Decoupled Direct Payments Under Base Acreage and Yield Updating Uncertainty: An Investigation of Agricultural Chemical Use

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Abstract

Decoupled payments were thought to have minimal impacts on current production decisions and input use. However, the literature has identified several mechanisms through which decoupled payments become coupled. We analyze the effects of uncertainty regarding future policy changes on farm-level production decisions and input use, focusing on farmers' expectations of base acreage and yield updating. Using farm-level data, we find positive relationships between both decoupled and other government payments and real per acre expenditures on agricultural chemicals. Furthermore, there is evidence that decoupled payments may affect the intensive margin more than other government payments.

Keywords: decoupled payments, input use, intensive margin, updating

JEL classification: Q12, Q18

I. Introduction

When first introduced, decoupled support policies were thought to have minimal impacts on current production decisions and input use since they are based on historic acreage and yields rather than current production, prices, or inputs (Alston & Hurd, 1990; Blandford, de Gorter, and Harvey, 1989; Borges & Thurman, 1994; Rucker, Thurman, & Sumner, 1995; and Sumner & Wolf, 1996). However, several mechanisms by which decoupled payments have the potential to alter production decisions in the current period have been identified in the literature. For example, uncertainty regarding the ability to update base acreage and yields upon which decoupled payments are calculated can influence current production decisions, leading to increased acreage (affecting the extensive margin) or altering the product mix or input mix (affecting the intensive margin).

Decoupled payments were first introduced to U.S. agricultural policy with the Federal Agriculture Improvement and Reform (FAIR) Act in 1996, which began implementing Production Flexibility Contract (PFC) payments to farm operators based on historic acreage and yields. These subsidies were introduced to comply with World Trade Organization (WTO) obligations outlined in the Uruguay Round Agreement on Agriculture (AoA) requiring a reduction in trade-distorting agricultural support. Direct payments were continued in subsequent Farm Bills. The Farm Security and Rural Investment Act of 2002 (FSRI) gave farmers the option of updating their base acreage and yields, essentially allowing farmers to change the historical acreage and yield upon which their decoupled payments were based. The Food, Conservation, and Energy Act of 2008 (FCE) continued decoupled payments but gave farmers the option of foregoing a portion of their direct payments to obtain Average Crop Revenue Election (ACRE) program payments based on both national market price and state average yields. The 2008 Farm

Bill permitted farmers to adjust base acreage once again to allow for the addition of newly covered commodities.

Several mechanisms by which decoupled payments may have the potential to influence current production decisions have been identified since their introduction to U.S. policy. Direct payments may alter the farmer's set of risk preferences due to insurance and wealth effects (Hennessy, 1998), ease credit constraints by increasing total wealth (Burfisher & Hopkins, 2004; Goodwin & Mishra, 2006), and change allocations of land, labor and other inputs (Ahearn, El-Osta, & Dewbre, 2006; Kirwan, 2009). In addition, there is evidence that agricultural decoupled subsidies keep farms in production that would otherwise exit the market, leading to inflated aggregate production (Chau & deGorter, 2005; deGorter, Just & Kropp, 2008).

Furthermore, decoupled payments may indirectly affect current production through uncertainty of future government payments and expectations of those payments. This is especially true if updating of base acres and yields is allowed such as it was in the 2002 and 2008 Farm Bills. Goodwin and Mishra (2006) show that uncertainty regarding future decoupled payments affects the optimal allocation of acreage amongst crops planted. Furthermore, Bhaskar and Beghin (2010) show that if a farmer believes that he might be allowed to update his base acreage or yields in the future, then he has the incentive to increase his plantings in the current period. This ultimately leads to a change in aggregate production and/or a change in the types and quantities of inputs used in production.

Moreover, some agricultural inputs are known to have negative environmental impacts, particularly the use of fertilizer, herbicides and insecticides. Previous research has found that decoupled payments change input decisions with possible environmental consequences (Orazem & Miranowski, 1994; Wu, 1999; Adams et al., 2001). Our paper contributes to this area of growing research by analyzing the impacts of decoupled payments on the use of agricultural chemicals in the presence of uncertainty of base acreage and yield updating. We find a positive relationship between both decoupled and other government payments and per acre expenditures on agricultural chemicals. In addition, we find evidence that decoupled payments may affect agricultural chemical use (the intensive margin) more than other government payments.

Summary of U.S. decoupled payment programs

The 1996 FAIR Act eliminated many supply controls on field crops and introduced Production Flexibility Contracts (PFC). Farms producing wheat, feed grains (corn, barley, grain, sorghum, and oats), rice, and upland cotton were allowed a one-time enrollment for a seven-year contract where eligibility was dependent on participation in a production adjustment program between 1991 and 1995[1]. PFC payments were determined by the crop specific payment rate, yield, and base acres in a historic planting period (Young & Shields, 1996). However, producers were free to plant any crops (with limitations on fruits, vegetables and specialty crops) on their historical acres, allowing for more flexibility in the mix of commodities planted as well as the total acreage planted. For example, a farm could receive a payment based on historic oat acreage but currently plant only wheat and corn.

In the 2002 FSRI Act, PFC were replaced with fixed direct payments (FDP) that were similar to PFC. FDP were expanded to include soybeans, other oilseeds, and peanuts[2] (ERS, 2002; Young & Shields, 1996), allowing farmers with historic acreage in those commodities to update their payment acreage and yields to allow for these newly covered commodities. The FSRI Act also allowed farmers to chose the way their total base acres and yields were calculated.

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[1] The production adjustment program was from the 1990 Farm Bill.
[2] Special provisions are made concerning peanuts.

Farmers could now choose to have their payment yield calculated one of three ways. Two additional ways to determine base acreage were also introduced.

The 2002 FSRI Act also introduced counter-cyclical payments (CCP) as another form of income support, replacing the Market Loss Assistance (MLA) Program[3] introduced in 1998 as a supplement to the FAIR Act. Like PFC and fixed direct payments, CCP are based on historic, not current, production. The primary difference between the two types of policies is that CCP are only instituted when the effective price is less than the target price set in the FSRI Act and therefore is only "partially" decoupled as CCP are still linked to current prices (ERS, 2008).

The newest decoupled policy was introduced in the 2008 FCE Act. Average Crop Revenue Election (ACRE) provides participants with a guaranteed revenue flow that is based on both national market price and state average yields. Farmers are given direct payments totaling 90 percent of the product of the 'five-year benchmark state yield' and the 'two-year ACRE program guarantee price.' The ACRE benchmark state yield is a commodity and state specific measure of the fitted average yield per planted acre; the ACRE program guarantee price is a national commodity specific two-year average market price (ERS, 2008). If ACRE revenue for the state *and* farm is less than the program guarantee and the benchmark farm, participants receive a payment (ERS, 2008). Producers enrolled in ACRE must remain enrolled until 2012 and are not eligible for CCP. Enrollment in ACRE also reduces all fixed direct payments to the farm by 20 percent. The program covers wheat, corn, barley, grain sorghum, oats, upland cotton, rice, soybeans, other oilseeds, peanuts, dry peas, lentils, small chickpeas, and large chickpeas.

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[3] Classification of MLA payments is disputed: Burfisher and Hopkins (2004) suggest MLA's are tied to market price and therefore fully coupled and would be classified within the Amber Box, while Adams et al. (2001) analyze MLA payments side-by-side PFC payments as fully decoupled.

The ACRE program differs from previous support programs because the payments are based on moving average yields and price, not a set time period as is seen with PFC and FDP. Because producers base their decision to participate in ACRE on the historic and expected variability in prices, the program works as a partially decoupled policy similar to CCP. Both ACRE and CCP are viewed as insurance programs linked to price.

With each new Farm Bill, changes in the way payment acres and payment yields are calculated permit farmers to update their base acreage and yield. Ultimately, updating base and/or yield affects the future value of payments due to participation in the support program. If a farmer comes to expect updating every seven to ten years, he or she may change production now to increase the payout in the future. This is demonstrated more formally in the next section.

II. Theory

We assume that farmers maximize their expected utility of wealth, including farm profits and off-farm income. Furthermore, farmers will allocate both acreage and other inputs to maximize profit. Equation (1) illustrates the expected utility maximization problem of a typical farmer where both acreage A and quantity of inputs X are choice variables. Let E be the expectation operator over the random variables, output prices and yields, and $U(\cdot)$ be a concave continuously differentiable von Neumann-Morgenstern utility function suggesting farmers are risk averse.

$$(1) \qquad V = \underset{\{A_{it}, X_{ijt}\}}{Max} E\left[\sum_{t=0}^{T} U\left(\delta^{t} g_{t}(\cdot) + \delta^{\hat{t}} h_{t}(\cdot)\right)\right]$$

$$\text{s.t.} \qquad \Psi_{it|\phi} A_{it} \leq F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$$

$$\sum_{i}^{I} A_{it} = A_{t}$$

$$\gamma = [0,1]$$

where $g_t(\cdot) = \pi_t(\cdot) + I_t + W_{t-1}$

$$\pi_t(\cdot) = \sum_{i=1}^{I}\left[(P_{it} + PS_{it})\Psi_{it|\phi}A_{it} - (\sum_{j=1}^{J}\omega_{ijt}X_{ijt}) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right] + DP_t\left(\cdot\right) + G_t$$

$$DP_t\left(\cdot\right) = \sum_{i=1}^{I}\left(\alpha_{it}S_{it}\Psi_{iH}\left(F_H\left(X_i, A_i, \varepsilon_i\right)\right)B_{it}\left(A_H\right)\right)$$

$$h_t(\cdot) = \gamma VB + (1-\gamma)VNB\,.$$

The function $g_t\left(\cdot\right)$ is the sum of the profit function $\pi_t\left(\cdot\right)$, income from off-farm activities at time t, I_{it}, and a measure of initial wealth in time t-1, W_{t-1}. The Discount factor is δ^t. Profit is specified as the difference of costs and revenue plus decoupled government payments, $DP_t\left(\cdot\right)$ and decoupled lump sum government payments, G_t.

Revenue is the summation of the product of price, yield, and acres planted summed over i crops, where P_{it} is the price of the i^{th} crop at time t, Ψ_{it} is the yield per acre of crop i at time t subject to land quality ϕ, and A_{it} is acres planted of the i^{th} crop at time t. Fully coupled price supports PS_{it} are the sum of all per-unit production subsidies and deficiency payments at price P_{it}.

Costs are a summation of fixed and variable costs associated with each crop i. The cost of input j associated with the i^{th} crop at time t is the product of ω_{ijt}, the unit cost of input j, and X_{ijt}, the amount of input j associated with i^{th} crop at time t. Let r_{it} be the per-acre cost of land associated with the i^{th} crop at time t. Thus, r_{it} can represent the per acre rental rate of land to the tenant for the i^{th} crop at time t or the opportunity cost associated with using that acre for the next best use if the land is owned. C_{it} are fixed costs associated with the i^{th} crop at time t and are a function of production decisions in the previous time period, meaning that acreage decisions are inter-temporal.

Direct decoupled payments (e.g., fixed direct payments, production flexibility contracts) are represented by equation $DP_t(\cdot)$ and are a function of an α_{it} percentage of S_{it} the payment rate per crop, historic yield Ψ_{iH} per crop *i,* and base acres B_{it} for each crop *i* summed over the *i* crops. Historic yield is a function of the production function in a historic time period *H*. Base acres are a function of historic acreage A_H. Thus, decoupled direct payments are not a function of current prices, production, or inputs. Within $DP_t(\cdot)$, the only variables that vary with time *t* relate to the amount of support $\alpha_{it}S_{it}$ each farmer receives, which depends on the policy in place at that time.

The function $h_t(\cdot)$ introduces a term from Bhaskar and Beghin (2010) that allows for the future policy benefits to depend on whether or not updating actually occurs and accounts for the farmer's expectation of updating occurring. Let $\gamma \in [0,1]$ be the farmer's subjective probability of future base and/or yield updating. If $\gamma = 0$, a farmer is certain that updating will be not allowed in future policies. If $\gamma = 1$, a farmer is 100 percent certain that base updating will be allowed in future farm policies. The function $h_t(\cdot)$ is discounted at by the discount factor $\delta^{\hat{t}}$, where $\hat{t}$ corresponds to the time period in which the future payment benefits are realized.

VB is defined as the value of the payment if updating occurs, and *VNB* is the value of the payment if updating does not occur. If no updating is the true state of the world, then *VNB* is awarded. Conversely, if updating is the true state of the world, then *VB* is awarded.

The farmer's utility maximization problem has three constraints: first, the farmer is constrained by the technology he employs. Hence, output, $\Psi_{it|\phi}A_{it}$, is a function of all inputs X_{ijt}, acres planted A_{it}, and a stochastic element ε_{it} allowing for exogenous variants such as weather. Second, the sum of total acres planted of the *i* crops must be less than or equal total acres operated. It is possible to optimize profit by having idle acreage A_{idle}. Thus, if both harvested acreage and idle acreage are included in the profit maximization model, then the constraint binds. Lastly, the farmer's subjective probability of updating is constrained to be between 0 and 1.

Production decisions are made with output price, yield and policy uncertainty. X_{ijt} and A_{it} are choice variables and all other variable are exogenous. Costs from inputs are assumed known when acreage decisions are made because most costs are sustained at planting. Thus, within the profit function, uncertainty lies within revenue, not costs. Hence, yield and price are treated as random variables. Furthermore, total acreage planted is not fixed across time because farmers can buy, rent, or lease more land.

Without loss of generality, equations (2) and (3) below illustrate the necessary first order conditions corresponding to the farmer's utility maximization problem summarized in equation (1). Equation (2) consists of two parts: the first term is the standard profit maximizing condition where the value of the marginal product associated with input *j* is equal to its price, ω_{ijt}, (note that the value of the marginal product is a function of both output price and price supports) for each time *t*, crop *i,* and input *j.* The second term is due to updating. Note that the two terms have different discount factors since the farmer receives part of the benefit in time *t* and part of the benefits in time $\hat{t}$. Equation (3) consists of three terms. First, the value of the marginal product is equal to the rental rate r_{it}, for each time *t* and crop *i*. The third term is due to updating, while the middle term captures the inter-temporal nature of acreage decisions.

(2) $$\frac{\partial V}{\partial X_{ijt}} = \delta^{t}\left[\left(P_{it} + PS_{it}\right)\left\{\frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it}\right)}{\partial X_{ijt}}\right\} - \omega_{ijt}\right] + \delta^{\hat{t}}\gamma\left[\frac{\partial DP_{t}(\cdot)}{\partial X_{ijt}}\right] = 0$$

(3) $$\frac{\partial V}{\partial A_{it}} = \delta^t \left[\left(P_{it} + PS_{it}\right) \left\{ \frac{\partial F\left(X_{it}, A_{it}, \varepsilon_{it}\right)}{\partial A_{it}} \right\} - r_{it} \right] - \delta^{t-1} \left[\frac{\partial C_{it}\left(A_{it-1}\right)}{\partial A_{it}} \right] + \delta^{\hat{t}} \gamma \left[\frac{\partial DP_t(\cdot)}{\partial A_{it}} \right] = 0$$

If $\gamma = 0$, then the terms included for to account for the farmer's expectations of updating in Equations (2) and (3) become zero and decoupled payments are not coupled to production. However, if farmers have a non-zero subjective probability of updating, there is a link between decoupled payments and current input use and acreage decisions; the greater γ, the greater the link between current acreage and input decisions and future program crop payments (Bhaskar & Beghin, 2010). Based on findings of Coble, Miller, and Hudson (2008), it is expected that $\gamma > 0$ will be true for some, but not all farmers[4]. If a farmer expects updating to occur, either through government policy changes or the implicit policy design (in the case of ACRE), he or she may alter current farm production decisions in order to optimize future profits. The first order conditions allow decoupled payments to impact production decisions through increased acreage (extensive margin), changes in the mix of crops produced, or through changes in input use (intensive margin).

The fully coupled nature of price supports is also seen in the first order conditions. Acreage and input decisions depend not only on market prices, but the government price support PS_{it} as well. Lump-sum government payments G_t do not appear in either Equation (2) or (3), indicating that they do not influence production decisions.

Therefore, we expect positive relationships between the use of agricultural chemicals and both decoupled and coupled governments payments. Although we expect the relationship between both decoupled and other governments payments and agricultural chemical use to be

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[4] In a 2005 survey conducted by the National Agricultural Statistics Survey (NASS), about 40 percent of respondents from Iowa and Mississippi expected base acreage and yield updating would be allowed in the 2008 Farm Bill.

positive, the magnitude of the effect of decoupled direct payments may be greater than or less than coupled government payments depending on the size of coupled price supports (PS_{it}), decoupled farm subsidies ($\alpha_{it}S_{it}$), and the discount rate δ. This hypothesis is tested in the next section using weighted ordinary least squares regression analysis.

III. Empirics

Data

Cross-sectional data collected annually by the U.S. Department of Agriculture (USDA) is used in the analysis. From 1984 to 1995 Farm Cost and Returns Surveys (FCRS) were collected from a representative sampling of farmers; in 1996 these surveys were replaced with the Agricultural Resource and Management Survey (ARMS). Data from 1991 to 2008 is used in this paper to identify changes in the use of fertilizer and other agricultural chemicals due to the initial implementation of decoupled direct payments in 1996 with the passing of the FAIR Act and/or policy changes in 2002 (FSRI Act) and 2008 (FCE). Data from 1991 to 1995 are obtained from FCRS and data from 1996 to 2008 are obtained from the Farm Structure and Finance (Phase III) ARMS. These data sources were selected because they contain information on government payments, value of production, output, input expenses, and other farm and farmer characteristics at the farm-level.

ARMS and FCRS data have known sampling weights. Each observation is given a weight reflecting the probability of being selected; therefore, whole population estimations can be constructed using a much smaller sample size than would otherwise be required. All results are obtained using the appropriate weights.

We limit our analysis to those farms with more than more than 50 percent of their total value of production coming from program crop commodities because decoupled direct payments are paid to farmers with historic plantings of the eleven program crops. Therefore, any farmer with more than half of their total value of production coming from the following commodities is included in the analysis: general cash grain, wheat, corn, soybean, sorghum, rice, cotton, peanut, and other. General grain crops refer to farms that are not specializing in a specific crop, but the sum of barley, corn, oats, rice, sorghum, soybean and wheat makes up at least half of all sales revenue. Oilseeds and pulse crops (e.g., lentils, peas, and chick peas) are categorized under 'other.'

We further limit our analysis to the Heartland region as defined by USDA. This region spans 543 counties in nine states: Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, Ohio, and South Dakota. However, only three of the states (Indiana, Illinois, and Iowa) are wholly contained in the Heartland. The other six states only have some counties included in the Heartland, while the other parts of the state are categorized in a different region. Since the current regional classifications were not developed until 1995 and regional data therefore does not exist prior to 1995, this analysis focuses on an extended Heartland region encompassing all counties located in the nine states listed above. The Heartland was chosen because it boasts the largest concentration of cropland (27 percent of the nation's cropland) and crop value (23 percent) (Heimlich, 2000). In addition, all but one program crop, peanuts, is grown in the Heartland, thus farmers in this region face growing conditions that enable them to maximize profits by changing their crop mix.

We also limit the analysis to include only farms where the primary operator claims his/her occupation as farm work since farmers that have other sources of income and are farming as a hobby or in retirement might engage in a different decision making process. Lastly, we restrict our analysis to include only farms with total acres operated greater than zero[5]. It may seems counterintuitive to report negative acres operated on a farm, however, land owners may rent or lease farm acres to other farmers through a sharecropping or rental agreement; this land is then deducted from the total number of acres owned by the primary operator, rented from others, or leased from others (ERS, 2003). Negative total acres operated would therefore suggest that more land is being rented out or leased to other producers than operated by the primary operator. In that regard, more income may come from renting land than farm production, and hence landlords might also engage in a different decision making process.

Factors affecting agricultural chemical use

Given our hypothesis regarding the positive relationship between agricultural chemical use and government payments (both coupled and decoupled), we estimate the effects of these payments on fertilizers and other agricultural chemical expenditures while controlling for other farm and farmer characteristics. The two dependent variables are adjusted fertilizer expenditures per total acres operated (FERT) and adjusted other agricultural chemical expenditures per total acres operated (CHEM). Note agricultural chemicals include all agricultural chemicals not classified as fertilizer. Both dependent variables are adjusted using the producer price index for pesticides, fertilizer, and other agricultural chemical manufacturing[6] to account for inflation. While the analysis would be improved by using quantities of fertilizer and other agricultural chemicals rather than expenditures, this information is not available.[7] Table 1 summarizes the variables used the analysis.

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[5] This limitation is particularly important as almost all variables are adjusted with respect to total acres operated.
[6] Pesticides, fertilizer, and other agricultural chemical manufacturing is industry code 3253.
[7] ARMS Phase II does contain data on quantities of fertilizers and agricultural chemicals used, however financial data, including information on government payments, is only collected in Phase III.

Table 1. Variables Used in OLS Regression Analysis

Variable	Definition	Exp. Sign
FERT	Fertilizer expenditures divided by total acres operated, adjusted using PPI	
CHEM	Agricultural chemical expenditures divided by total acres operated, adjusted using PPI	
HBARLEY	Harvested acres of barley divided by total acres operated	(+ or -)
HCORN	Harvested acres of corn divided by total acres operated	(+ or -)
HCOTTON	Harvested acres of cotton divided by total acres operated	(+ or -)
HOATS	Harvested acres of oats divided by total acres operated	(+ or -)
HSORGH	Harvested acres of sorghum divided by total acres operated	(+ or -)
HSOY	Harvested acres of soybean divided by total acres operated	(+ or -)
HWHEAT	Harvested acres of wheat divided by total acres operated	(+ or -)
ACRESOP	Total acres operated per farm	(+)
WEALTH	Total farm financial assets less total farm financial debts (wealth) per total acres operated, adjusted using CPI	(+ or -)
AGE	Age of primary farm operator	(+ or -)
TENURE	Ratio of owned to operated acres	(+)
DP	Total decoupled direct payments per total acres operated, adjusted using CPI[a]	(+)
GOV	Government payments less decoupled payments per total acres operated, adjusted using CPI	(+)
WACF	Weighted average cost of fertilizer, adjusted using PPI[b]	(+)
WACAC	Weighted average cost of agricultural chemicals, adjusted using PPI[b]	(+)
INSURE	Ratio of insurance costs to total expenditures per farm, adjusted using CPI	(+)
SOLVE	Ratio of total farm financial debt to total farm financial assets (solvency), adjusted using CPI	(+)
DP*INSURE	Interaction term: decoupled direct payments & insurance expenditures	(-)
DP*SOLVE	Interaction term: decoupled direct payments & solvency	(-)
GOV*INSURE	Interaction term: government payments & insurance expenditures	(-)
GOV*SOLVE	Interaction term: government payments & solvency	(-)
TIME	Time trend	(+ or -)
TIMESQ	Time trend squared	(+ or -)
COUNTY	County dummy variables	(+ or -)

Notes: a: Decoupled payments include production flexibility contracts, fixed direct payments, and counter-cyclical payments. b: WACF and WACAC include prices for all seven crops in model.

Since expenditures on fertilizer and agricultural chemicals are reported at the farm-level in the dataset and prices are not reported, it is necessary to construct price measures for these inputs. Weighted average costs of fertilizer (WACF) and agricultural chemicals (WACAC) are computed using the following functions.

(4) $$WACF = \sum_{i=1}^{7} P_{it}^{F} \left(\frac{A_{it}}{A_{Tt}} \right)$$

(5) $$WACAC = \sum_{i=1}^{7} P_{it}^{AC} \left(\frac{A_{it}}{A_{Tt}} \right).$$

In the first equation, P_{it}^{F} is the per acre cost of fertilizer for commodity *i* in time *t* and is multiplied by the ratio of acres harvested of commodity *i* in time *t* A_{it} to total acres harvested of the seven program crops with fertilizer price information in time *t* A_{Tt}. Equation (5) is identical except P_{it}^{AC}, the per acre cost of agricultural chemicals for commodity *i* in time *t* replaces P_{it}^{F}. P_{it}^{F} and P_{it}^{AC} are adjusted using the producer price index for pesticides, fertilizer, and other agricultural chemical manufacturing to account for inflation. Price data used in WACF and WACAC calculations is collected at a regional level from the USDA Economic Research Service's Cost and Returns Report. WACF and WACAC are used in the regression analysis as a measure of prices for fertilizer and other agricultural chemicals, respectively. We expect an increase in WACF will increase FERT and an increase in WACAC will increase CHEM.

Harvested acres of the seven program crops used to calculate the weighted average cost functions are included in the analysis as independent variables (HBARLEY, HCORN, HCOTTON, HOATS, HSORGH, HSOY, and HWHEAT). These variables are normalized with respect to total acres operated hence they represent the farm-level crop mix. Because the variables are normalized, an increase in harvested acres of any one of the seven crops necessarily changes the crop mix. Hence, the expected signs of the coefficients on these variables cannot be determined. For example, if HOATS decreases but total acres operated remains the same, these acres must have been replaced by another crop or idled; if the replacement crop uses more fertilizer and agricultural chemicals per acre, the decrease in HOATS will increase FERT and CHEM. If the acres of oats are replaced with a crop using less fertilizer and agricultural chemicals, the relationship will be negative. Total acres operated (ACRESOP) is also included to represent the acreage of non-program crops and as a size control since economies of size may be possible.

Coupled and decoupled direct payments are represented by GOV and DP. DP includes production flexibility contracts, fixed direct payments, and countercyclical payments received by farmers. GOV is calculated as all other government payments. ARMS and FCRS surveys do not always distinguish between coupled payments, such as deficiency payments, and lump sum payments such as conservation program payments. Therefore, GOV represents coupled and lump sum payments. Both variables are adjusted using CPI.

Several farmer characteristics are also include in the regression model. Wealth (WEALTH) measured as total farm financial assets less total farm financial debts per total acres operated, adjusted using CPI is included. As wealth increases, fertilizer and agricultural chemical expenditures may increase because more funds are available; this would be particularly true at low levels of wealth. Conversely, since fertilizers and agricultural chemicals may act as possible insurance against low yield (Ramaswami, 1992; Hennessy 1998), there is an incentive for farmers with low levels of wealth to apply more fertilizers and pesticides.

Similarly, the age of the primary operator (AGE) may be positively or negatively related to fertilizer and agricultural chemical use. A young operator may be more inclined to minimize fertilizer and chemical use due to concerns about health and/or the environment, while an older operator may be more knowledgeable about crop production and hence use less fertilizer and agricultural chemicals.

The ratio of owned-to-operated acres (TENURE) may affect FERT and CHEM because landowners may have a greater incentive to increase yields by increasing their use of production inputs. Furthermore, decoupled direct payments are paid to farm operators, not landowner; however an estimated 20 to 25 percent of the payment is capitalized into increased rental rates (Kirwan, 2009). Hence, tenure is an important variable.

Two measures of risk are included in the model: INSURE and SOLVE. INSURE is the ratio of insurance costs to total expenditures per farm, adjusted using CPI. The more risk averse a farmer is, the more insurance he may purchase relative to other expenditures. If fertilizer and other agricultural chemicals are risk reducing inputs, then positive relationships between risk aversion and the dependent variables are expected. SOLVE is the solvency ratio measured as total farm financial debt to total farm financial assets, adjusted using CPI. Solvency acts as measure of financial risk. A farmer that is less solvent may increase the use of risk reducing inputs to insure a good yield to avoid defaulting on debt obligations. Moreover, solvency indicates whether a farmer is credit constrained (Goodwin & Mishra, 2006); the more debt a farmer has, the less likely he can access more credit. A positive relationship between SOLVE and the dependent variables therefore suggests that financially risky farmers view fertilizer and agricultural chemicals as risk reducing inputs and/or decoupled payments relax credit constraints thus providing possible coupling mechanism. Currently there is some debate in the literature regarding whether agricultural chemicals are risk reducing or risk increasing (Horowitz & Lichtenberg, 1993; Rajsic, Weersink, & Gandorfer, 2009; Ramaswami, 1992). Our results may help determine the nature of these inputs. Four interaction terms are included to allow the effects of both government payments and decoupled payments to vary with different levels of risk aversion and solvency.

Since the data spans 17 years, a time trend is included in analysis. A positive relationship between the dependent variables and TIME implies that from 1991 to 2008, fertilizer or agricultural chemical use has increased over time. A positive coefficient on TIMESQ would imply this is occurring at an increasing rate. The expected sign of the coefficients on these variables is uncertain. Increased use of plants genetically modified to encourage greater yields may reduce the amounts of either production input over time. On the other hand, increased use of low-tillage crop management plans may increase the use of agricultural chemicals because more weeds are encouraged to grow on low- or no-till land.

Lastly, dummy variables for each county (COUNTY) are included in the model to account for variability not captured by the other regressors, specifically: 1) transportation costs for volatile fertilizers that may vary across counties, 2) differences in soil and land quality across counties, and 3) unobserved growing conditions such as drought and disease that may vary by county.

The model can be summarized by Equations (6) and (7). The only differences between the equations are the dependent variables and the weighted average cost functions. Note that there is no intercept to allow all county dummies to remain in the model for ease of interpretation. HCROP is a term used to identify harvested acres divided by total acres operated of the seven program crops in the model.

(6)

$$FERT = \sum_{i=1}^{7} \alpha_i HCROP_i + \alpha_8 ACRESOP + \alpha_9 WEALTH + \alpha_{10} DP + \alpha_{11} GOV + \alpha_{12} AGE + \alpha_{13} TENURE + \alpha_{14} WACF + \alpha_{15} INSURE + \alpha_{16} SOLVE + \alpha_{17} DP*INSURE + \alpha_{18} DP*SOLVE + \alpha_{19} GOV*INSURE + \alpha_{20} GOV*SOLVE + \alpha_{21} TIME + \alpha_{22} TIMESQ + \sum_{k=1}^{K} \alpha_k COUNTY_k + \varepsilon$$

(7)

$$CHEM = \sum_{i=1}^{7} \beta_i HCROP_i + \beta_8 ACRESOP + \beta_9 WEALTH + \beta_{10} DP + \beta_{11} GOV + \beta_{12} AGE + \beta_{13} TENURE + \beta_{14} WACAC + \beta_{15} INSURE + \beta_{16} SOLVE + \beta_{17} DP*INSURE + \beta_{18} DP*SOLVE + \beta_{19} GOV*INSURE + \beta_{20} GOV*SOLVE + \beta_{21} TIME + \beta_{22} TIMESQ + \sum_{k=1}^{K} \beta_k COUNTY_k + \varepsilon$$

Summary statistics

Table 3 contains summary statistics of all variables within the model as well as two variables that were not included due to endogeneity (net farm income, NINCOME) and missing observations in some years (primary operator's years of farm experience, YEARSEXP). Additionally, summary statistics for non-normalized harvested acres of all program crops are included (ABARLEY, ACORN, ACOTTON, AOATS, AOILSEED, APEANUT, APULSE, ASORGH, ASOY, AWHEAT). After limited our analysis as described above, the sample consisted of 25,571 farms.

Between 1991 and 2008, average fertilizer expenditures per acres operated (FERT) was $16.48, slightly greater than the average agricultural chemical expenditure per acres operated (CHEM) of $12.08. The mean weighted average cost of fertilizer was slightly higher than the mean weighted average cost of agricultural chemicals, signifying that fertilizer is on average more expensive per acre to apply than agricultural chemicals. The difference in average fertilizer and agricultural chemical expenditures per acre may also come from differences in quantities used. The large standard deviation for both expenditures reflect differences in what each farm produces; since farms are not homogenous, per acre expenditures for production inputs varies dramatically across farms.

Table 2. Summary Statistics, 1991-2008

Variable	Mean	Std. Dev.	Min	Max
FERT	$16.48	$138.28	$0.00	$358.81
CHEM	$12.08	$100.05	$0.00	$198.28
WACF	$25.40	$76.97	$5.08	$53.58
WACAC	$16.72	$50.70	$0.66	$60.32
ABARLEY*	1.93	248.64	0	◆
ACORN*	224.91	3298.34	0	◆
ACOTTON*	1.08	384.22	0	◆
AOATS*	2.09	177.66	0	◆
AOILSEED*	2.18	337.55	0	◆
APEANUT*	0.00	0.00	0	◆
APULSE*	1.35	225.94	0	◆
ARICE*	0.64	256.03	0	◆
ASORGH*	4.70	347.36	0	◆
ASOY*	207.44	2926.94	0	◆
AWHEAT*	41.05	1706.81	0	◆
HCORN	0.32	2.24	0	1.00
HCOTTON	0.001	0.27	0	1.00
HSORGH	0.01	0.46	0	0.91
HSOY	0.30	2.09	0	1.00
HBARLEY	0.002	0.20	0	0.75
HOATS	0.01	0.27	0	0.64
HWHEAT	0.04	1.04	0	0.99
ACRESOP	671.44	8,436.66	1.00	◆
TENURE	0.56	9.31	0	161.00
AGE	54	15	17	98
YEARSEXP*	29.80	14.0	0	75
WEALTH	$1,198.03	$43,369.70	$(1,240.24)	$315,709.35
NINCOME*	$52,295.87	$133,540.57	$(158,312.26)	$2,874,809.57
INSURE	0.06	0.54	0	0.83
SOLVE	0.10	5.68	0	140.34
DP	$4.88	$73.59	$0.00	$305.25
GOV	$9.81	$147.76	$(3.71)	$545.34

Notes: Number of observations is 25,071 except for WACF and WACAC, which have 24,140 observations, APULSE and AOILSEED, which have 7,214, SOLVE, which has 25,050 observations, and YEARSEXP, which has 13,957 observations. *Some variables are not in the model: YEARSEXP is defined as the primary operator's years of farm experience and NINCOME is defined as net farm income. Crop variables beginning with A (instead of H) are not normalized and represent all program crops. ◆Maximums cannot be reported due to disclosure restrictions on the data.

Total acres operated (ACRESOP) averaged 671. On average, operators rent 44 percent of the acres they operate (TENURE). The average farm allocates 32 percent of total acres operated to corn (HCORN) and 30 percent to soybeans (HSOY). Furthermore, a Pearson correlation coefficient of 0.28 between HCORN and HSOY suggest that farmers harvesting corn are likely to harvest soybeans as expected since famers generally produce these two crops together or in rotation. Cotton is only grown in Missouri, with slightly more than 14 acres harvested per farm on average. Note that peanuts are not grown by any farm in the sample.

Examining the Pearson correlation coefficients between harvested program crops and the dependent variables FERT and CHEM shows that there is a significant 0.52 correlation between the percentage of total acres operated that are corn (HCORN) and fertilizer expenditures (FERT) as well as a 0.45 correlation between HCORN and agricultural chemical expenditures (CHEM). On average corn requires the most fertilizers and agricultural chemicals of any program crop.

The average age of the primary farm operator is 54. On average, the primary operator has almost 30 years of experience working on a farm (YEARSEXP). We included only AGE in the model as a proxy for farm experience because of the high correlation (0.80) between the two variables and the lack of information pertaining to work experience in some of the sample years.

The mean of wealth adjusted with respect to acres operated to account for farm size is approximately $1,200 with a standard deviation of $43,000. The average net farm income (NINCOME) is $52,295.87 and also has a large standard deviation of $133,540.57. The large standard deviations indicate an uneven distribution of wealth and income across the sampled farms. In fact, 74 percent of farms' total value of production is greater than $100,000 annually. On average, farms spend 6 percent of all expenditures on insurance, including subsidized crop insurance required to participate in most government crop programs. The average farm sampled has a solvency ratio of 0.10, indicating that the farms in the sample have very little debt on average.

Eighty-eight percent of all sampled farms receive decoupled payments after their introduction in 1996. The average farm collects $5.00 in decoupled direct payments (DP) per operated acre and almost twice that in all other government payments (GOV). Again, there is a wide range of farms represented and large standard deviations for both GOV and DP.

Estimation results

Ordinary least squared regression analysis is used to estimate Equations (6) and (7) using the appropriate sample weights to test the hypothesis that there exists a positive relationship between both decoupled direct payments and other government payments and the use of agricultural chemicals. The resulting coefficients and standard errors are reported in Table 3. The effects of the county dummy variables (COUNTY) are not reported due to the large number of counties in the sample[8].

Model 1: Fertilizers (1991 – 2008)

All but two variables (WEALTH and GOV*SOLVE) have coefficients that are statistically different than zero at a 5 percent level of significance in Model (1). Harvested acres of all program crops per total operated acres were found to have a positive and significant relationship with fertilizer expenditures, with harvested corn acreage having the largest coefficient and oats having the smallest. Although precise relationships should not be implied by the coefficients, the magnitudes suggest that an increase in acreage allotted to corn will increase fertilizer expenditures more than an increase in acreage allotted to oats. These results reflect the important role of crop mix in the consumption of fertilizer. Total acres operated had a small but

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[8] There 547 counties in the extended Heartland region.

positive significant relationship with fertilizer expenditures per acre. These results imply any effects due economies of size are small and a farm's product mix is more important than total acreage when determining fertilizer and agricultural chemical expenditures per acre.

Table 3. Fertilizer and Agricultural Chemical OLS Regression Results

	Models			
	Fertilizer (1)		Other Agricultural Chemical (2)	
	Coefficient	Std. Error	Coefficient	Std. Error
HBARLEY	13.43***	3.84	1.59	2.91
HCORN	28.70***	0.67	15.77***	0.39
HCOTTON	16.41***	3.66	35.84***	2.97
HOATS	6.97**	2.83	-13.72***	2.20
HSORGH	16.40***	1.76	11.79***	1.31
HSOY	8.36***	0.72	11.86***	0.37
HWHEAT	15.24***	1.01	7.94***	0.88
ACRESOP	0.0005***	0.00009	0.0004***	0.00007
WEALTH	0.000009	0.00007	0.0003***	0.00006
DP	0.19***	0.02	0.17***	0.01
GOV	0.11***	0.01	0.04***	0.01
AGE	-0.03***	0.01	-0.003	0.004
TENURE	2.53***	0.21	1.35***	0.15
WACF/WACAC[a]	0.17***	0.02	0.12***	0.03
INSURE	-23.78***	2.50	-17.98***	1.85
SOLVE	1.58***	0.55	2.34***	0.41
DP*INSURE	-0.74***	0.27	-0.57***	0.20
DP*SOLVE	-0.09**	0.04	-0.20***	0.03
GOV*INSURE	-0.49***	0.14	0.18*	0.10
GOV*SOLVE	-0.03	0.04	0.12***	0.03
TIME	-0.23***	0.06	0.68***	0.04
TIMESQ	0.02***	0.003	-0.04***	0.003
Observations	24,118		24,118	
Adjusted R^2	0.399		0.342	

Notes: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.
a: WACF used for Fertilizer model, WACAC used for Other Agricultural Chemical model.
County dummy variables are not reported due to the large number of counties in the sample.

The coefficient on age is negatively significant, indicating that older farmer spend less on fertilizer per acre operated than younger farmers. This supports the proposition that farmers with more experience use less fertilizer, perhaps because they are familiar with other methods, or are reluctant to apply more fertilizer. Landowners spend more on fertilizer per acre than those that rent.

The two time trend variables together suggest that over time, fertilizer expenditures have decreased at an increasing rate. This may be due to technological advances in production practices such as genetically modified crops that require less fertilizer.

The coefficient on INSURE is significantly negative, suggesting more risk averse farmers use less fertilizer. There are two possibilities justifications for this unexpected result. First, some farmers may view fertilizer as a risk-increasing input, meaning that risk-averse farmers would decrease their use of fertilizer. Whether fertilizer is risk-increasing or decreasing is debated in the literature. Second, the percent of total farm expenditures spent on insurance may be too simplistic a measure of a farmer's level of risk aversion, particularly within this model where there may be endogeneity issues due to the dependent variable FERT being a portion of total expenditures.

Contrarily, the effect of the proxy for financial risk, SOLVE, is positive and significant. If a farmer is less solvent (and therefore has a greater solvency ratio), he will increase his use of risk-reducing inputs like fertilizer to insure a good yield and avoid defaulting on debt obligations. Furthermore, SOLVE also serves as a proxy for a farmer's degree of credit constraint and the positive relationship suggests that decoupled direct payments affect a farmer's ability to access credit.

As hypothesized, an increase in decoupled direct payments and government payments both increases fertilizer expenditures by a small but statistically significant amount. Coupled government payments, which make up the majority of payments included in GOV, are based on production, inputs, or prices and are known to increase input use. However, decoupled direct payments are, in theory, not based on production, inputs, or prices unless they are linked by any of the coupling mechanisms previously discussed. The results for Model (1) suggest that decoupled direct payments can influence a farmer's decision to use fertilizers.

Expected signs are found for all four interaction-terms included to allow government payments and decoupled direct payments to vary with different levels of risk, although the interaction between government payments per acre and solvency is not statistically significant. The results for DP*INSURE and DP*SOLVE suggest that there are three avenues by which decoupled direct payments may affect fertilizer expenditures: first, directly as seen through DP, second, indirectly through changes in risk preferences (DP*INSURE), and third, indirectly through changes in financial risk preferences (DP*SOLVE). The marginal effect of government payments on fertilizer use calculated at the mean is 0.08. Since GOV consist of both coupled and lump sum transfers, the marginal effect of GOV should be viewed as the lower bound on the effect of coupled payments. The marginal effect of decoupled direct payments on fertilizer use evaluated at the mean is 0.14, suggesting that the total effect of DP on FERT is greater than the total effect of GOV on FERT. This result is not insignificant. It suggests that decoupled payments can affect the intensive margin more than coupled government payments.

Model 2: Agricultural Chemicals (1991 – 2008)

The results for Model (2) are similar to the results for Model (1). Only two variables are insignificant at 5 percent significance: percent of total acres operated that are barley (HBARLEY) and age. Over time, agricultural chemical expenditures per acre increased at a decreasing rate. Only one variable, ratio of insurance expenditures to total expenditures (INSURE), had a coefficient with an unexpected signs, indicating that other agricultural chemicals might be a risk-increasing input.

Contrary to Model (1), the coefficients on HOATS is negative and significantly, suggesting that oats require fewer agricultural chemicals to produce than the other program crops in the model. The coefficients associated with the seven program crops differ across crops and indicate that crop mix is an important determinant of agricultural chemical use per acre. For example, the coefficient for HCOTTON implies that a 1 percent increase of total acres operated used for cotton production increases agricultural chemical expenditures per acre by approximately $35.84, while a 1 percent increase of harvested corn acres increase agricultural chemical expenditures by $15.77 per acre. Similar to Model (1), total acres operated is statistically significant but small.

The effects of government payments (GOV) and decoupled direct payments (DP) on agricultural chemical expenditures per acre are positive and small, but statistically significant. Furthermore, the coefficients on the interaction terms indicated that government payments affect agricultural chemical expenditures per acre through changes in risk preference and/or credit constraints. The marginal effects of government payments on agricultural chemicals decrease with an increase in solvency and/or insurance expenditures. The marginal effects of GOV and DP evaluated at the means are 0.06 and 0.11, respectively.

Structural breaks due to policy change

Structural breaks in 1996, 2002, and 2008 are expected due to policy changes in those years. If decoupled direct payments increase fertilizer and agricultural chemical use, a structural break should occur in 1996. If updating alters farmers' decisions about production inputs, specifically fertilizer and agricultural chemicals, a structural break should be found in 2002. Because there is no data available after 2008, the hypothesis that changes in the 2008 Farm Bill lead to a structural break cannot be tested using this data. Therefore, Chow tests are conducted to test for structural breaks at 1996 and 2002 (Chow, 1960). To test for lags or expectations of these policy changes, we also conduct iterative Chow tests (Bai and Perron, 2003).

Model 3: Fertilizers (Structural Breaks in 1996 & 2004)

An iterative Chow test suggests that structural breaks occur in Model (1) in 1996 and 2004. Thus, there are significant differences within these three subsets of the full model (years 1991 through 2008) and comparing coefficients across these three subsets indicates which characteristics are unique to each subset. As shown in Table 4, the coefficient for HSOY decreases significantly with each subset, going from about 11 in the first subset, then 7 in the second subset, and finally 3 in the third subset. This implies that within each subset, an increase in the amount of harvested acres of soybeans increases fertilizer expenditures by less and less. Possible causes may be changes in soybean production practices or the type of soybeans used due to biotechnology. The effect of HBARLEY is only significant in the first subset. Also, the effect of HOATS is positive and significant in the first subset and negative in the second subset.

With the introduction of decoupled direct payments in 1996, the magnitude of the effect of government payments decreases. Between 2004 and 2008, the magnitude of the coefficient on GOV remains almost the same, but the magnitude of the coefficient on DP increases, implying that after 2004 an increase in decoupled direct payments had a larger impact on fertilizer expenditure per acre operated than prior to the enactment of the FSRI Act. Perhaps this is because of the introduction of updating. The marginal effects of government payments evaluated at the mean for the three subsets are: 0.21 for 1991 to 1995, 0.07 from 1996-2003, and 0.06 2004-2008. The marginal effects of decoupled payments on fertilizer expenditures evaluated at the mean also change after 1996: 0.14 from 1996 to 2001 and 0.22 between 2002 and 2008.

Table 4. Fertilizer OLS Regression Results with Structural Breaks in 1996 and 2004

	1991-1995		1996-2003		2004-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HCORN	27.69***	1.76	26.69***	1.05	39.49***	1.33
HCOTTON	19.25**	8.56	11.78**	5.10	26.13***	8.74
HSORGH	19.59***	3.60	13.73***	2.50	24.00***	6.57
HSOY	11.33***	1.95	6.36***	1.16	1.06	1.50
HBARLEY	17.52***	6.34	11.52*	7.16	-11.42	17.06
HOATS	25.86***	6.13	-12.55***	4.31	-9.75	6.20
HWHEAT	13.17***	2.28	16.12***	1.62	15.82***	2.02
ACRESOP	0.001***	0.0003	0.0005***	0.001	0.0003**	0.0001
WEALTH	-0.001***	0.0002	0.001***	0.002	0.0005***	0.0001
DP	-	-	0.12***	0.03	0.39***	0.04
GOV	0.29***	0.03	0.09***	0.02	0.09***	0.03
AGE	-0.05***	0.01	-0.03***	0.01	-0.01	0.01
TENURE	6.50***	0.52	2.53***	0.39	0.12	0.30
WACF	0.18***	0.07	0.05	0.04	-0.05	0.04
INSURE	-20.96***	5.44	-26.60***	3.87	-11.96**	5.53
SOLVE	4.31***	1.48	0.97	0.70	9.63***	2.50
DP*INSURE	-	-	0.45	0.40	-2.68***	0.50
DP*SOLVE	-	-	-0.11**	0.05	-0.45**	0.18
GOV*INSURE	-0.87***	0.34	-0.62***	0.18	-0.60	0.46
GOV*SOLVE	-0.33***	0.09	0.12**	0.05	0.01	0.15
TIME	0.11	0.54	-4.00***	0.50	3.33	2.87
TIMESQ	0.04	0.09	0.20***	0.03	-0.07	0.09
Observations	*4,755*		*9,747*		*9,616*	
Adjusted R^2	*0.501*		*0.408*		*0.450*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

Finding a structural break two years after the FSRI Act was enacted indicates that farmers were hesitant to change their on-farm decisions until after they saw how the policy would affect them. If a farmer expects government policies to change regularly, it may be optimal to wait and see how the new policy may impact him or her. Because fertilizer is such an integral part of the production of program crops, farmers might be reluctant to change their input decisions. However, these conjectures may be unnecessary; an additional Chow test indicates that there is no statistically significant difference between the model with structural breaks at 1996 and 2002 and the hypothesized one with breaks at 1996 and 2002[9].

Model 4: Agricultural Chemicals (Structural Breaks in 1996 & 2000)

A similar iterative Chow test for the agricultural chemical model indicates that there is a statistically significant difference between the hypothesized model with structural breaks in 1996 and 2002 and a model with structural breaks in 1996 and 2000[10], shown in Table 5. The break occurring in 2000 instead of 2002 could be due to farmer's anticipation of new policies. This would be the opposite of what was explained in the previous fertilizer model.

However, the most likely cause of this structural break is not policy related. In 2000, the patent for Monsanto's chemical herbicide Roundup expired, reducing the price of glyphosphate (generic Roundup) dramatically and increasing the volume used in the United States (Baccara et. al, 2003). Farmers use this herbicide due to the "broad-spectrum weed control, low cost and simplicity" (Shaner, 2000) and have decreased the use of other herbicides in place of using glyphosphate. Most likely, the effects of Roundup dominated any structural break due to policy changes in 2002.

Each of the seven program crops in the model have similar coefficients to those found in Model (2) presented in Table 3, with the exception of HSORGH, which is smaller in magnitude in the first subset, but not statistically significant. Also, the WACAC coefficient is only statistically different from zero in the third subset. This is somewhat surprising as it may suggest that the price of agricultural chemicals does not affect total agricultural expenditures per operated acres.

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[9] The F-statistic is 0.858 with a p-value of 1.
[10] The F-statistic is 1.983 with a p-value of 0.

Table 5. Agricultural Chemical OLS Regression Results with Structural Breaks in 1996 and 2000

	1991-1995		1996-1999		2000-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HCORN	15.89***	0.98	12.83***	1.03	14.95***	0.54
HCOTTON	35.94***	8.00	17.17**	7.90	26.35***	3.97
HSORGH	3.31	2.88	11.44***	2.87	15.04***	2.66
HSOY	11.01***	1.00	14.55***	0.94	10.45***	0.49
HBARLEY	0.49	5.18	-0.45	8.23	1.23	6.34
HOATS	-11.59**	5.41	0.42	5.27	-9.79***	3.29
HWHEAT	8.01***	2.44	8.68***	2.45	10.00***	1.21
ACRESOP	0.00***	0.00	0.00	0.00	0.00***	0.00
WEALTH	0.00***	0.00	0.00***	0.00	0.00***	0.00
DP	-	-	0.37***	0.03	0.14***	0.02
GOV	0.15***	0.02	0.03	0.03	0.01	0.01
AGE	-0.03***	0.01	-0.02**	0.01	0.01	0.01
TENURE	2.53***	0.41	1.13**	0.47	0.54***	0.18
WACAC	0.12	0.09	0.23***	0.09	0.20***	0.05
INSURE	-23.17***	4.37	-14.95***	4.40	-11.70***	2.75
SOLVE	3.75***	1.19	7.19***	1.56	0.39	0.46
DP*INSURE	-	-	-1.67***	0.45	-0.80***	0.25
DP*SOLVE	-	-	-0.57***	0.12	-0.04	0.03
GOV*INSURE	-0.41	0.27	0.41	0.31	0.29**	0.12
GOV*SOLVE	0.00	0.07	0.12	0.10	0.05	0.03
TIME	2.56***	0.48	11.81***	2.04	2.13***	0.33
TIMESQ	-0.32***	0.08	-0.83***	0.14	-0.09***	0.01
Observations	*4,755*		*5,060*		*14,303*	
Adjusted R^2	*0.430*		*0.458*		*0.339*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

Comparing the three subsets, the absence of decoupled direct payments is evident before 1996. After their introduction at that time, a positive and statistically significant relationship is found between DP and agricultural chemical expenditures per acre. In the second subset, the effects of both interaction terms with DP are negative and significant. The effect of other government payments is negative in the second subset (1996-2001) but not significant. Otherwise, the effects of government payments per operated acre are similar to those found in

Model (2). However, the interaction terms show a weaker relationship in all three subset than in Model (2). GOV*INSURE is only significant between 1996 and 2001 and GOV*SOLVE is not significant in any of the three models. The marginal effects of government payments per acre operated for the three subsets are: 0.13 for 1991-1995, 0.07 for 1996-1999, and 0.34 2000-2008. The marginal effects of decoupled payments per acre operated after 1996 are 0.22 for 1996-1999 and 0.09 for 2000-2008.

The time trend variables are significant in the first two subsets, suggesting that between 1991 and 1999, agricultural chemical expenditures have increased at a decreasing rate.

IV. Implications and Conclusions

Truly decoupled payments should not affect a farmer's optimal allocation of acreage or inputs since these payments are based on historic production and yields rather than current production, prices or inputs. However, several mechanisms that cause decoupled payments to become coupled have been identified in the literature. One mechanism by which decoupled payments become coupled, and thus may impact current production decisions, is through expectations of future policy changes. If a farmer believes that he might be able to update his base acreage and/or yield in the future either through policy changes or the implicit policy design (in the case of ACRE), then he has incentive to alter his production decision in the current period in order to maximize future profits and his expected utility. Since the introduction of decoupled payments in 1996, updating has been allowed in both subsequent Farm Bills.

Therefore, we expected a positive relationship between the use of agricultural chemicals and decoupled payments. Although we expected the relationships between both decoupled and coupled governments payments and agricultural chemical use to be positive, the magnitude of the effect of decoupled direct payments relative to the magnitude of the effect of coupled government payments depends on the levels of coupled price supports, decoupled subsidies, and the discount rate.

Using annual cross-sectional data weighted ordinary least squares regression results indicate positive relationships between both decoupled government payments and other government payments and the expenditures of fertilizer and other agricultural chemicals (which includes all other agricultural chemicals not classified as fertilizer) per acres operated. Since we controlled for price movements and adjusted expenditures using the appropriate PPI, we assume that these relationships indicate positive relationships between government payments and agricultural chemical use.

Between 1996 and 2004 the marginal effect of decoupled payments on fertilizer expenditures per acres operated evaluated at the mean was 0.14, after 2004 this figure increased to 0.22. Relative to the marginal effects of other government payments on fertilizer expenditures per acres operated for the same time periods, decoupled direct payments increased fertilizer expenditures by 2 or 3 times as much. Similar results hold for other agricultural chemicals between 1996 and 2000. After 2000, the marginal effects of other government payments on agricultural chemicals were close to 4 times greater than those for decoupled direct payments. Collectively, the results indicate that decoupled payments may affect the intensive margin more that other types of government payments and hence might lead to greater production distortions. Since other government payments consisted of both coupled and lump sum transfers, the marginal effects other government payments should be viewed as the lower bound on the marginal effects of coupled payments. However, since coupled payments made up the majority of the transfers categorized as other government payments, there is some evidence that decoupled payments may affect the intensive margin more than coupled payments.

Although impacts of the newest decoupled direct payment program, Average Crop Revenue Election (ACRE), on production decisions could not be tested empirically, an important implication comes from the theoretical section. The ACRE program introduced in 2008 set historic yields to an Olympic moving average, meaning that each year the historic period upon which payments are calculated changes. Therefore, this policy may implicitly create a link between current acreage and input decisions and future program crop payments and hence ACRE payments become coupled.

To more fully understand the link between decoupled payments, updating and agricultural chemical use more research is needed. First, the lack of panel data prevents tracking of year to year changes in a specific farmer's production decisions. Panel data would grant a better understanding of how both the extensive and intensive production margins are impacted by policy changes. Second, future research should aim to further separate other government payments into lump sum transfers and coupled payments. Lastly, quantities of fertilizer and agricultural chemicals per acre should be used in the analysis rather farm-level total expenditures. Quantity data could also be used to determine how decoupled direct payments affect environmental quality by examining the use of particularly environmentally hazardous fertilizer and agricultural chemicals.

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