U.S. Farmers' Insurance Choices under Expected Utility Theory and Cumulative Prospect Theory

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May 25, 2016

Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

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Towards explaining regional differences in U.S. farmers' crop insurance choices, we propose a budget heuristic effect within the standard Expected Utility Theory (EUT) framework and conduct theoretical and simulation analyses. We also disentangle the effects of various aspects the cumulative prospect theory (CPT) framework in a separate simulation analysis.

Key words: agricultural (crop and livestock) insurance, cumulative prospect theory, budget heuristics, mental accounting.

JEL codes: D81, D82, G22, G28, Q12, Q18

1.Introduction

The average coverage levels for revenue crop insurance products for corn, soybeans and wheat in the U.S. have been increasing, especially after the 2008 Farm Bill; nevertheless, the observed trend has not been evenly distributed across the U.S. (Schnitkey and Sherrick, 2014). The counties in the Corn Belt had predominantly higher coverage levels (that exceeded 75%), while the counties in the Great Plains and the South had predominantly lower coverage levels (that were at 70% or below). The question then remains why differential uptake of crop insurance coverage in Corn Belt versus the Great Plains and the South?

The standard decision making framework under uncertainty, Expected Utility Theory (EUT), predicts that a risk-averse, rational farmer facing actuarially fair premium rates—without

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even requiring any subsidy—should buy insurance at the highest possible level, which would be 85% with individual crop insurance plans. Given the farmers' observed suboptimal choices, some considered Cumulative Prospect Theory (CPT) as an alternative decision framework (Babcock, 2015). CPT is originally developed in Tversky and Kahneman (1992) as part of behavioral economics movement in order to explain some of the anomalies that are not compatible with EUT. Meanwhile, one factor often considered in explaining farmers' sub-optimal crop insurance coverage choices is farmers' budget constraints, yet this factor is overlooked in Babcock (2015). Actually, budget constraint effect can be found not only in the standard economics but also in behavioral economics as well. In the latter, it is often referred as budget heuristics, can be implicit or explicit, and can apply to high income individuals as part of mental accounting (Thaler, 2008). Under such heuristic, farmers may begin with a set amount of money and ask the agent to find them the best value within that constraint.

In addition to coverage level choices, insurance plan and unit type choices are also of some interest. Revenue Protection (RP) policy is by far the most popular insurance plan among farmers. An educational website (farmdoc.com) often recommends that cost-conscious farmers may choose Revenue Protection with Harvest Price Exclusion (RP-HPE) policy. Yield Protection (YP) policy seems more popular in the South. One reason for the latter is that value of yield risk reduction is substantial relative to that from price risk reduction for certain crops in that region. At the same time, yield policy is cheaper than revenue policies. Moreover, farmers have markedly shifted their preferences from basic and optional units over to enterprise units since a provision of the 2008 Farm Bill increased subsidy rates for enterprise units.(Actually, the premiums in enterprise units are less than those in other units, while the subsidy dollars are about the same.) These observed trends are in line with the finding that farmers have some aversion for

paying out of pocket premium in Du, Feng and Hennessy (2016) and are consistent with the budget heuristics hypothesis considered here.

2. Modeling Strategy

Multiple approaches are available towards modeling U.S. farmers' insurance choices. Some will be highlighted in the following.

The standard EUT framework can be found in Ehrlich and Becker (1972); Chambers and Quiggin (2002); Bulut, Collins and Zacharias (2012); Bulut and Collins (2014); Bulut (2016); Du, Feng and Hennessy (2016); and Louaas and Picard (2016). Particularly, Bulut (2016) studies the effect of systemic risk and overconfidence by considering game theoretic interaction between government and farmers. In addition, Du, Feng and Hennessy (2016) suggest that farmers may be prone to a cognitive bias in evaluating benefits of insurance based on past outcomes. As mentioned earlier, CPT is developed in Tversky and Kahneman (1992) and implemented to crop insurance by Babcock (2015). Botzen and Bergh (2009) provides an application of CPT to risk of flooding and climate change and highlights the linkages among EUT, rank dependent utility and CPT models. Eckles and Wise (2013) provide an application of CPT to determine if such preferences can explain consumers' choice for low deductible insurance.

On the other hand, the studies estimating the responsiveness of crop insurance demand based on econometric regression models include Goodwin (1993), O'Donoghue (2014); and Woodard (2015). (The latter finds much more responsive crop insurance demand compared with the previous literature.) Other studies using Random Utility Models (RUMs) within Discrete Choice Models framework to identify the determinants of crop insurance choices include Sherrick et al. (2004); Du, Feng, and Hennessy (2016); and Johansson and Worth (2016).

Towards explaining aforementioned differences in farmers' insurance choices, we begin

by proposing a budgets heuristic effect within the standard EUT framework and provide a theoretical and simulation analyses. After that, we explore the effects of various components of the CPT framework in a separate simulation analysis. Finally, we provide future directions and conclude.

2.1 An Application of Budget Heuristics Effect

We begin with insurance decision with individual plan of insurance only, as a representation of the pre-2014 Farm Bill environment. As in Bulut, Collins and Zacharias (2012), the "representative" farmer is assumed to have a linear mean-variance preference function specified as

$$\tilde{U}_x = M - \pi x - E[\tilde{l}_x] - 0.5\lambda\sigma^2_{\tilde{l}_x}, \tag{1}$$

where $\tilde{U}$ is the farmer's utility, M is the farmer's initial income, π is premium per unit of insurance coverage level, x is coverage level, $E[\tilde{l}_x]$ is the farmer's expected loss with coverage, λ is the risk aversion parameter, $\sigma^2_{\tilde{l}_x}$ is the variance of the farmer's loss with coverage. The superscript "~" refers to random variables throughout.

If the farmer holds x units of coverage with individual insurance, then the expected loss of the farmer with coverage is

$$E[\tilde{l}_x] = p_l l(1-x), \tag{2}$$

where p_l is the probability of loss and l is the amount of loss prospect. The variance of the loss of the farmer when the farmer has coverage units of x is

$$\sigma^2_{\tilde{l}_x} = \sigma^2_{\tilde{l}}(1-x)^2, \tag{3}$$

where σ_l^2 is the variance of the farmer's loss when there is no protection available. Plugging the resulting expressions for $E[\tilde{l}_x]$ and $\sigma_{\tilde{l}_x}^2$ in equation (1), the objective function is fully developed in terms of decision variable x.

The farmer's problem is to maximize the utility function in equation (1) by choosing a non-negative level of coverage x. Solving the necessary and sufficient first-order condition (F.O.C.) yields demand for insurance (denote with $\hat{x}$) as

$$\hat{x} = 1 + \frac{1}{\lambda \sigma_l^2}(-\pi + p_l l) . \tag{4}$$

If the insurance is actuarially fair, that is, premium rate equals expected loss, then the strictly risk averse individual will choose $\hat{x} = 1$, that is, insure completely.[1]

We now introduce the budget constraint effect. Denote the budget constraint per unit of exposure with $b > 0$. Whenever the budget constraint is binding, $\pi > b$ should hold. Assume so. One can write the coverage demand under budget constraint as

$$\hat{x} = \min\left\{1 + \frac{(-\pi + p_l l)}{\lambda \sigma_l^2}, \frac{b}{\pi}\right\} . \tag{5}$$

Denote the actuarially fair premium rate with π^f. Then, $\pi^f = p_l l$ holds. One can observe the following.

Lemma 1. *Under actuarially fair premium rates, a binding budget constraint leads to underinsurance.*

[1] See also Example 6.C.1. on page 187 in Mas-Colell, Whinston, and Green (1995).

From equation (5), evaluating the optimal coverage demand at the actuarially fair premium rate results in $\hat{x} = \min\left\{1, \frac{b}{\pi^f}\right\} < 1$ as $\pi^f > b$ holds. Define the deductible as $\hat{d} = 1 - \hat{x} > 0$.

Suppose that some policymakers derive disutility from observed under insurance and attempt to solve this problem by offering an area plan towards protecting the deductible; hence, the Supplemental Coverage Option (SCO) of the 2014 Farm Bill arises. (The reader is referred to Bulut and Collins (2014) for the detailed description and formulation of the SCO.) Denote the coverage level with that option as y. Now, $0 \le y = \hat{d}$ where $\hat{d}$ is the deductible as defined earlier. Denote the premium rate for SCO coverage with ψ. Based on the joint distribution of the individual and area losses,[2] one can obtain the actuarially fair premium rate for SCO as

[2] Denote the random outcome of whether a loss occurred for the farmer and the area with S_i and S_a, respectively and the joint events with (S_i, S_A). Then, the joint distribution of the individual and the area losses is as follows: both the individual and the area see a loss, $(1,1)$ with probability p_{lL}; the individual sees a loss but the area does not, $(1,0)$ with probability p_{lN}; the individual does not see a loss but the area does, $(0,1)$ with probability p_{nL}; and neither the individual nor the area sees a loss, $(0,0)$ with probability p_{nN}. Furthermore, the probabilities for joint events can be written as $p_{lL} = p_l p_L + \rho r_l r_L$; $p_{lN} = p_l(1-p_L) - \rho r_l r_L$; $p_{nL} = (1-p_l)p_L - \rho r_l r_L$; and $p_{nN} = (1-p_l)(1-p_L) + \rho r_l r_L$, where ρ is the correlation coefficient between the loss events, r_l is the standard deviation of event S_i and r_L is the standard deviation of event S_A. The standard deviations are defined as $r_l = \sqrt{p_l(1-p_l)}$ and $r_L = \sqrt{p_L(1-p_L)}$. In addition, the covariance term between the events S_i and S_A is $Cov(S_i, S_A) = \rho r_l r_L$. The value of the correlation coefficient parameter must be consistent with the probabilities being all non-negative. From these relationships, one can re-obtain the marginal probability of losses as $p_l = p_{lL} + p_{lN}$ and $p_L = p_{lL} + p_{nL}$. For simplicity, we assume that $\text{maximum}\{p_l, p_L\} \le 0.5$, which is sufficient to obtain $p_{nN} > \text{maximum}\{p_{lN}, p_{nL}\}$ and $p_{nN} \ge p_{lL}$. Finally, we also assume that $p_{lN} > 0$ and $p_{nL} > 0$.

$\psi^f = p_{lL} l + p_{nL} l$. That is, SCO could potentially pay for l, the entire loss prospect for the individual (the conditional value at risk) whenever area triggers. One can reexpress ψ^f as

$$\psi^f = p_L l . \tag{6}$$

Farmer's problem in equation (1) can be rewritten as

$$\tilde{U}_{xy} = M - \pi x - \psi \underbrace{(1-x)}_{=y} - E[\tilde{l}_{xy}] - 0.5\lambda\sigma^2_{\tilde{l}_{xy}} , \tag{7}$$

where $\tilde{U}_{xy}$, $E[\tilde{l}_{xy}]$ and $\sigma^2_{\tilde{l}_{xy}}$ pertain to individual coverage combined with SCO and are the counterparts to those defined following equation (1). Particularly,

$E[\tilde{l}_{xy}] = p_{lL} \underbrace{(l - l(1-x) - lx)}_{=0} + p_{lN} l(1-x) + p_{nL}\left(-l(1-x)\right)$, which can be reexpressed as

$$E[\tilde{l}_{xy}] = \underbrace{(p_{lN} - p_{nL})}_{>0} l(1-x) > 0 . \tag{8}$$

Note that due to the aggregation involved in arriving at the probability of loss for area (Bulut, 2016; Appendix 8), one can deduce that $p_l > p_L$ which in turn implies, $(p_{lN} - p_{nL}) > 0$. For the variance, one can use the alternative formulation $\sigma^2_{\tilde{l}_{xy}} = E[(\tilde{l}_{xy})^2] - \left(E[\tilde{l}_{xy}]\right)^2$. To that end, one can obtain $E[(\tilde{l}_{xy})^2] = p_{lN} l^2 (1-x)^2 + p_{nL}\left(-l(1-x)\right)^2 = (p_{lN} + p_{nL}) l^2 (1-x)^2$. Using the preceding two expressions, one writes

$$\sigma^2_{\tilde{l}_{xy}} = h^2_{\tilde{l}} (1-x)^2 , \tag{9}$$

where $h^2_{\tilde{l}} = (p_{lN} - p_{nL})\left(\frac{(p_{lN} + p_{nL})}{(p_{lN} - p_{nL})} - (p_{lN} - p_{nL})\right) l^2$ is the variance expression analog to $\sigma^2_{\tilde{l}}$ from equation (3).

From the first order condition (F.O.C.) of the maximization of the farmer's problem given in equation (7) with respect to x, one can obtain the optimal individual coverage demand in the presence of SCO as

$$\hat{x}^1 = 1 + \frac{(-\pi + \psi) + (p_{lN} - p_{nL})l}{\lambda h}; \tag{10}$$

$$\hat{y} = 1 - \hat{x}^1.$$

Now, using the actuarially fair premium rates, one can claim the following.

Lemma 2. *Under actuarially fair premium rates, the farmer does not demand any SCO coverage.*

Plugging the actuarially fair premium rates, that is, $\pi^f = p_l l$ and $\psi^f = p_L l$ in equation (10) and using $(p_l - p_L) = (p_{lN} - p_{nL})$, one obtains $\hat{x}^1 = 1$ and $\hat{y} = 0$.

One can further observe the following.

Lemma 3. *Consider actuarially fair premium rates and a binding budget constraint. Whenever $b < \psi^f$ holds, buying the entire deductible is not feasible.*

The preceding lemma points out a policy design issue when farmers are operating under a budget heuristic. Based on foregoing we can state the following.

Proposition 1. *Suppose that premium rates are actuarially fair, the budget constraint is binding and $b \geq \psi^f$ holds so that buying the entire deductible is feasible. The farmer still does not demand any SCO coverage.*

The proof is provided in Appendix 1. In the absence of subsidy rate differential between the underlying individual coverage and SCO, the farmer would be better off by spending the entire

crop insurance budget on individual coverage because of its risk reduction advantage compared with the area plan.

We now turn to the study of budget heuristics effect within a simulation analysis. The simulation results for Texas cotton and Kansas wheat in Bulut and Collins (2014) are initially updated for the 2015 price environment and a hypothetical budget constraint effect is then added to that analysis. The budget constraint is taken as the amount spent on the assumed policy choice pre-farm bill, while using the same premium rates for the underlying base product pre-and post-farm bill. Because RP plan of insurance is the most popular and farmers can be found at various levels of coverage, RP at all coverage levels are considered. Other policy types could also be considered.

Table 1 presents the Texas cotton results. It is evident that farmers who initially choose RP at 70% and below coverage levels are not interested in purchasing STAX. Table 2 presents the Kansas wheat results. A similar result can be observed. Farmers who initially choose RP at 75% and below coverage levels are not interested in purchasing SCO. We expound on these findings in the following.

Because SCO or STAX costs money, in order to satisfy the budget constraint considered here, farmer has to consider buying down from initial individual plan or switching to a cheaper one such as RP-HPE or YP. In doing so, the subsidy rate at the incrementally higher coverage level with the individual plan versus that of SCO or STAX becomes critical. Also recall that in the case of SCO, the farmer has to buy the entire deductible up to 86% (see Lemma 3). For farmers at lower coverage levels to begin with, the subsidy rates with the enterprise units are already high (see table 3), and the coverage can be increased incrementally. As such, SCO or

STAX can be viable option only if the farmer is already at high coverage levels (above 75% and 70%, respectively).

2.2 An Application of Cumulative Prospect Theory (CPT)

In modeling how individuals make decisions under uncertainty, the standard EUT framework states that an individual first finds out the level utility she derives at each possible outcome and weigh them with the objective probabilities. The alternative decision framework CPT blends economics and psychology and states that the individual would compare each possible outcome to a reference point first and code those outcomes as gains or losses. The individual would then weigh the values she is deriving from gains or losses with the subjective probabilities. Particularly, the CPT framework builds on the following components: *(i) a loss aversion effect*: pain from a loss would count at least twice as much as the pleasure of a gain of the same size, that is, losses loom larger than the gains; *(ii) a curvature effect*: the individual would feel increasingly desensitized as the size of losses or gains gets increasingly large; *(iii) a probability weighting effect*: the individual would overweight the small probabilities for rare gains or losses , while underweighting the moderate probabilities for more common gains or losses.

By initially maintaining the assumptions of actuarially fair premium rates, risk averse and rational farmers, we apply the preceding two decision frameworks to farmers' crop insurance choices as follows:

Based on the EUT framework, Bulut and Collins (2014) analyze farmers' optimal choices between crop insurance and the 2014 Farm Bill's supplemental revenue options for six representative crop-county combinations. As expected, farmers tend to choose highest possible

coverage levels in the absence of new supplemental options—except the Texas Cotton case.[3] For the CPT framework, following the steps provided in Babcock (2015), we wrote a code for the CPT methodology using MATLAB software and applied it to the simulated revenue distribution for corn in Champaign County, Illinois from Bulut and Collins (2014).

We refer the reader to Babcock (2015) regarding the further description and formulation of the CPT methodology (see also Botzen and Berg, 2009). One key aspect of CPT is the determination of reference point which distinguishes losses from gains from a farmer's perspective. Babcock (2015) looks at three representative crop-county combinations and can obtain relatively low coverage level choices for a particular reference point. In this case, the farmer compares the indemnity payment with the farmer-paid-premium and registers a loss if the former is less than the latter. As such, Babcock (2015) presents this calculation as the risky investment (narrow) framing of insurance. Nevertheless, this kind of gain or loss calculation is mathematically tantamount to farmer not caring about the deductible.[4] Once it can be assumed

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[3] Subsidy structure may reduce coverage demand at high levels even under EUT maximization framework. The farmer may gain from premium subsidies (reflected as more indemnity per dollar of farmer paid premium) with the RP plan as coverage increases (more so when price-yield correlation is stronger, such as the case Midwest corn or soybeans, Du et al. 2013). However, the subsidy rates for individual plans decrease at an increasing rate at high coverage levels (see table 3 here). That may force the farmer to weigh risk-reduction gain against possible loss of subsidy dollars. Bulut and Collins (2014) show that this very trade-off results in the concave shape of the valuation functions at high coverage levels. Crop-county combinations where the value of yield risk reduction is substantial relative to that from price risk reduction (such as the case in Texas cotton or Montana spring wheat) show a flatter valuation of RP at high coverage levels, hence incrementally less net gain or even possibly net loss and a stronger incentive to buy-down in the presence of the 2014 Farm Bill's supplemental revenue programs.

[4] First we collect the notation to be used: χ is the variable measuring gain or loss; M is the farmer's initial wealth and subsumes cost of production; p_b is base insurance price; p_h is harvest insurance price; q^{APH} is APH yield; a denotes acres planted –assume away this parameter by setting it to $a = 1$ for simplicity; q^f is the realized farm level yield; I is the indemnity, x is the

that farmers do not care about the deductible, it is not all that surprising then to find farmers would choose relatively low coverage levels. However, the preceding assumption is not consistent with the proliferation of shallow loss programs in the 2014 Farm Bill and with the investment view of insurance in the literature. For instance, Eckles and Wise (2013), a study cited by Babcock (2015), emphasize the role of deductible in modeling insurance as investment.

For a proper reference point, Expected Crop Value (ECV) plus the farmer's initial wealth should be suitable when the farmer chooses RP-HPE or YP plans of insurance. ECV is what insurance is based on and represents the farmers' expectation. For a farmer who chooses RP plan of insurance, which is a popular choice, a more sensible reference point is the expected crop value of its harvest price protection (ECVHPP) plus the farmer's initial wealth. Because RP policy comes with a higher farmer-paid premium, the farmer is revealing—through the choice of RP —that the harvest price option should matter.

Having analyzed the reference point, we now turn to other aspects of the CPT. We consider 12 sets of parameters organized in two categories. The first category is called "Null" and indicated with "0". The other category is called "Alternative" and indicated with "1". The latter is after Tversky and Kahneman (1992). Each category consists of six sets of parameters

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coverage level with the RP plan of insurance; Π_{FP} is the farmer paid premium amount; and M^f is the farmer's final wealth at harvest. Then, $I = \max\left\{x \max\{p_b, p_h\} q^{APH} - p_h q^f, 0\right\}$ and $M^f = M + I + p_h y^f - \Pi_{FP}$ hold. Now, the reference point, denote it with R_*, should be $R_* = M + p_h y^f$ in order to obtain $\chi = M^f - R_* = I - \Pi_{FP}$ as the gain or loss outcome. In other words, the underlying reference point that derives the gain/loss outcome $\chi = I - \Pi_{FP}$, whereby the farmer comparing the farmer paid premium with the indemnity, is R_* and R_* doesn't take the deductible into account. Note that the reference point indicated with R_3 in equation (6), col. 2, p. 4, Babcock (2015) differs from R_*, and yet the end result for the farmer's gain/loss calculation is the same.

base case and five additional scenarios. This is done to disentangle effects of various aspects of CPT. Each category is then evaluated under three insurance environments. The first environment does not consider any insurance option. The second environment considers RP plan of insurance, but without any subsidy. The third environment considers subsidized RP plan of insurance with the subsidy rates that are currently in place in the crop insurance program.

In line with the CPT literature, we denote the exponent (curvature) parameter of the value function with α and parameters of the probability weighting function with γ for gains and δ for losses. Differently, we use the notation ξ for the loss aversion coefficient as the notation λ is already in use for risk aversion coefficient in equation (1).

Null Category: Base case assumes the following: $\alpha = 1$, that is, linear value function; hence, no curvature; $\xi = 1$, that is, no loss aversion; $\gamma = \delta = 1$, that is, neither probability overweighting nor underweighting. The scenarios represent various changes in the parameters used in the base case. The scenarios include: SA 1 adds curvature by setting $\alpha = 0.88$; SA 2 adds more curvature[5] by setting $\alpha = 0.75$; SA 3 adds loss aversion by setting $\xi = 2.25$; SA 4 adds probability overweighting by assuming $\gamma = 0.61$ and $\delta = 0.69$; SA 5 considers probability underweighting by assuming $\gamma = 1.161$ and $\delta = 1.169$. Note that under each scenario the remaining parameters assume their base case of the category.

[5] Increasing the value of the exponent towards one makes the value function more linear and is tantamount to decreasing the curvature. Decreasing the value of the exponent from one makes the value function more concave (convex) on the gain (loss) domain and is tantamount to increasing the curvature. Accordingly, the marginal value at $1 gain relative to the marginal value at $350 gain should be higher when the exponent parameter takes the value of 0.75 instead of 0.88, that is, when there is more curvature in the value function. The opposite is erroneously stated in Babcock (2015), p. 10, col. 2, bottom of the page.

Alternative Category: Base case assumes the following: $\alpha = 0.88$ for curvature; $\xi = 2.25$ for loss aversion; $\gamma = 0.61$ and $\delta = 0.69$, that is, probability overweighting. Once again, these are the parameter values reported in Tversky and Kahneman (1992). The scenarios represent various changes in the parameters used in the base case. The scenarios include: SA 1 drops the curvature by setting $\alpha = 1$; SA 2 adds more curvature by setting $\alpha = 0.75$; SA 3 drops loss aversion by setting $\xi = 1$; SA 4 drops probability overweighting by assuming $\gamma = \delta = 1$; SA 5 considers probability underweighting by assuming $\gamma = 1.161$ and $\delta = 1.169$. Note again that under each scenario the remaining parameters assume their base case of the category.

The CPT methodology based on the parameter values under the preceding two categories are applied by assuming a reference point of ECVHPP (plus initial wealth) to Illinois corn wealth outcomes from the simulation in Bulut and Collins (2014). The resulting Certainty Equivalent values (CEs) under aforementioned three insurance environments are presented in figure 1.

Under Null Category, for the base case scenario the farmer is indifferent between insurance and not having insurance if there are no subsidies available, just as the risk neutral individual would be indifferent towards actuarially fair insurance in the standard EUT framework. Whereas under Alternative Category, the base case scenario indicates that farmer would buy insurance without any subsidy (the CE value is less negative; hence bigger in this case than that under no insurance case). Recall that the base case reflects the parameter values in Tversky and Kahneman (1992). This prediction does not appear to be realistic; however, in light of the historical experience with the subsidy rates in crop insurance program (Collins and Bulut, 2011). To find out which aspect of the CPT causing this perverse result we look at the scenarios under each category.

Going back to Null Category, the CE values under SA 1, SA 2, and SA 5 indicate that the farmer would not buy insurance without any subsidy. On the other hand, the CE values under SA 3 and SA 4 indicate that the farmer would buy insurance without any subsidy. Thus, the curvature effects and probability underweighting are working against insurance option, whereas loss aversion and probability overweighting effects are working in favor of insurance option. In the base case and all scenarios, the farmer would buy insurance with subsidy and would choose 85% coverage level.

The findings with Alternative Category in the scenarios are mirroring those with Null Category. In the base case and all scenarios except SA 5, the farmer would buy insurance without subsidy. That means the probability underweighting considered in SA 5 dominates the other effects. Finally, when subsidy is available, the farmer would buy insurance and at the highest coverage level, 85% with RP plan of insurance.

4. Conclusion

We have done theoretical and simulation analyses of the representative farmer's crop insurance choices and demonstrated that a simple budget constraint (heuristic) effect within the standard Expected Utility Theory (EUT) framework has potential to explain the observed regional differences in crop insurance uptake. The proposed explanation has implications for the SCO and STAX products of the 2014 Farm Bill as well. In a separate simulation analysis, we have also looked into the effects of various components of the Cumulative Prospect Theory (CPT) to determine if this alternative decision making framework can provide additional insights into farmers' crop insurance choices.

Crop insurance premium rates are typically higher in the Great Plains and South compared with the Midwest. If farmers across regions operated under a heuristic that allocates

similar amount of dollars per acre for crop insurance, the product would feel expensive for those farmers in the Great Plains and South despite the price being commensurate with the underlying risk, that is, actuarially fair. Farmers may be forming these heuristics by comparing crop insurance cost to a benchmark expenditure, which could be some other item in their production budget or the premium for conventional lines of insurance.[6] Another contributing factor influencing the formation of such heuristics could be persistence of *ad hoc* disaster aid over time and the evolution of farm programs. For instance, the 2014 Farm Bill's Agricultural Risk Coverage (ARC) and Price Loss Coverage (PLC), both are free to farmers. Direct payments, which are repealed in the 2014 Farm Bill, were naturally free and didn't require farmers to show any loss or produce for that matter. Over the time period from 2008 to 2012, the crops that are typically grown in the Great Plains and South such as wheat, upland cotton, peanuts and rice benefited more from commodity programs—in terms of as a percent of production value—than corn and soybeans which are typically grown in the Midwest (Collins, 2013).

The theoretical and simulation analyses indicate that the farmer would not choose area based insurance plan over individual plan with comparable subsidy rates under the budget constraint. These findings are in line with the observed low uptake of STAX by cotton producers and SCO by producers of other crops. Furthermore, the effect and the adaptation of the 2014 Farm Bill's Actual Production History Yield Exclusion (APH YE) option are expected to be concentrated in Southern Plains, at least for soybeans and wheat (Coppess, et al. 2014). If APH YE option induces farmers to lower their nominal coverage with the individual plan so that they can capture a higher subsidy rate, then that would work against the desirability of SCO or STAX.

[6] This view would be in line with the effect of budget heuristics in flood insurance Kunreuther and Kerjan (2013).

That would also suggest that the combination use of SCO and APH YE may not be viable option. Based on foregoing, whenever farmers are operating under a budget constraint, SCO or STAX does not appear to be the solution, if that is the legislative intent, to stoke up the coverage levels in counties who had predominantly low coverage levels (below 70%) such as those in the Great Plains and the South.

Based on a simulation analysis of the effects of various components of the CPT framework, we find that the effects of curvature of the value function and probability underweighting would work against crop insurance option, whereas the effects of loss aversion and probability overweighting effects would work in favor of it (figure 1). We observe that a form of probability underweighting instead of probability overweighting would generate the opposite effect. The direction of bias ultimately needs to be determined at field experiments involving U.S. farmers.[7] Regarding the proper reference point, we have argued that, on top of a farmer's initial wealth, the expected crop value with harvest price protection for RP plan of insurance and expected crop value for other individual plans would make sense. In the absence of budget heuristics, with the preceding reference point in place, whenever farmers prefer insurance over no insurance, they go for the highest possible coverage 85%. This finding is consistent with that in Babcock (2015) at comparable reference points. We have argued against one other reference point considered in Babcock (2015) because the farmer's gain/loss calculation in that case is tantamount to the farmer not caring about the deductible. It appears

[7] It may be worth noting that the parameters of the model in Tversky and Kahneman (1992) were estimated in 1992 based on the median values obtained from an experiment involving 25 graduate students at the University of California in Berkeley and Stanford University. To our knowledge, these parameters have not been estimated for U.S. farmers, at least not recently. Thus, it makes sense to cautiously apply these parameter values to U.S. farmers and carry out extensive sensitivity analysis.

that a potential budget constraint would have similar effects under EUT or CPT frameworks; hence, could explain the observed low coverage levels in the latter as well.

The choices based on the EUT framework reflect what farmers should be doing in terms of crop insurance choices. While the choices based on EUT or CPT under budget heuristics, a form of CPT such as with the probability underweighting effect could be reflecting what they actually do. Understanding these effects can be important in designing subsidy structure that can efficiently induce high enough insurance coverage levels in order to deter major disaster aids in the future. Furthermore, the findings point out the importance of properly presenting, demonstrating or framing the value of available options to farmers and it may have implications regarding education, training and policy design.

5. Future Directions

The budget heuristics effect pointed out here raises several questions. What is the nature of the decision process that determines the initial amount of money for crop insurance (as we have alluded to this somewhat earlier)? In relation to the preceding comment, is the initial amount of money to shop for crop insurance coverage optimally allocated? Given the amount a farmer spends, taking that as the farmer's budget, could the farmer do better, perhaps by switching to different insurance unit or policy (see RP at 60% row and RP at 55% row in tables 1 and 2, respectively as examples)?

To that end, some concepts from the standard Demand Theory, such as two-step budgeting, may be useful (Moschini et al. 1994). In the first stage, money can be allocated into broad categories. Three main categories can be considered: land costs (rent), non-land costs (fertilizer, etc.), and risk management (crop insurance, etc.). In the second-stage, intra-category money allocations can be made and conditional demands would arise. Conditional demands

within a category depend on the prices and budget allocated for that category. The latter depends on all prices (including those outside of a given category) and the overall income. These observations may have implications for studies estimating the price elasticity of crop insurance demand.

Furthermore, a related concept to budget heuristics is "reference price", and that also originates from Thaler (2008) as part of mental accounting. Farmers may be considering a "reference price" or "fair price" compared to the actuarially fair price they face. When the reference price is less than the actuarially fair price, upon paying the latter, farmers may be deriving some "transactional disutility". That would be consistent with the modeling of farmers' aversion for out of pocket payments in Du, Hennessy and Feng (2016). Bulut (2016) also points out that both farmers' disaster aid expectations and overconfidence result in a similar price effect; hence, it sheds some light on the determinants of reference price. Future research can further look into disentangling the "reference price" and "budget heuristics" effects in farmers' insurance decisions.

Finally, the simulation analyses here can be extended to 2015 or 2016 crop year and the other crop-county combinations included in Bulut and Collins (2014). The analysis of the supplemental revenue programs along with crop insurance choices can also be useful application of CPT should complement the EUT-based analysis in the preceding study.

Table 1. Representative Farmer's Top Choices Post- 2014 Farm Bill under a Budget Constraint [a]
(Texas Irrigated Upland Cotton in 2015, 100 acres in Hale County)

Assumed Policy Choice Pre-Farm Bill	Assumed Budget Constraint ($/acre) [b]	Top Choice Post-Farm Bill under the Budget Constraint	Effect on Base CI Product	Buy STAX?
RP at 85%	52.33	RP at 75% and STAX	Buy-Down 10 ppt	Yes
RP at 80%	31.00	RP at 75% and STAX	Buy-Down 5 ppt	Yes
RP at 75%	19.24	RPHPE at 60% and STAX	Switch and Buy-Down 15 ppt	Yes
RP at 70%	14.35	RP at 70%	None	No
RP at 65%	12.21	RP at 65%	None	No
RP at 60%	10.29	RPHPE at 65%	Switch and Buy-Up 5 ppt	No
RP at 55%	8.59	RP at 55%	None	No
RP at 50%	7.09	RP at 50%	None	No

[a] Base case scenario, for a representative irrigated cotton farm in Hale County, TX with a 100 acre enterprise unit. Risk premium is 10%. The base insurance price is $0.64/lb. Farm APH is 915 lb/ac. The ratio of the standard deviation (SDEV) of farmer's yield to the SDEV of county yield is obtained as 2.07. Farm-county yield correlation is 0.5, resulting in the farmer's beta value of 1.03 = (0.5*2.07). STAX policies are at 90% coverage w/ 80% subsidy rate and 1.2 protection factor.

[b] The budget constraint is taken as the amount spent on the assumed policy choice pre-farm bill, while using the same premium rate for the underlying base product pre-and post-farm bill.

Table 2. Representative Farmer's Top Choices Post- 2014 Farm Bill under a Budget Constraint [a]
(Kansas Dryland Winter Wheat in 2015, 100 acres in McPherson County)

Assumed Policy Choice Pre-Farm Bill	Assumed Budget Constraint ($/acre) [b]	Top Choice Post-Farm Bill under the Budget Constraint	Effect on Base CI Product	Buy SCO?
RP at 85%	14.96	RP at 80% , SCO and PLC	Buy-Down 5 ppt	Yes
RP at 80%	8.20	RP at 75% , SCO and PLC	Buy-Down 5 ppt	Yes
RP at 75%	4.68	RP at 75% and PLC	None	No
RP at 70%	3.19	RP at 70% and PLC	None	No
RP at 65%	2.48	RP at 65% and PLC	None	No
RP at 60%	1.91	RP at 60% and PLC	None	No
RP at 55%	1.46	YP at 60% and PLC	Switch and Buy-Up 5 ppt	No
RP at 50%	1.10	RP at 50% and PLC	None	No

[a] Base case scenario, for a representative dryland winter wheat farm in McPherson County, KS with a 100 acre enterprise unit. Risk premium is 10%. The base insurance price is $6.3/bu. ARC County benchmark price is $6.805/bu. PLC reference price is $5.50/bu. Farm APH is 47 bu/ac. The ratio of the standard deviation (SDEV) of farmer's yield to the SDEV of county yield is obtained as 1.49. Farm-county yield correlation is 0.7, resulting in the farmer's beta value of 1.04 (0.7*1.49).

[b] The budget constraint is taken as the amount spent on the assumed policy choice pre-Farm Bill, while using the same premium rates for the underlying base product pre-and post-farm Bill.

Table 3. Subsidy Rates for Units of Individual Plans versus SCO and STAX Subsidy Rates

Coverage	Subsidy Rates for Optional Units	Subsidy Rates for Enterprise Units	Subsidy Rate for SCO	Subsidy Rate for STAX
85%	0.38	0.53	0.65	0.80
80%	0.48	0.68	0.65	0.80
75%	0.55	0.77	0.65	0.80
70%	0.59	0.80	0.65	0.80
65%	0.59	0.80	0.65	0.80
60%	0.64	0.80	0.65	0.80
55%	0.64	0.80	0.65	0.80
50%	0.67	0.80	0.65	0.80

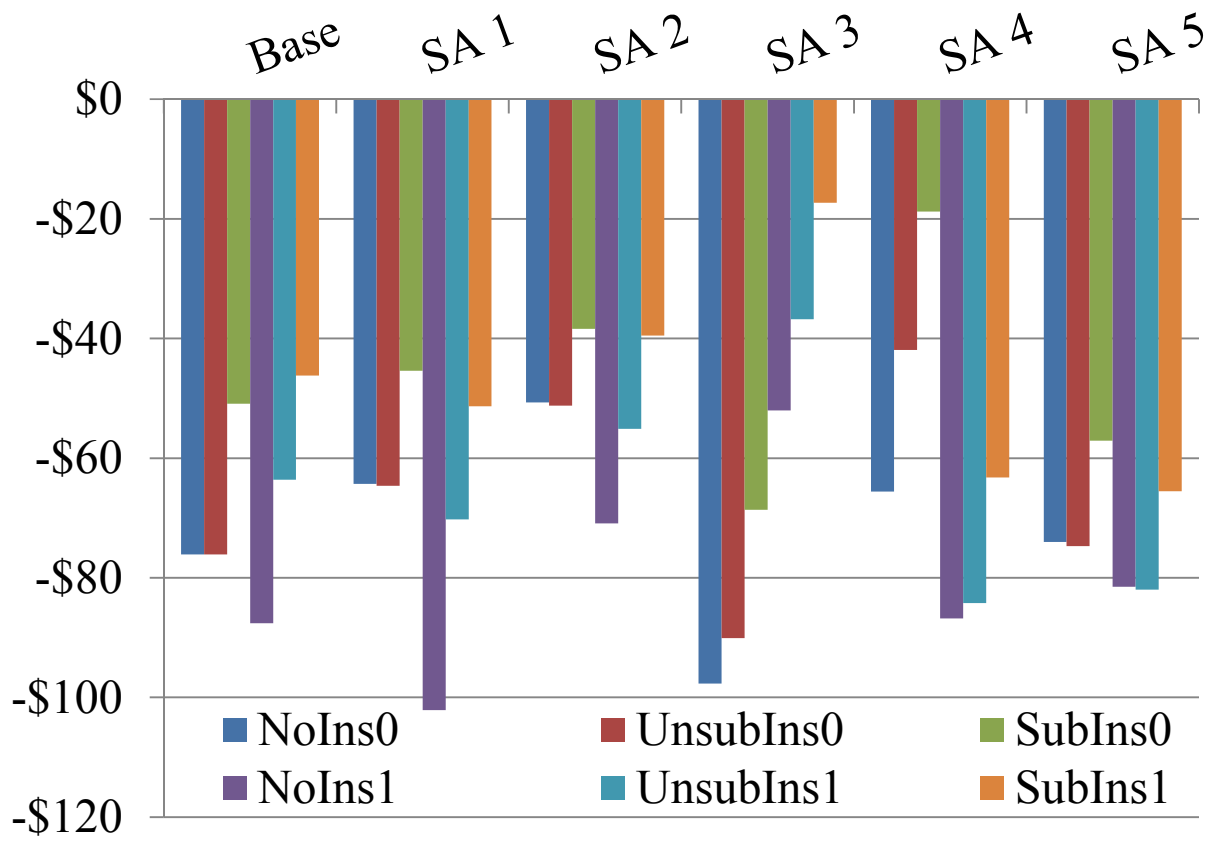

Figure 1. Certainly Equivalent Values under Cumulative Prospect Theory (CPT) framework for 12 sets of parameter values collected in two categories. The first category is called "Null" and indicated with "0". The other category is called "Alternative" and indicated with "1". The latter category involves the parameter values in Tversky and Kahneman (1992) Each category consists of six sets of parameters: base case and five additional scenarios. See the text for their description. These two categories are then analyzed under three insurance environments No insurance, Unsubsidized insurance and Subsidized insurance, which are represented with the legends "NoIns", "UnsubIns" and "SubIns", respectively. The simulation analysis is for Illinois Corn in the 2014 price environment (see Bulut and Collins, 2014 for details).

Appendix 1. A Proof of Proposition 1.

Suppose that premium rates are actuarially fair and $b > \psi^f$ holds so that buying the entire deductible through SCO is feasible. Two candidate solutions will be evaluated. The first solution is called Null Solution and denoted with $(x_b^0, y = 0)$. The second solution is called Alternative Solution and denoted with $(x_b^1, y = 1 - x_b^1)$. Note that the superscripts "0" and "1" henceforth indicate the respective candidate solutions.

The null solution corresponds to the solution in the absence of SCO and is obtained under a binding budget, From equation (5), one obtains x_b^0 as

$$x_b^0 = \frac{b}{\pi^f} = \frac{b}{p_l l}. \tag{11}$$

The deductible in this case would be

$$(1 - x_b^0) = \frac{1}{p_l l}(p_l l - b). \tag{12}$$

Alternative solution corresponds to the solution where individual policy and SCO are considered together and the budget is still binding (more on this momentarily). That is, under this alternative, farmer considers buying down from individual policy and substituting SCO for it.

Here we collect the elements of the utility function. The utility in this case should be equal to that in equation (1) evaluated at x_b^0. We reexpress that utility in the presence of SCO and denote it with $\tilde{U}_{xy}^0$.

$$\tilde{U}_{xy}^0 = M - \pi^f x_b^0 - \psi 0 - E[\tilde{l}_{xy}^0] - 0.5\lambda\sigma_{\tilde{l}_{xy}^0}^2, \tag{13}$$

where $E[\tilde{l}_{xy}^0]$ is obtained after plugging x_b^0 in equation (2); hence

$$E[\tilde{l}_{xy}^0] = p_l l(1 - x_b^0) = (p_l l - b) \tag{14}$$

Meanwhile, $\sigma^2_{\tilde{l}^0_{xy}}$ is obtained after plugging x^0_b in equation (3); hence

$$\sigma^2_{\tilde{l}^0_{xy}} = \sigma^2_l (1 - x^0_b)^2 = \left(\frac{1}{p_l} - 1 \right) (p_l l - b)^2 . \tag{15}$$

Plugging preceding expressions in equation (13) and re-expressing, one obtains

$$\tilde{U}^0_{xy} = M - b - (p_l l - b) - 0.5\lambda \left(\frac{1}{p_l} - 1 \right) (p_l l - b)^2 . \tag{16}$$

We now turn to the alternative solution. This solution accommodates the SCO coverage within a budget constraint. Solving $\pi x^1_b + \psi (1 - x^1_b) = b$ yields

$$x^1_b = \frac{(b - \psi)}{(\pi - \psi)} . \tag{17}$$

We reexpress that utility in the presence of SCO and denote it with $\tilde{U}^1_{xy}$:

$$\tilde{U}^1_{xy} = M - \pi^f x^1_b - \psi (1 - x^1_b) - E[\tilde{l}^1_{xy}] - 0.5\lambda \sigma^2_{\tilde{l}^1_{xy}} . \tag{18}$$

At the actuarially fair premium rates, notice that $b > \psi^f$ is necessary for a positive individual coverage. Plugging the actuarially fair premium rates in equation (17) yields

$$(1 - x^1_b) = 1 - \frac{(b/l - p_L)}{(p_l - p_L)} = \frac{p_l - b/l}{(p_{lN} - p_{nL})} . \tag{19}$$

Plugging the preceding expression back in equation (8), the expected loss in this case would be

$$E[\tilde{l}^1_{xy}] = (p_{lN} - p_{nL}) l (1 - x^1_b) = (p_l l - b) . \tag{20}$$

Meanwhile, $\sigma^2_{\tilde{l}^1_{xy}}$ is obtained after plugging x^1_b in equation (9); hence

$\sigma^2_{\tilde{l}^1_{xy}} = h^2_{\tilde{l}} (1 - x^1_b)^2 = (p_{lN} - p_{nL}) \left(\frac{(p_{lN} + p_{nL})}{(p_{lN} - p_{nL})} - (p_{lN} - p_{nL}) \right) l^2 \left(\frac{(p_l - b/l)}{(p_{lN} - p_{nL})} \right)^2$, which in turn can be written as

$$\sigma^2_{\tilde{l}^1_{xy}} = \left(\frac{1}{\frac{(p_{lN} - p_{nL})^2}{(p_{lN} + p_{nL})}} - 1 \right) l^2 (p_l - b/l)^2 \,. \tag{21}$$

Plugging preceding expressions in equation (18) and re-expressing, one obtains

$$\tilde{U}^1_{xy} = M - b - (p_l l - b) - 0.5\lambda \left(\frac{1}{\frac{(p_{lN} - p_{nL})^2}{(p_{lN} + p_{nL})}} - 1 \right) (p_l l - b)^2 \,. \tag{22}$$

Note that the expected losses are the same from equations (14) and (20), and the premiums paid are also the same (the budget). The relative values of utilities given in equations (13) and (22) are then determined based on following:

$\frac{(p_{lN} - p_{nL})^2}{(p_{lN} + p_{nL})} = \underbrace{\frac{(p_{lN} - p_{nL})}{(p_{lN} + p_{nL})}}_{<1} (p_{lN} - p_{nL}) = \underbrace{\frac{(p_{lN} - p_{nL})}{(p_{lN} + p_{nL})}}_{<1} (p_l - p_L) < p_l$. Then, $\sigma^2_{\tilde{l}^1_{xy}} > \sigma^2_{\tilde{l}^0_{xy}}$ would hold ,

that is, the farmer achieves higher risk reduction under the latter. Thus, the farmer derives higher utility under null solution and does not demand any SCO coverage when the budget constraint is prevailing. ■

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