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

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We analyze the impacts of agricultural subsidies on farm-level production decisions and input use under price, yield, and policy uncertainty for a risk-averse farmer. Using U.S. farm-level data and weighted ordinary least squares, we find that decoupled payments had little impact on agricultural chemical expenditures (our proxy for use) when the payments were first introduced in 1996. However, after 2004 there is a positive, significant relationship between decoupled payments and agricultural chemical expenditures. The results suggest that updating, introduced in 2002, and expectations of future updating caused decoupled payments to become coupled to current input use and, ultimately, production.

Key Words**:** decoupled payments, expectations, input use, production decisions, updating

Agricultural decoupled support payments were first introduced in the United States under the Federal Agriculture Improvement and Reform Act (1996 Farm Bill). Under the 1996 Farm Bill, farm operators received production flexibility contract (PFC) payments based on historic acreage and yields. These decoupled payments were introduced to comply with World Trade Organization (WTO) obligations requiring a reduction in trade-distorting agricultural support outlined in the Uruguay Round Agreement on Agriculture (AoA). By definition, decoupled support is not linked to current production or market prices.

Although PFC payments were supposed to be phased out prior to the enactment of the 2002 Farm Bill, they were continued in two subsequent farm bills. The Farm Security and Rural Investment Act of 2002 (2002 Farm Bill) (P.L. 107-17) also gave farmers the option of updating their base acreage and yields, essentially allowing farmers to change the historic acreage and yields upon which their decoupled payments were based. While updating was not explicitly allowed in the Food, Conservation, and Energy Act of 2008 (2008 Farm Bill) (P.L. 110-234), the bill permitted farmers to adjust their base acreage to allow for the addition of newly covered commodities. The 2008 Farm Bill also gave farmers the option of foregoing a portion of their decoupled payments to obtain Average Crop Revenue Election (ACRE) program payments based on Olympic moving averages of the national market price, state yields, and farm-level yields. Since ACRE payments are based on a moving average of farm-level yields, updating is essentially embedded in the policy design.

While early research on decoupled payments concluded that these payments have a minimal impact on output levels and thus on trade (e.g., Rucker, Thurman, and Sumner 1995, Rucker and Thurman 1990, Borges and Thurman 1994, Blandford, de Gorter, and Harvey 1989), more recent research has identified several mechanisms through which decoupled payments can potentially influence current production decisions. For example, decoupled payments may

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alter farmers' risk preferences due to insurance and wealth effects (Hennessy 1998), ease credit constraints by increasing total wealth (Burfisher and Hopkins 2004, Goodwin and Mishra 2006), and change farmers' allocations of land, labor, and other inputs (Ahearn, El-Osta, and Dewbre 2006, Kirwan 2009). In addition, there is evidence that decoupled agricultural subsidies keep farms that would otherwise exit the market in business and thus inflate aggregate production (Chau and de Gorter 2005, de Gorter, Just, and Kropp 2008).

Furthermore, farmers' expectations of and uncertainty about future decoupled payments may indirectly affect their current production decisions. Goodwin and Mishra (2006) showed that uncertainty regarding future decoupled payments affects the optimal allocation of acreage amongst crops planted. In addition, Bhaskar and Beghin (2010), using data from an experimental farm in Iowa, showed that if a risk-averse farmer believes that he might be allowed to update his base acreage or yields in the future, then the farmer has an incentive to increase his current acreage and/or to increase current yields by applying more fertilizer.

Building on Bhaskar and Beghin's work, we analyze the impact of decoupled payments on farmers' use of agricultural chemicals in the presence of uncertainty regarding the ability to update base acreage and yield. We use U.S. farm-level data obtained from the annual U.S. Department of Agriculture (USDA) Farm Cost and Returns Survey (FCRS) and the Agricultural Resource Management Survey (ARMS) by the National Agricultural Statistics Service. Unfortunately, these surveys do not ask questions regarding quantities of agricultural chemicals used at the farm level. Therefore, we use real expenditures per acre as a proxy for the quantity of agricultural chemicals used. As a robustness check, we also analyze per-acre quantities of nitrogen, phosphate, and potash using field-level data. Due to the survey design of ARMS field-level data, this analysis is limited to corn producers. The empirical results suggest that updating, introduced in 2002, caused decoupled payments to become coupled to current input use and hence current production.

We hereafter present an overview of U.S. agricultural supports, followed by a review and extension of Bhaskar and Beghin's (2010) theoretical model of how decoupled payments under policy uncertainty impact current production and input use. We then provide empirical evidence of the impact of updating on agricultural chemical use and, finally, discuss the implications of our findings.

Overview of Decoupled Payment Programs in the United States

For the majority of the twentieth century, high agricultural prices were maintained through coupled price supports and government procurement of surpluses. Coupled payments are tied, or "coupled," to current market prices and current production. Although the Food Security Act of 1985 (P.L. 99-198) reduced the role of price supports and supply control, allowing agricultural commodity prices to more closely align with the market, the essential structure of agricultural support did not change significantly until the introduction of decoupled direct payments under the PFC program in the 1996 Farm Bill following signing of the AoA in 1994.

Through the PFC program, farm operators received payments based on historic (base) acres and yields regardless of current plantings. Farmers producing wheat, corn, barley, grain, sorghum, oats, rice, and upland cotton (referred to as program crops) and participating in a corresponding support program during the base period of 1991 to 1995 were eligible to receive PFC payments. While PFC payments were determined by crop specific payment rates and historic planting in the base period, producers were free to plant any crops (with limitations on fruits and vegetables) on their base acres (Young and Shields 1996). Hence, the payments were "decoupled"—they were not tied to current production, prices, or inputs, unlike the production-enhancing coupled payments they replaced.

The 2002 Farm Bill replaced PFC payments with fixed direct payments (FDPs). While similar to the PFC program, the FDP program was expanded to include soybeans, other oilseeds, and peanuts (Economic Research Service 2002). The bill also gave farmers the option to update their base acreage and yields. Farmers were allowed to choose from several methods for calculation of the base levels. Ultimately, granting farmers the ability to update base acreage and/or yields affects the value of the government payments they will receive in the future. If a farmer expects updating, he or she may alter current production to increase payouts in the future. This is demonstrated more formally in the next section.

The 2002 Farm Bill also introduced counter-cyclical payments (CCPs) to replace the Market Loss Assistance (MLA) Program introduced in 1998 as a supplement to the 1996 Farm Bill. Like the PFC and FDPs, CCPs are based on historic, not current, production. However, CCP are only instituted when the current year's effective price is less than the target price set in the 2002 Farm Bill. Therefore, CCPs are "partially" decoupled because they are linked to current prices (Economic Research Service 2008).[1]

The 2008 Farm Bill continued both FDPs and CCPs and added the Average Crop Revenue Election (ACRE) program. ACRE is a whole-farm program with payments triggered by both state-level and farm-level benchmarks. The farm-level benchmark is the farm's expected revenue based on a five-year moving average of the farm's yields. Producers who enrolled in ACRE had to remain enrolled until 2012 and were not eligible for CCPs. Enrollment in ACRE also reduced the amount of FDPs to the farmer by 20 percent (Economic Research Service 2008). The program covers wheat, corn, barley, grain sorghum, oats, upland cotton, rice, soybeans, other oilseeds, peanuts, dry peas, lentils, and chickpeas.

The ACRE program differs from previous decoupled support programs because payments are based on Olympic moving averages of yields and prices rather than on historical plantings in a specific base period. Because a producer bases his or her decision about whether to participate in ACRE on historic and expected variability in prices, the program functions as a partially decoupled policy similar to the CCP. Given that a farmer's expected revenue, and hence the trigger for receiving a payment, is calculated using a moving average of farm-level yields, updating is essentially embedded in the policy design.

In addition to the coupled, decoupled, and partially decoupled payments already discussed, producers receive other forms of government support that have the potential to impact production. For example, many producers participate in subsidized crop insurance programs or receive disaster payments following natural catastrophes such as droughts, floods, and tornadoes. Because these programs provide benefits that offset adverse market conditions or poor production decisions, they have the potential to change farmers' risk attitudes and alter their production decisions. Farmers also participate in conservation programs (such as the Conservation Reserve Program) that essentially pay operators to take fragile land out of production. Government programs that remove land from production impact both current production levels and input use.

Theory

We assume that farmers maximize their expected utility of wealth, including farm profit and off-farm income, by choosing the optimal allocation of acreage and other production inputs. Equation 1 illustrates the expected utility maximization problem of a typical farmer when 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 let $U(\cdot)$ be a concave, continuously differentiable von Neumann-Morgenstern utility function suggesting the farmer is risk-averse.

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

s.t.

$$\Psi_{it|\phi} = F(X_{ijt}, \varepsilon_{it})$$

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

where

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

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

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

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

$$\gamma \in [0,1].$$

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[1] The classification of MLA payments is disputed. Burfisher and Hopkins (2004) suggest that MLA payments are tied to market prices and therefore fully coupled, while Adams et al. (2001) consider MLA payments as fully decoupled.

The function $g_t(\cdot)$ is the sum of the farm's profit function, $\pi_t(\cdot)$, income from off-farm activities at time t, I_t, and initial wealth in time $t - 1$, W_{t-1}. The discount factor is δ^t. Profit is the difference between revenue (including coupled price supports) and costs plus decoupled government payments, $DP_t(\cdot)$, and lump-sum government payments, G_t, where P_{it} is the price of the ith crop at time t, PS_{it} represents the fully coupled per-unit subsidy (e.g., coupled direct payment) at price P_{it}, $\Psi_{it|\phi}$ is the per-acre yield of crop i at time t subject to land quality ϕ, and A_{it} is the number of acres planted of the ith crop at time t. The cost of input j associated with the ith crop at time t is the product of ω_{ijt}, which represents the unit cost of input j, and X_{ijt}, which represents the amount of input j used to produce the ith crop at time t. The variable per-acre cost of land associated with the ith crop at time t is r_{it}. Fixed costs associated with the ith crop at time t, C_{it}, is a function of production decisions in the previous time period.

Direct decoupled payments (e.g., the PFC and FDPs), represented by the equation $DP_t(\cdot)$, are a function of the α_{it} percentage of S_{it} (the payment rate per crop); the historic yield, Ψ_{iH}, for crop i; and the base acres, B_{it}, for crop i. Historic yield is a function of production in the historic time period H and base acreage is a function of the historic acreage, A_H. Thus, decoupled direct payments are not a function of current price, production, or inputs.

The function $h_t(\cdot)$ uses notation from Bhaskar and Beghin (2010) that allows future policy benefits to depend on whether updating occurs and that 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 $\gamma = 0$, the farmer is certain that updating will not be allowed in future policies. If $\gamma = 1$, the farmer is certain that updating will be allowed in future farm policies. The function $h_t(\cdot)$ is discounted by the discount factor $\delta^{t'}$ where t' corresponds to the time period in which the future payment benefits are realized and $t' = T + 1$. VB is defined as the value of future government payments if updating occurs; VNB is the value of future government payments if updating does not occur. If $\gamma = 0$, payments are not coupled to production through anticipated updating. However, if farmers have a non-zero subjective probability of being able to update, then expectations of future decoupled payments influence current input use and acreage decisions. The greater γ is, the greater the link between current decisions regarding acreage and inputs and future program-crop payments (Bhaskar and Beghin 2010). Based on the findings of Coble, Miller, and Hudson (2008), we expect that $\gamma > 0$ will be true for some but not all farmers.[2] If a farmer expects updating to occur, either through government policy changes or implicit incorporation in the policy design (as in the case of ACRE), he or she may alter current farm production decisions to optimize future profits.

The farmer's expected utility maximization problem has two constraints. First, the farmer is constrained by the technology she or he employs. Hence, output (yield) per acre, $\Psi_{it|\phi}$, is a function of all inputs, X_{ijt}, and a stochastic element, ε_{it}, that allows for exogenous variants such as weather, pest infestations, and disease. Second, the sum of the total number of acres planted of I crops must be less than or equal to the total acres operated. It is possible to optimize profit by having idle acreage, A_{idle}. Thus, if both planted acreage and idled acreage are included in the profit maximization model, the constraint binds. Note, however, that total acreage operated is not fixed across time because farmers can buy, rent, or lease more land.

We assume that production decisions are made in the presence of uncertainty regarding output prices, yields, and future policy regimes. Input costs are assumed to be known when acreage decisions are made. Thus, within the profit function, uncertainty lies with revenue, not cost. The farmer recursively solves the problem presented in equation (1) by selecting acreage and other inputs to maximize the expected value of his utility function. This yields I reduced-form acreage equations:

$$(2)\ A_{it} = f(P_t, PS_t, A_{t-1}, \omega_t, r_t, W_{t-1}, G_t, DP_t, \gamma, VB, VNB)$$

and J reduced-form input equations:

$$(3)\ X_{jt} = f(P_t, PS_t, A_{t-1}, \omega_t, r_t, W_{t-1}, G_t, DP_t, \gamma, VB, VNB).$$

The fully coupled nature of price supports causes acreage and input decisions to depend not only on market prices but also on government price

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

supports, PS_{it}. Lump-sum government payments, G_t, should not directly influence production decisions; however, G_t impacts a farmer's wealth level and hence has the potential to influence current production, particularly for a risk-averse farmer. Furthermore, if the farmer has a non-zero subjective probability of updating, then expectations of future decoupled payments influence current production decisions by impacting acreage decisions, altering the crop mix, and/or changing the use of other inputs. Therefore, we expect positive relationships between the use of agricultural chemicals and both coupled and decoupled government payments. The magnitude of the effect of decoupled direct payments will likely vary from that of coupled government payments based on the size of coupled price supports, expected future decoupled farm subsidies, and the discount rate. These hypotheses are tested in the next section.

Empirical Evidence

Data

We use cross-sectional farm-level data collected annually by USDA to identify the relationship between government payments and agricultural chemical use and to examine potential changes in the use of agricultural chemicals in response to (i) initial implementation of decoupled direct payments in 1996 and (ii) revisions of the policy in 2002. The period of analysis is 1991 through 2008. Data for 1991 through 1995 come from the FCRS (Farm Cost and Returns Survey) and data for 1996 through 2008 come from the Farm Structure and Finance (Phase III) Agricultural Resource Management Survey (ARMS). These two sources provide information on government payments, value of production, output, input expenses, and other farm and farmer characteristics. Additional data regarding fertilizer use are obtained from the Production Practices and Cost and Returns Report (Phase II) of ARMS. The Phase II survey is a crop-specific field-level survey of enterprise management techniques, resource use, chemical use, and returns. Only a few commodities are surveyed each year. We use 2001 and 2005 Phase II data collected for corn, the primary crop grown in our region of interest.

Both FCRS and ARMS are stratified samples. Each observation in the sample is given a weight reflecting the probability of being selected. The weights are determined by USDA and are adjusted to ensure that key variables in the sample data are representative of U.S. agriculture. All results in this study are obtained using the appropriate weights.

We limit our analysis to farms that generate more than 50 percent of their total value of production from program crop commodities—general cash grain, wheat, corn, soybean, sorghum, rice, cotton, peanut, and other crops (oilseeds and pulse crops)—since decoupled direct payments (the PFC and FDPs) are paid to farmers with historic plantings of these crops. General cash grain refers to farmers who do not specialize in a specific crop; instead, the sum of sales revenue obtained from barley, corn, oats, rice, sorghum, soybeans, and wheat make up at least half of the farm's sales revenue.

USDA has defined the central section of the United States where agricultural production is concentrated as the "Heartland" region. This region boasts the largest concentration of crop land (27 percent) and of crop value (23 percent) in the United States (Heimlich 2000). All but one program crop, peanuts, is grown in the Heartland; thus, farmers in this region face growing conditions that enable them to maximize profit by changing the crop mix. Hence, the Heartland region is ideal for this analysis. However, the current regional classifications were not developed until 1995 so earlier regional data do not exist. Consequently, this analysis focuses on an extension of the Heartland region that encompasses all of the counties located in Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, Ohio, and South Dakota.

We also limit the analysis to farms in which the primary operator claims his occupation as farm work since hobby and retirement farmers may engage in different decision-making processes. Lastly, we restrict our analysis to include only farms for which total acres operated is greater than zero.[3]

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[3] Landowners 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, which can result in total acres operated being negative (Economic Research Service 2003). A negative total acres operated suggests that more land is being rented out or leased to other producers than used by the primary operator. In that regard, a farmer's income may come more from renting land than production and landlords also may engage in different decision-making processes. This limitation is particularly important because the majority of the variables are calculated on a per-acre basis with respect to the number of total acres operated.

Factors Affecting Agricultural Chemical Use

Given our hypotheses regarding the positive relationship between use of agricultural chemicals and government payments (both coupled and decoupled), we estimate the effects of payments on the use of fertilizers and other agricultural chemicals (all chemical inputs not classified as fertilizer) while controlling for farm and farmer characteristics. Unfortunately, the ARMS Phase III data do not contain information on quantities of fertilizers and other chemicals used at the farm level. Farmers are asked to report only agricultural chemical expenditures. The ARMS Phase II data set contains quantity data collected at the field level, making whole-farm analysis difficult. Since government payments impact the mix of crops, the number of acres of each crop planted, and the use of inputs, farm-level analysis is important. Furthermore, financial data, including information on government payments, is collected only in the Phase III survey.

By linking the data from Phases II and III via a producer identifier, we construct a data set that contains information on farm-level agricultural chemical expenditures, field-level fertilizer use, and farm-level financial information. The farmers who participated in each phase's survey varies and the Phase II survey is not conducted every year, thus combining the two data sets greatly reduces the number of observations and years available for analysis. In fact, corn farmers responded to both Phase II and Phase III surveys only in 2001 and 2005.[4] As a result, we conduct the analysis using both expenditure and quantity data. We focus on the expenditure data because they are collected every year at the farm level.

The dependent variables are real fertilizer expenditures per acre operated (*Fertilizer*), real other agricultural chemical expenditures per acre operated (*Other Chemicals*), pounds of nitrogen applied per acre of planted corn (*Nitrogen*), pounds of phosphate applied per acre of planted corn (*Phosphate*), and pounds of potash applied per acre of planted corn (*Potash*). Total farm-level expenditures on fertilizers and other agricultural chemicals, the number of acres operated, and pounds of nitrogen, phosphate, and potash applied are reported directly in the ARMS. We deflate both *Fertilizer* and *Other Chemicals* using the producer price index (PPI) for pesticide, fertilizer, and other agricultural chemical manufacturing so that *Fertilizer* and *Other Chemicals* serve as proxies for the quantities of fertilizer and other agricultural chemicals used at the farm level, respectively.

Farm-level input price information is also absent from the data set. Thus, we use fertilizer price indexes published by USDA's Economic Research Service (2010) as a proxy for farm-level fertilizer prices. USDA reports an index for all fertilizers and separate indexes for nitrogen and phosphate. We use the price index for all fertilizers in the analysis as a proxy for price when *Fertilizer* and *Potash* are the dependent variables. The price indexes for nitrogen and phosphate are used when *Nitrogen* and *Phosphate* are the dependent variables. Unfortunately, there is no similar index for other agricultural chemicals; therefore, we use the PPI for pesticide, fertilizer, and other agricultural chemical manufacturing as a proxy for price in the analysis of *Other Chemicals*.

In addition, we include the expected price of corn (*Expected Price*) when *Nitrogen*, *Phosphate*, and *Potash* are the dependent variables because farmers typically make production decisions under price uncertainty. More specifically, we use the average price of a standard corn futures contract for September delivery in the previous October since production decisions are typically made around that time (Bloomberg 2010).

Several variables are included in the regression model to control for the farm-level crop mix, which is likely to impact farm-level agricultural chemical expenditures. These variables are constructed by dividing the number of harvested acres for the seven program crops by total acres operated (*Barley*, *Corn*, *Cotton*, *Oats*, *Sorghum*, *Soybeans*, and *Wheat*). The expected signs of the coefficients on these variables cannot be determined. For example, if *Oats* decreases but total acres operated remains the same, the acres taken out of oat production must have been replaced by another crop or idled. Thus, the sign of the coefficient on *Oats* depends on whether the replacement crop uses more or less agricultural chemicals per acre than growing oats did. Furthermore, we assume that farmers select a mix of crops such that utility is maximized and, hence, the crop mix also provides information pertaining to price expectations. Total acres operated (*Acres Operated*) is included to represent the acreage of nonprogram crops and

[4] Corn farmers also responded to Phase II and III in 1996, but the Phase II data for 1996 lack the producer identifier necessary for linking the data sets.

to control for possible economies of size. Since *Nitrogen*, *Phosphate*, and *Potash* are constructed using only corn production data, crop mix is not important and those variables are omitted from these analyses.

In accordance with the theoretical model, we include both decoupled and other government payments per acre. The variable *Decoupled Payments* represents decoupled direct payments (the PFC and FDPs) and *Other Payments* is defined as all other government payments except indemnity payments. The ARMS and FCRS surveys do not always distinguish between coupled payments, disaster payments, and lump-sum payments. Therefore, *Other Payments* represents coupled (e.g., deficiency payments), partially decoupled (e.g., CCPs), and lump-sum payments (e.g., CRPs). Both *Decoupled Payments* and *Other Payments* are deflated using the consumer price index.

Wealth (*Wealth*) is included in the model and is measured as real total farm financial assets less real total farm financial debts per total acres operated. As wealth increases, fertilizer and other agricultural chemical expenditures may increase because more funds are available; this is especially likely when wealth levels are low. Conversely, since fertilizers and other agricultural chemicals can act as insurance against low yield (Ramaswami 1992, Hennessy 1998), there is an incentive for risk-averse farmers with limited wealth to apply more fertilizer and other agricultural chemicals.

Net farm income is not included in the model due to the endogenous relationship between income and expenditures. Furthermore, off-farm income is not included since there is no information for it in the data set prior to 1996. When the analysis is limited to 1996 through 2008 and off-farm income is included in the model, the other parameter estimates for years 1996 through 2008 do not change significantly.

We included the age of the primary operator (*Age*) in the model as a proxy for farmer experience because of the high correlation (0.80) between the two variables and the lack of information about experience in some of the sample years. *Age* may be positively or negatively related to agricultural chemical use. For example, a young operator may be more inclined to minimize fertilizer and chemical use due to concerns about health and/or the environment; alternatively, an older operator may be more knowledgeable about crop production and hence use less fertilizer and other agricultural chemicals.

The ratio of owned to operated acres (*Tenure*) may affect *Fertilizer* and *Other Chemicals* because operators who are also 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 landowners. However, an estimated 20 to 25 percent of the payments are capitalized into increased rental rates (Kirwan 2009).

Following Goodwin and Mishra (2006), we include measures of risk-aversion and financial risk in our model. *Insurance* is the ratio of insurance cost to total expenditures, which serves as a measure of risk-aversion. The more risk-averse a farmer is, the more insurance she or he purchases relative to other expenditures. If fertilizer and other agricultural chemicals are risk-reducing inputs, then we expect positive relationships between the degree of risk-aversion and the dependent variables. The farm's solvency ratio (*Solvency*), measured as real total farm financial debt to real total farm financial assets, provides a measure of financial risk exposure. A farmer who is less solvent may use more risk-reducing inputs to ensure a good yield and avoid defaulting on debt obligations. Moreover, the solvency ratio indicates whether a farmer is credit-constrained (Goodwin and Mishra 2006); farmers with higher *Solvency* ratios are more likely to be credit-constrained because they have used more of their total borrowing capacity. A positive relationship between *Solvency* and the dependent variables therefore suggests that financially risky farmers view fertilizers and other agricultural chemicals as risk-reducing inputs and/or the presence of decoupled payments relaxes the credit constraint and provides another possible coupling mechanism. Currently, there is some debate in the literature regarding whether agricultural chemicals are risk-reducing or risk-increasing inputs (Horowitz and Lichtenberg 1993, Rajsic, Weersink, and Gandorfer 2009, Ramaswami 1992). Our results may help determine the nature of these inputs. Four interaction terms are included to allow for the effects of both fully or partially coupled government payments and decoupled payments to vary with levels of risk-aversion and solvency.

Lastly, we include dummy variables for each county to account for cross-county variability that is not captured by the other regressors, specifically (i) transportation costs for volatile fertilizers, (ii) differences in soil and land quality, and (iii) unobserved growing conditions such as drought and disease. We estimate the model without an intercept, which allows us to keep all of the county dummy variables in the model for ease of interpretation.

Ideally, we would also include a measure of each farmer's subjective probability that updating will occur and of the farmer's discount rate in the model. However, that information is not available in the data set.

Summary Statistics

Summary statistics for the Phase III sample and the combined Phase II and Phase III sample are reported in Table 1. We discuss only the key variables. For the Phase III sample, the means of *Fertilizer* and *Other Chemicals* are \$19.61 and \$13.94, respectively. On average, farmers in the combined Phase II and III sample used 140 pounds of nitrogen, 54.2 pounds of phosphate, and 64.2 pounds of potash per acre of corn.

Farms in the Phase III sample operated 1,280 acres (*Acres Operated*) on average, while the average farm in the combined Phase II and III sample operated 1,689 acres, suggesting that farms specializing in corn production tend to be larger. In the Phase III sample, the average farm allocated 35 percent of total acres operated to corn (*Corn*) and 33 percent of total acres operated to soybeans (*Soybeans*). In the combined Phase II and III sample, the average farm allocated 39 percent of total acres operated to corn and 37 percent to soybeans, suggesting that farmers generally produce these two crops together or in rotation.

Eighty-eight percent of farms in the Phase III sample received decoupled payments after their introduction in 1996. Following the introduction of decoupled payments, on average, farms in the sample received \$7.50 in decoupled direct payments per acre. On average, corn farmers in the combined Phase II and III sample collected more *Other Payments* than *Decoupled Payments*.

Estimation Results

The results of the weighted ordinary least squares regression analyses of farm-level expenditures on fertilizer and other agricultural chemicals are reported in Table 2. The effects of the county dummy variables are not reported due to the large number of counties in the sample.[5]

Fertilizers 1991–2008. We conduct the regression analysis of farm-level fertilizer expenditures twice: once using the USDA (2010) fertilizer price index as a proxy for fertilizer price and then we repeat the analysis using the PPI for pesticide, fertilizer, and other agricultural chemical manufacturing as the proxy for price. As shown in Table 2, the parameter estimates are similar for both price proxies so we focus our discussion on the results obtained using the USDA price index. The results when no price proxy is included are also similar.[6] As Table 2 indicates, the relationship between the proportion of harvested acres to total acres operated is positive and significant for most of the variables. Exceptions in terms of planting and inputs are oats and real fertilizer expenditures per acre. These results suggest that an increase in the number of acres allotted to corn will increase fertilizer expenditures more than an increase in acres allotted to any other program crop and that an increase in acres allotted to oats will increase fertilizer expenditures the least. This finding reflects the important role of crop mix in consumption of fertilizers. The effect of total acres operated is small but positive and significant, implying that effects due to economies of size are small. Furthermore, landowners tend to spend more on fertilizer per acre than those who rent.

There are three avenues by which government payments can affect fertilizer expenditures: directly, as seen with direct payments (*Decoupled Payments* and *Other Payments*); indirectly through an impact on risk preferences (*Decoupled Payments*Insurance* and *Other Payments*Insurance*); and indirectly through an impact on financial risk (*Decoupled Payments*Solvency* and *Other Payments*Solvency*). When considering direct effects, increases in decoupled direct payments and/or in government payments raise fertilizer expenditures by a small but statistically significant amount. As shown in Table 3, the mean marginal effect of *Decoupled Payments* on *Fertilizer* for the 1991 through 2008 sample suggests that an additional dollar of direct payment per acre will increase fertilizer expenditures per acre by an

[5] There are 764 counties in the extended Heartland region.

[6] These results are available from the authors upon request.

Table 1. Summary Statistics, Phase III (1991–2008) and Phases II and III (2001 and 2005)

	Phase III		Phases II and III	
Variable	Mean	Standard Deviation	Mean	Standard Deviation
Fertilizer	\$19.61	\$14.15	\$20.94	\$13.07
Other Chemicals	\$13.94	\$10.44	\$14.54	\$8.59
Nitrogen	–	–	140.03	57.16
Phosphate	–	–	54.20	46.68
Potash	–	–	64.24	68.38
Acres of Barley	1.93	248.64	0.09	27.48
Acres of Corn	224.91	3,298.34	358.44	4,455.27
Acres of Cotton	1.08	384.22	0.45	303.51
Acres of Oats	2.09	177.66	4.34	724.60
Acres of Oilseeds	2.18	337.55	12.07	122.72
Acres of Peanuts	0	0	0	0
Acres of Pulse	1.35	225.94	6.12	57.30
Acres of Rice	0.64	256.03	4.19	61.59
Acres of Sorghum	4.7	347.36	2.52	238.14
Acres of Soybeans	207.44	2,926.94	337.81	4,755.55
Acres of Wheat	41.05	1,706.81	38.85	1,616.61
Barley	0.003	0.02	0.0001	0.002
Corn	0.35	0.21	0.39	0.16
Cotton	0.005	0.06	0.002	0.03
Oats	0.003	0.02	0.002	0.02
Sorghum	0.01	0.04	0.002	0.02
Soybeans	0.33	0.19	0.37	0.16
Wheat	0.05	0.11	0.03	0.07
Acres Operated	1,280.21	1,378.48	1,688.53	1,765.49
Tenure	0.4554182	1.2144568	0.39	0.33
Age	52.8232284	12.4220885	53	12
Wealth	\$899.79	\$3,639.32	\$726.31	\$787.21
Income	\$52,295.87	\$133,540.57	\$24,521.05	\$737,908.74
Insurance	0.05	0.04	0.05	0.03
Solvency	0.12	0.90	0.09	0.11
Decoupled Payments	\$6.90	\$7.45	\$10.94	\$8.34
Other Payments	\$7.33	\$11.37	\$15.53	\$10.59

Notes: The number of observations in the Phase III data set is 25,598 except for *Acres of Pulse* and *Acres of Oilseed*, which have 7,214 observations. The number of observations in the combined Phase II and Phase III data set is 870. The range of the variables cannot be reported due to disclosure restrictions on the data.

Table 2. Fertilizer and Other Agricultural Chemicals: Ordinary Least Square Regression Results

	Fertilizer Using USDA Price Index		Fertilizer Using PPI		Agricultural Chemicals Using PPI	
Price	0.015	***	2.654	***	–3.119	***
	(0.001)		(0.180)		(0.135)	
Barley	11.986	***	12.041	***	1.920	
	(3.815)		(3.816)		(2.859)	
Corn	33.413	***	33.445	***	16.333	***
	(0.434)		(0.434)		(0.325)	
Cotton	18.984	***	18.957	***	40.131	***
	(3.619)		(3.620)		(2.712)	
Oats	3.517		3.565		–16.142	***
	(2.738)		(2.739)		(2.052)	
Sorghum	15.574	***	15.556	***	11.802	***
	(1.738)		(1.739)		(1.303)	
Soybeans	4.744	***	4.705	***	11.900	***
	(0.427)		(0.427)		(0.320)	
Wheat	17.953	***	17.984	***	6.378	***
	(0.904)		(0.905)		(0.678)	
Acres Operated	0.0004	***	0.0004	***	0.0003	***
	(0.00009)		(0.0001)		(0.0001)	
Tenure	0.164	**	0.167	**	0.236	***
	(0.081)		(0.081)		(0.061)	
Age	0.004		0.004		0.009	**
	(0.005)		(0.005)		(0.004)	
Wealth	0.000005		0.00001		0.00002	*
	(0.00002)		(0.00002)		(0.00001)	
Insurance	–17.529	***	–17.584	***	–8.012	***
	(1.789)		(1.789)		(1.341)	
Solvency	2.592	***	2.588	***	2.159	***
	(0.521)		(0.521)		(0.390)	
Other Payments	0.040	***	0.041	***	0.027	***
	(0.008)		(0.008)		(0.006)	
Decoupled Payments	0.212	***	0.207	***	0.260	***
	(0.018)		(0.018)		(0.013)	
*Decoupled Payments*Insurance*	–0.750	***	–0.743	***	–1.135	***
	(0.265)		(0.265)		(0.198)	
*Decoupled Payments*Solvency*	–0.196	***	–0.196	***	–0.187	***
	(0.035)		(0.035)		(0.026)	
*Other Payments*Insurance*	–0.072		–0.073		–0.050	
	(0.056)		(0.056)		(0.042)	
*Other Payments*Solvency*	0.050	*	0.050	*	0.107	***
	(0.030)		(0.030)		(0.022)	
Number of observations	25,576		25,576		25,576	
R-square	0.459		0.459		0.427	

Notes: *, **, and *** indicate significance at α = 10 percent, 5 percent, and 1 percent, respectively. Robust standard errors are shown in parentheses. County dummy variables are not reported due to the large number of counties in the sample.

average of 15 cents while an additional dollar of other government payments will raise fertilizer expenditures by an average of 4 cents. Thus, there is evidence that decoupled payments can affect real per-acre fertilizer expenditures (our proxy for fertilizer use) more than other government payments.

Coupled government payments, which make up the majority of *Other Payments*, are based on production, inputs, and/or prices and are known to increase the use of inputs. Decoupled payments, on the other hand, theoretically are not based on production, inputs, or prices unless they become linked by mechanisms previously discussed. As shown in Table 3, neither the marginal effect of *Decoupled Payments* nor the marginal effect of *Other Payments* on *Fertilizer* is significantly different from zero. Since *Other Payments* consists of both coupled and lump-sum transfers, the marginal effect of *Other Payments* should be viewed as the lower bound on the true effect of coupled payments.

The mean marginal effect of *Insurance* is negative and significant, suggesting that farmers who are more averse to risk tend to use less fertilizer, an unexpected result. It may be that some farmers view fertilizer as a risk-increasing input. Additionally, the proportion of total farm expenditures directed to insurance may be too simplistic a measure of a farmer's level of risk-aversion, particularly in this model since inclusion of the dependent variable in the calculation of

Table 3. Mean Marginal Effects of Decoupled Direct Payments, Other Government Payments, Insurance, and Solvency

	Other Payments		Decoupled Payments		Insurance		Solvency	
Fertilizer								
1991–2008	0.0425		0.1524		–22.5581	***	1.8458	
	(0.045)		(0.179)		(4.923)		(1.348)	
1991–1995	0.1431	***	–		–31.3933	***	1.9655	
	(0.026)		–		(4.878)		(1.234)	
1996–2003	0.0139		0.1544		–23.2316	***	1.9138	
	(0.066)		(0.251)		(5.732)		(1.644)	
2004–2008	0.0008		0.2892	**	–31.5571	**	4.4665	*
	(0.021)		(0.134)		(15.943)		(2.449)	
Other Chemicals								
1991–2008	0.0367		0.1818		–15.1332	**	1.9406	
	(0.096)		(0.174)		(7.319)		(1.673)	
1991–1995	0.1011	***	–		–21.6543	***	3.5032	*
	(0.036)		–		(3.995)		(2.080)	
1996–2003	0.0166		0.1885		–17.3366	*	1.0876	
	(0.045)		(0.142)		(9.077)		(0.899)	
2004–2008	0.0119		0.1914	**	–14.5473		1.8330	
	(0.007)		(0.081)		(9.496)		(1.401)	
Nitrogen	0.6893	***	0.6133		73.3931		–40.7388	**
	(0.153)		(0.312)		(88.745)		(14.558)	
Phosphate	0.6740		–0.1346		14.8859		–15.1044	
	(0.406)		(0.594)		(151.476)		(41.610)	
Potash	1.2249	**	0.0273		–76.0946		36.6254	***
	(0.418)		(0.134)		(151.852)		(6.985)	

Notes: *, **, and *** indicate significance at $\alpha = 10$ percent, 5 percent, and 1 percent, respectively. Standard errors are shown in parentheses.

total expenditures may invoke endogeneity issues. Excluding *Insurance* from the regression analysis does not significantly impact the other parameter estimates. Contrarily, the marginal effect of *Solvency* is positive but not significant.

Other Agricultural Chemicals 1991–2008. Results for the regression analysis pertaining to *Other Chemicals* are similar to those for *Fertilizer* except that the effect of *Oats* is now negative and significant. Again, the mean marginal effect of *Insurance* is negative, indicating that other agricultural chemicals may be viewed as a risk-increasing input. The direct effects of other government payments and decoupled direct payments on other agricultural chemical expenditures per acre are positive and small but statistically significant. However, the mean marginal effects of *Other Payments* and *Decoupled Payments* are not significantly different from zero.

Nitrogen, Phosphate, and Potash. Table 4 reports the results of the regression that analyzes quantities (pounds) of nitrogen, phosphate, and potash applied per acre. As shown, there is a positive and significant relationship between *Other Payments* and *Phosphate* and between *Other Payments* and *Potash*. The mean marginal effect of *Other Payments* on both *Nitrogen* and *Potash* is significant and positive (as shown in Table 3), while the marginal effect of decoupled payments (*Decoupled Payments*) on *Nitrogen*, *Phosphate*, and *Potash* is not significantly different from zero. The mean marginal effect of *Other Payments* on *Nitrogen* is 0.69; this indicates that an additional dollar of other government payments per acre will increase per-acre nitrogen applications by 0.69 pounds per acre. While the mean marginal effect of *Other Payments* on *Nitrogen* and on *Potash* is significantly different than zero, it is unlikely that an increase in *Other Payments* would have a significant impact on production; an additional dollar of *Other Payments* leads to only a minute increase in the amount of these chemicals applied. Table 3 also shows that the mean marginal effect of *Solvency* on *Nitrogen* is –40.7; a one-point increase in the solvency ratio decreases the per-acre application of nitrogen by 40.7 pounds on average. This suggests that farmers with more debt use less nitrogen. Contrarily, the mean marginal effect of *Solvency* on *Potash* is positive and significant. Thus, it is unclear if fertilizers are a risk-reducing or risk-increasing input.

Table 4. Nitrogen, Phosphate, and Potash: Ordinary Least Square Regression Results

	Nitrogen	Phosphate	Potash
Price	0.012	0.102	0.004
	(0.117)	(0.153)	(0.164)
Acres Operated	0.002	–0.002	–0.003 *
	(0.002)	(0.001)	(0.002)
Tenure	–8.172	–0.576	17.622
	(10.711)	(8.531)	(11.331)
Age	0.079	–0.076	–0.150
	(0.242)	(0.193)	(0.256)
Wealth	–0.007	0.005	0.002
	(0.004)	(0.004)	(0.005)
Insurance	194.196	300.914 **	179.869
	(182.455)	(145.323)	(193.008)
Solvency	–60.009	–85.511 *	23.437
	(56.463)	(44.972)	(59.729)
Other Payments	0.576	1.194 ***	1.897 ***
	(0.596)	(0.475)	(0.631)
Decoupled Payments	1.166 **	–0.159	0.140
	(0.588)	(0.469)	(0.622)
*Decoupled Payments*Insurance*	–10.626	–8.274	–3.504
	(7.697)	(6.131)	(8.142)
*Decoupled Payments*Solvency*	–0.185	4.709 **	0.687
	(2.814)	(2.241)	(2.976)
*Other Payments*Insurance*	–0.295	–12.590 **	–14.013 *
	(8.158)	(6.498)	(8.630)
*Other Payments*Solvency*	1.371	1.217	0.365
	(2.613)	(2.081)	(2.764)
Expected Price	0.256	–0.024	–0.025
	(0.243)	(0.195)	(0.260)
No. of observations	870	870	870
R-square	0.642	0.660	0.720

Notes: *, **, and *** indicate significance at α = 10 percent, 5 percent, and 1 percent, respectively. Robust standard errors are shown in parentheses. County dummy variables are not reported due to the large number of counties in the sample.

The results obtained when using quantities of specific fertilizers indicate that *Other Payments* significantly impacts fertilizer use. However, the relationship is less apparent when fertilizer expenditures are analyzed. One possible reason for the lack of significance of the marginal effect of government payments on *Fertilizer* and *Other Chemicals* could be the large period of time covered by the data set, which spans several policy regimes. Thus, we next explore possible structural breaks in the models of *Fertilizer* and *Other Chemicals* generated by changing policies.

Structural Breaks due to Policy Changes

The introduction of decoupled direct payments in 1996 could generate a structural break if it altered fertilizer and other agricultural chemical use. Furthermore, if updating alters farmers' decisions regarding production and input use, a structural break should be found in 2002 corresponding to the introduction of updating. Data are not available after 2008 so we cannot test the hypothesis that changes in the 2008 Farm Bill led to a structural break. Therefore, iterative Chow tests (Bai and Perron 2003) were employed to test for expected structural breaks in 1996 and 2002. The iterative Chow tests suggest that structural breaks occur in 1996 and 2004 for both *Fertilizer* and *Other Chemicals*. A structural break occurring two years after enactment of the 2002 Farm Bill indicates that farmers delayed changing their production decisions until after they had some time to observe how the policy affected them. If farmers expect government policies to change regularly, it may be optimal for them to wait and see the possible impacts of the new policy. Structural breaks in the models for *Nitrogen*, *Phosphate*, and *Potash* cannot be tested because the combined Phase II and III sample consists of only two years of data.

Model of Fertilizer with Structural Breaks in 1996 and 2004. Table 5 presents the results of the model for *Fertilizer* with structural breaks in 1996 and 2004. As shown, with the introduction of decoupled direct payments in 1996, the magnitude of the direct effect of *Other Payments* decreases and becomes insignificant. After 2004, the direct effect of *Decoupled Payments* is significant and positive. For 2004 through 2008, the magnitude of the coefficient on *Decoupled Payments* is greater than in the preceding time period.

The mean marginal effects for the three time periods suggested by the structural breaks are presented in Table 3. For 1991 through 1995, an additional dollar of *Other Payments* increases *Fertilizer* by 14 cents on average. The mean marginal effect of *Other Payments* decreases significantly after the introduction of decoupled payments in 1996. In fact, it is not significantly different from zero for 1996 through 2003 or for 2004 through 2008. Conversely, while the marginal effect of *Decoupled Payments* is not significant for 1996 through 2003, it is positive and significant after 2004 with an additional dollar of *Decoupled Payments* increasing *Fertilizer* by 29 cents on average. It is likely that the increase in the mean marginal effect of *Decoupled Payments*, and hence the change in the relationship between decoupled payments and fertilizer expenditures, was caused by the introduction of updating in the 2002 Farm Bill. The mean marginal effect of *Insurance* is negative and significant in all time periods, while the mean marginal effect of *Solvency* is positive for 2004 through 2008. Thus, it is unclear if fertilizer is a risk-reducing or risk-increasing input.

Model of Other Agricultural Chemicals with Structural Breaks in 1996 and 2004. The results for the model of *Other Chemicals* with structural breaks in 1996 and 2004 are presented in Table 6 and are similar to those obtained for the *Fertilizer* model. The coefficient on *Other Payments* is positive and significant for 1991 through 1995. After the introduction of decoupled payments in 1996, the direct effect of *Other Payments* is not significantly different than zero while the direct effect of *Decoupled Payments* is significant and positive. The mean marginal effect of *Other Payments* on *Other Chemicals* is positive and significant for 1991 through 1995; however, after 1996, it is no longer significantly different than zero (see Table 3). The mean marginal effect of *Decoupled Payments* on *Other Chemicals* is positive and significant for 2004 through 2008. Again, this positive, significant relationship after 2004 may reflect the impact of updating on farmers' production decisions.

Implications and Conclusions

Payments that are truly decoupled should not affect a farmer's optimal allocation of acreage or inputs since such payments are based on historic production and yields rather than current

Table 5. Fertilizer: Ordinary Least Square Regression Results with Structural Breaks in 1996 and 2004

	1991–1995		1996–2003		2004–2008	
Price	0.025		0.015	***	0.004	***
	(0.017)		(0.001)		(0.001)	
Barley	17.481	***	10.491	*	0.985	
	(6.189)		(6.458)		(16.600)	
Corn	32.421	***	34.063	***	38.931	***
	(1.080)		(0.494)		(0.753)	
Cotton	21.619	**	17.354	***	23.926	***
	(8.952)		(3.935)		(8.616)	
Oats	31.629	***	–13.296	***	–6.263	
	(5.540)		(3.398)		(5.987)	
Sorghum	20.265	***	17.064	***	22.619	***
	(3.703)		(2.169)		(6.615)	
Soybeans	7.535	***	4.507	***	3.712	***
	(1.105)		(0.477)		(0.757)	
Wheat	18.154	***	17.686	***	18.092	***
	(1.967)		(1.100)		(1.807)	
Acres Operated	0.0017	***	0.0003	***	0.0002	*
	(0.0003)		(0.0001)		(0.0001)	
Tenure	4.942	***	–0.426	***	–0.321	***
	(0.486)		(0.095)		(0.102)	
Age	–0.049	***	0.003		–0.004	
	(0.013)		(0.006)		(0.010)	
Wealth	–0.000089	***	0.00028	***	0.00015	***
	(0.00002)		(0.00004)		(0.00005)	
Insurance	–26.643	***	–17.225	***	–16.068	***
	(4.342)		(2.303)		(3.536)	
Solvency	0.764		3.235	***	7.739	***
	(1.432)		(0.590)		(2.355)	
Other Payments	0.146	***	0.002		–0.013	
	(0.020)		(0.009)		(0.014)	
Decoupled Payments	–		0.227	***	0.458	***
			(0.019)		(0.038)	
*Decoupled Payments*Insurance*	–		–0.913	***	–2.764	***
			(0.269)		(0.466)	
*Decoupled Payments*Solvency*	–		–0.249	***	–0.413	*
			(0.042)		(0.235)	
*Other Payments*Insurance*	–0.414	***	0.094		0.393	***
	(0.103)		(0.095)		(0.157)	
*Other Payments*Solvency*	0.105		0.065	**	–0.069	
	(0.080)		(0.034)		(0.092)	
No. of observations	4,901		20,675		10,407	
R-square	0.583		0.474		0.572	

Notes: *, **, and *** indicate significance at α = 10 percent, 5 percent, and 1 percent, respectively. Robust standard errors are shown in parentheses. County dummy variables are not reported due to the large number of counties in the sample.

Table 6. Other Agricultural Chemicals: Ordinary Least Square Regression Results with Structural Breaks in 1996 and 2004

	1991–1995	1996–2003	2004–2008
Price	6.524 ***	–3.492 ***	–2.123 ***
	(1.675)	(0.136)	(0.153)
Barley	6.383	2.725	11.009
	(4.949)	(4.706)	(10.270)
Corn	18.224 ***	15.471 ***	15.156 ***
	(0.864)	(0.360)	(0.466)
Cotton	42.297 ***	33.157 ***	15.535 ***
	(7.158)	(2.868)	(5.331)
Oats	–13.223 ***	–10.566 ***	–0.832
	(4.431)	(2.476)	(3.704)
Sorghum	4.572	18.184 ***	14.009 ***
	(2.961)	(1.581)	(4.093)
Soybeans	11.638 ***	11.898 ***	8.674 ***
	(0.884)	(0.348)	(0.468)
Wheat	8.116 ***	6.873 ***	7.503 ***
	(1.573)	(0.801)	(1.118)
Acres Operated	0.0008 ***	0.0001	0.0002 ***
	(0.0002)	(0.0001)	(0.0001)
Tenure	2.677 ***	0.056	–0.015
	(0.389)	(0.069)	(0.063)
Age	–0.024 **	0.010 **	0.013 **
	(0.010)	(0.004)	(0.006)
Wealth	0.00003	0.00009 ***	0.00004
	(0.00002)	(0.00003)	(0.00003)
Insurance	–17.765 ***	–9.243 ***	–4.448 **
	(3.472)	(1.678)	(2.188)
Solvency	1.478	1.708 ***	3.602 **
	(1.145)	(0.430)	(1.457)
Other Payments	0.090 ***	–0.003	0.007
	(0.016)	(0.006)	(0.009)
Decoupled Payments	–	0.273 ***	0.293 ***
		(0.014)	(0.023)
*Decoupled Payments*Insurance*	–	–1.411 ***	–1.672 ***
		(0.196)	(0.288)
*Decoupled Payments*Solvency*	–	–0.130 ***	–0.238 *
		(0.030)	(0.146)
*Other Payments*Insurance*	–0.339 ***	0.296 ***	0.135
	(0.082)	(0.070)	(0.097)
*Other Payments*Solvency*	0.177 ***	0.044 *	–0.027
	(0.064)	(0.024)	(0.057)
No. of observations	4,901	20,675	10,407
R-square	0.532	0.458	0.488

Notes: *, **, and *** indicate significance at α = 10 percent, 5 percent, and 1 percent, respectively. Robust standard errors are shown in parentheses. County dummy variables are not reported due to the large number of counties in the sample.

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 impact current production decisions, is through expectations of future policy changes. Risk-averse farmers who believe that there will be opportunities to update base acreages and/or yields in the future have an incentive to alter current production practices in order to maximize future government payments and expected utility. After the introduction of decoupled payments to U.S. agriculture in 1996, some degree of updating has been included in all subsequent farm bills.

Using annual cross-sectional, farm-level data for U.S. farms, we examined potential connections between government payment regimes and the use of agricultural fertilizers and other chemicals. We find that introduction of decoupled payments in 1996 had little impact on the use of fertilizers and other chemicals as indicated by the lack of significance of the mean marginal effects of decoupled payments on fertilizer and other chemical expenditures per acre operated. In addition, the marginal effects of other government payments on both fertilizer expenditures and other agricultural chemical expenditures per acre operated became insignificant following the introduction of decoupled payments. However, after 2004, the mean marginal effects of decoupled payments on both fertilizer expenditures and other agricultural chemical expenditures are positive and significant. Given that updating was introduced in 2002, the results suggest that updating and expectations of future updating may have caused decoupled payments to become coupled to current input use and ultimately production. Since we control for price movements and adjusted expenditures using appropriate price proxies, we conclude that there is a positive relationship between decoupled payments and agricultural chemical use. Thus, our results support earlier findings by Bhaskar and Beghin (2010): if a risk-averse farmer believes he or she will be allowed to update base acreage and/or yields in the future, she or he will use more fertilizer in the current production period to boost yields.

Although the impact of the newest program of decoupled direct payments, Average Crop Revenue Election (ACRE, introduced in 2008), on production decisions could not be tested empirically, the structure of the program itself has implications for farmers' behavior.cThe ACRE program identifies historic yields through a five-year Olympic moving average, meaning that each year the historic period on which payments are calculated changes. Therefore, this policy implicitly creates a link between current acreage and input decisions and future program crop payments, and ACRE payments hence become coupled.

To more fully understand the link between decoupled payments, updating, and agricultural chemical use, additional research is needed. The current lack of panel data prevents tracking of year-to-year changes in a specific farmer's production decisions. Access to such panel data would grant a better understanding of how production decisions are impacted by policy changes. Also, future research should aim to further separate other government payments into lump-sum transfers and coupled payments. Further research also is needed to identify the impact of ACRE payments on production decisions.

References

Adams, G., P. Westhoff, B. Willott, and R.E. Young. 2001. "Do 'Decoupled' Payments Affect U.S. Crop Area? Preliminary Evidence from 1997–2000." *American Journal of Agricultural Economics* 83(5): 1190–1195.

Ahearn, M.C., H. El-Osta, and J. Dewbre. 2006. "The Impact of Coupled and Decoupled Government Subsidies on Off-Farm Labor Participation of U.S. Farm Operators." *American Journal of Agricultural Economics* 88(2): 393–408.

Bai, J., and P. Perron. 2003. "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics* 18(1): 1–22.

Bhaskar, A., and J.C. Beghin. 2010. "Decoupled Farm Payments and the Role of Base Acreage and Yield Updating under Uncertainty." *American Journal of Agricultural Economics* 92(3): 849–858.

Blandford, D., H. de Gorter, and D. Harvey. 1989. "Farm Income Support with Minimal Trade Distortions." *Food Policy* 14: 268–273.

Bloomberg. 2010. "Monthly Corn Futures Contract Prices, 1995–2007, Bloomberg LP." Unpublished database (accessed April 2 2010). A copy of this material is on file with the authors.

Borges, R., and W. Thurman. 1994. "Marketing Quotas and Random Yields: Marginal Effects of Inframarginal Subsidies on Peanut Supply." *American Journal of Agricultural Economics* 76: 809–817.

Burfisher, M.E., and J. Hopkins, eds. 2004. "Decoupled Payments in a Changing Policy Setting." Agricultural Economic Report AER838, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

Chau, N.H., and H. de Gorter. 2005. "Disentangling the Consequences of Direct Payment Schemes in Agriculture on Fixed Costs, Exit Decisions, and Output." *American Journal of Agricultural Economics* 87(5): 1174–1181.

Coble, K.H., J.C. Miller, and M. Hudson. 2008. "Decoupled Farm Payments and Expectations for Base Updating." *Review of Agricultural Economics* 30(1): 27–42.

de Gorter, H., D.R. Just, and J.D. Kropp. 2008. "Cross-subsidization due to Inframarginal Support in Agriculture: A General Theory and Empirical Evidence." *American Journal of Agricultural Economics* 90(1): 42–54.

Economic Research Service. 2002. "2002 Farm Bill: Provisions and Economic Implications." ERS, U.S. Department of Agriculture, Washington, D.C.

————. 2003. "2003 ARMS Costs and Returns Report Version 1." ERS, U.S. Department of Agriculture, Washington, D.C.

————. 2008. "2008 Farm Bill Side-by-Side." ERS, U.S. Department of Agriculture, Washington, D.C. Available at http://www.ers.usda.gov/FarmBill/2008/Titles/TitleIcommodities.htm (accessed August 2011).

Economic Research Service. 2010. "Fertilizer Use and Prices." ERS, U.S. Department of Agriculture, Washington, D.C. Available at http://www.ers.usda.gov/Data/FertilizerUse (accessed August 2011).

Goodwin, B.K., and A.K. Mishra. 2006. "Are 'Decoupled' Farm Program Payments Really Decoupled? An Empirical Evaluation." *American Journal of Agricultural Economics* 88(1): 73–89.

Heimlich, R. 2000. "Farm Resource Regions." Agricultural Information Bulletin 760, ERS, U.S. Department of Agriculture, Washington, D.C.

Hennessy, D.A. 1998. "The Production Effects of Agricultural Income Support Policies under Uncertainty." *American Journal of Agricultural Economics* 80(1): 46–57.

Horowitz, J.K., and E. Lichtenberg. 1993. "Insurance, Moral Hazard, and Chemical Use in Agriculture." *American Journal of Agricultural Economics* 75(4): 926–935.

Kirwan, B.E. 2009. "The Incidence of U.S. Agricultural Subsidies on Farmland Rental Rates." *Journal of Political Economy* 117(1): 138–164.

National Agricultural Statistics Service. 2011. Unpublished data on the Agricultural Resource Management Survey, Phase II and Phase III. NASS, U.S. Department of Agriculture, Washington, D.C.

Rajsic, P., A. Weersink, and M. Gandorfer. 2009. "Risk and Nitrogen Application Levels." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 57(2): 223–239.

Ramaswami, B. 1992. "Production Risk and Optimal Input Decisions." *American Journal of Agricultural Economics* 74(4): 860–869.

Rucker, R., and W. Thurman. 1990. "The Economic Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program." *Journal of Law and Economics* 33(2): 483–515.

Rucker, R., W. Thurman, and D. Sumner. 1995. "Restricting the Market for Quota: An Analysis of Tobacco Production Rights with Corroboration from Congressional Testimony." *Journal of Political Economy* 103(1): 142–175.

Young, C.E., and D.A. Shields. 1996. "1996 FAIR Act Frames Farm Policy for Seven Years." Economic Research Service, U.S. Department of Agriculture, Washington, D.C. Available at http://www.ers.usda.gov/publications/agoutlook/aosupp.pdf (accessed (August 2011).