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The Impact of Rising Corn Prices on the Conservation Reserve Program: An Empirical Model

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1. INTRODUCTION

Due to a rising middle class and an expansion in ethanol production, corn demand has surged in the last decade. While farmers have seen their profits exponentially increase and rural states have experienced an economic revival, there are increasing concerns that high commodity prices have led and could lead to unintended harmful environmental effects. The most pronounced of which is the chance that higher crop prices are luring farmers to withdraw retired land from conservation, specifically from the Conservation Reserve Program (CRP). Administered by the U.S. Department of Agriculture (USDA), the CRP program was first established in 1985 in order to control the supply of agricultural goods. However, beginning in the 1990's, it was transformed into a program aimed at protecting millions of acres of land across the nation with the objective of reducing water runoff and sedimentation, improving water quality, establishing wildlife habitat and enhancing forest and wetland resources. The program encourages farmers to retire environmentally sensitive cropland into conservation, allowing the growth of natural vegetative cover such as native grasses and trees (Natural Resources Conservation Service, 2011). In exchange for placing their land into the program and signing an agreement to not cultivate the land, farmers receive an annual rental payment. Participants can choose to enroll in either a 10 or 15-year contract (Farm Service Agency, 2011). However, with growing corn demand, the media and academic sources have begun to question the extent to which rising prices have affected the composition of CRP enrollment. There is a popular belief that under high crop prices, landowners can earn a higher return from shifting retired land back into production than what they would otherwise receive in annual CRP rental payments. If this shift is in fact taking place, the environmental repercussions could be exponential. Thus, this paper asks: what is the effect of corn prices on CRP acreage enrollment to date?

The existing literature has focused on the application of simulation models to forecast the effect that various corn prices will have on the CRP program. The models construct CRP supply functions, which establish a postulated set of parameters such as corn price, corn yield and CRP rental rates. Specifically, Hellerstein and Malcolm (2011) in their study, *The Influence of Rising Commodity Prices on the Conservation Reserve Program*, construct a likely-to-bid model, which simulates how many acres would be offered to the CRP program on a national basis, if the program were to start over and accept land in one hypothetical sign-up. They hold the values of a postulated set of parameters constant, while adjusting the price of corn in order to simulate different scenarios. Broadly, they find that if high commodity prices are sustained, landowner interest in the CRP will begin to precipitously drop off. They estimate that if crop prices and CRP rental rates seen since 2007 were to remain constant over the long run, the quantity as well as the environmental quality of CRP acreage will decline. They conclude that the 2007 CRP rental rates would need to be raised by roughly 60 percent in order to offset the long-term impact of high crop prices. Secchi and Babcock (2007) similarly construct a CRP supply curve and use a steady state model, but use a long-term equilibrium to estimate the effects of a given crop price level in the state of Iowa. They estimate that if corn were to remain at $3 a bushel in the long run, of the existing two million acres of CRP land in Iowa, roughly a million acres would be returned to crop production. Babcock and Hart (2008), do not describe their methods, however predict that if 2008 crop prices persist and CRP policy remains unchanged, two million acres of CRP land could be returned to crop production per year for the next ten years as contracts expire. Thus, in examining the relationship between corn prices and CRP acreage, the existing literature has focused on projections for the state of Iowa and at a national level.

The purpose of this paper is to examine the effect that corn prices, corn yield, corn acreage, the gross state product and the 2008 Farm Bill have on the number of acres enrolled in the CRP program within the Corn Belt region. The first three models are linear and take into account varying time lags for the price of corn. Since the existing literature has found that corn acreage can be relatively price inelastic in the short term, this thesis uses a time lag of three years in Models 3-5. This factor is explained in greater depth later in the empirical model section. The fourth model uses a panel set which takes into account unobserved state statistics to estimate the effects of the independent variables listed above on CRP enrollment. The fifth model examines the impact that corn prices, corn yield and gross state product have on the percentage of CRP acreage relative to corn acres planted. This model creates a new dependent variable, in order to assess whether CRP acreage or corn acreage is increasing relative to the other. This thesis places particular emphasis on the fourth and fifth models as they account for unobserved state statistics and avoid omitted variable bias and heteroscedasticity.

The contribution of this work is the construction of an empirical model, which examines historical data for several variables and their impact on the number of acres enrolled in the CRP program. To date, the existing literature has not applied regression analysis to explore the relationship between corn prices and CRP acreage. The existing research has rather focused on the application of simulation models to forecast the composition of CRP enrollment under hypothetical corn price scenarios. While Secchi and

Babcock (2007) account for corn yield within their constructed CRP supply curves, it is held constant within all of the simulations. This thesis suggests that corn yield can independently impact CRP enrollment. Additionally, while Hellerstein & Malcolm (2011) focused on aggregate national data and Secchi & Babcock focused on Iowa, this thesis pays specific attention to the Corn Belt region. Finally, the existing literature has not explored the relationship between corn acreage planted and CRP acreage, or the impact of corn prices on the ratio of these two variables. Thus, this thesis contributes to the existing literature through the application of regression analysis, the inclusion of new variables and the examination of the Corn Belt region.

Through regression analysis, the data estimates a significant, negative correlation between corn prices and CRP enrollment. The results suggest that corn prices become more significant as the time lag grows larger. Prices are initially insignificant with a time lag of one year, significant at the 10 percent level with a time lag of two years, significant at the 5 percent level with a time lag of three years and significant at the 1 percent level when unobserved state statistics are taken into account with a time lag of three years. The fourth model, which incorporates the unobserved state statistics through a panel data set, suggests that an increase in corn prices by $1 will lead to a reduction of 135,263 CRP acres within the Corn Belt. The fifth model, suggests that a $1 rise in corn prices will cause a 2.35 percent decline in CRP acreage relative to corn acreage. This estimate is particularly relevant, as the first four models depicted corn acreage and CRP acreage to be increasing simultaneously. Corn yield was estimated to be insignificant, with a negative coefficient in all models. The data describes a significant, negative correlation between gross state product and CRP acreage in the first three linear models; however this significance disappears in the fourth and fifth model when unobserved state statistics are accounted for. The 2008 Farm Bill policy dummy was shown to be insignificant, with a positive coefficient in all models. Thus, in conclusion, this thesis supports the existing literature, which states that rising corn prices will lead to the reduction in CRP acreage; while the remaining variables tested were found to be insignificant in the fourth and fifth panel model.

Section two examines the existing research on the CRP program and the simulation models, which have been constructed to project future changes in the program. Section three discusses the methodology of this paper, which includes data collection, empirical models used and expectations of results, with the support of existing research. Section four concludes with an examination of the results and a discussion of the implications.

2. LITERATURE REVIEW

The exponential surge in the demand and prices of agricultural commodities starting in 2005 have led to a number of unsubstantiated and speculative reports concerning the withdrawal of land in the Conservation Reserve Program (CRP). Much of the existing literature refers to the expansion in ethanol production as a driving force behind rising prices and the potential withdrawal of CRP land. To date, there is little academic research that has collected and analyzed data in order to explore the relationship between corn prices and the CRP program. The few studies that exist focus on constructing CRP supply curve models and running simulations to project future changes in the program.

Secchi and Babcock (2007), in simulating the relationship between corn prices and CRP acreage enrollment, focus on the state of Iowa. Iowa, with two million acres enrolled in the CRP, is a particularly relevant region, as it produces more corn and ethanol than any other state. In order to examine the effect of crop prices on the CRP program, they construct CRP supply curves by estimating whether enrolled acres would gross higher earnings by remaining enrolled in the CRP program or if they were returned to crop production. In order to construct the curve, they factor in crop prices, crop yields, CRP rental rates[1] and the land's suitability to produce corn, measured through the Corn Suitability Rating (CSR). In estimating the net return to crop production, Secchi and Babcock apply 2007 cost-of-production statistics for Iowa. Thus, in estimating the effect of a given crop price on the future composition of CRP acreage, they hold the cost-of-production and yield constant. However, based on historical data, it is highly unlikely that these variables will remain constant. Between 2000 and 2010, the National Agricultural Statistics Service reported that the average corn yield in Iowa increased by 20.88 percent from 144 bushels per acre to 182 bushels per acre (NASS, 2011a). Advances in technology, seed strains, fertilizers and pesticides have raised the productivity of agricultural land over the last decade. Based on historical trends, we can likely expect to see additional increases in the corn yield per acre in future years. Further, it is widely projected that the price of petroleum will continue to increase due to rising global demand and declining supplies. As a result, the price of fertilizers and pesticides, which are petroleum based, will likely rise as well (Tyner, 2009). An increase in operational costs would subsequently decrease earnings per acre. Secchi and Babcock use the cost-of-production and corn yield in their CRP supply

[1] This thesis did not incorporate CRP rental payments, which are distributed annually by the USDA to landowners, as available data is limited. Currently, the USDA only discloses national aggregate annual rental payments for the years 2001-2009. In future studies, incorporating these payments will be important in assessing the historical demand for CRP land. While important, this thesis rationalized the exclusion of this data based on the observation that CRP rental rates have experienced a steady average growth rate.

curve function, however do not simulate the effect that either of these variables could have on CRP enrollment independent of a rise in corn prices.[2] In contrast, this thesis suggests that a rise in the corn yield could have an impact on CRP enrollment with all other values held constant.

In order to assess the impact of corn prices on the supply curve, all other values are held constant. Secchi and Babcock estimate that when corn is $3 per bushel, a little less than half of the two million CRP acres would be returned to production. However, they estimate that roughly half of the land returned to production would be Highly Erodible Land (HEL) and thus be planted in a corn-soybean rotation.[3] In order to simulate how the USDA may respond to higher crop prices to maintain enrollment, Secchi and Babcock increase rental rates by 25%, 50%, 75%, and 100% in order to estimate the CRP supply curves under higher payments. They argue that the USDA would have to increase annual payments from $200 million to $314 million in order to limit the withdrawal of CRP acreage to less than 200,000 acres. As Secchi and Babcock note, their paper makes the assumption that profit is the principal factor in a landowner's decision-making process concerning CRP enrollment. This thesis makes the same presumption. However, there are a number of reasons why landowners may choose to enroll their acres in the program beyond profit considerations.

Hellerstein and Malcolm (2011) construct a likely-to-bid (LTB) model that simulates offers to the CRP national general signup. Specifically, the LTB model estimates the

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[2] The inclusion of petroleum and fertilizer prices, which reflect operational costs, resulted in problems with multicollinearity in the original empirical model constructed by this thesis. As a result, these variables were excluded from the final models.

[3] Farmers will often cultivate farmland in a corn-soybean rotation. This method is practiced to minimize erosion, to help control diseases and pests, and maintain soil nutrients. Further, soybeans deposit nitrogen in the soil, whereas corn consumes more nitrogen than other food crop.

composition of the CRP program if it were to start over and enroll land in one hypothetical sign-up. The LTB model uses a similar approach to the one Secchi and Babcock apply, in that a steady state model is assumed. The model starts with a set of parameters, including crop prices, crop yields, production costs, CRP rental payments, and the Environmental Benefits Index (EBI) score,[4] holds them constant and forecasts the long-term composition of CRP acreage. In this way, there are limitations to the LTB model, similar to Secchi and Babcock's model, in that the results do not necessarily reflect projections of future trends, but rather begin to depict a hypothetical relationship between corn prices and CRP enrollment. Rather than illustrating a hypothetical scenario, this thesis explores the historical relationship to date.

In analyzing possible changes to CRP enrollment, Hellerstein and Malcolm construct four central scenarios: Baseline; MediumPrice; Renewable Fuel Standard (RFS); and HighPrice. The Baseline scenario assumes values demonstrated in 2005 for the parameters listed above. The MediumPrice scenario holds values seen in 2007 constant. The RFS scenario estimates corn prices that will likely prevail if ethanol production expands from 6.5 billion to 15 billion gallons and applies the MediumPrice values for the remaining parameters. The HighPrice scenario is based on high crop prices observed in the summer of 2008 and applies the MediumPrice values for the remaining parameters. For each of the scenarios, Hellerstein and Malcolm estimate two variants, one which holds CRP rental rates constant and the second which increases CRP rental rates by 60%. While the LTB model considers a different value for annual rental payments, similar to Secchi and Babcock, they overlook the potential effects of other parameters that make up the CRP supply curve on

[4] Data for the Environmental Benefits Index (EBI) on a state-to-state basis is not provided to the public. Data for national EBI scores are only available for the years 2001 to 2009.

CRP enrollment. Most notably, the LTB model neglects to take into account the effect that a rising corn yield could have on CRP acreage.

Under the MediumPrice scenario, it was found that landowners would offer 28.8 million acres if a one-time hypothetical sign up were to occur. If, however, annual rental payments were to be raised by 60 percent under this scenario, the model estimates the number of acres offered would increase to 45 million acres. The incorporation of a RFS adjusted scenario, which accounts for an adjustment in corn prices with an expansion in ethanol production to 15 billion gallons, results in a two percent reduction in offers relative to the MediumPrice scenario and a reduction in the average EBI score of two percent. Hellerstein and Malcom (2011) indicate that under the RFS scenario, the acreage withdrawn from the program would likely be more productive land and have a higher environmental benefit. Secchi and Babcock similarly recognize that highly productive land tends to have a lower enrollment, as it can generate higher returns from production. Thus, the most productive CRP land will tend to exit the program first. However, as corn prices rise, Secchi and Babcock argue that less productive land will increasingly be able to generate higher returns from production than CRP payments. Despite these arguments, neither study accounts for the historical or forecasted variance in corn yield in estimating CRP enrollment.

Hellerstein and Malcolm (2011) note that maintaining a general enrollment of 30 million acres could be potentially achieved with a moderate increase in CRP rental rates. However, while the enrollment goal could be met, there is a high likelihood that this would translate into lower average EBI scores per acre, as landowners with more productive, yet environmentally sensitive land would opt to withdraw or not offer their land to the program. Hellerstein and Malcolm argue that in order to preserve the current level of environmental benefits provided by the CRP program, annual rental payments would need to double.

Despite claims that higher crop prices will cause farmers to withdraw land from the CRP program, Wilson et al. (2007) questions whether this will in fact happen in practice. He argues that the ease of pulling land out of the CRP program is not as easy as posed. According to the existing rules, farmers who want to opt out of a CRP contract would have to return all of the money they were paid in that contract in addition to liquidated damages which would be equivalent to 25 percent of one annual payment, plus other fees. Wilson et al. (2007) argues that as a result, it is unlikely that much CRP land will be withdrawn for the purpose of production without some type of change in the rules. However, in making this argument, Wilson et al. does not take into account the impact that crop prices could have on CRP acreage if they were to be sustained over the long-term.

Hellerstein and Malcolm (2011) examine national aggregate data, while Secchi and Babcock (2007) focus strictly on Iowa. In contrast, this thesis focuses on the Corn Belt, a region in the Midwest that covers seven states. The Corn Belt includes Indiana, Illinois, Iowa, Missouri, Nebraska, Ohio and Kansas. Of the 87.87 million acres planted with corn nationwide in 2009, 54.4 million acres were produced in the Corn Belt, equating to roughly 62.7 percent of the nation's corn acreage (NASS, 2011a). Secchi and Babcock chose to focus exclusively on Iowa due to its status as the number one corn producing state in the nation. This thesis followed a similar methodology in choosing a region, which could accurately reflect changes in the corn market.

3. EMPIRICAL MODEL

Data

Data was collected for each of the seven states included in the Corn Belt region; Indiana, Illinois, Iowa, Missouri, Nebraska, Ohio and Kansas; for the period between 1986 and 2010. This thesis collected the data from three primary sources; the National Agricultural Statistics Service (NASS), the Farm Service Agency (FSA), and the Bureau of Economic Analysis (BEA). Both the NASS and FSA are branches of the United States Department of Agriculture (USDA). The USDA and its respective branches are the most comprehensive sources for agricultural data in the United States. Data on the cumulative enrollment of acres in the CRP program by state (the dependent variable) was collected from the FSA. Data on corn acreage planted, the price of corn per bushel (marketing year average price) and the annual yield of corn (bushels/acre) were collected from the NASS. Data for the gross state product (GSP) was collected from the BEA. Since the Conservation Reserve Program (CRP) was first created in 1985, the dependent variable in this thesis is limited to 25 observations. Data on the price and yield of corn on a state-to-state basis was only available for the period between 1991 and 2009. Similarly, data for GSP during 2010 was unavailable. A complete list of the dependent and independent variables applied in this thesis are shown in Table 1.

Data Observations

As shown in Table 2, the mean CRP enrollment for the seven states in the Corn Belt region between 1986 and 2010 is roughly 1.04 million acres. However, as indicated in the standard deviation of 626,223.9 acres, there is a wide range in enrollment across the seven states. In 2010, Iowa had 1,638,546 acres enrolled, in stark contrast to Indiana which had a mere 287,388.44 acres enrolled. At first glance of the data, it appears that CRP acreage have been declining for the seven states. Using the example of Iowa and Indiana; in 1993, Iowa had 2,203,794 acres enrolled and Indiana had 453,481 acres; by 2005 Iowa had 1,917,574 acres enrolled and Indiana had 292,990 acres (NRCS, 2011).

The mean corn price for the region between 1991 and 2009 is $2.57. As the literature suggests, corn prices have risen at an unprecedented rate in the past several years. During 2000, corn prices between the seven states ranged from $1.75 to $1.9. By 2006, the range increased to $3.17 to $2.89. By 2008, prices reached historical highs with a range of $4.21 to $3.92 (NASS, 2011b)

The mean corn yield for the region between 1991 and 2009 is 140 bushels, with a standard deviation of 22.90 bushels. Geographical conditions can dictate yields due to differences in soil conditions and weather, however it appears that corn yields have been increasing over time for each state in the Corn Belt region. In 1991, corn yields ranged from 107 to 92 bushels, by 2000 the range was 151 to 126 bushels and by 2010 the range was 182 to 153 bushels (NASS, 2011b).

The mean corn acreage planted for the region between 1989 and 2010 is 7,365,909 acres, with a standard deviation of 3,553,884 acres. In 1989, with 12.6 million acres planted, Iowa had the most acreage planted of the seven states. The smallest state, by acreage, was Missouri with 2.4 million acres. By 2010, Iowa had 13.7 million acres panted, while Missouri had 3.1 million acres (NASS, 2011a). Thus, it appears that corn acreage has increased over the time period examined.

The mean gross state product (GSP) for the region between 1986 and 2009 is $199.33 million, with a standard deviation of $143.11 million. The seven states included in the Corn Belt region, all largely rural-based economies have significantly lower average GSPs than other states. In 1986, the GSP ranged from $218.70 million to $26.05 million, with Illinois at the upper end and Nebraska at the lower end. By 2000, the range was between $474.44 million and $57.23 million. By 2009, the range rose to $621.1 million and $84.58 million (BEA, 2010). The GSP per state has been incrementally increasing each year, the only noticeable contraction occurs in 2009, a result of the Great Recession.

The mean ratio of CRP acreage to corn acreage is 19.3%, with a standard deviation of 18.29%. As the mean ratio indicates, the Corn Belt on average has significantly more land planted with corn than CRP acreage. The seven states included in the Corn Belt, vary widely in both CRP acreage and corn acreage. Missouri has the fewest acres planted with corn, yet has the largest percentage of CRP acreage to corn acreage. In 1995, it had a ratio of 102.92% yet in 2010 this number had dramatically fallen to 46.41%. Nonetheless, this is more than twice the ratio that the second largest state has, as CRP acreage comprised 21.59% of corn acreage in Minnesota during 2010. Indiana has the lowest percentage of acreage devoted to the CRP program, with a height of 8.53% in 1995 and a low of 4.79% in 2007. Based on observations of the data, it appears that CRP acreage as a percentage of corn acreage has been on average declining for the past decade and a half.

The Empirical Model

The existing literature has largely been limited to simulation models to forecast the effects of agricultural prices on the future composition of the CRP program. Further, while they take into account corn yield in the CRP supply functions, they do not account for how it could affect CRP acreage independently. This thesis constructs four empirical models, which examine the effect that corn prices, corn yield, corn acreage planted, gross state domestic product (GSP) and the 2008 Farm bill have on CRP acreage enrollment in the Corn Belt region. The fifth model creates a new dependent variable, CRP acreage as a percentage of corn acreage. This model examines how the independent variables listed above affect CRP and corn acreage relative to one another.

Model 1, 2 & 3:

$$CRPA_t = \beta_0 + \beta_1 CornP_{1t} + \beta_2 CornY_{2t} + \beta_3 CornAP_{3t} + \beta_4 GSP_{4t} + \beta_5 FoodBillDummy_{5t} + \varepsilon_t$$

The first three models use a linear regression to estimate the results. The first model incorporates a time lag of one year for the price of corn, the second model incorporates a time lag of two years and the third model incorporates a time lag of three years. An array of time lags were included since the existing literature suggests that corn acreage is price inelastic in the short term, as a result of human behavior and the structure of CRP contracts. A more thorough explanation of the time lag can be found in the Expectations section below.

CRPA represents the number of acres enrolled in the CRP program, CornP represents the marketing year average price of corn per bushel, Corn AP represents the number of acres planted with corn, GSP represents the gross state domestic product measured in millions of current dollars, and the FarmBillDummy represents the introduction of the 2008 Farm Bill, which capped the maximum enrollment of CRP land at 32 million acres. A list of the abbreviations and their definitions are shown in Table 1.

Model 4:

$$CRPA_{it} = \alpha_i + \beta_0 + \beta_1 CornP_{1it} + \beta_2 CornY_{2it-3} + \beta_3 CornAP_{3it} + \beta_4 GSP_{4it} + \beta_5 FoodBillDummy_{5it} + \varepsilon_{it}$$

The fourth model, incorporates a time lag of three years and uses a random effects model to estimate the panel data equations. The benefit of using a panel set is that unobserved state characteristics are taken into account. There are differences between states that do not change over time, such as cultural and geographic characteristics. As Studenmund emphasizes in *Using Econometric: A Practical Guide,* published in 2010, an additional advantage of a panel set is that it avoids omitted variable problems that might otherwise appear in cross-sectional studies. The omitted variables are represented as α_i. Without the inclusion of α_i, the prior three models could have suffered from omitted variable bias particularly if α_i are fixed. In estimating the panel data model in this thesis, a random effects model was estimated in order to control for heteroscedasticity.[5]

Expectations

For the first four models, this thesis expects for there to be a negative relationship between the dependent variable and the four independent variables. Thus, this thesis hypothesizes that as there is an increase in the price of corn (β_1), the corn yield per acre (β_2), the number of corn acres planted (β_3), and the gross state product (β_4), there will be subsequent decline in the number of acres enrolled in the CRP program. Explanations of these expectations are detailed in the paragraphs below, with the support of the existing literature. This thesis included a policy dummy for the 2008 Farm Bill, which capped the maximum allowed enrollment of CRP land to 32 million acres, a steep drop from the 36.77 million acres enrolled in 2007 (NASS, 2011a). As a result, one would expect for there to be a negative relationship between CRP enrollment and the 2008 Farm Bill.

This thesis expects that as corn prices increase, it will become increasingly more profitable for farmers to put retired land back into production (estimate of $\beta_1 > 0$). As a

[5] The Hausman test indicates the Random Effects (RE) model is more efficient than the Fixed Effects (FE) model.

result, in order to take advantage of higher crop prices, this thesis hypothesizes that farmers will withdraw land from the CRP program thereby reducing CRP acreage. The existing literature by and large supports this hypothesis. Streitfeld reported that due to the boom in agricultural prices in 2007, farmers took back as many acres as there are in Rhode Island and Delaware (2008). Hellerstein and Malcolm (2011) forecast the effects on the quantity and quality of the land enrolled in the CRP program if annual rental payments and high commodity prices remained constant. It found that if crop prices remained at their 2007 levels, the CRP program would have difficulty in maintaining its goal of 32 million acres. As Hellerstein (2010) notes, due to current predictions of high crop prices for the next several years, the opportunity cost of retiring cropland is likely going to remain high. Thus, with high crop prices farmers may not only be inclined to withdraw land, but the number of new contracts may also fall.

Since much of the existing literature has suggested that the effect of corn prices on CRP enrollment may be inelastic in the short term, my empirical model takes into account different time lag factors for the price of corn. Babcock and Hart's findings (2008) support this methodology as they suggest in their article *Options for the Conservation Reserve Program*, that the aggregate supply of agricultural planted acreage has been relatively price inelastic in the short term. They cite the fact that the USDA forecasted a mere 1 percent increase in crop acreage planted between 2007 and 2008, despite a significant rise in crop prices. Some farmers may wait to put land back into production until they are assured that prices will settle and stay at a high level. Hellerstein and Malcolm (2011) note that per-acre rental payments under the CRP are closely related to non-irrigated cropland rental rates. If farmers need to make additional investments in equipment, such as irrigation, in order to open up land for production they may wait until they are confident that crop prices will remain high. The assumptions underlying Secchi and Babcock's (2007) supply curve analysis support the use of a time lag, as their model, which estimates a reduction in CRP acreage is based on a long-term equilibrium.

Further, since contracts are signed for a 10-year or 15-year period, only a certain number of contracts expire each year. Wilson et al. (2007) notes that withdrawing land (opting out) before a contract ends is rare as landowners incur a severe penalty. Thus, it would make sense that prices may not take full effect for a few years due to the inability for farmers to withdraw their land in the short term. Thus, due to corn acreage that is price inelastic in the short term and the length of contracts, there is a high likelihood that there is a time lag between an increase in corn prices and the withdrawal of acreage for cultivation. Consequently, with the inclusion of a time lag factor, the results will likely provide a more accurate picture of the relationship between corn prices and CRP acreage.

This thesis expects that as the corn yield per acre increases, it will subsequently become more profitable to cultivate idle land (estimate of $\beta_2 > 0$). Earnings per acre of cropland is principally a function of corn prices and corn yield. As discussed, if prices rise, the market value of each bushel of corn would increase, thereby increasing earnings per acre. Similarly, if the corn yield or productivity of cropland increases, an acre of land can produce a greater number of bushels, which would consequently increase earnings per acre. In constructing the CRP supply curve in their model, Secchi and Babcock (2007) also take into account corn yield in assessing the potential earnings per plot of land. Thus, this thesis presumes that as the agricultural value of an acre increases, it would become more profitable for farmers to return their land to crop production rather than maintaining their land enrolled in the CRP program. As a result, this thesis predicts that as corn prices and yield increase, CRP enrollment would decline as existing contracts would opt-out and new offers would decline.

This thesis expects that as corn acreage planted increases, at least a portion of the additional cropland will be taken out of conservation (estimate of $\beta_3 > 0$). Thus, this thesis hypothesizes that as corn acreage increases, there will be a subsequent decline in CRP enrollment. Babcock and Hart (2008) suggest that aggregate supply of corn can either come from an expansion in cropland in other nations or the conversion of land enrolled in the CRP program. While the sources of additional cropland may not be strictly limited to these two options, Babcock and Hart support my prediction that CRP land would be one of the primary sources of new corn acreage.

This thesis expects that as the Gross State Product (β_4) rises, there will be a complimenting increase in CRP acreage. The existing literature has not explored or mentioned a relationship between these two variables, however this thesis suggests that as states achieve a higher level of income, the conservation of land becomes increasingly more important.

Model 5:

$$CRP / CornAP_{it} = \alpha_i + \beta_0 + \beta_1 CornP_{1it-3} + \beta_2 CornY_{2it} + \beta_3 GSP_{3it} + \beta_4 FoodBillDummy_{4it} + \varepsilon_{it}$$

By looking at the data on corn acreage planted and CRP acreage, it did seem possible that the two variables were increasing simultaneously. As a result, I decided to create a new dependent variable, which calculates CRP acreage as a percentage of corn acreage, expressed as (CRP A/Corn AP). By replacing the original dependent variable, CRP acreage, with a ratio, we can better understand whether corn acreage or CRP acreage is increasing relative to the other given a change in the independent variables. Thus, in the fifth model, CRP/Corn AP is regressed against corn price, corn yield, GSP and the 2008 Farm Bill policy dummy, as included in the previous four models, with the exclusion of corn acreage as it is now included in the dependent variable. A time lag of three years for the price of corn was applied, as done in the fourth model. Further, in order to take unobserved state statistics into account and avoid omitted variable bias and heteroscedasticity, a random effects panel model was applied as described for the fourth model.

Prior to running the model, this thesis hypothesized that there would be a negative relationship between corn prices and corn acreage as a percentage of corn acreage. As the percentage of (CRP A/Corn AP) gets larger it means that CRP acreage is increasing relative to corn acreage. Thus, this thesis predicted that as corn prices rise, CRP acreage as a percentage of corn acreage would decline. This thesis expected the remaining independent variables, corn yield, GSP and the 2008 Farm Bill policy dummy to also have negative coefficient as described in models one to four.

4. CONCLUSION

As expected, results from the first three linear models, indicate that there is a negative relationship between corn prices and CRP enrollment. As shown in Table 3, corn prices are insignificant with a time lag of one year, significant at the 10% level with a time lag of two years and significant at the 5% level with a time lag of three years. According to Model 2, if the price of corn rises by a $1, CRP acreage in the Corn Belt will subsequently decline by 207,087.1 acres. According to Model 3, if the price of corn rises by a $1, CRP land in the Corn Belt will subsequently decline by 251,524.2 acres. The results from Model 4, which include a time lag of three years, accounts for unobserved state statistics, avoids omitted variable bias and heteroscedasticity indicates that corn prices are negative and significant at the 1% level. According to Model 4, a $1 rise in the price of corn will lead to a reduction of 135,263 CRP acres in the Corn Belt. Thus, corn prices in relation to CRP acreage, are originally insignificant with a time lag of one year and then become increasingly significant as the time lag is extended and unobserved state statistics are accounted for. These models demonstrate that CRP enrollment will not react immediately to a rise in prices. Rather, it may take three or more years for prices to have an effect on the CRP program.

The negative relationship observed between corn prices and CRP acreage supports claims made in the existing literature, particularly in reference to the impact of prices over the long-term. Hellerstein and Malcolm (2011) use simulation models with a long run equilibrium to estimate the effect that prices could have on the CRP program. They estimate that if high commodity prices seen in 2007 are sustained, the quantity and environmental quality of CRP acreage will significantly decline. They estimate that the 2007 CRP rental payments would need to be raised by roughly 60 percent in order to offset the long-term impact of high crop prices. Secchi and Babcock (2007) estimate that if corn prices remain at $3 a bushel in the long run, roughly half of the existing two million CRP acres in Iowa would be returned to crop production. In contrast to the ambiguity of a long-term equilibrium, this thesis focused on a specific time period of three years to estimate the effect of an incremental increase of $1 in corn prices.

As expected, the corn yield had a negative coefficient in all five models, however was not significant in any model. Results for GSP, indicate that it has a negative and significant relationship with CRP acreage in the first three models, however the significance disappears in the fourth and fifth models, which take into account unobserved state statistics and avoid omitted variable bias and heteroscedasticity. The estimates of the coefficient for the 2008 Farm Bill policy dummy were negative in all five models, which was contrary to the expectations of this thesis. However, these results were not significant for any model. These results were interesting as one would inherently expect for there to be a negative relationship as the 2008 Farm Bill capped the maximum CRP enrollment at 32 million acres, which was roughly 4.77 million acres less than the peak in 2007 (NSAA, 2011a). The bill effectively forced the USDA to either sign fewer new contracts or to simply allow contracts to expire.

Models 1 to 4 suggest that corn acreage planted and CRP acreage have been simultaneously increasing between 1986 and 2009. Model 4, which takes unobserved state statistics into account and avoids omitted variable bias and heteroscedasticity, indicates that as corn acreage planted increases by 1 acre, there is a subsequent increase of .0758759 CRP acres. Since corn and CRP acreage are increasing simultaneously, Model 5 was particularly relevant in estimating the effects of corn prices on the ratio of the two factors. The data suggests a significant, negative correlation between corn prices and CRP acreage as a percentage of corn acreage. According to Model 5, if the price of corn rises by a $1, CRP land as a percentage of corn acreage will decline by 2.35 percent. The simultaneous increase of CRP acreage and corn acreage conflicts with Roberts et al. (2007) idea that as demand for cropland increases the rate of grassland conversion would rise. It also conflicts with Babcock and Hart's (2008) idea that CRP acreage would account for the bulk of new additional cropland, however there are alternative explanations. In order for corn acreage and CRP acreage to be simultaneously increasing there would either need to be a rise in the total aggregate supply of agricultural land or a rising percentage of total agricultural land to be devoted to corn. The report, *Wheat: Market Outlook*, published in March 2010, by the Economic Research Service of the USDA, forecasted that farmers would plant less wheat and more corn for the following year due to proportionately higher corn prices. Tyner and Taheripour (2008) observes that one of the implications of increased corn prices is that farmers are transitioning lands once dedicated to growing wheat, soy, barley and other grains to corn as it has become more profitable to do so. Thus, rather than strictly putting conservation land back into production, farmers could be potentially switching from other traditional crops to corn, thereby increasing the percentage of total agricultural land devoted to corn. Transitioning from one type of crop to corn would be particularly relevant in instances where the price of corn rises faster than other agricultural commodities. If it becomes more profitable for farmers to switch acreage from wheat to corn, as Tyner and Taheripour suggest, they will likely do so based on the assumption that they are rational actors and seek to maximize their gains.

Transitioning from other crops to corn would have important environmental implications, as corn requires more nitrogen fertilizer, insecticides and pesticides than any other food crop (Pimentel, 2003), effectively making it a major contributor to water pollution. These chemicals are distributed on open fields, and through leaching and runoff, can be easily transported to local groundwater, streams and other water networks.[6] This is of particular consequence as the nutrients in fertilizer cause algae to grow at an accelerated rate in water bodies, a process often referred to as cultural eutrophication. The process of eutrophication is detrimental to water bodies, as it results in the significant depletion of

[6] Run-off occurs when soil is infiltrated to its full capacity and the excess water flows over land, while leaching is the process with which material seeps through soil.

available oxygen, causing a phenomenon known as "dead zones" (Sawyer, 1966). The EPA estimates that due to leaching and runoff, over 210 million pounds of nitrogen feed into the Mississippi River each year, causing a dead zone in the Gulf of Mexico that spans 7,900 square miles during the summer months (Associated Press, 2007). While corn is not the sole contributor to this problem, it is clear that a rise in corn acreage would likely exacerbate this environmental crisis.

There is the potential that additional corn acreage could arise from the re-cultivation of idle farmland or the conversion of forests/plains not currently held in the CRP. Farms have historically rotated growing soybeans and corn; however, according to Fargione et al. (2009), some farmers are increasingly planting corn on the same plot of land year after year in order to meet rising demand. While grasslands or forests may not be converted into agricultural land under this scenario, there would still be a number of negative environmental externalities associated with this transition. Fargione et al. (2009) outline that continuous corn production requires greater amounts of fertilizer, which subsequently leads to greater nitrate leaching. Pikul et al. (2005) find that continuous corn makes cropland more susceptible to buildups of soil pathogens and lowers annual yields by about 14 percent. The lower yields from continuous corn subsequently means that more land is required to meet the same demand, placing further pressure to open up new land for agriculture.

Policy Implications

There are severe environmental implications associated with the withdrawal of CRP acreage when corn prices rise. The Economic Research Service (ERS) of the USDA conservatively estimates that CRP results in annual benefits of $1.3 billion[7] in the form of reduced soil erosion, improved water quality and increased wildlife populations (Hellerstein, 2010). The ERS does not account for the monetary benefits of carbon sequestration, ecosystem protection and other benefits that are more difficult to quantify. The importance of CRP land can be particularly understood, when Pimentel (1996) points out that corn production leads to serious erosion in the United States, eroding 18 times faster than the rate of soil formation. Considering that the CRP program targets land that is particularly susceptible to soil erosion, the impact of corn production would be magnified on these types of lands.

Beyond the destructive effects of agribusiness corn production on the landscape, there would be significant impacts on wildlife populations if land is put back into production. Fargione et al. (2009) cites a study on grassland birds in North and South Dakota, which indicates that approximately two million grassland birds of five different species would be lost if the CRP did not exist in either of the two states. Reynolds (2005), as cited in Fargione et al., estimates that the CRP land in the prairie pothole region contributes an extra 2.1 million ducks to the fall flight each year. It is not hard to understand the benefits associated with maintaining land under the CRP, especially when investigating the wildlife and environmental effects that corn production would alternatively have.

A decline in CRP acreage due to high corn prices, and the subsequent impact on the environment and wildlife populations has additional economic and social implications.

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[7] If one were to divide the net benefit of $1.3 billion by the reported 31.3 million enrolled CRP acres in 2010, one would find that each acre provides roughly $41.54 in benefits. Based on the findings of this thesis, that a $1 rise in corn prices leads to a reduction of 135,263 CRP acres, environmental benefits would subsequently decline by $5.62 million for each $1 in corn prices.

CRP land has been a haven for outdoor recreational activities such as hunting, fishing, boating and wildlife viewing over the past two and half decades (Sullivan et al., 2004). Hunting associations such as Ducks Unlimited and Pheasants Forever have begun to collectively organize in lobbying the USDA to increase payments in order to prevent the reduction of hunting ranges (Streitfeld, 2008). Hellerstein and Patrick (2008), using a receipts-based method, estimate that national CRP recreational expenditures total roughly $290 million. As a result, a reduction in CRP land could affect the quality of these recreational trips and lead to the reduction and geographical distribution of trip expenditures, a source of revenue for rural economies.

There is a growing body of literature that has connected the expansion of ethanol production to a rise in corn prices. Today, over 40 percent of U.S.-grown corn goes towards the production of ethanol, an exponential increase from the reported 8 percent in 2000 (Richardson, 2011). Of the 10.6 billion gallons of ethanol produced in 2010, 90 percent of the feedstock was derived from corn (State Energy Conservation Office, 2011). Between 2000 and 2010, ethanol production surged by more than 747 percent (Renewable Fuels Association, 2011). The United States has become the single largest producer of ethanol in the world. Fortenbery and Park (2008) analyzed the impact of ethanol production on U.S. corn prices between 1995 and 2006 using a three state least analysis. They found that ethanol production contributed to a 41-cent increase in corn prices, between September 2006 and September 2007, which was roughly half of the price increase observed. A study by McNew and Griffith (2005), used a sample of twelve ethanol plants that opened between 2001 and 2002 and found that corn prices rose 12.5 cents in the neighboring region. While the studies come up with different results, they both support the conclusion that ethanol has contributed to the rise in corn prices, which carries important implications for this thesis.

Model 4 indicates that a rise in corn prices leads to the reduction in CRP acreage. If ethanol production were partially responsible for causing corn prices to rise, it would by default indicate that ethanol production has been an important factor in determining CRP enrollment. According to Model 4, if the price of corn rises by a $1, CRP land in the Corn Belt will decline by 135,263 acres over a three-year period. Applying Fortenbery and Park's estimate that ethanol production leads to a 41-cent increase in corn prices to the coefficient found in this thesis, indicates that CRP land in the Corn Belt would decline by 55,457.83 acres as a result of ethanol production. If McNew and Griffith's estimate were applied, CRP land would decline by 16,231.56 acres. The fact that an expansion in ethanol production leads to the unintended consequence of declining CRP acreage has important policy implications.

Under the Energy and Independence Security Act of 2007, the Renewable Fuel Standard (RFS) mandated that 9 billion gallons of ethanol to be blended into gasoline by 2008 and 36 billion gallons by 2022 (EPA, 2010). However, this piece of legislation was in part passed under the presumption that ethanol is a renewable fuel, which emits fewer greenhouse gas emissions than gasoline (Farrell et al., 2006). Research conducted by the Argonne National Laboratory (ANL), which is used by federal agencies, indicates that in the short run ethanol will emit 20 percent fewer GHG emissions than conventional gasoline, when taking production, distribution and consumption into account. However, the ANL indicates that if an expansion in ethanol production leads to a large-scale conversion of forests or grasslands into new agricultural land, the change in land use could in fact offset any reduction in GHG emissions by ethanol (Gecan et al., 2009). CRP land, planted with natural vegetative cover, plays an important role in absorbing carbon dioxide. Plowing CRP land and transforming it into cropland would dramatically alter the GHG emissions associated with producing ethanol. Thus, the withdrawal of CRP land to expand ethanol production, as suggested in this thesis, would not only threaten wildlife habitat and environmental quality as mentioned, but also has the potential to undercut any type of environmental claim supporting ethanol as a green biofuel.

In addition to government mandates, potentially more problematic, is the fact that the ethanol industry receives billions of dollars in subsidies. Commonly, industries that impose negative externalities are either taxed or regulated. Yet, instead, each gallon of ethanol currently receives a Volumetric Ethanol Excise Tax Credit (VEETC) of 51 cents. Further, there is an import tariff on ethanol of 54 cents per gallon and an ad valorum tax of 2.5 percent (Rapier, 2010). A recent report from Rice University's Baker Institute for Public Policy used data from the U.S. Government Accountability Office to conclude that for the year 2008, the U.S. distributed $4 billion in subsidies in order to replace approximately 2 percent of the U.S. gasoline supply. Consequently, taxpayers are funding ethanol at an estimated $82 per barrel or $1.95 per gallon, which is on top of the gasoline retail price (2010). Koplow estimates that subsidies are actually closer to a range of $5.1 to $6.8 billion per year (2006). By subsidizing the industry so heavily, the government has created an artificial market that would not otherwise exist. Add on to this the fact that the corn industry has independently received subsidies totaling $73.8 billion between 1995 and 2009 (Environmental Working Group, 2010). Through legislation and subsidies in favor of ethanol and corn, the government has effectively created a market that has propped up corn prices, which has subsequently resulted in the reduction of CRP acreage as shown in this thesis. It seems ironic that an industry funded by federal direct and indirect subsidies is consequently leading to the deterioration of CRP land, another federally funded program. While by no direct intention, the government's support for ethanol is fundamentally undermining the success of the CRP program. This finding further brings into question the benefits of ethanol, and if subsidization is in fact an efficient use of taxpayer money. If the government aims to minimize the withdrawal of CRP land, it might consider cutting ethanol production mandates and or subsidies to prevent further inflation of corn prices.

If high corn prices are leading to the withdrawal of CRP acreage as shown in this thesis, there is a high likelihood that grasslands, forests or plains not listed under the CRP are also facing pressure to be converted into agricultural land. While the USDA tracks the environmental benefits of enrolled CRP land, there are certainly millions of 'outside' acres that similarly provide wildlife, soil, air, and water quality benefits. Thus, the impact on the environment and outdoor recreation activities would likely be magnified, as unregulated and unaccounted landscapes are converted to farmland. Based on the existing literature, it is clear that the removal of CRP land for the purpose of expanding crop production will likely to lead to the deterioration of air and water quality, wildlife populations and the aesthetic value of conservation landscapes. Further, with ethanol expansion projected to rise exponentially in the future, it is highly likely that corn prices will continue to rise, subsequently placing additional pressure on the CRP program. Secchi & Babcock and Hellerstein & Malcolm accurately argue that the USDA may need to raise CRP rental payments in order to offset rising corn prices, however policy options are by no means limited to rental rates. Baker and Galik (2009) suggest that the program should seek alternative adjustments to increase income from enrollment, such as allowing landowners to sell carbon offset credits. While politically controversial, the government should additionally reexamine its narrow support of ethanol and corn with the understanding that high prices not only inflate the cost of food, but leads to the deterioration of conservation land.

APPENDIX:

Table 1:

Variables	
CRPA *(dependent)*	cumulative enrollment in the Conservation Reserve Program (Acres)
CRPA/CornAP (*dependent*[2])	CRP acreage as a percentage of corn acreage planted
CornP	marketing year average price, measured in $/BU
CornP (lag 1)	marketing year average price, measured in $/BU (with a time lag of 1 year)
CornP (lag 2)	marketing year average price, measured in $/BU (with a time lag of 2 years)
CornP (lag 3)	marketing year average price, measured in $/BU (with a time lag of 3 years)
CornY	corn yield year average measured in bushels/acre
CornAP	area planted with corn (Acres)
GSP	gross state product (millions of current dollars)
Farm Bill Dummy	accounts for the introduction of the 2008 Farm Bill, which capped the maximum enrollment of CRP land at 32 million acres

Table 2:

	Mean	Std. Dev.	Sample size
CRPA	1,043,636	626,223.9	175
CornP	2.573459	.7353211	133
CornY	140.0075	22.89981	133
CornAP	7,365,909	3,553,884	154
GSP	199,327.3	143,108.7	168
CRPA/CornAP	.1930854	.182857	154

Results of the Models

Table 3: CRP Acreage

	Model 1	Model 2	Model 3	Model 4[8]
Corn AP	.0696797*** (.0135402)	.0691893*** (.0137148)	.0642145*** (.0145272)	.0758759*** (.0216257)
Corn P (lag 1)	-37079.39 (108133.7)	No	No	No
Corn P (lag 2)	No	-207087.1* (105574.7)	No	No
Corn P (lag 3)	No	No	-251524.2** (107462.7)	-135263*** (37513.17)
Corn Y	-3244.939 (2409.563)	-3471.477 (2415.901)	-1483.927 (2846.7)	-288.3155 (1092.31)
GSP	-1.857436*** (.3002767)	-1.822349*** (.2997564)	-1.806927*** (.2997486)	-.3613602 (.3391151)
Farm Bill Dummy	262341.6 (246652.4)	475935.8 (213244.3)	1915122.5 (441406.9)	32846.18 (53121.49)
State Effects	No	No	No	Yes
Constant	1554659 (384699.5)	1969887 (412272.9)	1834813 (441406.9)	987006.1 (987006.1)
R^2	0.3843	0.4019	0.4043	0.1645
$\overline{R}_2$	0.3587	0.3754	0.3762	No
Wald chi2(5)	No	No	No	25.24~
N	126	119	112	112

All standard errors are in parentheses
* indicates significance at 10% level of significance
** indicates significance at 5% level of significance
*** indicates significance at 1% level of significance
~ P-value is significant, 0.0001

[8] The calculated test statistics, although negative is less than the critical value. Hence, we reject the null hypothesis, thus the random effects model is efficient.

Table 4: CRP/Corn AP

	Model 5
Corn P (lag 3)	-.0235317* (.0135049)
Corn Y	-.0004254 (.0003886)
GSP	-1.18e-07 (1.34e-07)
FarmBill Dummy	.0135041 (.0191338)
Constant	.3312137 (.07957)
R^2	0.0580
Wald chi2(4)	6.75~
N	112

All standard errors are in parentheses
* indicates significance at 10% level of significance
** indicates significance at 5% level of significance
*** indicates significance at 1% level of significance
~ (P-value is insignificant, 0.1497)

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