5
coef b14 -1 b15 -1
coef b16 -1 b17 -1
coef b18 -1 b19 -1
coef c2 -15 i2 -.5
coef b22 15
coef b23 -5 b24 -1
coef b25 -1 b26 -1
coef b27 -1 b28 -1
coef b29 -1
coef c3 -15 i3 -.5
coef b33 15 b34 -1
coef b35 -1 b36 -1
coef b37 -1 b38 -1
coef b39 -1
```

*own-price = 1, cross price ==0, all others 0

```

*coef c1 0 i1 0
*coef b11 1
*coef b12 0 b13 0
*coef b14 0 b15 0
*coef b16 0 b17 0
*coef b18 0 b19 0
*coef c2 0 i2 0
*coef b22 1
*coef b23 0 b24 0
*coef b25 0 b26 0
*coef b27 0 b28 0
*coef b29 0
*coef c3 0 i3 0
*coef b33 1 b34 0
*coef b35 0 b36 0
*coef b37 0 b38 0
*coef b39 0

test 13.904*(b11**2)

test 13.904*(b12*(b11**2))

test 13.904*(b13*(b11**2))

test 13.904*(b14*(b11**2))

test 40.472*(b12*(b11**2))

test 40.472*((b12**2)*(b11**2)+(b22**2))

test 40.472*(b12*b13*(b11**2)+ b23*(b22**2))

test 40.472*(b12*(b11**2)*b14 + b24*(b22**2))

test 431.099*(b13*(b11**2))

test 431.099*(b12*(b11**2)*b13 + b23*(b22**2))

test 431.099*((b13**2)*(b11**2) + (b23**2)*(b22**2)+ b33**2)

test 431.099*((b13)*(b11**2)*b14 + (b23)*(b22**2)*b24 + (b34)*(b33**2))

stat yhat

end

```

COMPUTER CODE FOR CHAPTER FOUR
ECONOMIC EFFECTS ON PRODUCERS FROM REDUCING
NITROGEN POLLUTION IN WHEAT PRODUCTION

Appendix C

COMPUTER CODE FOR CHAPTER FOUR ECONOMIC EFFECTS ON PRODUCERS FROM REDUCING NITROGEN POLLUTION IN WHEAT PRODUCTION

*Gauss code for nitrogen data

```
new;
CLS;
library pgraph, ef;
/* Load Data */
load data[704,26]=I:\cafddata710new.txt;
data=rev(sortc(data,1));

k1= 1;
n= rows(data);
k2= n;
year1= data[k1:k2,15];
year2= data[k1:k2,16];
year3= data[k1:k2,17];
year4= data[k1:k2,18];
year5= data[k1:k2,19];
year6= data[k1:k2,20];
long= data[k1:k2,2];//was easting
lat= data[k1:k2,3];//was northing
elevation=data[k1:k2,6];
year= data[k1:k2,1];
protein= data[k1:k2,8];
nitrogen= data[k1:k2,11];
nsupply= data[k1:k2,12];
springN= data[k1:k2,10];
lostN= data[k1:k2,9];
slope= data[k1:k2,4];
aspect= data[k1:k2,5];
yield= data[k1:k2,7];
wc= data[k1:k2,22];
wb= data[k1:k2,23];
wp= data[k1:k2,24];
sp= data[k1:k2,25];
```

```

sc= data[k1:k2,26];
sb= data[k1:k2,21];
mslope= meanc(slope);
mn=meanc(nsupply);

//create minimum elevation
melevation=minc(elevation);
nelevation= elevation-melevation;
maspect= meanc(aspect);
mslope= meanc(slope);
mnelevation = meanc(nelevation);
mnsupply=meanc(nsupply);
snsupply=stdc(nsupply);

//Create distance matrix for 2006
k3=109;
change1=zeros(k3,k3);
for k (k1,k3,1);
    for l (k1,k3,1);
        change1[k,l]=lat[k,1]-lat[l,1];
    endfor;
endfor;
w1 = zeros(k3,k3);
for i (k1,k3,1);
    for j (k1,k3,1);
        w1[i,j]=atan((sqrt((cos(long[j])*sin(change1[i,j]))^2+(cos(long[i])*sin(long[j])-
            sin(long[i])*cos(long[j])*cos(change1[i,j]))^2))/(sin(long[i])*sin(long[j])+cos(long[i])*cos(lo
            ng[j])*cos(change1[i,j]))));
    endfor;
endfor;
try =eye(k3);
try= try+w1;
try=1./(try);
w1=try-eye(k3);
w1=.74983359.*w1;

//Create distance matrix for 2005
k4=k3;
k5=227;
k6=k5-k4;
change2=zeros(k6,k6);
for k (k1,k6,1);
    for l (k1,k6,1);
        change2[k,l]=lat[k+k3,1]-lat[l+k3,1];
    endfor;

```



```

endfor;
w2 = zeros(k6,k6);
for i (k1,k6,1);
  for j (k1,k6,1);
w2[i,j]=atan((sqrt((cos(long[j+k3])*sin(change2[i,j]))^2+(cos(long[i+k3])*sin(long[j+k3])-
  sin(long[i+k3])*cos(long[j+k3])*cos(change2[i,j]))^2))/(sin(long[i+k3])*sin(long[j+k3])+cos
  (long[i+k3])*cos(long[j+k3])*cos(change2[i,j]))));
  endfor;
endfor;
try =eye(k6);
try= try+w2;
try=1./(try);
w2=try-eye(k6);
w2=.74983359.*w2;

//Create distance matrix for 2004
k7=k5;
k8=349;
k9=k8-k7;
change3=zeros(k9,k9);
for k (k1,k9,1);
  for l (k1,k9,1);
  change3[k,l]=lat[k+k5,1]-lat[l+k5,1];
  endfor;
endfor;
w3 = zeros(k9,k9);
for i (k1,k9,1);
  for j (k1,k9,1);
w3[i,j]=atan((sqrt((cos(long[j+k5])*sin(change3[i,j]))^2+(cos(long[i+k5])*sin(long[j+k5])-
  sin(long[i+k5])*cos(long[j+k5])*cos(change3[i,j]))^2))/(sin(long[i+k5])*sin(long[j+k5])+cos
  (long[i+k5])*cos(long[j+k5])*cos(change3[i,j]))));
  endfor;
endfor;
try =eye(k9);
try= try+w3;
try=1./(try);
w3=try-eye(k9);
w3=.74983359.*w3;

//Create distance matrix for 2003
k10=k8;
k11=461;
k12=k11-k10;
change4=zeros(k12,k12);
for k (k1,k12,1);
  for l (k1,k12,1);

```

```

change4[k,l]=lat[k+k8,1]-lat[l+k8,1];
endfor;
endfor;
w4 = zeros(k12,k12);
for i (k1,k12,1);
for j (k1,k12,1);
w4[i,j]=atan((sqrt((cos(long[j+k8])*sin(change4[i,j]))^2+(cos(long[i+k8])*sin(long[j+k8])-
sin(long[i+k8])*cos(long[j+k8])*cos(change4[i,j]))^2))/(sin(long[i+k8])*sin(long[j+k8])+cos
(long[i+k8])*cos(long[j+k8])*cos(change4[i,j]))));
endfor;
endfor;
try =eye(k12);
try= try+w4;
try=1./(try);
w4=try-eye(k12);
w4=.74983359.*w4;

//Create distance matrix for 2002
k13=k11;
k14=588;
k15=k14-k13;
change5=zeros(k15,k15);
for k (k1,k15,1);
for l (k1,k15,1);
change5[k,l]=lat[k+k11,1]-lat[l+k11,1];
endfor;
endfor;
w5 = zeros(k15,k15);
for i (k1,k15,1);
for j (k1,k15,1);
w5[i,j]=atan((sqrt((cos(long[j+k11])*sin(change5[i,j]))^2+(cos(long[i+k11])*sin(long[j+k11])-
sin(long[i+k11])*cos(long[j+k11])*cos(change5[i,j]))^2))/(sin(long[i+k11])*sin(long[j+k11])
)+cos(long[i+k11])*cos(long[j+k11])*cos(change5[i,j]))));
endfor;
endfor;
try =eye(k15);
try= try+w5;
try=1./(try);
w5=try-eye(k15);
w5=.74983359.*w5;

//Create distance matrix for 2001
k16=k14;
k17=704;
k18=k17-k16;
change6=zeros(k18,k18);

```

```

for k (k1,k18,1);
for l (k1,k18,1);
change6[k,l]=lat[k+k14,1]-lat[l+k14,1];
endfor;
endfor;
w6 = zeros(k18,k18);
for i (k1,k18,1);
for j (k1,k18,1);
w6[i,j]=atan((sqrt((cos(long[j+k14])*sin(change6[i,j]))^2+(cos(long[i+k14])*sin(long[j+k14])-
sin(long[i+k14])*cos(long[j+k14])*cos(change6[i,j]))^2))/(sin(long[i+k14])*sin(long[j+k14]
)+cos(long[i+k14])*cos(long[j+k14])*cos(change6[i,j]))));
endfor;
endfor;
try =eye(k18);
try= try+w6;
try=1./(try);
w6=try-eye(k18);
w6=.74983359.*w6;

//Create elevation matrix (dummies, 1 if point is higher, 0 otherwise)
elevation2=zeros(k2,k2);
for i (k1,k2,1);
for j (k1,k2,1);
if elevation[j,1]-elevation[i,1]>0;
elevation2[i,j]=1;
elseif elevation[j,1]-elevation[i,1]<0;
elevation2[i,j]=.001;
endif;
endfor;
endfor;

//create zero matrices for yearly weighting matrix-a block diagonal!!
a2=zeros(k3,k6);
a3=zeros(k3,k9);
a4=zeros(k3,k12);
a5=zeros(k3,k15);
a6=zeros(k3,k18);
a7=zeros(k6,k3);
a8=zeros(k6,k9);
a9=zeros(k6,k12);
a10=zeros(k6,k15);
a11=zeros(k6,k18);
a12=zeros(k9,k3);
a13=zeros(k9,k6);
a14=zeros(k9,k12);
a15=zeros(k9,k15);

```

```

a16=zeros(k9,k18);
a17=zeros(k12,k3);
a18=zeros(k12,k6);
a19=zeros(k12,k9);
a20=zeros(k12,k15);
a21=zeros(k12,k18);
a22=zeros(k15,k3);
a23=zeros(k15,k6);
a24=zeros(k15,k9);
a25=zeros(k15,k12);
a26=zeros(k15,k18);
a27=zeros(k18,k3);
a28=zeros(k18,k6);
a29=zeros(k18,k9);
a30=zeros(k18,k12);
a31=zeros(k18,k15);

```

```

ww1=w1~a2~a3~a4~a5~a6;
ww2=a7~w2~a8~a9~a10~a11;
ww3=a12~a13~w3~a14~a15~a16;
ww4=a17~a18~a19~w4~a20~a21;
ww5=a22~a23~a24~a25~w5~a26;
ww6=a27~a28~a29~a30~a31~w6;
WW=ww1|ww2|ww3|ww4|ww5|ww6;

```

```

////////////////////////////////////
////////////////////////////////////
//USE THE FOLLOWING CODE TO create weight matrix that includes elevation
//WW=WW.*elevation2;
////////////////////////////////////
////////////////////////////////////

```

```

/*Row Normalize Weighting Matrix*/
fun=zeros(k2,1);
newW=ones(k2,1);
fun=WW*newW;
WW=WW./fun;
////*****
ap=cos(aspect);
app=sin(aspect);
apsla=(ap).*slope;
apslb=(app).*slope;
apnea=(ap).*nelevation;
apneb=(app).*nelevation;
nesl=nelevation.*slope;
//try n supply squared

```

```

nnsupply=nsupply^2;
lnsupply=ln(nsupply);
a1a=nsupply.*(ap);
a1b=nsupply.*(app);
a2=nsupply.*(slope);
a3=nsupply.*(nelevation);
a4a=nsupply.*(apsla);
a4b=nsupply.*(apslb);
a5a=nsupply.*(apnea);
a5b=nsupply.*(apneb);
a6=nsupply.*(nesl);
//b1a=nnsupply.*(ap);
//b1b=nnsupply.*(app);
b2=nnsupply.*(slope);
//b3=nnsupply.*(nelevation);
b4=cos(aspect^2);
b4a=nsupply.*b4;
b5=sin(aspect^2);
b5a=nsupply.*b5;
b6=nsupply.*slope^2;
b7=nsupply.*nelevation^2;
//a4a~a4b~a5a~a5b~a6~b4a~b5a~b6~b7
//GRID SEARCH on rho FOR YIELD EQUATION
Y=yield;

// constant includes nitrogen and weather spring pea
X=ones(k2,1)~year1~year5~year4~year3~year2~sb~sc~wc~wp~wb~nsupply~nnsupply~ap~app
~slope~nelevation~a1a~a1b~a2~a3;
/*Calculated OLS estimates*/
//kk= rank(X);
__con = 0;

{vnam,m,ybols,stb,vc,stderr,ysigma,cx,rsq,resid,dwstat}=ols(0,Y,X);
xs=x[.,2:21];
xc=xs-meanc(xs)';
ssq=diag(xc'xc);
xc=xc./sqrt(ssq)';
corr=xc'xc;
//corr;
detcorr=det(corr);
invcorr=inv(corr);
vif=diag(invcorr);

//OUTPUT BETAS FROM ELEVATION MODEL
output file = I:\outvif.csv on;
format /rd 5,6;

```

```

print vif;
output off;

// GRID SEARCH
_qn_RelGradTol=.01;
_qn_MaxIters =100;
p=-1;
I=eye(k2);
sigsq=ysigma^2;
k100=cols(X)+1;
ybstart=sigsq|ybols;
store1=zeros(1,1);
j=-1;
do while j<1;
p=j;

{ybWs,f,g,ret} = QNewton(&mlnw,ybstart);
store1=store1|f;
j=j+0.1;
endo;

proc mlnW(theta);
local ehat, sig2, lnL, try, e, omeg ;
try=theta[2:k100];
sig2=theta[1];
e=y-x*try;
omeg=e*e';

ehat=y-p*WW*y-x*try;

lnL=ln(det(I-p*WW))-n/2*ln(2*pi)-N/2*ln(sig2)-1/(2*sig2)*ehat'omeg*ehat;
retp(-lnL);
endp;
/////END YIELD GRID SEARCH

//GRID SEARCH on rho FOR PROTEIN EQUATION
Y=protein;
// constant includes nitrogen and weather spring pea
X=ones(k2,1)~year1~year5~year4~year3~year2~sb~sc~wc~wp~wb~nsupply~nnsupply~ap~app
~slope~nelevation~a1a~a1b~a2~a3;
/*Calculated OLS estimates*/
//kk= rank(X);
__con = 0;

{vnam,m,pbols,stb,vc,stderr,psigma,cx,rsq,resid,dwstat}=ols(0,Y,X);
xs=x[.,2:21];

```

```

xc=xs-meanc(xs)';
ssq=diag(xc'xc);
xc=xc./sqrt(ssq)';
corr=xc'xc;
//corr;
detcorr=det(corr);
invcorr=inv(corr);
vifp=diag(invcorr);

// GRID SEARCH
p=-1;
I=eye(k2);
sigsq=psigma^2;
pbstart=sigsq|pbols;
store2=zeros(1,1);
k100=cols(X)+1;
j=-1;
do while j<1;
p=j;

{pbWs,f,g,ret} = QNewton(&mlnw,pbstart);
store2=store2|f;
j=j+0.1;
endo;

proc mlnW(theta);
local ehat, sig2, lnL, try, e, omeg ;
try=pbstart[2:k100];
sig2=pbstart[1];
e=y-x*try;
omeg=e*e';
ehat=y-p*WW*y-x*try;
lnL=ln(det(I-p*WW))-n/2*ln(2*pi)-N/2*ln(sig2)-1/(2*sig2)*ehat'omeg*ehat;
retp(-lnL);
endp;
/////END PROTEIN GRID SEARCH

//GRID SEARCH on rho FOR Nitrogen LOSS EQUATION
Y=lostN;
// constant includes nitrogen and weather spring pea
X=ones(k2,1)~year1~year5~year4~year3~year2~sb~sc~wc~wp~wb~nsupply~nnsupply~ap~app
~slope~nelevation~a1a~a1b~a2~a3;
/*Calculated OLS estimates*/
//kk= rank(X);
__con = 0;

```

```

{vnam,m,nbols,stb,vc,stderr,nsigma,cx,rsq,resid,dwstat}=ols(0,Y,X);

xs=x[.,2:21];
xc=xs-meanc(xs)';
ssq=diag(xc'xc);
xc=xc./sqrt(ssq)';
corr=xc'xc;
//corr;
detcorr=det(corr);
invcorr=inv(corr);
vifn=diag(invcorr);

// GRID SEARCH
p=-1;
I=eye(k2);
sigsq=nsigma^2;
nbstart=sigsq|nbols;
store3=zeros(1,1);
k100=cols(X)+1;
j=-1;
do while j<1;
p=j;

{nbWs,f,g,ret} = QNewton(&mlnw,nbstart);
store3=store3|f;
j=j+0.1;
endo;

proc mlnW(theta);
local ehat, sig2, lnI, try, e, omeg ;
try=theta[2:k100];
sig2=theta[1];
e=y-x*try;
omeg=e*e';
ehat=y-p*WW*y-x*try;
lnI=ln(det(I-p*WW))-n/2*ln(2*pi)-N/2*ln(sig2)-1/(2*sig2)*ehat'omeg*ehat;
retp(-lnI);
endp;
/////END NITROGEN LOST GRID SEARCH
////////////////////////////////////
////////////////////////////////////
//STOP HERE WITH ABOVE CODE SO CORRECT rho's CAN BE PUT INTO THE SUR!!!!!!
////////////////////////////////////
////////////////////////////////////

// Put estimated rho values in here:

```



```

py=0.0;
pp1=-.1;
pn=-.8;

/* Run the Nelder-Meade minimization algorithm to try to find the FIML estimates.
** The procedure ofn() (at the end of the program file) links the objective function
** to the function that the Nelder-Meade algorithm attempts to minimize. See the
** Nelder-Meade code in the procs directory if more details are desired. */

bstart1= py|ybstart[2:22];
bstart= pp1|pbstart[2:22];
bstart = bstart1|bstart;
bstart2 = pn|nbstart[2:22];
bstart = bstart|bstart2;

ymat=yield~protein~lostN;
xmat=X;

wz=zeros(k2,k2);
WWW=WW~wz~wz|wz~WW~wz|wz~wz~WW;
II=eye(rows(www));

neldtol = 1e-5;
bfiml = nelder(bstart,&logfiml,20000,0,neldtol,0);
/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
  local q,LL,sighat, resid, invsig, beta, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  beta = b[2:22];
  beta = beta~b[24:44];
  beta = beta~b[46:66];
  p1 = b[1];
  p2 = b[23];
  p3 = b[45];
  pp=p1~0~0|0~p2~0|0~0~p3;
  wm=(WW*yamat);
  resid = -ymat*gamm - wm*pp- xmat*beta;
  sighat = resid'resid/n;
  resid = resid * chol(inv(sighat))';
  p11=ones(k2,1);
  p11=p11*p1;
  p22=p11*p2;
  p33=p11*p3;

```

```

ppp=p11|p22|p33;
LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sihat)) + ln(abs(det(gamm)));

retp(-LL);
endp;

/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
local logfiml:proc;

retp(logfiml(bstart));
endp;

/* Calculate the asymptotic covariance matrix */

gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
beta = bfiml[2:22];
beta = beta~bfiml[24:44];
beta = beta~bfiml[46:66];
p1 = bfiml[1];
p2 = bfiml[23];
p3 = bfiml[45];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
resid = -ymat*gamm - wm*pp- xmat*beta;
sihat = resid'resid/n;
z1 = wm[.,1]~x;
z2 = wm[.,2]~x;
z3 = wm[.,3]~x;
temp = inv(sihat);
block11 = temp[1,1]*z1'z1;
block12 = temp[1,2]*z1'z2;
block13 = temp[1,3]*z1'z3;
block21 = temp[2,1]*z2'z1;
block22 = temp[2,2]*z2'z2;
block23 = temp[2,3]*z2'z3;
block31 = temp[3,1]*z3'z1;
block32 = temp[3,2]*z3'z2;
block33 = temp[3,3]*z3'z3;
blockx =
(block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
_svdtol = 1.0e-20;
cov = inv(blockx);

```

```

//calculate standard error
sfiml = sqrt(diag(cov));
//calculate z-statistic
zzz=bfiml./sfiml;

//OUTPUT BETAS FROM MODEL with NO ELEVATION
output file = I:\outbfimlNOEnew.csv on;
format /rd 5,6;
print bfiml zzz ;
output off;

//log-like for no elevation model
gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
betax = bfiml[2:22];
betax = betax~bfiml[24:44];
betax = betax~bfiml[46:66];
p1 = bfiml[1];
p2 = bfiml[23];
p3 = bfiml[45];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
resid = -ymat*gamm - wm*pp- xmat*betax;
sighat = resid'resid/n;
resid = resid * chol(inv(sighat));
p11=ones(k2,1);
p11=p11*p1;
p22=p11*p2;
p33=p11*p3;
ppp=p11|p22|p33;
LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

////////////////////////////////////
////////////////////////////////////
//END OF CODE FOR SPATIAL WEIGHTS MATRIX WITH ALL POINTS
//NOW MOVE TO ESTIMATE MODEL WITH SPATIAL WEIGHTS MATRIX THAT
ONLY HAS POINTS HIGHER IN ELEVATION
////////////////////////////////////
////////////////////////////////////
WW=ww1|ww2|ww3|ww4|ww5|ww6;
//USE THE FOLLOWING CODE TO create weight matrix that includes points higher in
elevation
WW=WW.*elevation2;

```

```

////////////////////////////////////
////////////////////////////////////
/*Row Normalize Weighting Matrix*/
fun=zeros(k2,1);
newW=ones(k2,1);
fun=WW*newW;
WW=WW./fun;

// Put estimated rho values in here:
py=0.0;
pp1=-.1;
pn=-.73;

bstart1= py|ybstart[2:22];
bstart= pp1|pbstart[2:22];
bstart = bstart1|bstart;
bstart2 = pn|nbstart[2:22];
bstart = bstart|bstart2;

ymat=yield~protein~lostN;
xmat=X;
wz=zeros(k2,k2);
WWW=WW~wz~wz|wz~WW~wz|wz~wz~WW;
II=eye(rows(www));
neldtol = 1e-5;
bfimle = nelder(bstart,&logfiml,20000,0,neldtol,0);
/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
    local q,LL,sighat, resid, invsig, beta, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
    gamm = -1|0|0;
    gamm = gamm~(0|-1|0);
    gamm=gamm~(0|0|-1);
    q = cols(gamm);
    beta = b[2:22];
    beta = beta~b[24:44];
    beta = beta~b[46:66];
    p1 = b[1];
    p2 = b[23];
    p3 = b[45];
    pp=p1~0~0|0~p2~0|0~0~p3;
    wm=(WW*ymat);
    resid = -ymat*gamm - wm*pp- xmat*beta;
    sighat = resid'resid/n;
    resid = resid * chol(inv(sighat))';
    p11=ones(k2,1);
    p11=p11*p1;

```

```

p22=p11*p2;
p33=p11*p3;
ppp=p11|p22|p33;
LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

retp(-LL);
endp;
/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
local logfiml:proc;

retp(logfiml(bstart));
endp;
/* Calculate the asymptotic covariance matrix */
gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
beta = bfimle[2:22];
beta = beta~bfimle[24:44];
beta = beta~bfimle[46:66];
p1 = bfimle[1];
p2 = bfimle[23];
p3 = bfimle[45];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
resid = -ymat*gamm - wm*pp- xmat*beta;
sighat = resid'resid/n;
z1 = wm[.,1]~x;
z2 = wm[.,2]~x;
z3 = wm[.,3]~x;
temp = inv(sighat);
block11 = temp[1,1]*z1'z1;
block12 = temp[1,2]*z1'z2;
block13 = temp[1,3]*z1'z3;
block21 = temp[2,1]*z2'z1;
block22 = temp[2,2]*z2'z2;
block23 = temp[2,3]*z2'z3;
block31 = temp[3,1]*z3'z1;
block32 = temp[3,2]*z3'z2;
block33 = temp[3,3]*z3'z3;
blockx =
(block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
_svdtol = 1.0e-20;
cove = inv(blockx);
//calculate standard error

```

```

sfimle = sqrt(diag(cove));
//calculate z-statistic
zzze=bfimle./sfimle;

//OUTPUT BETAS FROM ELEVATION MODEL
output file = I:\outbfimlElevation.csv on;
format /rd 5,6;
print bfimlE zzzE;
output off;

//log-like for elevation model
gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
betaz = bfimle[2:22];
betaz = betaz~bfimle[24:44];
betaz = betaz~bfimle[46:66];
p1 = bfimle[1];
p2 = bfimle[23];
p3 = bfimle[45];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
resid = -ymat*gamm - wm*pp- xmat*betaz;
sighat = resid'resid/n;
resid = resid * chol(inv(sighat))';
p11=ones(k2,1);
p11=p11*p1;
p22=p11*p2;
p33=p11*p3;
ppp=p11|p22|p33;
LLe = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));
print LLe;
////////////////////////////////////
//TEST HYPOTHESIS ONE
////////////////////////////////////
//calculate the log-likelihood for the model without spatial autocorrelation
////////////////////////////////////
bstart1= ybols;
bstart= pbols;
bstart = bstart1|bstart;
bstart2 = nbols;
bstart = bstart|bstart2;

ymat=yield~protein~lostN;

```

```

xmat=X;

neldtol = 1e-5;
bfimlols = nelder(bstart,&logfiml,20000,0,neldtol,0);
/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
  local q,LL,sighat, resid, invsig, beta, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  beta = b[1:21];
  beta = beta~b[22:42];
  beta = beta~b[43:63];

  resid = -ymat*gamm - xmat*beta;
  sighat = resid'resid/n;
  resid = resid * chol(inv(sighat));

  LL = - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

  retp(-LL);
endp;
/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
  local logfiml:proc;

  retp(logfiml(bstart));
endp;
/* Calculate the asymptotic covariance matrix */
gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
beta = bfimlols[1:21];
beta = beta~bfimlols[22:42];
beta = beta~bfimlols[43:63];

resid = -ymat*gamm - xmat*beta;
sighat = resid'resid/n;
resid = resid * chol(inv(sighat));

sighat = resid'resid/n;
z1 = x;
z2 = x;
z3 = x;

```

```

temp = inv(sighat);
  block11 = temp[1,1]*z1'z1;
  block12 = temp[1,2]*z1'z2;
  block13 = temp[1,3]*z1'z3;
  block21 = temp[2,1]*z2'z1;
  block22 = temp[2,2]*z2'z2;
  block23 = temp[2,3]*z2'z3;
  block31 = temp[3,1]*z3'z1;
  block32 = temp[3,2]*z3'z2;
  block33 = temp[3,3]*z3'z3;
  blockx =
  (block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
  _svdtol = 1.0e-20;
  cove = inv(blockx);
  //calculate standard error
  sfimlols = sqrt(diag(cove));
  //calculate z-statistic
  zzzols=bfimlols./sfimlols;

//OUTPUT BETAS FROM ELEVATION MODEL
output file = I:\outbfimlols.csv on;
format /rd 5,6;
print bfimlols zzzols;
output off;

//log-like for OLS model
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  betaols = bfimlols[2:22];
  betaols = betaols~bfimlols[22:42];
  betaols = betaols~bfimlols[43:63];
  resid = -ymat*gamm - xmat*betaols;
  sighat = resid'resid/n;
  resid = resid * chol(inv(sighat));

  LLols = - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));
print LLols;
////////////////////////////////////
////////////////////////////////////
////////////////////////////////////
////////////////////////////////////TEST HYPOTHESIS TWO////////////////////////////////////
//////////////////////////////////// CALCULATE LOG LIKELIHOOD FOR MODEL WITH ALL POINTS
WW=ww1|ww2|ww3|ww4|ww5|ww6;
/*Row Normalize Weighting Matrix*/

```



```

fun=zeros(k2,1);
newW=ones(k2,1);
fun=WW*newW;
WW=WW./fun;

// Put estimated rho values in here:
py=0.0;
pp1=-.1;
pn=-.73;

bstart1= py|ybstart[2:22];
bstart= pp1|pbstart[2:22];
bstart = bstart1|bstart;
bstart2 = pn|nbstart[2:22];
bstart = bstart|bstart2;

ymat=yield~protein~lostN;
xmat=X;
wz=zeros(k2,k2);
WWW=WW~wz~wz|wz~WW~wz|wz~wz~WW;
II=eye(rows(www));
neldtol = 1e-5;
bfimlne = nelder(bstart,&logfiml,20000,0,neldtol,0);
/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
    local q,LL,sighat, resid, invsig, beta, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
    gamm = -1|0|0;
    gamm = gamm~(0|-1|0);
    gamm=gamm~(0|0|-1);
    q = cols(gamm);
    beta = b[2:22];
    beta = beta~b[24:44];
    beta = beta~b[46:66];
    p1 = b[1];
    p2 = b[23];
    p3 = b[45];
    pp=p1~0~0|0~p2~0|0~0~p3;
    wm=(WW*ymat);
    resid = -ymat*gamm - wm*pp- xmat*beta;
    sighat = resid'resid/n;
    resid = resid * chol(inv(sighat))';
    p11=ones(k2,1);
    p11=p11*p1;
    p22=p11*p2;
    p33=p11*p3;
    ppp=p11|p22|p33;

```

```

LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

retp(-LL);
endp;
/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
  local logfiml:proc;

  retp(logfiml(bstart));
endp;
/* Calculate the asymptotic covariance matrix */
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  beta = bfimlne[2:22];
  beta = beta~bfimlne[24:44];
  beta = beta~bfimlne[46:66];
  p1 = bfimlne[1];
  p2 = bfimlne[23];
  p3 = bfimlne[45];
  pp=p1~0~0|0~p2~0|0~0~p3;
  wm=(WW*yamat);
  resid = -ymat*gamm - wm*pp- xmat*beta;
  sighat = resid'resid/n;
  z1 = wm[.,1]~x;
  z2 = wm[.,2]~x;
  z3 = wm[.,3]~x;
temp = inv(sighat);
  block11 = temp[1,1]*z1'z1;
  block12 = temp[1,2]*z1'z2;
  block13 = temp[1,3]*z1'z3;
  block21 = temp[2,1]*z2'z1;
  block22 = temp[2,2]*z2'z2;
  block23 = temp[2,3]*z2'z3;
  block31 = temp[3,1]*z3'z1;
  block32 = temp[3,2]*z3'z2;
  block33 = temp[3,3]*z3'z3;
  blockx =
  (block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
  _svdtol = 1.0e-20;
  cove = inv(blockx);
  //calculate standard error
  sfimlne = sqrt(diag(cove));
  //calculate z-statistic
  zzze=bfimlne./sfimlne;

```

```
//OUTPUT BETAS For all points MODEL
output file = I:\outbfimlnoelevation.csv on;
format /rd 5,6;
print bfimlne zzze;
output off;

//log-like for all points model
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  betane = bfimlne[2:22];
  betane = betane~bfimlne[24:44];
  betane = betane~bfimlne[46:66];
  p1 = bfimlne[1];
  p2 = bfimlne[23];
  p3 = bfimlne[45];
  pp=p1~0~0|0~p2~0|0~0~p3;
  wm=(WW*yamat);
  resid = -yamat*gamm - wm*pp- xmat*betaz;
  sighat = resid' resid/n;
  resid = resid * chol(inv(sighat));
  p11=ones(k2,1);
  p11=p11*p1;
  p22=p11*p2;
  p33=p11*p3;
  ppp=p11|p22|p33;
  LLne = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));
print LLne;

//////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////////
//HO: elevation
//HA: no elevation
// yhat is then no elevation

//estimate yhatx on z to obtain dx and ez,x.

  ppe=.0043~0~0|0~-.1026~0|0~0~-.6179;
  ppne=.0114~0~0|0~-.1031~0|0~0~-.6495;

//calculate sig squared
  sighat = residz'residz/n;
//calculate yhat
  yhatz = wm*ppne + xmat*betane;
```

```

// Put estimated rho values in here:
py=.0043;
pp1=-.1026;
pn=-.6179;
a=0;

bstart1= py|ybstart[2:22];
bstart= pp1|pbstart[2:22];
bstart = bstart1|bstart;
bstart2 = pn|nbstart[2:22];
bstart = bstart|bstart2|a;

xmat=X;
wz=zeros(k2,k2);
WWW=WW~wz~wz|wz~WW~wz|wz~wz~WW;
II=eye(rows(www));
nelddtol = 1e-5;
bfimlee = nelder(bstart,&logfiml,20000,0,nelddtol,0);
/*****J TEST*****/
/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
    local q,LL,sighat,a, resid, invsig, betazx, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
    gamm = -1|0|0;
    gamm = gamm~(0|-1|0);
    gamm=gamm~(0|0|-1);
    q = cols(gamm);
    betazx = b[2:22];
    betazx = betazx~b[24:44];
    betazx = betazx~b[46:66];
    p1 = b[1];
    p2 = b[23];
    p3 = b[45];
    a = b[67];
    pp=p1~0~0|0~p2~0|0~0~p3;
    wm=(WW*yamat);
    resid = -ymat*gamm - (wm*pp+ xmat*betazx)*(1-a)-yhatz*a;
    sighat = resid'resid/n;
    resid = resid * chol(inv(sighat));
    p11=ones(k2,1);
    p11=p11*p1;
    p22=p11*p2;
    p33=p11*p3;
    ppp=p11|p22|p33;
    LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

    retp(-LL);

```

```

endp;
/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
    local logfiml:proc;

    retp(logfiml(bstart));
endp;

/* Calculate the asymptotic covariance matrix */
gamm = -1|0|0;
gamm = gamm~(0|-1|0);
gamm=gamm~(0|0|-1);
q = cols(gamm);
betazx = bfimlee[2:22];
betazx = betazx~bfimlee[24:44];
betazx = betazx~bfimlee[46:66];
p1 = bfimlee[1];
p2 = bfimlee[23];
p3 = bfimlee[45];
a = bfimlee[67];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
wy=yhatz;
resid = -ymat*gamm - (wm*pp+ xmat*betazx)*(1-a)-yhatz*a;
sigmat = resid'resid/n;
z11=temp*yhatz'yhatz;
z1 = wm[.,1]~x;
z2 = wm[.,2]~x;
z3 = wm[.,3]~x;
temp = inv(sigmat);
block11 = temp[1,1]*z1'z1;
block12 = temp[1,2]*z1'z2;
block13 = temp[1,3]*z1'z3;
block21 = temp[2,1]*z2'z1;
block22 = temp[2,2]*z2'z2;
block23 = temp[2,3]*z2'z3;
block31 = temp[3,1]*z3'z1;
block32 = temp[3,2]*z3'z2;
block33 = temp[3,3]*z3'z3;
blockx =
(block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
_svdtol = 1.0e-20;
cove = inv(blockx);
//calculate standard error
sfimlee = sqrt(diag(cove));
//calculate z-statistic

```

```

    zzzee=bfimlee./sfimlee;
print zzzee;

    see1=inv(z11);
    seee1=sqrt(diag(see1));

print z11;
print seee1;
////////////////////////////////////
//HO: no elevation
//HA: elevation
// yhat is then elevation
    beta = bfimle[2:22];
    beta = beta~bfimle[24:44];
    beta = beta~bfimle[46:66];
//estimate yhatx on z to obtain dx and ez,x.

    ppe=.0043~0~0|0~- .1026~0|0~0~- .6179;
    ppne=.0114~0~0|0~- .1031~0|0~0~- .6495;
//calculate ehat
    residz = -ymat*gamm - wm*ppz- xmat*beta;
//calculate sig squared
    sighat = residz'residz/n;
//calculate yhat
    yhatz = wm*ppe + xmat*beta;

// Put estimated rho values in here:
py=.0114;
pp1=-.1031;
pn=-.6495;
a=0;

bstart1= py|ybstart[2:22];
bstart= pp1|pbstart[2:22];
bstart = bstart1|bstart;
bstart2 = pn|nbstart[2:22];
bstart = bstart|bstart2|a;

xmat=X;
wz=zeros(k2,k2);
WWW=WW~wz~wz|wz~WW~wz|wz~wz~WW;
II=eye(rows(www));
nelddtol = 1e-5;
bfimleee = nelder(bstart,&logfiml,20000,0,nelddtol,0);
//*****J TEST*****//

```

```

/* Procedure for the concentrated log-likelihood function */
proc logfiml(b);
  local q,LL,sighat,a, resid, invsig, betazx, gamm, cnst, p1, p2, p3, pp, wm, p11, p22, p33, ppp;
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  betazx = b[2:22];
  betazx = betazx~b[24:44];
  betazx = betazx~b[46:66];
  p1 = b[1];
  p2 = b[23];
  p3 = b[45];
  a = b[67];
  pp=p1~0~0|0~p2~0|0~0~p3;
  wm=(WW*yamat);
  resid = -yamat*gamm - (wm*pp+ xmat*betazx)*(1-a)-yhatz*a;
  sighat = resid'resid/n;
  resid = resid * chol(inv(sighat));
  p11=ones(k2,1);
  p11=p11*p1;
  p22=p11*p2;
  p33=p11*p3;
  ppp=p11|p22|p33;
  LL = ln(det(II-ppp.*WWW)) - q*0.5*ln(2*pi) - 0.5*ln(det(sighat)) + ln(abs(det(gamm)));

  retp(-LL);
endp;
/* Procedure required by the Nelder-Meade algorithm */
proc ofn(&logfiml,bstart);
  local logfiml:proc;

  retp(logfiml(bstart));
endp;

/* Calculate the asymptotic covariance matrix */
  gamm = -1|0|0;
  gamm = gamm~(0|-1|0);
  gamm=gamm~(0|0|-1);
  q = cols(gamm);
  betazx = bfimleee[2:22];
  betazx = betazx~bfimleee[24:44];
  betazx = betazx~bfimleee[46:66];
  p1 = bfimleee[1];
  p2 = bfimleee[23];
  p3 = bfimleee[45];

```

```

a = bfimleee[67];
pp=p1~0~0|0~p2~0|0~0~p3;
wm=(WW*yamat);
wy=yhatz;
resid = -ymat*gamm - (wm*pp+ xmat*betazx)*(1-a)-yhatz*a;
sighat = resid'resid/n;
z11=temp*yhatz'yhatz;
z1 = wm[:,1]~x;
z2 = wm[:,2]~x;
z3 = wm[:,3]~x;
temp = inv(sighat);
block11 = temp[1,1]*z1'z1;
block12 = temp[1,2]*z1'z2;
block13 = temp[1,3]*z1'z3;
block21 = temp[2,1]*z2'z1;
block22 = temp[2,2]*z2'z2;
block23 = temp[2,3]*z2'z3;
block31 = temp[3,1]*z3'z1;
block32 = temp[3,2]*z3'z2;
block33 = temp[3,3]*z3'z3;
blockx =
(block11~block12~block13)|(block21~block22~block23)|(block31~block32~block33);
_svdtol = 1.0e-20;
cove = inv(blockx);
//calculate standard error
sfimlee = sqrt(diag(cove));
//calculate z-statistic

zzzee=bfimleee./sfimlee;
print zzzee;

see=inv(z11);
seee=sqrt(diag(see));

print z11;
print seee;

//////////
//TEST HYPOTHESIS three
//////////
c=zeros(2,66);

c[1,19]=.5;
c[1,20]=.5;
c[1,21]=-1;

```



```

c[2,21]=1;
c[2,22]=-1;

q=zeros(2,1);

{w1, pvalue}=MLR_Wald(c,bfimle,q,cove);
print "WALD Test Statistic";
print w1;

////////////////////////////////////
//TEST HYPOTHESIS four
////////////////////////////////////
c1=zeros(2,66);

c1[1,41]=.5;
c1[1,42]=.5;
c1[1,43]=-1;

c1[2,43]=1;
c1[2,44]=-1;

q=zeros(2,1);
{w1, pvalue}=MLR_Wald(c1,bfimle,q,cove);
print "WALD Test Statistic";
print w1;

////////////////////////////////////
//TEST HYPOTHESIS five
////////////////////////////////////
c=zeros(2,66);

c[1,63]=.5;
c[1,64]=.5;
c[1,65]=-1;

c[2,65]=1;
c[2,66]=-1;

q=zeros(2,1);

{w1, pvalue}=MLR_Wald(c,bfimle,q,cove);
print "WALD Test Statistic";
print w1;

////////////////////////////////////

```

```
////////////////////////////////////  
////////////////////////////////////  
end;
```

* The following GAMS code solves the constrained optimization problem for uniform application

```
sets    j /l1na, l1sa, l1mna, l1msa, l1hna, l1mlna, l1mlsa, l1mmna, l1mmsa, l1mhna, l1mhsa, l1hl1na, l1hm1na, l1hmsa,  
         hhna/  
        T/1,2,3,4,5,6,7,8,9,10,11/
```

```
;  
Parameters
```

```
prof(T)  
nisup(T)  
shadow(T)  
U11(T)  
poll(T)  
u(T)  
/1 100,  
2 500,  
3 400,  
4 300,  
5 250,  
6 200,  
7 180,  
8 160,  
9 140,  
10 120,  
11 114.68  
/
```

```
proteinprice(T)
```

```
    slope(j)  
/l1na 3.52,  
l1sa 3.52,  
l1mna 3.52,  
l1msa 3.52,  
l1hna 3.52,  
l1mlna 6.36,  
l1mlsa 6.36,  
l1mmna 6.36,  
l1mmsa 6.36,
```

mhna 6.36,
mhsa 6.36,
hlna 9.2,
hmna 9.2,
hmsa 9.2,
hhna 9.2

/

nelevation(j)

/llna 11.55,
llsa 11.55,
lmna 19.94,
lmsa 19.94,
lhna 3.52,
mlna 11.55,
mlsa 11.55,
mmna 19.94,
mmsa 19.94,
mhna 6.36,
mhsa 6.36,
hlna 11.55,
hmna 19.94,
hmsa 19.94,
hhna 9.2

/

aspect(j)

/llna 0,
llsa 3.14,
lmna 0,
lmsa 3.14,
lhna 0,
mlna 0,
mlsa 3.14,
mmna 0,
mmsa 3.14,
mhna 0,
mhsa 3.14,
hlna 0,
hmna 0,
hmsa 3.14,
hhna 0

/

share(j)

/llna .02698,
llsa .007102,

lmna 0.06534,
lmsa .0369318,
lhna 0.0113636,
mlna 0.0625,
mlsa .03267,
mmna 0.2599,
mmsa .2144886,
mhna 0.0639204,
mhsa .0625,
hlna 0.025568,
hmna 0.085227,
hmsa .0085227,
hhna 0.0369318
/ ;

Scalars

b0 /30.79 /
b1/0.117 /
b2/-0.000077 /
b3/-7.977 /
b4/1.602 /
b5/-0.278 /
b6/0.325 /
b7/0.026 /
b8/-0.0067 /
b9/0.000549 /
b10/-0.001032 /

b00 / 11.22 /
b11/0.016013 /
b12/-0.000013 /
b13/0.633 /
b14/-0.479 /
b15/-0.012 /
b16/0.0048 /
b17/-0.00188 /
b18/0.0015 /
b19/-0.000075 /
b20/-0.000071 /

b000 / -77.61 /
b21/0.745 /
b22/0.00013 /
b23/-20.809 /
b24/18.924 /
b25/8.120 /

b26/-0.808 /
b27/0.058 /
b28/-0.058 /
b29/-0.024 /
b30/0.0054 /

aspect1 /3.607/
slope1 / 6.37/
nelevation1 /19.95/

*low grain price
*gp/4.00/
*average grain price
*gp/4.63/
*high grain price
gp/5.44/

*low protein price
*prp/.005/
*prpl/- .1175/
*average protein price
*prp/.0028/
*prpl/- .0525/
*high protein price
prp/.0625/
prpl/- .025/

*low nitrogen price
*np/.25/
*average nitrogen price
*np/.31/
*high nitrogen price
np/.49/

*current prices
*np/.75/
*gp/9.12/
*prp / .00/
*prpl/- .02/

nsupply /160/
*for protein price use average n application
nsupply1 /313/

u1

```

proteinp
;
loop(T$(ord(T)>1),
if ((b00 + b11*nsupply1 + b12*nsupply1**2 + b13*cos(aspect1) + b14*sin(aspect1) +
    b15*slope1 +
b16*nelevation1 + b17*nsupply1*cos(aspect1) + b18*nsupply1*sin(aspect1) +
    b19*nsupply1*slope1 +
b20*nsupply1*nelevation1) - 14 > 0 , proteinprice(T)=prp;
else proteinprice(T)=prpl;
););

```

Variables

```

    ns
    profit
;

```

Positive Variable

```

ns
;

```

Equations

```

    profit      profit equation
    pollution
    constraint

```

```

;
profit.. profit =e= sum(j,share(j)*( gp*(b0 + b1*ns + b2*ns**2 + b3*cos(aspect(j)) +
    b4*sin(aspect(j)) + b5*slope(j)+
b6*nelevation(j) + b7*ns*cos(aspect(j)) + b8*ns*sin(aspect(j)) + b9*ns*slope(j) +
    b10*ns*nelevation(j) +
    (proteinp*((b00 + b11*ns + b12*ns**2 + b13*cos(aspect(j)) + b14*sin(aspect(j)) +
    b15*slope(j) +
b16*nelevation(j) + b17*ns*cos(aspect(j)) + b18*ns*sin(aspect(j)) + b19*ns*slope(j) +
b20*ns*nelevation(j) )-14)/.25)*(b0 + b1*ns + b2*ns**2 + b3*cos(aspect(j)) + b4*sin(aspect(j))
    + b5*slope(j)+
b6*nelevation(j) + b7*ns*cos(aspect(j)) + b8*ns*sin(aspect(j)) + b9*ns*slope(j) +
    b10*ns*nelevation(j) ))) - np*ns
;
pollution.. sum (j, share(j)*(b000 + b21*ns + b22*ns**2 +
b23*cos(aspect(j)) + b24*sin(aspect(j)) + b25*slope(j) +
b26*nelevation(j) + b27*ns*cos(aspect(j)) + b28*ns*sin(aspect(j)) + b29*ns*slope(j)+
b30*ns*nelevation(j) )) =l= u1-44.69
;
constraint.. ns =g= nsupply
;
model fun / all /;

```

```

option lp=bdmlp;
loop(T$(ord(T)>1),
u1=u(T);
proteinp=proteinprice(T);
option lp=bdmlp;
solve fun using nlp maximizing profitt
;
prof(T)=profit.l;
nisup(T)=ns.l;
shadow(T)=pollution.m;
U11(T)=pollution.up;
poll(T)=pollution.l;
);
file out/'H:\Dissertation\Nitrogen Use\Simulation\run.txt'/;put out;
put /;
put'T          Profit    N    NSupply    Shadow    Pollution    pollconstraint    U1';put/;
loop (T, put T.tl,prof(T),nsupply, nisup(T), shadow(T), poll(T), u(T), U11(T) ;put/);
put/;
putclose out;

```

*The following GAMS code solves the variable rate problem

```

sets    j /llna, llsa, lmna, lmsa, lhna, mlna, mlsa, mmna, mmsa, mhna, mhna, hlna, hmna, hmsa,
        hhna/
        T/1,2,3,4,5,6,7,8,9,10,11/
;
Parameters
prof(T)
nisup(T)
shadow(T)
U11(T)
poll(T)
u(T)

/1 1000,
2 1000,
3 1000,
4 1000,
5 1000,
6 1000,
7 1000,
8 1000,
9 1000,
10 1000,
11 1000

```

/

slope(j)

/llna 3.52,
llsa 3.52,
lmna 3.52,
lmsa 3.52,
lhna 3.52,
mlna 6.36,
mlsa 6.36,
mmna 6.36,
mmsa 6.36,
mhna 6.36,
mhsa 6.36,
hlna 9.2,
hmna 9.2,
hmsa 9.2,
hhna 9.2

/

nelevation(j)

/llna 11.55,
llsa 11.55,
lmna 19.94,
lmsa 19.94,
lhna 3.52,
mlna 11.55,
mlsa 11.55,
mmna 19.94,
mmsa 19.94,
mhna 6.36,
mhsa 6.36,
hlna 11.55,
hmna 19.94,
hmsa 19.94,
hhna 9.2

/

aspect(j)

/llna 0,
llsa 3.14,
lmna 0,
lmsa 3.14,
lhna 0,
mlna 0,
mlsa 3.14,

mmna 0,
mmsa 3.14,
mhna 0,
mhsa 3.14,
hlna 0,
hmna 0,
hmsa 3.14,
hhna 0

/
 share(j)
/llna .02698,
llsa .007102,
lmna 0.06534,
lmsa .0369318,
lhna 0.0113636,
mlna 0.0625,
mlsa .03267,
mmna 0.2599,
mmsa .2144886,
mhna 0.0639204,
mhsa .0625,
hlna 0.025568,
hmna 0.085227,
hmsa .0085227,
hhna 0.0369318
/ ;

Scalars

b0 /30.79/
b1/0.117/
b2/-0.000077/
b3/-7.977 /
b4/1.602 /
b5/-0.278 /
b6/0.325 /
b7/0.026 /
b8/-0.0067 /
b9/0.000549 /
b10/-0.001032 /

b00 / 11.22 /
b11/0.016013 /
b12/-0.000013 /
b13/0.633 /
b14/-0.479 /

b15/-0.012 /
b16/0.0048 /
b17/-0.00188 /
b18/0.0015 /
b19/-0.000075 /
b20/-0.000071 /

b000 / -77.61 /
b21/0.745 /
b22/0.00013 /
b23/-20.809 /
b24/18.924 /
b25/8.120 /
b26/-0.808 /
b27/0.0581 /
b28/-0.0578 /
b29/-0.02429 /
b30/0.005413 /

proteinprice1
proteinprice2
proteinprice3
proteinprice4
proteinprice5
proteinprice6
proteinprice7
proteinprice8
proteinprice9
proteinprice10
proteinprice11
proteinprice12
proteinprice13
proteinprice14
proteinprice15

a1
a2
a3
a4
a5
a6
a7
a8
a9
a10
a11

a12
a13
a14
a15

* cllna / .399304/
* cllsa/ .10511/
* clmna/ 0.967/
* clmsa/ .5465/
* clhna/ 0.16818/
* cmlna/ 0.925/
* cmlsa/ .483516/
* cmmna/ 3.84652/
* cmmsa/ 3.17442/
* cmhna/ 0.946022/
* cmhsa/ .925/
* chlna/ 0.378406/
* chmna/ 1.26126/
* chmsa/ .126136/
* chhna/ 0.546591/

cllna /0/
cllsa/ 0/
clmna/ 0/
clmsa/0/
clhna/0/
cmlna/ 0/
cmlsa/ 0/
cmmna/ 0/
cmmsa/0/
cmhna/0/
cmhsa/ 0/
chlna/0/
chmna/ 0/
chmsa/ 0/
chhna/ 0/
nsupply/313/

*low grain price
gp/4.00/
*average grain price
*gp/4.63/
*high grain price
*gp/5.44/

*low protein price

```

prp/.005/
prpl/-.1175/
*average protein price
*prp/.0028/
*prpl/-.0525/
*high protein price
*prp/.0625/
*prpl/-.025/

```

```

*low nitrogen price
np/.25/
*average nitrogen price
*np/.31/
*high nitrogen price
*np/.49/

```

```

nitrogen pollution
u1/400/

```

```

*current prices
*np/.75/
*gp/9.12/
*prp/0.00/
*prpl /-.02/
;
*loop(j$(ord(j)>1),
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('llna')) + b14*sin(aspect('llna')) +
b15*slope('llna') +
b16*nelevation('llna') + b17*nsupply*cos(aspect('llna')) + b18*nsupply*sin(aspect('llna')) +
b19*nsupply*slope('llna') +
b20*nsupply*nelevation('llna')) - 14 > 0 , proteinprice1=prp;
else proteinprice1=prpl;
);

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('llsa')) + b14*sin(aspect('llsa')) +
b15*slope('llsa') +
b16*nelevation('llsa') + b17*nsupply*cos(aspect('llsa')) + b18*nsupply*sin(aspect('llsa')) +
b19*nsupply*slope('llsa') +
b20*nsupply*nelevation('llsa')) - 14 > 0 , proteinprice2=prp;
else proteinprice2=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('lmna')) + b14*sin(aspect('lmna')) +
    b15*slope('lmna') +
b16*nelevation('lmna') + b17*nsupply*cos(aspect('lmna')) + b18*nsupply*sin(aspect('lmna')) +
    b19*nsupply*slope('lmna') +
b20*nsupply*nelevation('lmna')) - 14 > 0 , proteinprice3=prp;
else proteinprice3=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('lmsa')) + b14*sin(aspect('lmsa')) +
    b15*slope('lmsa') +
b16*nelevation('lmsa') + b17*nsupply*cos(aspect('lmsa')) + b18*nsupply*sin(aspect('lmsa')) +
    b19*nsupply*slope('lmsa') +
b20*nsupply*nelevation('lmsa')) - 14 > 0 , proteinprice4=prp;
else proteinprice4=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('lhna')) + b14*sin(aspect('lhna')) +
    b15*slope('lhna') +
b16*nelevation('lhna') + b17*nsupply*cos(aspect('lhna')) + b18*nsupply*sin(aspect('lhna')) +
    b19*nsupply*slope('lhna') +
b20*nsupply*nelevation('lhna')) - 14 > 0 , proteinprice5=prp;
else proteinprice5=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mlna')) + b14*sin(aspect('mlna')) +
    b15*slope('mlna') +
b16*nelevation('mlna') + b17*nsupply*cos(aspect('mlna')) + b18*nsupply*sin(aspect('mlna')) +
    b19*nsupply*slope('mlna') +
b20*nsupply*nelevation('mlna')) - 14 > 0 , proteinprice6=prp;
else proteinprice6=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mlsa')) + b14*sin(aspect('mlsa')) +
    b15*slope('mlsa') +
b16*nelevation('mlsa') + b17*nsupply*cos(aspect('mlsa')) + b18*nsupply*sin(aspect('mlsa')) +
    b19*nsupply*slope('mlsa') +
b20*nsupply*nelevation('mlsa')) - 14 > 0 , proteinprice7=prp;
else proteinprice7=prpl;
);

```

```

if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mmna')) + b14*sin(aspect('mmna'))
    + b15*slope('mmna') +
b16*nelevation('mmna') + b17*nsupply*cos(aspect('mmna')) +
    b18*nsupply*sin(aspect('mmna')) + b19*nsupply*slope('mmna') +
b20*nsupply*nelevation('mmna')) - 14 > 0 , proteinprice8=prp;
else proteinprice8=prpl;

```

```
);
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mmsa')) + b14*sin(aspect('mmsa'))
+ b15*slope('mmsa') +
b16*nelevation('mmsa') + b17*nsupply*cos(aspect('mmsa')) + b18*nsupply*sin(aspect('mmsa'))
+ b19*nsupply*slope('mmsa') +
b20*nsupply*nelevation('mmsa')) - 14 > 0 , proteinprice9=prp;
else proteinprice9=prpl;
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mhna')) + b14*sin(aspect('mhna'))
+ b15*slope('mhna') +
b16*nelevation('mhna') + b17*nsupply*cos(aspect('mhna')) + b18*nsupply*sin(aspect('mhna'))
+ b19*nsupply*slope('mhna') +
b20*nsupply*nelevation('mhna')) - 14 > 0 , proteinprice10=prp;
else proteinprice10=prpl;
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('mhsa')) + b14*sin(aspect('mhsa'))
+ b15*slope('mhsa') +
b16*nelevation('mhsa') + b17*nsupply*cos(aspect('mhsa')) + b18*nsupply*sin(aspect('mhsa')) +
b19*nsupply*slope('mhsa') +
b20*nsupply*nelevation('mhsa')) - 14 > 0 , proteinprice11=prp;
else proteinprice11=prpl;
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('hlna')) + b14*sin(aspect('hlna')) +
b15*slope('hlna') +
b16*nelevation('hlna') + b17*nsupply*cos(aspect('hlna')) + b18*nsupply*sin(aspect('hlna')) +
b19*nsupply*slope('hlna') +
b20*nsupply*nelevation('hlna')) - 14 > 0 , proteinprice12=prp;
else proteinprice12=-0.053;
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('hmna')) + b14*sin(aspect('hmna'))
+ b15*slope('hmna') +
b16*nelevation('hmna') + b17*nsupply*cos(aspect('hmna')) + b18*nsupply*sin(aspect('hmna'))
+ b19*nsupply*slope('hmna') +
b20*nsupply*nelevation('hmna')) - 14 > 0 , proteinprice13=prp;
else proteinprice13=prpl;
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('hmsa')) + b14*sin(aspect('hmsa'))
+ b15*slope('hmsa') +
b16*nelevation('hmsa') + b17*nsupply*cos(aspect('hmsa')) + b18*nsupply*sin(aspect('hmsa')) +
b19*nsupply*slope('hmsa') +
```

```
b20*nsupply*nelevation('hmsa')) - 14 > 0 , proteinprice14=prp;  
else proteinprice14=prpl;  
);
```

```
if ((b00 + b11*nsupply + b12*nsupply**2 + b13*cos(aspect('hhna')) + b14*sin(aspect('hhna')) +  
    b15*slope('hhna') +  
    b16*nelevation('hhna') + b17*nsupply*cos(aspect('hhna')) + b18*nsupply*sin(aspect('hhna')) +  
    b19*nsupply*slope('hhna') +  
    b20*nsupply*nelevation('hhna')) - 14 > 0 , proteinprice15=prp;  
else proteinprice15=prpl;  
);
```

Variables

```
ns(j)  
proffit  
proffit1  
proffit2  
proffit3  
proffit4  
proffit5  
proffit6  
proffit7  
proffit8  
proffit9  
proffit10  
proffit11  
proffit12  
proffit13  
proffit14  
;
```

Positive Variable

```
ns
```

```
;
```

Equations

```
profit  
profit1  
profit2  
profit3  
profit4  
profit5  
profit6  
profit7  
profit8  
profit9
```

profit10
profit11
profit12
profit13
profit14

profit equation

pollution
pollution1
pollution2
pollution3
pollution4
pollution5
pollution6
pollution7
pollution8
pollution9
pollution10
pollution11
pollution12
pollution13
pollution14

constraint
constraint1
constraint2
constraint3
constraint4
constraint5
constraint6
constraint7
constraint8
constraint9
constraint10
constraint11
constraint12
constraint13
constraint14
constraint15

;
profit.. profit = e (gp*(b0 + b1*ns('llna') + b2*ns('llna')**2 + b3*cos(aspect('llna')) +
b4*sin(aspect('llna')) + b5*slope('llna')+
b6*nelevation('llna') + b7*ns('llna')*cos(aspect('llna')) + b8*ns('llna')*sin(aspect('llna')) +
b9*ns('llna')*slope('llna') + b10*ns('llna')*nelevation('llna') +

$$\begin{aligned}
& (\text{proteinprice1} * ((b00 + b11 * \text{ns}('llna') + b12 * \text{ns}('llna') ** 2 + b13 * \cos(\text{aspect}('llna')) + \\
& \quad b14 * \sin(\text{aspect}('llna')) + b15 * \text{slope}('llna') + \\
& b16 * \text{nelevation}('llna') + b17 * \text{ns}('llna') * \cos(\text{aspect}('llna')) + b18 * \text{ns}('llna') * \sin(\text{aspect}('llna')) + \\
& \quad b19 * \text{ns}('llna') * \text{slope}('llna') + \\
& b20 * \text{ns}('llna') * \text{nelevation}('llna') - 14) / .25) * (b0 + b1 * \text{ns}('llna') + b2 * \text{ns}('llna') ** 2 + \\
& \quad b3 * \cos(\text{aspect}('llna')) + b4 * \sin(\text{aspect}('llna')) + b5 * \text{slope}('llna') + \\
& b6 * \text{nelevation}('llna') + b7 * \text{ns}('llna') * \cos(\text{aspect}('llna')) + b8 * \text{ns}('llna') * \sin(\text{aspect}('llna')) + \\
& \quad b9 * \text{ns}('llna') * \text{slope}('llna') + b10 * \text{ns}('llna') * \text{nelevation}('llna')) - np * \text{ns}('llna') - cllna
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{pollution.. } (b000 + b21 * \text{ns}('llna') + b22 * \text{ns}('llna') ** 2 + \\
& \quad b23 * \cos(\text{aspect}('llna')) + b24 * \sin(\text{aspect}('llna')) + b25 * \text{slope}('llna') + \\
& b26 * \text{nelevation}('llna') + b27 * \text{ns}('llna') * \cos(\text{aspect}('llna')) + b28 * \text{ns}('llna') * \sin(\text{aspect}('llna')) + \\
& \quad b29 * \text{ns}('llna') * \text{slope}('llna') + \\
& b30 * \text{ns}('llna') * \text{nelevation}('llna')) = e = (a1) - 82.36
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{profit1.. } \text{profit1} = e = (gp * (b0 + b1 * \text{ns}('llsa') + b2 * \text{ns}('llsa') ** 2 + b3 * \cos(\text{aspect}('llsa')) + \\
& \quad b4 * \sin(\text{aspect}('llsa')) + b5 * \text{slope}('llsa') + \\
& b6 * \text{nelevation}('llsa') + b7 * \text{ns}('llsa') * \cos(\text{aspect}('llsa')) + b8 * \text{ns}('llsa') * \sin(\text{aspect}('llsa')) + \\
& \quad b9 * \text{ns}('llsa') * \text{slope}('llsa') + b10 * \text{ns}('llsa') * \text{nelevation}('llsa') + \\
& \quad (\text{proteinprice2} * ((b00 + b11 * \text{ns}('llsa') + b12 * \text{ns}('llsa') ** 2 + b13 * \cos(\text{aspect}('llsa')) + \\
& \quad \quad b14 * \sin(\text{aspect}('llsa')) + b15 * \text{slope}('llsa') + \\
& b16 * \text{nelevation}('llsa') + b17 * \text{ns}('llsa') * \cos(\text{aspect}('llsa')) + b18 * \text{ns}('llsa') * \sin(\text{aspect}('llsa')) + \\
& \quad \quad b19 * \text{ns}('llsa') * \text{slope}('llsa') + \\
& b20 * \text{ns}('llsa') * \text{nelevation}('llsa') - 14) / .25) * (b0 + b1 * \text{ns}('llsa') + b2 * \text{ns}('llsa') ** 2 + \\
& \quad b3 * \cos(\text{aspect}('llsa')) + b4 * \sin(\text{aspect}('llsa')) + b5 * \text{slope}('llsa') + \\
& b6 * \text{nelevation}('llsa') + b7 * \text{ns}('llsa') * \cos(\text{aspect}('llsa')) + b8 * \text{ns}('llsa') * \sin(\text{aspect}('llsa')) + \\
& \quad b9 * \text{ns}('llsa') * \text{slope}('llsa') + b10 * \text{ns}('llsa') * \text{nelevation}('llsa')) - np * \text{ns}('llsa') - cllsa
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{pollution1.. } (b000 + b21 * \text{ns}('llsa') + b22 * \text{ns}('llsa') ** 2 + \\
& \quad b23 * \cos(\text{aspect}('llsa')) + b24 * \sin(\text{aspect}('llsa')) + b25 * \text{slope}('llsa') + \\
& b26 * \text{nelevation}('llsa') + b27 * \text{ns}('llsa') * \cos(\text{aspect}('llsa')) + b28 * \text{ns}('llsa') * \sin(\text{aspect}('llsa')) + \\
& \quad b29 * \text{ns}('llsa') * \text{slope}('llsa') + \\
& b30 * \text{ns}('llsa') * \text{nelevation}('llsa')) = e = (a2) - 43.13
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{profit2.. } \text{profit2} = e = (gp * (b0 + b1 * \text{ns}('lmna') + b2 * \text{ns}('lmna') ** 2 + b3 * \cos(\text{aspect}('lmna')) + \\
& \quad b4 * \sin(\text{aspect}('lmna')) + b5 * \text{slope}('lmna') + \\
& b6 * \text{nelevation}('lmna') + b7 * \text{ns}('lmna') * \cos(\text{aspect}('lmna')) + b8 * \text{ns}('lmna') * \sin(\text{aspect}('lmna')) + \\
& \quad b9 * \text{ns}('lmna') * \text{slope}('lmna') + b10 * \text{ns}('lmna') * \text{nelevation}('lmna') + \\
& \quad (\text{proteinprice3} * ((b00 + b11 * \text{ns}('lmna') + b12 * \text{ns}('lmna') ** 2 + b13 * \cos(\text{aspect}('lmna')) + \\
& \quad \quad b14 * \sin(\text{aspect}('lmna')) + b15 * \text{slope}('lmna') + \\
& b16 * \text{nelevation}('lmna') + b17 * \text{ns}('lmna') * \cos(\text{aspect}('lmna')) + \\
& \quad \quad b18 * \text{ns}('lmna') * \sin(\text{aspect}('lmna')) + b19 * \text{ns}('lmna') * \text{slope}('lmna') + \\
& b20 * \text{ns}('lmna') * \text{nelevation}('lmna') - 14) / .25) * (b0 + b1 * \text{ns}('lmna') + b2 * \text{ns}('lmna') ** 2 + \\
& \quad b3 * \cos(\text{aspect}('lmna')) + b4 * \sin(\text{aspect}('lmna')) + b5 * \text{slope}('lmna') + \\
& b6 * \text{nelevation}('lmna') + b7 * \text{ns}('lmna') * \cos(\text{aspect}('lmna')) + b8 * \text{ns}('lmna') * \sin(\text{aspect}('lmna')) + \\
& \quad b9 * \text{ns}('lmna') * \text{slope}('lmna') + b10 * \text{ns}('lmna') * \text{nelevation}('lmna')) - np * \text{ns}('lmna') - clmna
\end{aligned}$$

```

;
pollution2.. (b000 + b21*ns('lmna') + b22*ns('lmna')**2 +
b23*cos(aspect('lmna')) + b24*sin(aspect('lmna')) + b25*slope('lmna') +
b26*nelevation('lmna') + b27*ns('lmna')*cos(aspect('lmna')) +
b28*ns('lmna')*sin(aspect('lmna')) + b29*ns('lmna')*slope('lmna')+
b30*ns('lmna')*nelevation('lmna') ) =e= (a3)-89.64
;
profit3.. profit3 =e= ( gp*(b0 + b1*ns('lmsa') + b2*ns('lmsa')**2 + b3*cos(aspect('lmsa')) +
b4*sin(aspect('lmsa')) + b5*slope('lmsa')+
b6*nelevation('lmsa') + b7*ns('lmsa')*cos(aspect('lmsa')) + b8*ns('lmsa')*sin(aspect('lmsa')) +
b9*ns('lmsa')*slope('lmsa') + b10*ns('lmsa')*nelevation('lmsa') +
(proteinprice4*((b00 + b11*ns('lmsa') + b12*ns('lmsa')**2 + b13*cos(aspect('lmsa')) +
b14*sin(aspect('lmsa')) + b15*slope('lmsa') +
b16*nelevation('lmsa') + b17*ns('lmsa')*cos(aspect('lmsa')) + b18*ns('lmsa')*sin(aspect('lmsa'))
+ b19*ns('lmsa')*slope('lmsa') +
b20*ns('lmsa')*nelevation('lmsa') )-14)/.25)*(b0 + b1*ns('lmsa') + b2*ns('lmsa')**2 +
b3*cos(aspect('lmsa')) + b4*sin(aspect('lmsa')) + b5*slope('lmsa')+
b6*nelevation('lmsa') + b7*ns('lmsa')*cos(aspect('lmsa')) + b8*ns('lmsa')*sin(aspect('lmsa')) +
b9*ns('lmsa')*slope('lmsa') + b10*ns('lmsa')*nelevation('lmsa')) ) - np*ns('lmsa') - clmsa
;
pollution3.. (b000 + b21*ns('lmsa') + b22*ns('lmsa')**2 +
b23*cos(aspect('lmsa')) + b24*sin(aspect('lmsa')) + b25*slope('lmsa') +
b26*nelevation('lmsa') + b27*ns('lmsa')*cos(aspect('lmsa')) + b28*ns('lmsa')*sin(aspect('lmsa'))
+ b29*ns('lmsa')*slope('lmsa')+
b30*ns('lmsa')*nelevation('lmsa') ) =e= (a4)-50.41
;
profit4.. profit4 =e= ( gp*(b0 + b1*ns('lhna') + b2*ns('lhna')**2 + b3*cos(aspect('lhna')) +
b4*sin(aspect('lhna')) + b5*slope('lhna')+
b6*nelevation('lhna') + b7*ns('lhna')*cos(aspect('lhna')) + b8*ns('lhna')*sin(aspect('lhna')) +
b9*ns('lhna')*slope('lhna') + b10*ns('lhna')*nelevation('lhna') +
(proteinprice5*((b00 + b11*ns('lhna') + b12*ns('lhna')**2 + b13*cos(aspect('lhna')) +
b14*sin(aspect('lhna')) + b15*slope('lhna') +
b16*nelevation('lhna') + b17*ns('lhna')*cos(aspect('lhna')) + b18*ns('lhna')*sin(aspect('lhna')) +
b19*ns('lhna')*slope('lhna') +
b20*ns('lhna')*nelevation('lhna') )-14)/.25)*(b0 + b1*ns('lhna') + b2*ns('lhna')**2 +
b3*cos(aspect('lhna')) + b4*sin(aspect('lhna')) + b5*slope('lhna')+
b6*nelevation('lhna') + b7*ns('lhna')*cos(aspect('lhna')) + b8*ns('lhna')*sin(aspect('lhna')) +
b9*ns('lhna')*slope('lhna') + b10*ns('lhna')*nelevation('lhna')) ) - np*ns('lhna') - clhna
;
pollution4.. (b000 + b21*ns('lhna') + b22*ns('lhna')**2 +
b23*cos(aspect('lhna')) + b24*sin(aspect('lhna')) + b25*slope('lhna') +
b26*nelevation('lhna') + b27*ns('lhna')*cos(aspect('lhna')) + b28*ns('lhna')*sin(aspect('lhna')) +
b29*ns('lhna')*slope('lhna')+
b30*ns('lhna')*nelevation('lhna') ) =e= (a5)-75.40
;

```

```

profit5.. profitt5 =e= ( gp*(b0 + b1*ns('mlna') + b2*ns('mlna')**2 + b3*cos(aspect('mlna')) +
    b4*sin(aspect('mlna')) + b5*slope('mlna')+
b6*nelevation('mlna') + b7*ns('mlna')*cos(aspect('mlna')) + b8*ns('mlna')*sin(aspect('mlna')) +
    b9*ns('mlna')*slope('mlna') + b10*ns('mlna')*nelevation('mlna') +
    (proteinprice6*((b00 + b11*ns('mlna') + b12*ns('mlna')**2 + b13*cos(aspect('mlna')) +
    b14*sin(aspect('mlna')) + b15*slope('mlna') +
b16*nelevation('mlna') + b17*ns('mlna')*cos(aspect('mlna')) +
    b18*ns('mlna')*sin(aspect('mlna')) + b19*ns('mlna')*slope('mlna') +
b20*ns('mlna')*nelevation('mlna') -14)/.25)*(b0 + b1*ns('mlna') + b2*ns('mlna')**2 +
    b3*cos(aspect('mlna')) + b4*sin(aspect('mlna')) + b5*slope('mlna')+
b6*nelevation('mlna') + b7*ns('mlna')*cos(aspect('mlna')) + b8*ns('mlna')*sin(aspect('mlna')) +
    b9*ns('mlna')*slope('mlna') + b10*ns('mlna')*nelevation('mlna')) ) - np*ns('mlna') - cmlna
;
pollution5.. (b000 + b21*ns('mlna') + b22*ns('mlna')**2 +
b23*cos(aspect('mlna')) + b24*sin(aspect('mlna')) + b25*slope('mlna') +
b26*nelevation('mlna') + b27*ns('mlna')*cos(aspect('mlna')) +
    b28*ns('mlna')*sin(aspect('mlna')) + b29*ns('mlna')*slope('mlna')+
b30*ns('mlna')*nelevation('mlna') ) =e= (a6)-59.55
;
profit6.. profitt6 =e= ( gp*(b0 + b1*ns('mlsa') + b2*ns('mlsa')**2 + b3*cos(aspect('mlsa')) +
    b4*sin(aspect('mlsa')) + b5*slope('mlsa')+
b6*nelevation('mlsa') + b7*ns('mlsa')*cos(aspect('mlsa')) + b8*ns('mlsa')*sin(aspect('mlsa')) +
    b9*ns('mlsa')*slope('mlsa') + b10*ns('mlsa')*nelevation('mlsa') +
    (proteinprice7*((b00 + b11*ns('mlsa') + b12*ns('mlsa')**2 + b13*cos(aspect('mlsa')) +
    b14*sin(aspect('mlsa')) + b15*slope('mlsa') +
b16*nelevation('mlsa') + b17*ns('mlsa')*cos(aspect('mlsa')) + b18*ns('mlsa')*sin(aspect('mlsa'))
    + b19*ns('mlsa')*slope('mlsa') +
b20*ns('mlsa')*nelevation('mlsa') )-14)/.25)*(b0 + b1*ns('mlsa') + b2*ns('mlsa')**2 +
    b3*cos(aspect('mlsa')) + b4*sin(aspect('mlsa')) + b5*slope('mlsa')+
b6*nelevation('mlsa') + b7*ns('mlsa')*cos(aspect('mlsa')) + b8*ns('mlsa')*sin(aspect('mlsa')) +
    b9*ns('mlsa')*slope('mlsa') + b10*ns('mlsa')*nelevation('mlsa')) ) - np*ns('mlsa') - cmlsa
;
pollution6.. (b000 + b21*ns('mlsa') + b22*ns('mlsa')**2 +
b23*cos(aspect('mlsa')) + b24*sin(aspect('mlsa')) + b25*slope('mlsa') +
b26*nelevation('mlsa') + b27*ns('mlsa')*cos(aspect('mlsa')) + b28*ns('mlsa')*sin(aspect('mlsa'))
    + b29*ns('mlsa')*slope('mlsa')+
b30*ns('mlsa')*nelevation('mlsa') ) =e= (a7)-20.32
;
profit7.. profitt7 =e= ( gp*(b0 + b1*ns('mmna') + b2*ns('mmna')**2 + b3*cos(aspect('mmna'))
    + b4*sin(aspect('mmna')) + b5*slope('mmna')+
b6*nelevation('mmna') + b7*ns('mmna')*cos(aspect('mmna')) +
    b8*ns('mmna')*sin(aspect('mmna')) + b9*ns('mmna')*slope('mmna') +
    b10*ns('mmna')*nelevation('mmna') +
    (proteinprice8*((b00 + b11*ns('mmna') + b12*ns('mmna')**2 + b13*cos(aspect('mmna')) +
    b14*sin(aspect('mmna')) + b15*slope('mmna') +

```

$$\begin{aligned}
& b16*nelevation('mmna') + b17*ns('mmna')*\cos(\text{aspect}('mmna')) + \\
& \quad b18*ns('mmna')*\sin(\text{aspect}('mmna')) + b19*ns('mmna')*\text{slope}('mmna') + \\
& b20*ns('mmna')*nelevation('mmna') -14)/.25)*(b0 + b1*ns('mmna') + b2*ns('mmna')**2 + \\
& \quad b3*\cos(\text{aspect}('mmna')) + b4*\sin(\text{aspect}('mmna')) + b5*\text{slope}('mmna'))+ \\
& b6*nelevation('mmna') + b7*ns('mmna')*\cos(\text{aspect}('mmna')) + \\
& \quad b8*ns('mmna')*\sin(\text{aspect}('mmna')) + b9*ns('mmna')*\text{slope}('mmna') + \\
& \quad b10*ns('mmna')*nelevation('mmna')) - np*ns('mmna') - cmmna
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{pollution7.. } (b000 + b21*ns('mmna') + b22*ns('mmna')**2 + \\
& b23*\cos(\text{aspect}('mmna')) + b24*\sin(\text{aspect}('mmna')) + b25*\text{slope}('mmna') + \\
& b26*nelevation('mmna') + b27*ns('mmna')*\cos(\text{aspect}('mmna')) + \\
& \quad b28*ns('mmna')*\sin(\text{aspect}('mmna')) + b29*ns('mmna')*\text{slope}('mmna'))+ \\
& b30*ns('mmna')*nelevation('mmna')) =e= (a8)-66.82
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{profit8.. } \text{profit8} =e= (gp*(b0 + b1*ns('mmsa') + b2*ns('mmsa')**2 + b3*\cos(\text{aspect}('mmsa')) + \\
& \quad b4*\sin(\text{aspect}('mmsa')) + b5*\text{slope}('mmsa'))+ \\
& b6*nelevation('mmsa') + b7*ns('mmsa')*\cos(\text{aspect}('mmsa')) + \\
& \quad b8*ns('mmsa')*\sin(\text{aspect}('mmsa')) + b9*ns('mmsa')*\text{slope}('mmsa') + \\
& \quad b10*ns('mmsa')*nelevation('mmsa') + \\
& \quad (\text{proteinprice9}*((b00 + b11*ns('mmsa') + b12*ns('mmsa')**2 + b13*\cos(\text{aspect}('mmsa')) + \\
& \quad b14*\sin(\text{aspect}('mmsa')) + b15*\text{slope}('mmsa') + \\
& b16*nelevation('mmsa') + b17*ns('mmsa')*\cos(\text{aspect}('mmsa')) + \\
& \quad b18*ns('mmsa')*\sin(\text{aspect}('mmsa')) + b19*ns('mmsa')*\text{slope}('mmsa') + \\
& b20*ns('mmsa')*nelevation('mmsa') -14)/.25)*(b0 + b1*ns('mmsa') + b2*ns('mmsa')**2 + \\
& \quad b3*\cos(\text{aspect}('mmsa')) + b4*\sin(\text{aspect}('mmsa')) + b5*\text{slope}('mmsa'))+ \\
& b6*nelevation('mmsa') + b7*ns('mmsa')*\cos(\text{aspect}('mmsa')) + \\
& \quad b8*ns('mmsa')*\sin(\text{aspect}('mmsa')) + b9*ns('mmsa')*\text{slope}('mmsa') + \\
& \quad b10*ns('mmsa')*nelevation('mmsa')) - np*ns('mmsa') - cmmsa
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{pollution8.. } (b000 + b21*ns('mmsa') + b22*ns('mmsa')**2 + \\
& b23*\cos(\text{aspect}('mmsa')) + b24*\sin(\text{aspect}('mmsa')) + b25*\text{slope}('mmsa') + \\
& b26*nelevation('mmsa') + b27*ns('mmsa')*\cos(\text{aspect}('mmsa')) + \\
& \quad b28*ns('mmsa')*\sin(\text{aspect}('mmsa')) + b29*ns('mmsa')*\text{slope}('mmsa'))+ \\
& b30*ns('mmsa')*nelevation('mmsa')) =e= (a9)-7.59
\end{aligned}$$

$$\begin{aligned}
& ; \\
& \text{profit9.. } \text{profit9} =e= (gp*(b0 + b1*ns('mhna') + b2*ns('mhna')**2 + b3*\cos(\text{aspect}('mhna')) + \\
& \quad b4*\sin(\text{aspect}('mhna')) + b5*\text{slope}('mhna'))+ \\
& b6*nelevation('mhna') + b7*ns('mhna')*\cos(\text{aspect}('mhna')) + b8*ns('mhna')*\sin(\text{aspect}('mhna')) \\
& \quad + b9*ns('mhna')*\text{slope}('mhna') + b10*ns('mhna')*nelevation('mhna') + \\
& \quad (\text{proteinprice10}*((b00 + b11*ns('mhna') + b12*ns('mhna')**2 + b13*\cos(\text{aspect}('mhna')) + \\
& \quad b14*\sin(\text{aspect}('mhna')) + b15*\text{slope}('mhna') + \\
& b16*nelevation('mhna') + b17*ns('mhna')*\cos(\text{aspect}('mhna')) + \\
& \quad b18*ns('mhna')*\sin(\text{aspect}('mhna')) + b19*ns('mhna')*\text{slope}('mhna') + \\
& b20*ns('mhna')*nelevation('mhna') -14)/.25)*(b0 + b1*ns('mhna') + b2*ns('mhna')**2 + \\
& \quad b3*\cos(\text{aspect}('mhna')) + b4*\sin(\text{aspect}('mhna')) + b5*\text{slope}('mhna'))+
\end{aligned}$$

$$b6*nelevation('mhna') + b7*ns('mhna')*\cos(\text{aspect}('mhna')) + b8*ns('mhna')*\sin(\text{aspect}('mhna')) + b9*ns('mhna')*\text{slope}('mhna') + b10*ns('mhna')*\text{nelevation}('mhna')) - np*ns('mhna') - cmhna$$

;

$$\text{pollution9.. } (b000 + b21*ns('mhna') + b22*ns('mhna')**2 + b23*\cos(\text{aspect}('mhna')) + b24*\sin(\text{aspect}('mhna')) + b25*\text{slope}('mhna') + b26*nelevation('mhna') + b27*ns('mhna')*\cos(\text{aspect}('mhna')) + b28*ns('mhna')*\sin(\text{aspect}('mhna')) + b29*ns('mhna')*\text{slope}('mhna') + b30*ns('mhna')*\text{nelevation}('mhna')) =e= (a10)-55.05$$

;

$$\text{profit10.. } \text{profit10} =e= (gp*(b0 + b1*ns('mhsa') + b2*ns('mhsa')**2 + b3*\cos(\text{aspect}('mhsa')) + b4*\sin(\text{aspect}('mhsa')) + b5*\text{slope}('mhsa') + b6*nelevation('mhsa') + b7*ns('mhsa')*\cos(\text{aspect}('mhsa')) + b8*ns('mhsa')*\sin(\text{aspect}('mhsa')) + b9*ns('mhsa')*\text{slope}('mhsa') + b10*ns('mhsa')*\text{nelevation}('mhsa') + (\text{proteinprice11}*((b00 + b11*ns('mhsa') + b12*ns('mhsa')**2 + b13*\cos(\text{aspect}('mhsa')) + b14*\sin(\text{aspect}('mhsa')) + b15*\text{slope}('mhsa') + b16*nelevation('mhsa') + b17*ns('mhsa')*\cos(\text{aspect}('mhsa')) + b18*ns('mhsa')*\sin(\text{aspect}('mhsa')) + b19*ns('mhsa')*\text{slope}('mhsa') + b20*ns('mhsa')*\text{nelevation}('mhsa')) -14)/.25)*(b0 + b1*ns('mhsa') + b2*ns('mhsa')**2 + b3*\cos(\text{aspect}('mhsa')) + b4*\sin(\text{aspect}('mhsa')) + b5*\text{slope}('mhsa') + b6*nelevation('mhsa') + b7*ns('mhsa')*\cos(\text{aspect}('mhsa')) + b8*ns('mhsa')*\sin(\text{aspect}('mhsa')) + b9*ns('mhsa')*\text{slope}('mhsa') + b10*ns('mhsa')*\text{nelevation}('mhsa')) - np*ns('mhsa') - cmhsa$$

;

$$\text{pollution10.. } (b000 + b21*ns('mhsa') + b22*ns('mhsa')**2 + b23*\cos(\text{aspect}('mhsa')) + b24*\sin(\text{aspect}('mhsa')) + b25*\text{slope}('mhsa') + b26*nelevation('mhsa') + b27*ns('mhsa')*\cos(\text{aspect}('mhsa')) + b28*ns('mhsa')*\sin(\text{aspect}('mhsa')) + b29*ns('mhsa')*\text{slope}('mhsa') + b30*ns('mhsa')*\text{nelevation}('mhsa')) =e= (a11)-15.82$$

;

$$\text{profit11.. } \text{profit11} =e= (gp*(b0 + b1*ns('hlna') + b2*ns('hlna')**2 + b3*\cos(\text{aspect}('hlna')) + b4*\sin(\text{aspect}('hlna')) + b5*\text{slope}('hlna') + b6*nelevation('hlna') + b7*ns('hlna')*\cos(\text{aspect}('hlna')) + b8*ns('hlna')*\sin(\text{aspect}('hlna')) + b9*ns('hlna')*\text{slope}('hlna') + b10*ns('hlna')*\text{nelevation}('hlna') + (\text{proteinprice12}*((b00 + b11*ns('hlna') + b12*ns('hlna')**2 + b13*\cos(\text{aspect}('hlna')) + b14*\sin(\text{aspect}('hlna')) + b15*\text{slope}('hlna') + b16*nelevation('hlna') + b17*ns('hlna')*\cos(\text{aspect}('hlna')) + b18*ns('hlna')*\sin(\text{aspect}('hlna')) + b19*ns('hlna')*\text{slope}('hlna') + b20*ns('hlna')*\text{nelevation}('hlna')) -14)/.25)*(b0 + b1*ns('hlna') + b2*ns('hlna')**2 + b3*\cos(\text{aspect}('hlna')) + b4*\sin(\text{aspect}('hlna')) + b5*\text{slope}('hlna') + b6*nelevation('hlna') + b7*ns('hlna')*\cos(\text{aspect}('hlna')) + b8*ns('hlna')*\sin(\text{aspect}('hlna')) + b9*ns('hlna')*\text{slope}('hlna') + b10*ns('hlna')*\text{nelevation}('hlna')) - np*ns('hlna') - chlna$$

;

$$\text{pollution11.. } (b000 + b21*ns('hlna') + b22*ns('hlna')**2 + b23*\cos(\text{aspect}('hlna')) + b24*\sin(\text{aspect}('hlna')) + b25*\text{slope}('hlna') + b26*nelevation('hlna') + b27*ns('hlna')*\cos(\text{aspect}('hlna')) + b28*ns('hlna')*\sin(\text{aspect}('hlna')) + b29*ns('hlna')*\text{slope}('hlna'))$$

$$b30*ns('hlna')*nelevation('hlna')) =e= (a12)-36.74$$

;

$$\begin{aligned} \text{profit12.. profit12} =e= & (gp*(b0 + b1*ns('hmna') + b2*ns('hmna')**2 + b3*cos(aspect('hmna')) \\ & + b4*sin(aspect('hmna')) + b5*slope('hmna')+ \\ b6*nelevation('hmna') + b7*ns('hmna')*cos(aspect('hmna')) + b8*ns('hmna')*sin(aspect('hmna')) \\ & + b9*ns('hmna')*slope('hmna') + b10*ns('hmna')*nelevation('hmna') + \\ & (\text{proteinprice13}*((b00 + b11*ns('hmna') + b12*ns('hmna')**2 + b13*cos(aspect('hmna')) + \\ & b14*sin(aspect('hmna')) + b15*slope('hmna') + \\ b16*nelevation('hmna') + b17*ns('hmna')*cos(aspect('hmna')) + \\ & b18*ns('hmna')*sin(aspect('hmna')) + b19*ns('hmna')*slope('hmna') + \\ b20*ns('hmna')*nelevation('hmna'))-14)/.25)*(b0 + b1*ns('hmna') + b2*ns('hmna')**2 + \\ & b3*cos(aspect('hmna')) + b4*sin(aspect('hmna')) + b5*slope('hmna')+ \\ b6*nelevation('hmna') + b7*ns('hmna')*cos(aspect('hmna')) + b8*ns('hmna')*sin(aspect('hmna')) \\ & + b9*ns('hmna')*slope('hmna') + b10*ns('hmna')*nelevation('hmna'))) - np*ns('hmna')- \\ & \text{chmna} \end{aligned}$$

;

$$\begin{aligned} \text{pollution12..} & (b000 + b21*ns('hmna') + b22*ns('hmna')**2 + \\ & b23*cos(aspect('hmna')) + b24*sin(aspect('hmna')) + b25*slope('hmna') + \\ & b26*nelevation('hmna') + b27*ns('hmna')*cos(aspect('hmna')) + \\ & b28*ns('hmna')*sin(aspect('hmna')) + b29*ns('hmna')*slope('hmna')+ \\ b30*ns('hmna')*nelevation('hmna')) =e= (a13)-44.01 \end{aligned}$$

;

$$\begin{aligned} \text{profit13.. profit13} =e= & (gp*(b0 + b1*ns('hmsa') + b2*ns('hmsa')**2 + b3*cos(aspect('hmsa')) + \\ & b4*sin(aspect('hmsa')) + b5*slope('hmsa')+ \\ b6*nelevation('hmsa') + b7*ns('hmsa')*cos(aspect('hmsa')) + b8*ns('hmsa')*sin(aspect('hmsa')) + \\ & b9*ns('hmsa')*slope('hmsa') + b10*ns('hmsa')*nelevation('hmsa') + \\ & (\text{proteinprice14}*((b00 + b11*ns('hmsa') + b12*ns('hmsa')**2 + b13*cos(aspect('hmsa')) + \\ & b14*sin(aspect('hmsa')) + b15*slope('hmsa') + \\ b16*nelevation('hmsa') + b17*ns('hmsa')*cos(aspect('hmsa')) + \\ & b18*ns('hmsa')*sin(aspect('hmsa')) + b19*ns('hmsa')*slope('hmsa') + \\ b20*ns('hmsa')*nelevation('hmsa'))-14)/.25)*(b0 + b1*ns('hmsa') + b2*ns('hmsa')**2 + \\ & b3*cos(aspect('hmsa')) + b4*sin(aspect('hmsa')) + b5*slope('hmsa')+ \\ b6*nelevation('hmsa') + b7*ns('hmsa')*cos(aspect('hmsa')) + b8*ns('hmsa')*sin(aspect('hmsa')) + \\ & b9*ns('hmsa')*slope('hmsa') + b10*ns('hmsa')*nelevation('hmsa'))) - np*ns('hmsa') - \text{chmsa} \end{aligned}$$

;

$$\begin{aligned} \text{pollution13..} & (b000 + b21*ns('hmsa') + b22*ns('hmsa')**2 + \\ & b23*cos(aspect('hmsa')) + b24*sin(aspect('hmsa')) + b25*slope('hmsa') + \\ & b26*nelevation('hmsa') + b27*ns('hmsa')*cos(aspect('hmsa')) + \\ & b28*ns('hmsa')*sin(aspect('hmsa')) + b29*ns('hmsa')*slope('hmsa')+ \\ b30*ns('hmsa')*nelevation('hmsa')) =e= (a14)-4.78 \end{aligned}$$

;

$$\begin{aligned} \text{profit14.. profit14} =e= & (gp*(b0 + b1*ns('hhna') + b2*ns('hhna')**2 + b3*cos(aspect('hhna')) + \\ & b4*sin(aspect('hhna')) + b5*slope('hhna')+ \\ b6*nelevation('hhna') + b7*ns('hhna')*cos(aspect('hhna')) + b8*ns('hhna')*sin(aspect('hhna')) + \\ & b9*ns('hhna')*slope('hhna') + b10*ns('hhna')*nelevation('hhna') + \end{aligned}$$

```

(proteinprice15*((b00 + b11*ns('hhna') + b12*ns('hhna')**2 + b13*cos(aspect('hhna')) +
  b14*sin(aspect('hhna')) + b15*slope('hhna') +
b16*nelevation('hhna') + b17*ns('hhna')*cos(aspect('hhna')) + b18*ns('hhna')*sin(aspect('hhna'))
  + b19*ns('hhna')*slope('hhna') +
b20*ns('hhna')*nelevation('hhna') )-14)/.25)*(b0 + b1*ns('hhna') + b2*ns('hhna')**2 +
  b3*cos(aspect('hhna')) + b4*sin(aspect('hhna')) + b5*slope('hhna')+
b6*nelevation('hhna') + b7*ns('hhna')*cos(aspect('hhna')) + b8*ns('hhna')*sin(aspect('hhna')) +
  b9*ns('hhna')*slope('hhna') + b10*ns('hhna')*nelevation('hhna')) ) - np*ns('hhna') - chhna
;
pollution14.. (b000 + b21*ns('hhna') + b22*ns('hhna')**2 +
b23*cos(aspect('hhna')) + b24*sin(aspect('hhna')) + b25*slope('hhna') +
b26*nelevation('hhna') + b27*ns('hhna')*cos(aspect('hhna')) + b28*ns('hhna')*sin(aspect('hhna'))
  + b29*ns('hhna')*slope('hhna')+
b30*ns('hhna')*nelevation('hhna') ) =e= (a15)-34.70
;
*constraint.. ns('llna')+ ns('llsa')+ ns('lmna')+ns('lmsa')+
  ns('lhna')+ns('mlna')+ns('mlsa')+ns('mmna') +ns('mmsa') +ns('mhna')+ns('mhsa')+ns('hlna')
  +ns('hmna')+ns('hmsa')+ns('hhna') =g= nsupply
constraint.. a1+a2+a3+a4+a5+a6+a7+a8+a9+a10+a11+a12+a13+a14+a15 =l= u1
;
constraint1.. ns('llna') =g= 156.07
;
constraint2.. ns('llsa') =g= 162.51
;
constraint3.. ns('lmna') =g= 170.85
;
constraint4.. ns('lmsa') =g= 152.51
;
constraint5.. ns('lhna') =g= 155.38
;
constraint6.. ns('mlna') =g= 148.28
;
constraint7.. ns('mlsa') =g= 108.79
;
constraint8.. ns('mmna') =g= 170.05
;
constraint9.. ns('mmsa') =g= 175.15
;
constraint10.. ns('mhna') =g= 157.93
;
constraint11.. ns('mhsa') =g= 140.11
;
constraint12.. ns('hlna') =g= 108.12
;
constraint13.. ns('hmna') =g= 148.53
;

```

```

constraint14.. ns('hmsa') =g= 112.43
;
constraint15.. ns('hhna') =g= 181.098
;

model fun / all /;

option lp=bdmlp;
*loop(T$(ord(T)>1),
*u1=u(T);

option lp=bdmlp;
solve fun using nlp maximizing profitt
;
solve fun using nlp maximizing profitt1
;
solve fun using nlp maximizing profitt2
;
solve fun using nlp maximizing profitt3
;
solve fun using nlp maximizing profitt4
;
solve fun using nlp maximizing profitt5
;
solve fun using nlp maximizing profitt6
;
solve fun using nlp maximizing profitt7
;
solve fun using nlp maximizing profitt8
;
solve fun using nlp maximizing profitt9
;
solve fun using nlp maximizing profitt10
;
solve fun using nlp maximizing profitt11
;
solve fun using nlp maximizing profitt12
;
solve fun using nlp maximizing profitt13
;
solve fun using nlp maximizing profitt14
;

*prof(T)=profitt.l;

```



```
*nisup(T)=ns.l;  
*shadow(T)=pollution.m;  
*U11(T)=pollution.up;
```

```
file out/'H:\Dissertation\Nitrogen Use\Simulation\runjosh.txt'/;put out;  
put /;
```

```
put' profit    profit1  profit2 profit3 profit4  profit5 profit6 profit7 profit8 profit9 profit10  
    profit11 profit12 profit13 profit14';put/;
```

```
put profit1 , profit1.1, profit2.1, profit3.1, profit4.1, profit5.1, profit6.1 , profit7.1, profit8.1,  
    profit9.1, profit10.1 , profit11.1 profit12.1 profit13.1 profit14.1;put/;  
put/;
```

```
put' pollution    pollution1  pollution2 pollution3 pollution4  pollution5 pollution6 pollution7  
    pollution8 pollution9 pollution10 pollution11 pollution12 pollution13 pollution14';put/;
```

```
put pollution.1 , pollution1.1, pollution2.1, pollution3.1, pollution4.1, pollution5.1, pollution6.1 ,  
    pollution7.1, pollution8.1, pollution9.1, pollution10.1 , pollution11.1 pollution12.1 pollution13.1  
    pollution14.1;put/;  
put/;
```

```
put' nsupply    nsupply1  nsupply2 nsupply3 nsupply4  nsupply5 nsupply6 nsupply7  
    nsupply8 nsupply9 nsupply10 nsupply11 nsupply12 nsupply13 nsupply14 nsupply15';put/;
```

```
put constraint1.1, constraint2.1, constraint3.1, constraint4.1, constraint5.1, constraint6.1 ,  
    constraint7.1, constraint8.1, constraint9.1, constraint10.1 , constraint11.1 constraint12.1  
    constraint13.1 constraint14.1 constraint15.1;put/;  
put/;
```

```
put' shadow    shadow1  shadow2 shadow3 shadow4  shadow5 shadow6 shadow7 shadow8  
    shadow9 shadow10 shadow11 shadow12 shadow13 shadow14';put/;
```

```
put pollution.m , pollution1.m, pollution2.m, pollution3.m, pollution4.m, pollution5.m,  
    pollution6.m , pollution7.m, pollution8.m, pollution9.m, pollution10.m , pollution11.m  
    pollution12.m pollution13.m pollution14.m;put/;
```

```
put/;  
putclose out;
```