Implication of 2014 Farm Policies for Wheat Production

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Abstract

We develop a model to comprehensively analyze the effects of 2014 Farm Bill wheat policies—loan deficiency payments (LDP), price loss coverage (PLC), agriculture risk coverage-county (ARC-CO), individual revenue protection crop insurance (RP), and supplemental coverage option (SCO)—on input use, yield, certainty equivalent, optimal RP insurance coverage level, expected payments, and premiums. The comparative static results show the directional impact of the coupling, wealth, and insurance effects for each policy. We calibrate the model to a representative dryland wheat farm in Kansas. The simulation results show that the expected LDP payment is zero for 2014, RP causes input use and yield to decline, and ARC-CO, PLC, and SCO result in higher input use and yield. Thus, both the theoretical and empirical results provide evidence of moral hazard associated with RP and SCO insurance. If the farmer selects only RP insurance, then the optimal coverage level is 85%, but drop to 50% if SCO is added. Based on certainty equivalent analysis, the optimal policy combination is RP with ARC-CO. The results also provide evidence that farmers would opt for crop insurance programs even without premium subsidies.

Keywords: Coupling, Wealth, and Insurance Effects; Farm Bill; Moral Hazard; Wheat

JEL: Q18, Q12, D24
1 Introduction

The emphases of farm bills in the previous three decades were on price supports and decoupled policies, which include deficiency payments, direct payments, countercyclical payments, commodity loan programs, average crop revenue election (ACRE), etc. Studies have analyzed the effects of the commodity programs on acreage response (Morzuch et al., 1980), production and trade (Young and Westcott, 2000), program participation rates (Lubben and Novak, 2010), and revenue risk mitigation (Cooper, 2010). While premium-subsidized crop insurance has been available to farmers since the Federal Crop Insurance Act of 1980, it was not the major focus of these earlier farm bills.\footnote{Knight and Coble (1997), Smith and Glauber (2012), Coble and Barnett (2013), Goodwin and Smith (2013), and Glauber (2013) provide a detailed review of U.S. crop insurance policies.}

Yet, studies have examined risk management strategies under crop insurance (King and Oamek, 1983), demand for Multiple Peril Crop Insurance (Smith and Baquet, 1996), the relationship between crop insurance and input use (Smith and Goodwin, 1996), moral hazard (Coble et al., 1997), viability of a private crop insurance market (Miranda and Glauber, 1997), whether crop insurance contracts were actuarially fair or over- or under-valued (Babcock, 2011), and yield versus revenue crop insurance program (Du et al., 2013). While these studies analyzed the past Farm Bill policies, we examine both commodity programs and crop insurance policies of the 2014 Farm Bill.

The Agricultural Act of 2014, commonly known as the 2014 Farm Bill, implemented the largest changes to commodity programs in recent decades by ending long standing price supports and decoupled payments and instead focusing on mitigating risk faced by farmers (Campiche, 2014). This new farm bill maintained the Loan Deficiency Payments (LDP) program\footnote{Note that Marketing Assistance Loans are also available to farmers, which are similar to LDP, but the farmer uses the crop as collateral.} from previous farm bills, expanded the existing individual crop insurance program, introduced Price Loss Coverage (PLC) and Agriculture Risk Coverage (ARC) programs, and established a new Supplemental Coverage Option (SCO) crop insurance program.

LDP and PLC are price protection programs and farmers receive payments when market price falls below specified levels. ARC is a revenue protection program, and farmers can select...
either the County (ARC-CO) or Individual Coverage (ARC-IC) revenue option. We consider only ARC-CO because, according to FSA/USDA (2015b), all wheat farmers that opted for ARC selected the county revenue option. Farmers can select either PLC or ARC, but not both. The crop insurance programs include individual crop insurance and Supplemental Coverage Option (SCO). The individual crop insurance program secured the largest government farm spending over the last few years. Farmers have three options under individual crop insurance: revenue protection (RP), revenue protection with harvest price exclusion (RP-HPE), and yield protection (YP). However, nationally RP is the most commonly selected individual crop insurance with 76% of farmers electing RP in 2014 (RMA/USDA, 2015). Under RP, farmers receive indemnity payments if actual market revenues fall below the revenue guarantee. RP is a "deep loss" program because revenue loss has to be substantial enough to receive insurance payments. For farmers to enroll in SCO, they have to participate in PLC and also an individual crop insurance plan. SCO is considered a "shallow loss" program because it is designed to pay a portion of the farmers’ deductibles not covered by individual crop insurance. Under both programs, the private insurance companies charge actuarially-fair premiums (expected indemnity), but the government subsidizes these premiums. These policies are expected to influence the production decisions and risk mitigating strategies of wheat farmers over the life of the Farm Bill.

Wheat is the second leading crop grown in the United States. With the national area harvested and yield remaining stable at an average of 49.1 million acres and 43 bu/acre for the period 2000-2014, the real value of wheat production has also remained stable at an average of $13.5 billion (NASS/USDA, 2015b). With 25% of the total base acres, wheat is the second most subsidized commodity after corn, with payments totaling $35.5 billion over the period 1995-2012 (EWG, 2012; Schnitkey and Zulauf, 2015). Over this period, production flexibility payments and crop insurance premium subsidies were the largest payments, totaling $9.6 billion and $8.2 billion.

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3 A farmer enrolls each crop on each farm under ARC-CO or all crop on each farm under ARC-IC.
4 A comparison of the 2014 Farm Bill to the previous farm bills reveals that ARC-CO replaced Average Crop Revenue Program, PLC replaced the Counter-Cyclical Program, and ARC-IC replaced Supplemental Revenue Assistance (Schnitkey and Zulauf, 2015).
5 SCO takes the same form as individual insurance in that if the farmer selects RP, then SCO also protects against revenue losses, and if the farmer selects YP, then SCO protects against yield loss.
respectively. Direct payments, market loss assistance, and loan deficiency payments were the next largest support programs at a total of $6.9 billion, $4.9 billion, $2.7 billion, respectively.

With major overhauls, the 2014 Farm Bill is expected to have a substantial impact on wheat production practices. To study these impacts, we consider a representative dryland winter wheat farm from Mitchell county in north central Kansas. Kansas is the largest winter wheat producing state with about 8.8 million acres harvested and a total production of about 317 million bushels or 25% of the national production (NASS/USDA, 2015a).

Since the implementation of the 2014 Farm Bill, studies have focused on the impact of the new policies on farmers’ attitude toward risk. Coble et al. (2013) analyzed the impact of sample size for individual RP and SCO insurance policies proposed under the 2014 Farm Bill using simulation data from known distributions. Their results showed that sample sizes of less than 30 can lead to misleading risk analysis. Cooper et al. (2015) analyzed the 2014 Farm Bill by regressing the ratio of SCO premium to the sum of SCO and RP premiums on the deep loss parameter, shallow loss parameter, and other variables and found that this ratio is about twice as sensitive to the deep loss coverage rate than to the shallow loss coverage rate. Hungerford et al. (2015) used price and yield simulation analyses and found that PLC, ARC, and SCO programs are effective in mitigating risk. Adhikari (2015) examined the coverage level of the 2014 Farm Bill crop insurance programs and showed that the optimal coverage level varies across counties and individual crop insurance with SCO results in better protection. Our study builds on this literature by comprehensively analyzing the effects of the 2014 Farm Bill’s wheat policies on optimal production and insurance decisions.

The objectives of this study are to 1) develop a theoretical model detailing the mathematical formulation of all commodity program (LDP, PLC, and ARC-CO) and crop insurance (RP and SCO) policies for a risk averse wheat farmer, 2) obtain coupling, wealth, and insurance effects and moral hazard impacts of variability in yield and price and derive comparative static results of these effects for each program, 3) model and nonparametrically estimate the bivariate wheat yield and price distribution, 4) calibrate the model to a representative Kansas wheat farm, and 5)
apply numerical optimization to the theoretical model and simulate the effects of various policies on input use, yield, coverage level, commodity program payments, and crop insurance payments.

2 Model

We develop a model of a representative dryland, risk averse wheat farmer faced with uncertainty over both price and yield. The farmer’s production function is $\tilde{y} = zx^\nu \tilde{\epsilon}$, where $\tilde{y}$ is farm-level stochastic yield per acre, $z$ is a productivity parameter, $x$ is a composite input (for empirical analysis below, we include all key inputs such as intermediate inputs, labor, and capital in the production technology), $\nu \in (0,1)$ is the returns to scale, and $\tilde{\epsilon}$ is a random variable, centered on one, representing yield variation. The farmer’s per acre market revenue ($R$) and total cost ($TC$) are

$$ R(x; \tilde{p}, \tilde{\epsilon}) = \tilde{p}\tilde{y} \text{ and } TC(x) = wx + f_o, $$

(1)

where $\tilde{p}$ is the random market price, $w$ is the input price, and $f_o$ is fixed costs.

2.1 Commodity Programs

As discussed in the introduction, the 2014 Farm Bill implements two price support policies (LDP and PLC) and a revenue protection policy (ARC) to mitigate risk and lessen fluctuations in market revenue. The LDP policy protects farmers against price volatility. Per acre payments ($PLDP$) under LDP are

$$ PLDP(x; \tilde{p}, \tilde{\epsilon}) = \max \left[ (p^{LR} - \tilde{p}) \tilde{y}, 0 \right], $$

(2)

where $p^{LR}$ is the loan rate. Equation 2 indicates that, if the market price falls below the loan rate, farmers receive payments equal to the difference between the loan rate and market price times farm-level yield. Because LDP payments depend on farm-level yield, farmers can alter input use to augment yield and receive larger government support; however, a trade off exists between higher government payments and higher cost of production.

Under the 2014 Farm Bill, farmers make a one-time election of PLC or ARC for the life of the Farm Bill. Farmers’ choice depends on their expectation of which program pays the largest government subsidies over the entire Farm Bill period. Nationally 271,445 wheat farmers elected
PLC on 27.0 million base acre (42%), and 527,343 signed up for ARC on 35.4 million base acres (58%) (FSA/USDA, 2015b). Therefore, it is important to model both PLC and ARC separately.\footnote{The enrollment data indicates that wheat farmers find the new farm bill policies more remunerative as evident from a large increase in farmer participation (89,617) and base acres (9.9 million) in ARC and PLC compared to the enrollment in Direct and Counter-Cyclical Program and Average Crop Revenue Election in 2013.}

The PLC program protects farmers against price shocks. PLC payments are based on a per-payment acre \( (a^P) \) which is equal to 85% of the base acre \( (a^B) \): \( a^P = 0.85a^B \). Per payment-acre government subsidies \( (PPLC) \) equal

\[
PPLC(\hat{p}) = \max \left[ (p^R - \max[\hat{p}, p^{LR}]), 0 \right] y^P, \tag{3}
\]

where \( p^R \) is the reference price established by the Farm Bill and \( y^P \) is payment yield equal to 90% of the five-year (2008-2012) average yield \( y \), \( y^P = 0.9y \).\footnote{Note that the farmer can also choose \( y^P \) to be 100% of the farm’s counter cyclical yield.} Thus, farmers receive payments as the difference between the reference price and the effective price (the maximum of the market price or the loan rate) times the payment yield times the payment acre. Since this policy does not depend on farm-level yield, farmers cannot alter input use to augment PLC payments.

We focus on ARC-CO only because no wheat farmers enrolled in ARC-IC (FSA/USDA, 2015b). ARC-CO insulates the farmer from revenue loss, and government support per payment-acre \( (PARC^{CO}) \) under this program equals

\[
PARC^{CO}(\hat{p}, \hat{\epsilon}) = \max \left\{ 0, \min \left[ (0.86p^Oy^{OC} - \max(\hat{p}, p^{LR})y^C), 0.1p^Oy^{OC} \right] \right\}, \tag{4}
\]

where \( p^O \) is the five-year olympic average\footnote{The olympic average excludes the highest and lowest values.} of national market price, \( y^{OC} \) is the five-year olympic average county yield, and \( y^C \) is the stochastic county yield which equals the average county yield \( y^C \) times the random variable \( \hat{\epsilon} \): \( y^C = y^C\hat{\epsilon} \). Under this program, farmers receive payments when per-acre county market revenues (the higher of the market price or loan rate times the county yield: \( \max[\hat{p}, p^{LR}]y^C \)) fall below the ARC per-acre revenue guarantee (86% of the benchmark county revenue calculated as the product of the five-year olympic national average market price and yield: \( 0.86p^Oy^{OC} \)). Payments equal the payment rate times payment acres \( a^P \), where the payment rate is equal to the lower of the difference between the revenue guarantee and county market revenues or 10% of benchmark revenues. Because the coverage rate is 86% and the maximum payment cannot
exceed 10% of the benchmark revenue, ARC-CO covers only losses between 76% and 86% of the benchmark revenue. The ARC-CO policy does not rely on farmer’s yield, and therefore, input decisions do not influence ARC payments.

### 2.2 Crop Insurance Programs

Farmers can also reduce risk from revenue volatility by participating in individual RP crop insurance and SCO insurance. We consider RP because it is the most popular form of individual crop insurance as 86% and 92% of wheat farmers in Kansas and Mitchell county, respectively, signed up for RP in 2014 (RMA/USDA, 2015). Wright and Pauly (1993) determine that the loss ratios (ratio of indemnities to premium payments) should be less than 0.7 for insurance to be viable without premium subsidies. The loss ratio for wheat ranges from 0.21 in South Dakota to 1.46 in Kansas to 2.26 in Oklahoma (Schnitkey, 2015a); thus, insurance markets for wheat may be unviable in several states without government subsidies. Consequently, the government subsidizes premiums for both RP and SCO insurance policies. Indemnity payments ($RPI$) per acre for individual RP insurance are

$$RPI(x, \alpha; \tilde{p}, \tilde{\varepsilon}) = \max \left[ 0, \max \left[ \tilde{p}, p^F \right] \alpha y^A - \tilde{p} \tilde{y} \right],$$

(5)

where $p^F$ is the futures/projected price, $\alpha$ is the coverage level chosen by the farmer, and $y^A$ is actual production history yield. Thus, farmers receive an indemnity payment if actual market revenues ($\tilde{p} \tilde{y}$) fall below the revenue guarantee which equals the higher of the market or futures price times the coverage level times the actual production history yield: $\max \left[ \tilde{p}, p^F \right] \alpha y^A$. The indemnity payments equal the difference between the revenue guarantee and market revenue. The actuarially-fair premium rate ($\theta^{RP}$) is defined as the expected indemnity payment:

$$\theta^{RP}(x, \alpha) = \int \int RPI \, dG(\tilde{p}, \tilde{\varepsilon}),$$

(6)

where $G(\tilde{p}, \tilde{\varepsilon})$ is the joint cumulative distribution function over the stochastic market price and yield. The premium subsidy $\sigma^{RP}(\alpha)$ received by the farmer depends on the selected coverage level $\alpha$. The net benefit ($PRP$) from RP insurance is

$$PRP(x, \alpha; \tilde{p}, \tilde{\varepsilon}) = RPI - (1 - \sigma^{RP}(\alpha)) \theta^{RP}.$$

(7)
Since the RP policy depends on farm-level yield, the farmer can influence RP payments by altering input uses to impact yield. Thus, the farmer can reduce input use to lower the yield, which can increase the probability of receiving indemnity payments, leading to moral hazard.

As noted in the introduction, the farmer can select SCO coverage only if they participate in PLC and have an individual insurance plan. Under individual RP coverage, the farmer chooses a coverage level ranging from 50%, by increments of 5%, to a top coverage level of 85%, implying the farmer’s deductible ranges from 50% to 15%. SCO was designed for farmers to insure against their RP deductible up to a maximum 86%, leaving producers responsible for 14% of the deductible. For example, if the farmer selects an individual RP coverage level at \( \alpha = 0.65 \), SCO can cover between 65% and 86% of the farmer’s RP deductible. Because we consider only RP, SCO coverage also protects against low revenues. The SCO per acre indemnity payment is

\[
SCOi(\alpha; \tilde{p}, \tilde{\epsilon}) = \min \left\{ \max\left[ \delta - \frac{\tilde{p}y^C}{\max (\tilde{p}, p^F) y^C}, 0 \right], (\delta - \alpha) \right\} y^A \max(\tilde{p}, p^F).
\] (8)

Under the SCO program, the farmer receives a payment if actual county revenue, \( \tilde{p}y^C \), is less than \( \delta = 0.86 \) of expected county revenues given by \( \max (\tilde{p}, p^F) y^C \). The SCO indemnity per acre is the product of the payment rate and the liability. The payment rate, given by the \( \min \{\bullet, \bullet\} \) function, is lower of the revenue payment factor (the first term in the \( \min \) function, i.e., the higher of the maximum deductible in excess of the percentage of county revenue short fall\(^9\) or zero) or the maximum payment rate \( (\delta - \alpha) \). The liability is the actual production history yield times the payment price: \( y^A \max (\tilde{p}, p^F) \). The actuarially-fair premium rate \( (\theta^{SCO}) \) is defined as the expected indemnity:

\[
\theta^{SCO}(\alpha) = \int \int [SCOi(\tilde{p}, \tilde{\epsilon})] dG(\tilde{p}, \tilde{\epsilon}).
\] (9)

\(^9\)The percentage short fall is \( \frac{\max (\tilde{p}, p^F) y^C - \tilde{p}y^C}{\max (\tilde{p}, p^F) y^C} \). The percentage deductible that farmers must bear is \( (1 - 0.86) \). Thus, the percentage short fall in excess of the percentage deductible is \( \frac{\max (\tilde{p}, p^F) y^C - \tilde{p}y^C}{\max (\tilde{p}, p^F) y^C} - (1 - 0.86) = 0.86 - \frac{\tilde{p}y^C}{\max (\tilde{p}, p^F) y^C} \).
The government subsidizes the SCO premium at $\sigma^{SCO} = 0.65$. Thus, the net benefit of SCO payment per acre ($PSCO$) is

$$PSCO(\alpha; \bar{p}, \bar{\varepsilon}) = SCO_i - \left(1 - \sigma^{SCO}\right) \theta^{SCO}.$$  

Because individual RP covers revenue losses up to the selected coverage level $\alpha$ and SCO covers losses (at the county level) between $\alpha$ and the maximum coverage level of 0.86, the former is known as “deep loss” coverage and the latter is known as “shallow loss” coverage. Since the SCO policy is not a function of farm-level yield, the farmer cannot influence the input decision to secure larger SCO indemnity payments.

### 2.3 Farmer’s Optimization Problem

The farmer maximizes expected utility from profits by choosing inputs in production and the individual RP coverage level $\alpha$:

$$\max_{x, \alpha} \int \int U [\pi(x, \alpha; \bar{p}, \bar{\varepsilon})] dG(\bar{p}, \bar{\varepsilon}),$$  

(10)

where profits are

$$\pi(x, \alpha; \bar{p}, \bar{\varepsilon}) = [R(x; \bar{p}, \bar{\varepsilon}) + PLDP(x; \bar{p}, \bar{\varepsilon}) + PRP(x, \alpha; \bar{p}, \bar{\varepsilon}) + PSCO(\alpha; \bar{p}, \bar{\varepsilon}) - TC(x)] a$$  

$$+ PPLC(\bar{p}) a^p,$$  

(11)

where $a$ is the total number of acres, for a farmer that selects PLC and SCO, and

$$\pi(x, \alpha; \bar{p}, \bar{\varepsilon}) = [R(x; \bar{p}, \bar{\varepsilon}) + PLDP(x; \bar{p}, \bar{\varepsilon}) + PRP(x, \alpha; \bar{p}, \bar{\varepsilon}) - TC(x)] a$$  

$$+ PARC^{CO}(\bar{p}, \bar{\varepsilon}) a^p$$  

(12)

for a farmer that selects ARC.

To compare the impact of policies on the farmer, we calculate the certainty equivalent

$$CE = U^{-1}(EU),$$  

(13)

where $EU$ is the expected utility given by equation (10).

### 2.4 Coupling, Wealth, and Insurance Effects

Based on the empirical evidence from Saha et al. (1994) that farmers exhibit decreasing absolute risk aversion (DARA), we consider a DARA utility function. Following Hennessy (1998), we de-
rive the coupling, wealth, and insurance effects of various policies. To obtain tractable analytical results, we model revenue risk, denoted by a single random variable $\xi$, which can either represent yield risk ($\varepsilon$) or price risk ($\bar{p}$). To simplify notation for the comparative statics, in profit equations (11) and (12), we denote government supports that depend on inputs—$PLDP(x; \bar{p}, \bar{e})$ and $PRP(x, \alpha; \bar{p}, \bar{e})$—as $m(x, Z, \xi)$ where $Z$ is a policy parameter and programs that do not rely on inputs—$PSCO(\alpha; \bar{p}, \bar{e})$, $PPLC(\bar{p})$, and $PARC\, CO(\bar{p}, \bar{e})$—as $k(D, \xi)$ where $D$ is a policy parameter.

The objective function is $\max_x \int U[\pi(x, \xi; Z, D)] dF(\xi)$ where $U[\bullet]$ represents a concave utility function and $F(\bullet)$ gives the distribution of $\xi$. Maximization of this objective function with respect to $x$ yields the first-order condition

$$\int U[\pi(x, \xi; Z, D)] \pi_x(x, \xi, Z, D) dF(\xi) = 0.$$  

Totally differentiate the first-order condition to obtain the effect of the policy variable $T$ (which can refer to either $Z$ or $D$) on input use

$$\frac{dx}{dT} = -\frac{1}{\Delta} \int U[\pi(x, \xi; Z, D)] \pi_x(x, \xi, Z, D) dF(\xi) + \frac{1}{\Delta} \int U[\pi(x, \xi; Z, D)] A[\pi(x, \xi; Z, D)] dF(\xi)$$

where $\Delta = \int (U[\pi(x, \xi; Z, D)] \pi_x(x, \xi, Z, D) + U[\pi(x, \xi; Z, D)] \pi_{xx}(x, \xi)) dF(\xi) < 0$ and $A[\pi(x, \xi; Z, D)] = -\frac{U[\pi(x, \xi; Z, D)]}{U[\pi(x, \xi; Z, D)]}$ denotes the absolute risk-aversion term. $\frac{dx}{dT}$ can be decomposed into the coupling, wealth, and insurance effects.

In equation (14), the first term represents the coupling effect:

$$-\frac{1}{\Delta} \int U[\pi(x, \xi; Z, D)] \pi_x(x, \xi, Z, D) dF(\xi).$$  

Note that if $T = Z$, then $\pi_{xZ}(\bullet) \neq 0$ and the coupling effect exists for LDP and RP because payments from these policies depend on input use. However, if $T = D$, then $\pi_{xD}(\bullet) = 0$ and the coupling effect does not exist for ARC-CO, PLC, and SCO because payments from these policies do not rely on inputs. Because both $-\frac{1}{\Delta}$ and marginal utility $U[\pi(\bullet)]$ are positive, the sign of the coupling effect, and thus the comparative static results of input use, follows the sign of $\pi_{xT}(\bullet)$. 

10
In equation (14), the wealth and insurance effects are intertwined in the term
\[ \frac{1}{\Delta} \int A[\bullet] \pi_T(\bullet) U_\pi[\bullet] \pi_x(\bullet) dF(\tilde{\xi}). \]
To separate the wealth and insurance effects, apply integration by parts to the above equation to obtain:
\[ -\frac{1}{\Delta} \int \int U_\pi[\bullet] \pi_x(\bullet) dF(\tilde{\xi}) J'(\bullet, \nu) d\nu, \] (16)
where \( J'(\bullet, \nu) = A_\pi[\bullet] \pi_{\tilde{\xi}}(\bullet) \pi_T(\bullet) + A[\bullet] \pi_{T_{\tilde{\xi}}}(\bullet). \)

Since \( \pi_{\tilde{\xi}}(\bullet) \geq 0 \) (verified in the Appendix), then \( \int U_\pi[\bullet] \pi_x(\bullet) dF(\tilde{\xi}) \leq 0 \) because marginal utility is positive and \( \pi_x(\bullet) \) is negative at low \( \tilde{\xi} \) and positive at high \( \tilde{\xi} \). Given \( -\frac{1}{\Delta} > 0 \), equation (16) is positive if \( J'(\bullet, \nu) \leq 0 \). We can decompose \( J'(\bullet, \nu) \) into the wealth effect \( (A_\pi[\bullet] \pi_{\tilde{\xi}}(\bullet) \pi_T(\bullet)) \) and the insurance effect \( (A[\bullet] \pi_{T_{\tilde{\xi}}}(\bullet)). \)

The sign of the wealth effect depends on each of the three terms. The sign of \( A_\pi[\bullet] \) is negative for DARA utility functions. For both price and yield risk, \( \pi_{\tilde{\xi}}(\bullet) > 0 \) for all policies.\(^{10}\)
Therefore, the sign of the wealth effect is opposite of \( \pi_T(\bullet) \). If \( \pi_T(\bullet) > (\)0, then the wealth component of \( J'(\bullet, \nu) < (\)0, and the signs of the comparative static results through the wealth effect are same as the sign of \( \pi_T(\bullet) \).

The sign of the insurance effect depends on each of the two terms. Since \( A[\bullet] > 0 \), the sign of the insurance effect is same as the sign of \( \pi_{T_{\tilde{\xi}}}(\bullet) \). If \( \pi_{T_{\tilde{\xi}}}(\bullet) > (\)0, then the insurance component of \( J'(\bullet, \nu) > (\)0, and the sign of the comparative statics through the insurance effect is opposite of \( \pi_{T_{\tilde{\xi}}}(\bullet) \).

Thus, under stochastic environment, even policies that are independent of input use can be coupled to production through the wealth and insurance effects.

2.4.1 Comparative Static Results

Here, we present the comparative static results for the impact of policy parameters \( (p^{LR}, p^R, \sigma^{RP}, \sigma^{SCO}, \text{ and } \delta) \), exogenous variables \( (p^O, y^P, y^{OC}, y^A, \text{ and } a^P) \), and the choice of the coverage level \( \alpha \) on input use. Since these analyses require a large number of derivatives for \( \pi_{\tilde{\xi}}(\bullet), \pi_T(\bullet), \)

\(^{10}\)Except for yield risk and RP policy where \( \pi_{\tilde{\xi}}(\bullet) < 0 \), which is dealt with in detail in the Appendix.
and $\pi_{T\bar{\xi}}$ for various policies in $T$ and stochastic environments $\bar{\xi} = \bar{\rho}$ and $\bar{\epsilon}$, we present a detailed mathematical analysis in the Appendix and summarize the comparative static results in Table 1.

LDP and RP policies have coupling effects because payments directly depend on input decisions, and thus the farmer can adjust input use to influence the payment from these policies. LDP and RP payments have a positive coupling effect through $p^{LR}$ and $\alpha$, respectively, because higher loan rate and RP coverage level increase the size and probability of payments, which the farmer can augment by increasing input use and yield. However, RP payments have a negative effect on input use through $\sigma^{RP}$ because higher subsidies increase the size of the government payments from this policy, resulting in an incentive for the farmer to shift revenue from the market to RP insurance payments. In addition, indemnity payments can be further increased by reducing input use and lowering yield. In contrast, PLC, ARC-CO, and SCO have no coupling effects because their payments do not directly depend on input use.

All policy parameters have a positive influence on input use through wealth effects, except RP’s $\alpha$ and SCO’s $y^A$ and $y^{OC}$, which have ambiguous impacts. A rise in $p^{LR}$, $p^R$, $y^P$, $a^P$, $\delta$, $p^O$, $\sigma^{RP}$, and $\sigma^{SCO}$ increases the size of payments under all five policies without additional cost to the farmer. These higher payments mitigate risk through income smoothing by compensating for low market revenue, and thus incentivize the farmer to use more inputs. Because $\alpha$ in RP and $y^A$ and $y^{OC}$ in SCO increase not only indemnity payments but also premium costs, income stabilization does not arise with high market revenue and may occur with low market revenue. As a result, the impacts of the wealth effect of these policy variables on input use is ambiguous.

Unlike the coupling and wealth effects, the insurance effects depend on many factors, and consequently, they vary depending on the policy parameter and the type of risk. Furthermore, insurance effects deal with how a shift in a policy parameter changes income smoothing. If a favorable shift in the policy parameter helps to smoothen income, $\pi_{T\bar{\xi}} < 0$, the farmer receives larger payouts in less fortunate states than in more fortunate states, then optimal input use increases. This occurs for $a^P$ in ARC-CO and $\alpha$ and $y^A$ in RP under yield risk and $y^P$ and $a^P$ in PLC and $a^P$ in ARC-CO. In contrast, if a favorable shift in the policy parameter does not act to stabilize income,
\( \pi_T \tilde{\zeta} > 0 \), the farmer receives smaller payouts in less fortunate states than in more fortunate states, then optimal input use decreases. This arises for \( p^{LR} \) in LDP under yield risk and \( \sigma^{RP} \) in RP and \( \sigma^{SCO} \) in SCO under yield and price risk. If a favorable shift in the policy parameter has an ambiguous impact on income stabilization, \( \pi_T \tilde{\zeta} \geq 0 \), payouts in less fortunate states exceed (falls short of) those in the more fortunate states, the optimal input use can increase (decrease). This materializes for \( \alpha \) and \( y^A \) in RP under price risk and \( y^A \) and \( y^{OC} \) in SCO under both price and yield risk. Finally, if \( \pi_T \tilde{\zeta} = 0 \), then the income smoothing effect is invariant to changes in policies and thus optimal input use is not impacted. This occurs in LDP for \( p^{LR} \) under price risk; in PLC for \( p^R \), \( y^P \), and \( a^P \) for yield risk and \( p^R \) under price risk; and in ARC-CO for \( \delta \), \( p^O \), and \( y^{OC} \) under both yield and price risk.

In summary, the comparative static results of the total coupling, wealth, and insurance effects illustrate the directional impacts on the optimal input use for each policy. For the LDP policy, the coupling and wealth effects have positive impacts on input use and the insurance effect (for yield variability) does not conform with these positive effects, resulting in an ambiguous total impact on the direction of optimal input use. For the PLC and ARC-CO policies, the coupling effect does not impact input use, the wealth effect is positive, and the insurance effect is either zero or positive and reinforce the wealth effect, leading to positive influence on the direction of optimal input use. For RP and SCO, the coupling, wealth, and insurance effects differ, and consequently the total effects on the direction of input use are ambiguous. Hence, any adjustment in input uses clearly bears out the moral hazard aspects of these two insurance policies.

3 Nonparametric Estimation of the Price and Yield Distributions

This section estimates the bivariate price and yield distribution using nonparametric methods. The price ($/bu) received by Kansas winter wheat farmer and yield (bu per acre) data for Mitchell county was obtained from QuickStat NASS/USDA (2015b) for the years 1949-2015.\(^{11}\) The real price was obtained by dividing the price data by the prices received index for food grains from

\(^{11}\)We assume that all farmers are identical and use county-level yield data to approximate the farm-level yield distribution (Gerlt et al., 2014), which abstracts from adverse selection.
ERS/USDA (2015). Next, we discuss detrending of the yield data. First, we regress yield on linear and quadratic time \((t = 1949, \ldots, 2014)\) regressors, and calculate the predicted values for yield and the error term: \(\hat{y}_t = \hat{\beta}_0 + \hat{\beta}_1 t + \hat{\beta}_2 t^2\) and \(\hat{e}_t = y_t - \hat{y}_t\). Second, we detrend the yield data relative to the predicted value of 2014: \(y^*_t = \hat{y}_T \left(1 + \frac{\hat{e}_t}{\hat{y}_t}\right)\) for \(T = 2014\) (also see Tejeda and Goodwin, 2008). The correlation coefficient of -0.193 captures the negative relationship between price and detrended yield. The mean, variance, and skewness are 5.99, 0.26, and 0.22, respectively, for the real price and 44.91, 104.60, and -0.08, respectively, for detrended yield.\(^{12}\)

Precise estimates of the distribution of price and yield are key to estimating accurate expected utility, actuarially-fair premium rates for RP and SCO, and expected payments for LDP, ARC-CO, and PLC. To obtain accurate estimates of the price and yield distributions free of any parametric assumptions, we estimate the bivariate kernel density, which accounts for the correlation between price and yield. Consider random real price and detrended yield data \((\tilde{p}, \tilde{y})\) of length \(n\). The nonparametric estimation of the joint distribution \(f_h\) at points \(P\) and \(Y\) is

\[
\hat{g}_h(P, Y) = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{h_p h_y} K \left( \frac{P - p_i}{h_p}, \frac{Y - y_i}{h_y} \right)
\]

(17)

where \(h_p\) and \(h_y\) are bandwidths and \(K(\bullet)\) is a multivariate kernel weight. For the estimation, we use Silverman’s (1986) rule to determine the bandwidths and the multivariate Gaussian kernel.

As discussed in the subsequent calibration section, we match the price and yield, and thus revenue, reported in the 2014 budget for winter wheat farmers in north central Kansas. Because the detrended average price in the historical data collected from NASS (NASS/USDA, 2015b) does not equal the price in the enterprise budget, we normalize the detrended price data by dividing each observation by its average, which generates a normalized price with a mean of one. Similarly, we apply this normalization to the historical yield data. We then multiply the price and yield in the enterprise budget, respectively, by the normalized random price and yield variables represented by the bivariate kernel density in equation (17). Consequently, expected revenue in the model equals the revenue in the enterprise budget. Figure 1 illustrates the contour plot or birds-eye-view of the

\(^{12}\)Following these detrending procedures, the real price and detrended yield data are stationary based on the Dickey Fuller and Augmented Dickey Fuller tests and homoskedastic according to the Breusch - Pagan test.
bivariate PDF and CDF; each line in the contour plot represents a constant probability level. The PDF contour plot reveals that the data are non-spherical, indicating that the data are non-normal. The CDF contour plot suggests an “S” shaped marginal CDF. Figure 2 plots these marginal PDFs and CDFs of price and yield, respectively. Both the marginal PDF plots for price and yield show a bimodal distribution in the lower tails. Bimodal and negatively skewed (a third moment for yield of -0.08) distributions are commonly found in yield data because of systematic events such as pests and diseases and catastrophic weather events in a county or region (Ker and Goodwin, 2000). However, bimodality is an anomaly in the price data as it is not commonly observed. Also, the price data has a long upper tail with a third moment of 0.22. The marginal CDF plots confirm the “S” shape suggested by the CDF contour plot. It is worth noting the bimodal distribution observed by nonparametrically estimating the joint distribution of yield and price cannot be ascertained through bivariate parametric distribution estimations.

4 Data, Source, and Calibration

We discuss the data, sources, and calibration of the production function $\tilde{y}$ and all other parameters specified in the model in equations (1)-(12). For the simulation analysis, we consider a Cobb-Douglas production function $\tilde{y} = z x_1^{\nu_1} x_2^{\nu_2} x_3^{\nu_3} \tilde{\varepsilon}$, where $x_1$, $x_2$, and $x_3$ are intermediate inputs, labor, and machinery, respectively, $\nu_1$, $\nu_2$, and $\nu_3$ are share parameters with $\nu_1 + \nu_2 + \nu_3 \leq 1$, and total cost is $TC = w_1 x_1 + w_2 x_2 + w_3 x_3 + f_o$. We utilize the Expo-Power utility function $U [\pi (x, \alpha; \tilde{p}, \tilde{y})] = 1 - \exp \left[ -\gamma \pi (x, \alpha; \tilde{p}, \tilde{y})^\beta \right]$ where $x = (x_1, x_2, x_3)$, $\beta = 1$ for constant absolute risk aversion, $\beta < 1$ for decreasing absolute risk aversion, and $\beta > 1$ for increasing absolute risk aversion utility function (Saha et al., 1994). The risk aversion coefficient $\gamma = 0.0005$ (Babcock et al., 1993) indicates a moderate level of risk and concavity of the expected utility function. According to Saha et al. (1994), U.S. farmers exhibit DARA utility with $\beta = 0.3654$. The 2014 enterprise budget for winter wheat in the north central region (Ibendahl et al., 2015) is used to collect data on the farm price, per acre yield, market returns, and cost of production for intermediate inputs, labor, and machinery. The price per bu and yield per acre are $5.64$ and $56$ bu, respectively. The data for intermediate inputs include seed, herbicide, insecticide, fungicide, fertilizer, and miscellaneous inputs.
inputs, labor, and machinery are utilized to calibrate the production function. The quantity of inputs is computed as the cost of inputs divided by the price of inputs. The share parameters of the production function are obtained as the ratio of input costs divided by the value of production. Using the data on yield, input quantities, and the share parameters, the total factor productivity \( z \) is computed. This calibration is based on the data from the enterprise budget which includes only the market revenue and the input costs but not any policy payments.

Next, we discuss parameters of the various government policies. The wheat reference price \( (p^R = 5.5) \) and future price \( (p^F = 5.37) \) are collected from Welch and Knapek (2014). The wheat loan rate \( (p^{LR} = 2.46) \) is obtained from FSA/USDA (2015a). We assume the representative farm harvested acreage \( a \) is 707 and the base acreage \( a^B \) is 500. The actual production history yield \( y^A \) is 39.99, which is the mean yield for the last 10 years, and the average yield over the period 2008-2012 \( y \) is 48.45.\(^{14}\) The county yield \( y^C \) is 44.91, taken as the detrended sample average for Mitchell county. The olympic average yield \( y^{OC} \) for Mitchell county is 47.33. The olympic average price \( p^O = 6.7 \) is taken from FSA/USDA (2015b). The 2014 Farm Bill specifies the premium subsidy for various RP coverage levels (Table 2) and the premium subsidy for SCO at a fixed level of 0.65 (Coble et al., 2014).

5 Simulation and Results

For the simulation analysis, we numerically optimize expected utility (10) to determine the optimal choice of inputs and RP coverage level, which are used to compute expected yield, certainty equivalent, commodity program payments, crop insurance premiums, and net crop insurance payments. Tables 3 and 4 report the simulation results of various policies under the 2014 Farm Bill on these variables.

5.1 Baseline Scenario: \( R \)

The profit in the baseline scenario is market revenue minus total cost:

\[
\pi (x; \tilde{p}, \tilde{\epsilon}) = [R(x; \tilde{p}, \tilde{\epsilon}) - TC(x)] a.
\]

\(^{14}\)The Mitchell county yield data is used to represent the farm-level production history yield data.
The baseline simulation includes only profits from market revenue and thus replicates the values of the endogenous variables in the calibration. The results indicate optimal input use of 112.280, 14.436, and 86.276, for intermediate inputs, labor, and machinery. These input levels generate an expected yield of 56 bu per acre, which replicates the yield data. The expected profit per acre resulting from this input use is $33.072 (not reported in the Table), and the certainty equivalent corresponding to this profit is $CE = 27.707$, implying the farmer would be willing to forfeit $5.365 per acre to eliminate uncertainty.

5.2 Scenarios 1-5: Individual Policy Impacts

After running the baseline, we consider a total of ten alternate scenarios. The first five scenarios examine the effects of LDP, RP, ARC-CO, PLC, and SCO individually on endogenous variables by comparing the results of each scenario and the baseline.

5.2.1 Scenario 1: R+LDP

The LDP policy protects the farmer from downward price risk from a bumper crop through a price floor. In this scenario, we add payments from LDP to the profits in the baseline:

$$\pi (x; \tilde{p}, \tilde{\varepsilon}) = [R(x; \tilde{p}, \tilde{\varepsilon}) + PLDP(x; \tilde{p}, \tilde{\varepsilon}) - TC(x)] a.$$ 

Because LDP payments depend on $x$, they are coupled to production not only through the coupling effect, but also through the wealth and insurance effects (see Table 1). These effects would arise only if the farmer receives LDP payments, i.e., with a market price below the loan rate. Because of the low wheat loan rate of $2.46$ relative to the market price of $5.64$ in 2014, the expected LDP payment ($PLDP$ integrated over the bivariate price and yield distribution) is zero. Consequently, this scenario does not influence the farmer’s production decisions and generates identical optimal input use and yield as in the baseline. The differences in certainty equivalents between the alternate and baseline scenarios indicate the increase in farmers income due to the benefits of the policy in the alternate scenario. Since LDP payments do not accrue, the certainty equivalent is the same as that in the baseline.
5.2.2 Scenario 2: R+RP

The RP policy insures farmer from yield and price perils. The profit in this scenario includes the payments from revenue protection:

$$\pi(x, \alpha; \tilde{p}, \tilde{\varepsilon}) = [R(x; \tilde{p}, \tilde{\varepsilon}) + PRP(x, \alpha; \tilde{p}, \tilde{\varepsilon}) - TC(x)] a.$$ 

The RP insurance policy influences farmer’s input use directly through the coupling effect as the payments depend on $x$ and indirectly through the wealth and insurance effects (refer to Table 1). The results show that input use declines, causing output to decrease by 3.763% to 53.893 bu. The reduction in input use underscores the moral hazard aspect of this insurance policy because it provides security to farmers by assuring indemnity payments when revenues are low which tempts the farmer to use less input. For the RP policy, the certainty equivalent increases by $1.701 from the baseline to $29.408, implying that the farmer benefits by participating in RP through risk mitigation. The results show an optimal insurance coverage level of 85% for RP with a corresponding subsidy level of 38% (see Table 2). Our findings corroborate the simulation results of Dismukes et al. (2013), which reported that all wheat farmers opted for high coverage level (i.e., greater than or equal to 75%). Outlaw (2014) documented from the available data that on average Kansas wheat farmers in 2013 elected coverage levels in the range of 70-75%.

The results indicate that the expected RP indemnity payment is $2.514 per acre with a net benefit of $0.955 per acre, calculated using equations (6) and (7), respectively. If moral hazard is controlled for, i.e., input use and yield levels of the baseline are maintained, the expected RP indemnity payment and net benefit decline to $2.072 and $0.787, respectively. This result highlights the influence of moral hazard in lowering input use to secure a larger expected indemnity payment. However, the farmer faces a trade off between higher indemnity payments versus higher premium cost and lower market revenues.
5.2.3 Scenario 3: R+ARC-CO

ARC-CO is a revenue protection program and the payments depend on price and county-level yield variability. The payments from ARC-CO are added to the baseline profits

$$\pi(x; \hat{p}, \hat{\epsilon}) = [R(x; \hat{p}, \hat{\epsilon}) - TC(x)]a + PARC^{CO}(\hat{p}, \hat{\epsilon}) a^P.$$ 

Since payments under the ARC-CO policy are independent of farm-level input use, this policy does not have a coupling effect and changes in production decisions arise only through the wealth and insurance effects. Both of these latter effects are positive and thus reinforce each other (see Table 1), leading to an increase in the use of all three inputs from those of the baseline by 1.388%. The higher input use leads to a yield increase from 56 bu to 56.544 bu. Even though ARC-CO is a decoupled policy in a deterministic environment, it does influence production decisions through the wealth and insurance effects—thus it is a coupled policy under stochastic yield and price. This result is consistent with the findings of Hennessy (1998). The certainty equivalent increases from the baseline value of $27,707 to $38,717, which indicates ARC-CO brings an additional benefit of $11.01. Participation in the ARC-CO program augments farmer’s profit by $16,546, the expected payment under this policy. This result is comparable to Schnitkey and Zulauf (2015) and Westhoff et al. (2015) who estimate an average ARC payment of $11 nationally for wheat for 2014. Schnitkey (2015b) estimates that farmers in some north central counties in Kansas will receive payments between $1 to $20 per acre, and in other counties farmers will receive payments between $20 and $40.

5.2.4 Scenario 4: R+PLC

PLC is a price protection program and does not depend on random yield at the farm or county level. The profit under this scenario includes payments from the PLC program:

$$\pi(x; \hat{p}, \hat{\epsilon}) = [R(x; \hat{p}, \hat{\epsilon}) - TC(x)]a + PPLC(\hat{p}) a^P.$$ 

Similar to the ARC-CO program, PLC is also a decoupled policy under deterministic conditions. However, under stochastic price risk, this policy is also coupled to production through wealth and insurance effects (refer to Table 1). Both of these effects are positive and augment input use and
yield, albeit only slightly. These effects are small compared to those under ARC-CO for two reasons. First, the *ex post* market price is above the reference price, and therefore any impact on input use arises only when the random market price falls below the reference price. Second, because yield risk does not impact this policy, the indirect wealth and insurance effects are dampened. The certainty equivalent under PLC is higher than that under the baseline by $3.513, highlighting the benefits of this policy. The price protection provided by this policy brings additional expected revenue of $5.744 to the farmer. This low payment compared to that of ARC-CO is a consequence of better market conditions with a relatively high market price for wheat in 2014. Westhoff et al. (2015) estimated the PLC payment to be low in the 2014 crop year, rise significantly in 2015, and remain fairly constant for the rest of the Farm Bill period. Their estimated annual average payment of $14 per-payment acre for the period 2014-2017 includes the smaller payment in 2014, and is thus comparable to our estimate of $5.744. Note that in the 2014 crop year, the actual market price is higher than the reference price and PLC payments did not accrue (Schnitkey and Zulauf, 2015). However, our study presents an ex-anti analysis of the effects of the stochastic nature of price and yield on optimal input use and government payments. The low expected PLC payment of $5.744 compared to a relatively higher expected ARC-CO payment of $16.546 also highlights the wheat farmers’ lower program participation in PLC versus ARC-CO; nationally 42% of base acres were enrolled in PLC versus 58% in ARC-CO. Sensitivity analysis of the reference price $p^R$ suggests that increasing the reference price by $0.41 to $5.91 would result in the expected PLC payment to equal the expected ARC-CO payment.

5.2.5 Scenario 5: R+SCO

Even though SCO requires farmers to elect RP and PLC, we examine the SCO policy separately to isolate its impact. The profit in this scenario includes payments under the SCO policy

$$\pi(x, \alpha; \tilde{p}, \tilde{\epsilon}) = [R(x; \tilde{p}, \tilde{\epsilon}) + PSCO(\alpha; \tilde{p}, \tilde{\epsilon}) - TC(x)]a.$$ 

SCO is also an insurance policy, but unlike the RP insurance policy, payments do not depend on input use. Thus, it does not have any coupling effect and all impacts on production decisions arise through the indirect wealth and insurance effects. Though the theoretical results of the sum of the
wealth and insurance effects are ambiguous (see Table 1), the empirical results indicate that—in contrast to RP insurance—optimal input use increases compared to the baseline, which leads to an increase in yield by 2.236% to 57.252 bu. Thus, as emphasized in Moschini and Hennessy (2001), moral hazard can cause farmers to increase input use to augment yield. Therefore, RP and SCO policies influence the farmer’s production decisions differently as SCO expands input use while RP reduces input use. The certainty equivalent under this policy increases by $8.532, indicating the significant value of this policy to the farmer. To ascertain the maximum SCO payment under various RP coverage levels, we ran this scenario for the range of $\alpha$ values given in Table 2. The coverage level that earns the farmer the maximum SCO payment is 0.50, which resulted in an expected indemnity payment of $10.022 and a net benefit of $6.514. Therefore, the farmer can expect higher payments from SCO than RP, but not as high as expected ARC-CO payments.

5.3 Scenarios 6-8: Complete Policy Impacts

Scenarios 6-8 build on the baseline by incorporating the sequence of policies that are available to wheat farmers under the 2014 Farm Bill. For policies that have a coupling effect, input use influences payments, which in turn impact the ex ante optimal input use. However, for policies without coupling effects, input use does not influence payments, but these payments do impact the ex ante input use indirectly through the wealth and insurance effects. Thus, these three scenarios highlight the feedback effects of policies that are dependent on input use as well as policies that are independent of input use.

5.3.1 Scenario 6: R+LDP+RP+ARC-CO

To reflect a realistic set of policies in which a farmer might enroll, this scenario includes LDP and RP and ARC-CO payments to baseline profits:

$$\pi(x, \alpha; \bar{p}, \bar{\varepsilon}) = [R(x; \bar{p}, \bar{\varepsilon}) + PLDP(x; \bar{p}, \bar{\varepsilon}) + PRP(x, \alpha; \bar{p}, \bar{\varepsilon}) - TC(x)]a + PARC^{CO}(\bar{p}, \bar{\varepsilon}) \alpha^P.$$  

A comparison of scenario 6 to the baseline shows the net effects of LDP, RP, and ARC-CO. Given that LDP does not influence input use for the year 2014, if these net effects are negative (positive), then RP dominates (is dominated by) ARC-CO. The results highlight that the decline in produc-
tion through the coupling, wealth, and insurance effects of RP overshadows the rise in production through the wealth and insurance effects of SCO, leading to a net decline in production by 2.795% to 54.435 bu. The high certainty equivalent ($40.267) in this scenario relative to the baseline and scenarios 2 and 3 indicates that the farmer prefers to include both RP and ARC-CO to obtain a larger income. ARC-CO does not alter the insurance environment and therefore does not impact the farmer’s choice of RP coverage level. Market revenue rises because yield rose modestly over Scenario 2. As a result, the premiums and net benefits decline modestly to $2.400 and $0.912, respectively. Because ARC-CO payments are independent of input use and yield, the expected payment does not change.

5.3.2 Scenario 7: R+LDP+RP+PLC

Because farmers must select either PLC or ARC-CO, in this scenario, we remove ARC-CO payments from scenario 6 and add PLC payments to the profit

\[
\pi(x; \tilde{p}, \tilde{e}) = [R(x; \tilde{p}, \tilde{e}) + PLDP(x; \tilde{p}, \tilde{e}) + PRP(x, \alpha; \tilde{p}, \tilde{e}) - TC(x)] + PPLC(\tilde{p}) - P.
\]

Similar to scenario 6, RP and PLC have opposing effects on inputs and yield. However, a comparison of scenario 7 and the baseline indicates that input use and yield decline because PLC only has small positive wealth and insurance impacts and the decline in yield from RP dominates. This result is also borne out by the comparison of scenario 7 and 2, indicating only a small increase in yield due to the introduction of PLC. The certainty equivalent of $32.932 in this scenario reveals that, while the farmer prefers RP and PLC together to the baseline with a certainty equivalent of $27.707, he/she does not find adding PLC to RP to be as beneficial as adding ARC-CO to RP with a certainty equivalent of $40.267 because ARC-CO has higher program payments than PLC in 2014. Since PLC has a small impact on input use and yield, it minimally reduces premium and net benefit of RP policy relative to scenario 2. And, given that PLC payments per payment-acre do not depend on input use, the expected PLC payment is equal to that in scenario 4.

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5.3.3 Scenario 8: R+LDP+RP+PLC+SCO

To buy insurance under SCO, a shallow loss insurance program designed to insure farmers against the RP deductible, a farmer has to participate in RP and PLC. Thus, this scenario adds net benefits from SCO to the profits in scenario 7:

\[
\pi(x, \alpha; \tilde{p}, \tilde{\epsilon}) = [R(x; \tilde{p}, \tilde{\epsilon}) + PLDP(x; \tilde{p}, \tilde{\epsilon}) + PRP(x, \alpha; \tilde{p}, \tilde{\epsilon}) + PSOCO(\alpha; \tilde{p}, \tilde{\epsilon}) - TC(x)]a + PPLC(\tilde{p}) \alpha^P.
\]

The Farm Bill fixes the premium subsidy under the SCO at 65% regardless of the farmer’s coverage level. In contrast to the scenarios 6 and 7, higher inputs and yield from PLC and SCO dominate the input and yield reduction from RP, which leads to a net increase in yield of 1.984% to 57.111 bu relative to that in the baseline. The addition of SCO to PLC results in a certainty equivalent of $40.042. Therefore, while the farmer is better off by adding SCO to PLC, scenario 6 with ARC-CO still has the highest certainty equivalent; thus the wheat farmer benefits the most from the policy combination under scenario 6.

An important result of this scenario is that the optimal coverage level under RP declines from 85% (with a 38% subsidy) to 50% (with a 67% subsidy) because, with the addition of SCO insurance, farmers would like to insure against revenue risk only at 50%, receive a large RP premium subsidy, and cover the larger RP deductible with SCO which has a larger premium subsidy (65%) and indemnity payments. Thus, a farmer with only 50% coverage under RP will benefit greater by participation in SCO. Because of the selection of the lowest coverage level for RP and the increase in yield, the premium rate in Scenario 8 declines to $0.270 with a net benefit of the RP policy of only $0.181 per acre.

5.4 Scenarios 9 and 10: Removal of Premium Subsidies

Do farmers participate in RP insurance program without a RP premium subsidy? To answer this question, we consider scenario 9 (which is scenario 2 without the RP premium subsidy) and compare the results of this scenario to those of the baseline. Similarly, do farmers benefit from RP and SCO insurance without the premium subsidies for both of these policies? To address this query, we consider scenario 10 (which is scenario 8 without RP and SCO premium subsidies) and compare
the results to those of the baseline. Table 5 presents the results of removing premium subsidies on input use, yield, coverage level, and expected utility, and Table 6 reports the effects of these subsidy eliminations on expected premiums and program payments.

Consistent with the results for scenario 2, even without the RP premium subsidy (scenario 9), RP reduces input use, leading to a slight decrease in yield to 55.459 bu. Also, in line with the results of scenario 8 above, inclusion of RP, PLC, and SCO without the premium subsidies (scenario 10) causes a modest increase in input use, which expands yield to 56.251 bu. However, removing premium subsidies does not alter the optimal RP coverage levels in these two scenarios. Therefore, if the farmer only includes RP with market revenue, the optimal coverage level is 0.85, but when the farmer also adds LDP, PLC, and SCO, the optimal RP coverage level drops to 0.50. Interestingly, even though net expected payment is zero under RP policy without a premium subsidy, the farmer still prefers to participate in RP insurance, as evident from the increase in the certainty equivalent by $0.799 to $28.506, because of the coupling effect and income stabilization through the wealth and insurance effects. In scenario 10, the certainty equivalent rises by $5.586 to $33.293, which implies the farmer is both better off relative to the baseline and RP policy without its premium subsidy.

Without subsidies, the premium declines for RP in scenario 9 to $2.185 and further falls for RP, PLC, and SCO in scenario 10 to $0.268. As previously discussed, because both PLC and SCO payments are independent of input use, the expected PLC payment and SCO premium do not change with the elimination of premium subsidies. In summary, according to the certainty equivalent analysis, the farmer gains with RP insurance even if government does not subsidize the premium, and inclusion of PLC and SCO without premium subsidies continues to shelter the farmer from risk and increase his/her wellbeing.

6 Discussion and Conclusion

This study formulates a theoretical model by comprehensively examining all commodity programs (LDP, PLC, and ARC-CO) and crop insurance policies (RP and SCO) for a risk averse wheat farmer. We perform comparative static analysis and show the directional impact of the coupling,
wealth, and insurance effects for each policy. We then model and nonparametrically estimate the 
bivariate wheat yield and price distribution for Mitchell county in Kansas. The model is calibrated 
to a representative Kansas wheat farm and numerical optimization is applied to simulate the effects 
of various policies on input use, yield, coverage level, certainty equivalent, commodity program 
payments, crop insurance payments.

In a stochastic environment with non-constant absolute risk aversion utility, government 
programs can influence input use and production decisions through three separate channels: cou-
pling, wealth, and insurance effects. The coupling effect arises when payments directly depend on 
input decisions. The wealth effect influences production through income smoothing from govern-
ment payments when perils occur. The insurance effect stems from how a shift in policy parameter 
changes the pattern of income smoothing.

The commodity programs include LDP, PLC, and ARC-CO. Because LDP payments di-
rectly depend on input use, LDP is coupled to production through the coupling, wealth, and insur-
ance effects. However, PLC and ARC-CO payments are independent of input use, and are coupled 
to production only through the wealth and insurance effects. The empirical results show that ex-
pected LDP for 2014 are zero, while expected PLC and ARC-CO payments are both positive. Both 
PLC and ARC-CO lead to higher input use and yield. However, because ARC-CO has a larger 
impact on yield, expected payments and certainty equivalent are larger compared to those of PLC, 
the representative Kansas wheat farmer would be better off selecting ARC-CO over PLC.

Nationally, wheat farmers elected to sign up 58% of their base acres in ARC-CO and 42% 
in PLC, which have important implications not only for risk management strategies, but also for 
government spending on farm programs and U.S. commitments to global trade negotiations (West-
hoff et al., 2015). This election depends on farmers’ perception about future market conditions. 
In particular, if farmers believe the market price is going to be higher, then they would prefer 
revenue protection under ARC-CO versus PLC which will result in small government payments. 
Under ARC-CO, the revenue benchmark is based on a moving five-year olympic average of price 
and yields. Since wheat prices were relatively high between 2010 and 2012 and current prices are
relatively low, farmers are expected to receive larger ARC-CO payments at the beginning of the
Farm Bill. However, toward the end of the Farm Bill, the moving averages will not include the high
prices, and consequently the ARC-CO payments are expected to decline. For PLC, reference prices
are fixed, and government payments depend largely on market price. Thus, if the market price is
high (low), government payments will be small (large). If market prices remain fairly low during
the life of the Farm Bill, then ARC-CO payment will continue to fall and reduce the farm pro-
gram spending, but PLC payments will not experience such declines and exacerbate the pressure
on government spending.

Since the ARC-CO policy has a built in maximum government support of 10% of the
benchmark revenue, total payments under ARC have a cap. In contrast, PLC payments are bound
by the difference between the reference price and loan rate, with a maximum of $125,000 per
farmer. Thus, if market price remains low, then total government support under PLC can be con-
siderably higher than ARC-CO payment. Also, because ARC-CO and PLC payments are meant to
support farmers under vulnerable market conditions, i.e., for low prices and revenues, government
payments could be large under these conditions and can exceed U.S. commitments/limits on do-
mestic support under the proposed Doha Development Round. In contrast, if farm revenues come
largely from markets, then U.S. obligations under the proposed Doha Development Round will be
readily met.

Crop insurance programs include individual RP protection and SCO. Because RP payments
depend on input use, RP is coupled to production through the coupling, wealth, and insurance
effects. However, SCO payments do not depend on input use, and are coupled to production only
through the wealth and insurance effects. The empirical results indicate that the farmer prefers
RP to no revenue insurance. The Farm Bill ties SCO to PLC and RP, and the farmer benefits
by enrolling in all three programs. However, RP and ARC-CO policies provide the most benefit
to the farmer. Removing RP and SCO premium subsidy reduces the input and yield effects of
these policies, but the farmer is still better off by participating in these insurance programs. Note,
this does not imply that the insurance market will be viable without any government assistance.
Agricultural insurance markets still suffer from systemic risk from widespread weather events (such as drought, hail, etc.) and pests and diseases. Thus, insurance agents may require government assistance to remain profitable due to these systematic perils.

References


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**Table 1: Comparative Statics of Policy Parameters**

<table>
<thead>
<tr>
<th>Policies</th>
<th>Parameters</th>
<th>Coupling</th>
<th>Wealth</th>
<th>Insurance</th>
<th>Total</th>
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<td>$p^{LR}$</td>
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<td>$\sigma^{RP}$</td>
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<td>Coverage Level</td>
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<td>60%</td>
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<td>70%</td>
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<tr>
<td>RP Premium Subsidy</td>
<td>67%</td>
<td>64%</td>
<td>64%</td>
<td>59%</td>
<td>59%</td>
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<tr>
<td>SCO Premium Subsidy</td>
<td>65%</td>
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<td>65%</td>
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### Table 3: Results on Production, Coverage level, and Certainty Equivalent

<table>
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<tr>
<th>Scenarios and Policies</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$x_3$</th>
<th>$y$</th>
<th>C.E.</th>
<th>$\alpha$</th>
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<tr>
<td>R</td>
<td>112.280</td>
<td>14.436</td>
<td>86.276</td>
<td>56.000</td>
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<td>Scenario</td>
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<tr>
<td>1: R+LDP</td>
<td>112.280</td>
<td>14.436</td>
<td>86.276</td>
<td>56.000</td>
<td>27.707</td>
<td>–</td>
</tr>
<tr>
<td>2: R+RP</td>
<td>106.299</td>
<td>13.667</td>
<td>81.681</td>
<td>53.893</td>
<td>29.408</td>
<td>0.85</td>
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<td>4: R+PLC</td>
<td>112.408</td>
<td>14.452</td>
<td>86.375</td>
<td>56.045</td>
<td>31.220</td>
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<tr>
<td>5: R+SCO</td>
<td>115.879</td>
<td>14.898</td>
<td>89.042</td>
<td>57.252</td>
<td>36.239</td>
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<td>6: R+LDP+RP+ARC-CO</td>
<td>107.829</td>
<td>13.863</td>
<td>82.856</td>
<td>54.435</td>
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<td>7: R+LDP+RP+PLC</td>
<td>106.371</td>
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<td>8: R+LDP+RP+PLC+SCO</td>
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### Table 4: Results on Expected Premiums and Program Payments

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<th>$E(PR)$</th>
<th>$E(PARC^C)$</th>
<th>$E(PPLC)$</th>
<th>$\theta^{SCO}$</th>
<th>$E(PSOC)$</th>
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<td>3: R+ARC-CO</td>
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<tr>
<td>5: R+SCO</td>
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<td>6.514</td>
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<td>6: R+LDP+RP+ARC-CO</td>
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<td>8: R+LDP+RP+PLC+SCO</td>
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### Table 5: Results on Production, Coverage level, and Certainty Equivalent Without Premium Subsidies

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<th>Scenarios and Policies</th>
<th>$x_1$</th>
<th>$x_2$</th>
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<th>$y$</th>
<th>$\alpha$</th>
<th>C.E.</th>
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<tr>
<td>Baseline</td>
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<tr>
<td>R</td>
<td>112.280</td>
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<td>86.276</td>
<td>56.000</td>
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<td>27.707</td>
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<td>9: R+RP</td>
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<td>10: R+LDP+RP+PLC+SCO</td>
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### Table 6: Results on Expected Premiums and Program Payments Without Premium Subsidies

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<th>Scenarios and Policies</th>
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<th>$E(\text{PPLC})$</th>
<th>$\theta^{SCO}$</th>
<th>$E(\text{PSCO})$</th>
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<tr>
<td>Baseline</td>
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<tr>
<td>R</td>
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<td>Scenario</td>
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<td>9: R+RP</td>
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Figure 1: Bivariate PDF and CDF Contour Plot

PDF Contour Plot: Detrend Yield and Real Price

CDF Contour Plot: Detrend Yield and Real Price

Figure 2: Marginal PDF and CDF of Price and Yield Data

Marginal PDF of Real Price

Marginal CDF of Real Price

Marginal PDF of Normalized Detrended Yield

Marginal CDF of Normalized Detrended Yield